Int J Public Health (2011) 56:25–36
DOI 10.1007/s00038-010-0159-y

ORIGINAL ARTICLE

Possible relationship among socio-economic determinants, knowledge and practices on lymphatic filariasis and implication for disease elimination in India

Perumal Vanamail · Subbaiah Gunasekaran

Received: 19 August 2008 / Revised: 30 April 2010 / Accepted: 6 May 2010 / Published online: 15 June 2010

Abstract

Objective To assess the socio-economic determinants, knowledge and practices on lymphatic filariasis in India and discuss the implications for elimination.

Methods A case–control study was undertaken to obtain knowledge and practice measures on various dimensions of the *Wuchereria bancroftian* filarial disease using a structured questionnaire. A structural equation model, a statistical technique for testing and estimating causal relationships using a combination of statistical data and qualitative causal assumptions, was developed.

Results Among the affected individuals, the model was able to explain more than 90% of the variance in awareness about the lymphatic filariasis, 58% of the variance in prevention aspects of the disease and 24% of the variance in people's knowledge about mosquitoes. The corresponding values in non-infected individuals were 49, 24 and 34%, respectively. A significant positive effect of education on awareness and prevention aspects of the disease was noted among the non-infected individuals. However, among the affected individuals, the awareness on various aspects of the disease was completely absent.

Conclusions The present analysis highlights the crucial role played by formal education on creating awareness about lymphatic filariasis and how to prevent this vector-borne disease. The importance of education on intervention measures against mosquito breeding and biting is also dealt with in the analysis for planning an effective and sustainable control program.

Keywords Causal model · Case–control study · Lymphatic filariasis · India

Introduction

Filariasis has been identified as one of the six diseases, which are targeted for elimination. The World Health Organization (WHO) has called for targeting lymphatic filariasis (LF) elimination by the year 2020 (Ottesen 2000). The main focus of intervention to interrupt transmission is to adopt administering a mass annual single dose (6 mg/kg of body weight) of diethylcarbamazine (DEC) with albendazole (400 mg). Although substantial progress has been made wherever the strategy has been successfully implemented to enhance compliance and to reduce infection levels in mosquitoes (Richards et al. 2005), in certain areas where LF infection prevalence has been reduced to less than 1%, either the elimination remains mysterious or the disease has resurged (Esterre et al. 2001; Sunish et al. 2002). This may be due to the intervention failure at the bottom level because of neglect of socio-cultural factors during the planning stages. In view of this, developing a model to understand the role and impact of socio-economic determinants, knowledge and practices on LF will be of potential value to identify the probable causes and their effect on the occurrence of filarial disease. This information will assist health planners and policy makers in devising appropriate and sustainable control strategies to eliminate LF.

S. Gunasekaran has retired from Pondicherry University.

P. Vanamail (✉)
Vector Control Research Centre, Medical Complex, Indira Nagar, Pondicherry 605 006, India
e-mail: pvanamail@gmail.com

S. Gunasekaran
School of Social Sciences and International Studies, Pondicherry University, Pondicherry, India

Since the early 1980s, structural equation modeling (SEM) analyses (Hoyle and Smith 1994) have been gaining prominence as they replaced the older traditional analytic methods of factor analysis and path analysis. SEM merges confirmatory factor analysis with path analysis and provides the means for constructing, testing and comparing comprehensive structural path models as well as comparing the goodness of fit of models and their adequacy across multiple groups (samples). SEM has many advantages over the traditional path analysis. One of the advantages is that it provides adjustment for the relative unreliability of the observed measures, overall goodness of fit measures and tests for comparing models. Further, the technique (i.e., SEM) explicitly recognizes the inherent perennial problem faced by social scientists related to the measurement error. SEM provides for simultaneous handling of measurement error and examining the fit between theory and data. Incorporation of structural relations among latent variables can be concluded by what is called the covariance structure model, more popularly known as the linear structural relationship (LISREL) model. For an effective and sustainable control program for LF elimination, a possible relationship among socio-economic determinants and other study variables such as knowledge on filarial disease transmission, treatment, prevention and local practices was established using SEM technique.

Methods

Study area

Filariasis has been known to be endemic in Pondicherry since 1957. The latest (1989) filarial infection prevalence rate in this area is 5.3% (Das et al. 1992) and the overall disease prevalence rate (proportion of individuals having at least one clinical manifestation of filariasis) is 6.6% (Surendran et al. 1996). It is also known to be an urban disease, which spreads from urban to rural area. Therefore, Pondicherry urban area was chosen as the study area for studying the role of socio-demographic characteristics in relation to the spread of this disease.

Study design and sample size

A case–control study design was adopted to compare the variation in the levels of knowledge and practices between ‘affected’ and ‘non-infected individuals’. The case–control study was considered to be appropriate to understand the potential risk factors that contribute to the progression of the disease. The required sample size was based on a case–control ratio of 1:1 with 95% confidence and 95% power (Kahn and Sempos 1989) to detect an odds ratio (OR) of at least two for the variable under investigation. From a preliminary study with a small sample, it was observed that the proportion of filarial cases in the lower income group was 0.43. Accordingly, in order to have an OR of filarial disease of at least two in the lower income group as compared to the higher income group, the sample size was found to be 264, i.e., 132 cases and 132 controls. An inclusion criterion for the case was that an individual affected with either lymphoedema or hydrocele and he/she should be in position to respond independently. For controls the inclusion criteria were that he/she should be non-infected for LF and should be in a position to respond independently. Accordingly, respondents covered were of three types, viz., (1) persons with lymphoedema; (2) hydrocele, which are the major clinical manifestations of LF (Surendran et al. 1996) in the study area and (3) non-infected individuals. Thus, a minimum sample size in each group of lymphoedema and hydrocele was fixed to be 135. Considering the total sample size of lymphoedema and hydrocele cases, the sample size of the non-infected individuals was fixed to be 270. The sample size was inflated by 40% to substitute for non-responsiveness and absenteeism during data collection. For cases, the address details of patients diagnosed with major clinical manifestations (lymphoedema or hydrocele), attending filariasis clinics from 1992 to 1997 at Vector Control Research Centre, State Filaria Control Unit and Government General Hospital, Pondicherry were listed and numbered serially and this cohort of patients formed the study population of the affected individuals. From the sample blood survey data (Manoharan et al. 1997) obtained in 1992, address details of ‘non-infected’ individuals for *W. bancrofti* infection were also listed and numbered serially and formed the study population for control. Respondents with minimum age of 15 years were included in the study. The required number of individuals from the respective study population was selected at random using EpiStat ver. 2000 software program. Each selected individual was located in his/her house and the nature and purpose of the study were explained to each respondent verbally. The respondent was assured that his/her identification as well as information would be kept confidential and the information provided by him/her shall be used for research purpose only. An attempt was made to determine the knowledge level on disease transmission, diagnosis, treatment and prevention, mosquito breeding and control and personal protection measures against mosquito bites.

Measures

The following data were collected using structured questionnaire:

1. socio-economic and demographic characteristics (age, income, education, standard of living) of the respondents;

2. knowledge on disease transmission, diagnosis, treatment and prevention measures;
3. knowledge on sources of mosquito breeding and mosquito control; and
4. practices towards treatment of the disease, the control of mosquito breeding and mosquito bite prevention.

Based on the data collected an attempt was made to quantify the level of knowledge and prevention measures on various aspects of the disease. All the questions with scientifically (based on the epidemiology of LF) accepted answers were scored as '1' and incorrect answers were scored as '0'. In a similar way, scores were given for reported practices against mosquito biting and mosquito breeding. For constructing the standard of living index, 14 items were included.

Though the sample size was determined with the intention of carrying out logistic regression analysis (Vanamail and Gunasekaran 2006), conventional regression analyses (logistic or linear) do not reveal the cause–effect relationship between the observed variables and the underlying factors. Also they are not useful in deriving out small number of underlying factors based on several observed variables. Since there was a large sample size (a requirement of minimum 10 observations per parameter to be estimated in SEM), the present work is focused on carrying out SEM model development of the data-set used for earlier studies (Vanamail and Gunasekaran 2006, 2008).

SEM development

The general specification of SEM (Hoyle and Smith 1994) involves the following components:

1. the number of measured variables;
2. the variance and covariance among the measured variables;
3. the number of common factors;
4. the relationships among measured (exogenous) variables and common factors;
5. the relationship among unique factors and measured (endogenous) variables; and
6. the variance and covariance among the unique factors.

The LISREL procedure allows estimation of a system of structural equations in which some variables are directly measurable. Some are non-measurable but can be measured by two or more fallible indicators. The equations describing the relationships between the measured indicators and the unmeasured constructs (latent variables) are part of what is called the 'measurement model'. A system of equations defining the hypothesized causal linkages among constructs is part of the 'structural model'. The measurement and the structural models permit the estimation of error terms and the correlation among them. The important advantage of LISREL over the more traditional regression-based techniques is that LISREL uses maximum likelihood estimation (MLE), while path-analysis models use the ordinary least squares (OLS) procedure.

For assessing the overall fit of the model to the data, LISREL version 8.7 (Student Edition) software package provides several tools such as chi-square, goodness of fit index (GFI), root mean square error of approximation (RMSEA), standard errors and t values for estimated parameters. Typically a RMSEA of less than 0.05 is required for a good model. The software also provides estimates of the error variances for the observed endogenous and exogenous variables.

Improvement of the model or model modification was decided based on χ^2 difference test for nested models (models that are subsets of each other) and Wald test for significance of parameter estimation.

In view of the theory and conceptual framework of SEM, the variables in the present study were classified into exogenous (independent) and endogenous (dependent) types. Study variables viz., 'age', 'gender' 'income', 'education (EDUCTN)' and standard of living (STDLIV) were taken as exogenous variables in the model. Among the two groups of individuals (i.e., affected and non-infected) investigation of the influence of these variables on the knowledge and practices was one of the prime interests. Therefore, endogenous study variables were knowledge on disease spread (KNDISSPD), knowledge on disease diagnosis (KNDIAG), knowledge on disease treatment (KNDISTRT), knowledge on disease prevention (KNDISPVT), knowledge on mosquito breeding and control (KNMOSBC), practice measures against mosquito biting (PRACTMBI) and prevention measures against mosquito breeding (PREVENTM). SEM model was developed and the effect of exogenous variables on endogenous variables was derived separately for the affected and non-infected individuals.

Among these seven endogenous variables, KNDISSPD and KNDISTRT were taken as indicators of a latent endogenous factor, 'awareness of disease' (AWARE). The variables, KNDIAG and KNDISPVT were considered to be the indicators of 'disease prevention index' (PREVENT). The other three variables, viz., KNMOSBC, PRACTMBI and PREVENTM were used as indicators of 'mosquito index' (MOSQUITO).

A hypothetical model between the observed and latent variables was formulated and described in Fig. 1 with the hypothetical paths of relationships on plausible causal sequences. A brief description of variables and coefficients that were involved in the model and their interpretations is presented in Table 1. As indicated earlier, the SEM used in

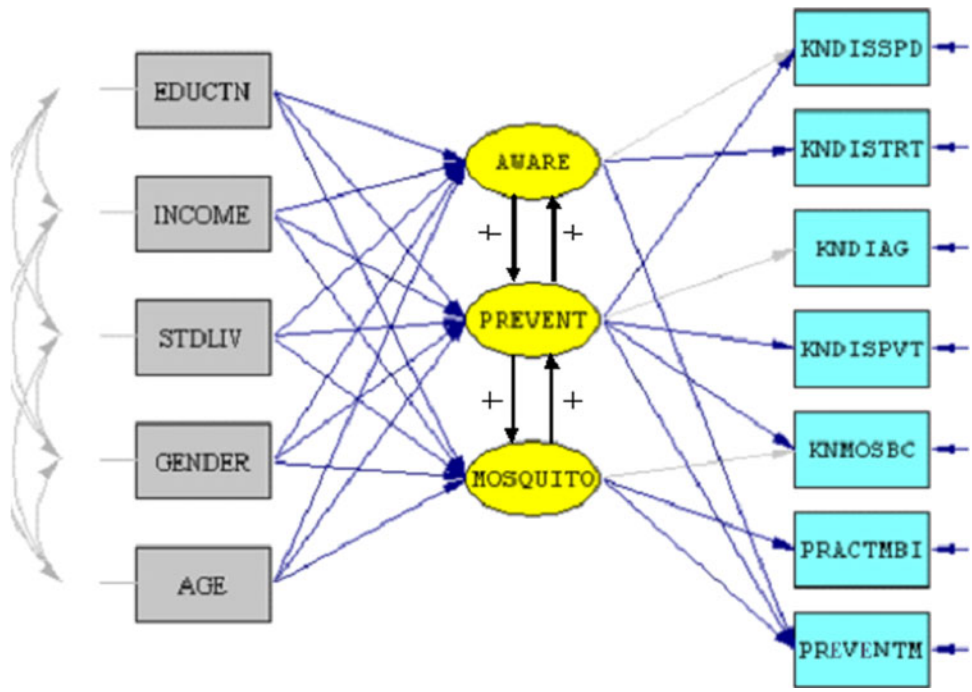

Fig. 1 Hypothetical causal model for lymphatic filariasis

the analysis was estimated with a set of procedures (LISREL) developed by Joreskog (1973, 1977) and Joreskog and Sorbom (1978, 1984).

Results

A total of 531 respondents consisting of 140 lymphoedema cases, 138 hydrocele cases and 253 non-infected individuals were covered in Pondicherry urban area. The average [±standard deviation (SD)] age of the respondents was 40.1 ± 16.5 years. Out of 531 respondents, 259 (48.8%) were females and the percentage (29.5%) of illiterates was significantly ($P < 0.01$) higher among the affected individuals than in non-infected individuals (15.0%). The average (±SD monthly income (Rs. 3,182 ± 2,367) was significantly ($t = 8.2$; $P < 0.001$) higher among non-infected individuals than in the affected individuals (1,752 ± 1,621). The mean (±SD) scores of the other study variables with respect to the type of respondents are presented in Table 2. The mean scores of all the study variables were significantly ($P < 0.05$) different among the types of individuals and further, to investigate the reasons for group differences, SEM was developed using the two groups of individuals.

SEM good fit and its indices

The process of SEM development is presented in "Appendix". The χ^2 value for the adequate model was 97.9 with 92 *df* ($P = 0.318$). RMSEA was found to be 0.016 with 90% confidence limits (0–0.037). Goodness of fit index was 0.96 and the good fit of the credible causal model is depicted in Fig. 2a, b. Of the overall chi-square value (97.9), contribution by the affected individuals was 32.9 (33%). Considering the fit of structural equations (the estimated squared multiple correlation for predicting the latent criterion variable from the latent predictors, having adjusted for measurement error), among the affected individuals, the model was able to explain more than 90% of the variance in awareness of the disease (AWARE), 58% of the variance in prevention aspects of disease (PREVENT), and 24% of the variance in mosquito aspects (MOSQUITO). The corresponding values in non-infected individuals were 49, 24 and 34%, respectively.

The parameters of estimation of the adequate fit of the SEM by maximum likelihood method for the affected and non-infected individuals are presented in Tables 3 and 4, respectively. Since most of the study variables were formed as a sum of item scores, the metric coefficients do not have a clear meaning. Therefore, standardized coefficients were calculated so that the metric is defined in terms of the spread of the distribution as measured in standard deviation units. Standardized coefficients are also useful to compare the effects of predictor variables that are measured in different units. Therefore, standardized coefficients are also presented along with the metric coefficients.

Among the affected individuals, the standardized coefficients for the measurement models on latent endogenous (Λ_y) indicate that 33% of variance in knowledge on disease treatment reproduced variation in

Table 1 Description of variables and parameters involved in the hypothetical causal model

Variables/parameters	Description	Matrix dimension	Range of values for the variables measured	
			Minimum	Maximum
Observed exogenous variables		5 × 1		
EDUCTN	No. of years of education		0	17
INCOME	Monthly income of individuals (rupees)		100	13,000
STDLIV	Score on standard of living		0	14
GENDER	Binary coded values		0	1
AGE	Completed years		15	88
Observed endogenous variables		7 × 1		
KNDISSPD	Knowledge score on disease transmission		0	11
KNDISTRT	Knowledge score on disease treatment		0	5
KNDIAG	Knowledge score on disease diagnosis		1	6
KNDISPVT	Knowledge score on disease prevention measures		1	6
KNMOSBC	Knowledge score on mosquito breeding and control		0	10
PRACTMBI	Score on practice measures against mosquito biting		0	4
PREVENTM	Score on prevention measures against mosquito breeding		0	2
Latent endogenous		3 × 1		
AWARE	Disease awareness factor		NA	NA
PREVENT	Disease prevention factor		NA	NA
MOSQUITO	Mosquito prevention factor		NA	NA
Coefficient matrices				
Λ_y	Endogenous loading	7 × 3	NA	NA
B	Endogenous path coefficients	3 × 3	NA	NA
Γ	Exogenous path coefficients	3 × 5	NA	NA
Measurement errors				
δ	Error in exogenous variables	5 × 1	NA	NA
E	Error in endogenous variables	7 × 1	NA	NA
Covariance matrices				
Φ	Covariance (exogenous)	5 × 5	NA	NA
Ψ	Residuals of endogenous factors	3 × 3	NA	NA
Θ_δ	Covariance (error in exogenous variables)	5 × 5	NA	NA
Θ_ε	Covariance (error in endogenous variables)	7 × 7	NA	NA
Measurement errors correlation matrix		5 × 7	NA	NA

NA not applicable

the latent variable 'disease awareness'. It implies that while the variance (22%) in knowledge on the disease spread was poor, the possibility of gaining more knowledge on the disease treatment during their long-term treatment process is high. Among the non-infected individuals, 45% of variance in knowledge on disease spread and 61% of variance in knowledge on disease treatment were explained by awareness. In the hypothetical model even though two indicators were set on 'disease prevention index', the model fitting for the affected individuals highlighted the role of three more indicators viz., KNDISTRT, PRACTMBI and PREVENTM. Of these five indicators, loading of KNDIAG and KNDISPVT on PREVENT were more than 55%. Among the non-infected individuals also, the loading of these two indicators was more than 55% on PREVENT. Of the three indicators of mosquito index, the loading of KNMOSBC and PRACTMBI was more than 60% among the affected individuals. The percent variance explained for the three indicators of mosquito index varied between 10 and 56% among the non-infected individuals.

On examining the nature of exogenous path coefficients (Gamma) among the affected individuals, a significant positive effect of 'standard of living' on mosquito index, awareness and prevention aspects of the disease was noted. Among the non-infected individuals, the effect of

Table 2 Mean score and standard deviation (SD) of different study variables by type of respondents and gender

Study variables/gender	Type of respondents					
	Lymphoedema		Hydrocele		Non-infected	
	Mean	SD	Mean	SD	Mean	SD
Knowledge on disease spread (KNDISSPD)						
Female	4.9	2.6	NA	NA	4.6	2.3
Male	6.1	2.4	3.8	2.3	5.8	2.2*
Overall	5.1	2.6	3.8	2.3	5.1	2.3*
Knowledge on disease diagnosis (KNDIAG)						
Female	3.8	1.7	NA	NA	3.5	1.8
Male	4.5	1.3	4.1	1.5	3.4	1.7*
Overall	3.9	1.7	4.1	1.5	3.5	1.8*
Knowledge on disease treatment (KNDISTRT)						
Female	2.7	1.2	NA	NA	1.6	1.6*
Male	3.0	1.4	2.4	1.6	2.4	1.8
Overall	2.8	1.2	2.4	1.6	2.0	1.7*
Knowledge on disease prevention (KNDISPVT)						
Female	2.9	1.1	NA	NA	3.1	1.1*
Male	3.1	1.1	3.7	1.2	3.7	1.0
Overall	2.9	1.1	3.7	1.2	3.4	1.1*
Knowledge on mosquito breeding and control (KNMOSBC)						
Female	3.7	1.6	NA	NA	4.4	2.0*
Male	4.0	2.2	3.6	1.7	5.5	2.0*
Overall	3.7	1.7	3.6	1.7	4.9	2.0*
Practice measures against mosquito biting (PRACTMBI)						
Female	1.2	0.7	NA	NA	1.7	0.7*
Male	1.3	0.8	1.1	0.7	1.7	0.8*
Overall	1.2	0.7	1.1	0.7	1.7	0.7*
Prevention measures against mosquito breeding (PREVENTM)						
Female	0.4	0.5	NA	NA	0.4	0.6
Male	0.3	0.5	0.6	0.6	0.5	0.5
Overall	0.3	0.5	0.6	0.6	0.5	0.5*

NA not applicable for females

* Group mean values are significantly different at $P < 0.05$

education on awareness and prevention aspects of the disease has emerged as significant positive effect.

While the income effect on prevention aspect of the disease was not substantial among the affected individuals, the effect was apparent on mosquito aspects among the non-infected individuals. Similarly, the gender effect on awareness was in the opposite direction among the affected and non-infected individuals. In both groups, the effect of the age factor on mosquito aspects shows a declining trend.

The total and standardized effects of observed exogenous on observed endogenous variables are presented in Table 5 for both the affected and non-infected individuals. While the effect of education on all aspects of the disease was completely absent in the affected individuals, the effect was well distinct among the non-infected individuals in awareness and prevention aspects of the disease. Since the affected individuals might have gained more knowledge on disease prevention aspects in the long-term process of treatment, the effect of income was not remarkable. However, among the non-infected individuals, a positive association between income and knowledge about mosquito was established. The standard of living index showed a significant positive association on all aspects of the disease among the affected individuals. With respect to KNDIAG and KNDISPVT, the effect of gender was prominent among the affected individuals and it was completely absent in the non-infected individuals. For the other endogenous variables, the effect of gender was generally different among the affected individuals compared to that of non-infected individuals. It was observed that the age is playing a role in increasing the level of KNDISSPD and KNDISTRT among the non-infected individuals and for the other variables, the effect of age was not distinct in both the groups.

Discussion

The analysis based on LISREL approach describes the theoretical possible causal relationships among the latent variables through a set of general linear equations. It is extremely flexible in that it can accommodate virtually any type of causal model, efficient over variable sample sizes, and robust for non-normality. In short, it is an efficient tool for exploring simultaneously both substantive and measurement relationship among the variables within a single theory-testing framework.

Since India contributes about 40% of the global burden of LF (Michael et al. 1996) and accounts for about 50% of the people at the risk of infection, elimination of the disease is targeted in the year 2015. Therefore, efforts to interrupt transmission and eliminate LF as a public health problem will certainly depend on effective mass drug administration and other public health interventions, including vector control and morbidity management. However, if elimination strategies are to succeed, in-depth socio-cultural understandings of the affected community is pivotal to maintain the sustainability of the program. Earlier studies (Ramaiah et al. 2005; Babu and Kar 2004; Mathieu et al. 2004) also emphasized that an intensive campaign of information, education, communication and advocacy is necessary if an effective mass drug administration were to be implemented.

The present study found serious gaps in understanding between knowledge of the cause of LF and how the disease is transmitted. The model also highlighted the essential part played by formal education on creating awareness of the

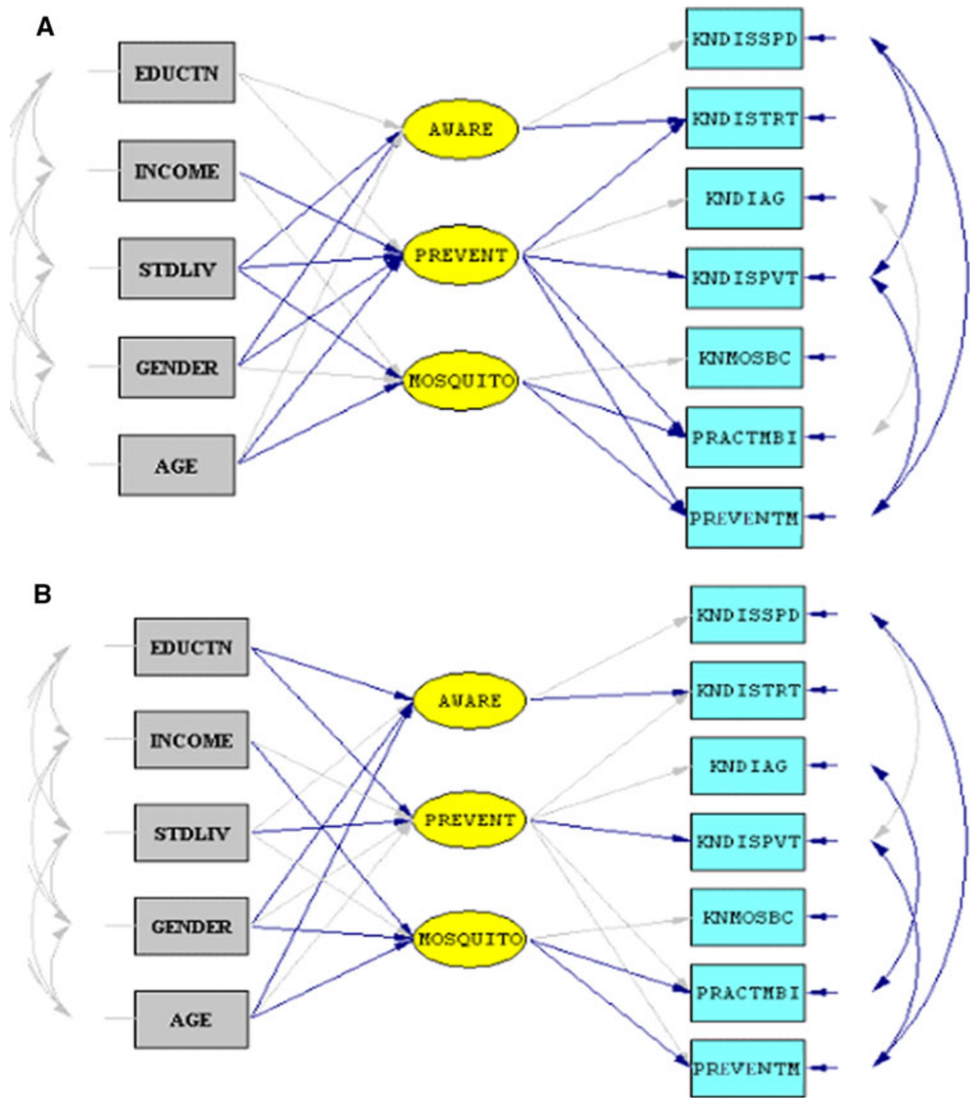

Fig. 2 **a** Plausible causal model for affected individuals. **b** Plausible causal model for non-infected individuals

disease, prevention aspects of the disease and mosquito biting. Education on disease transmission and practice measures against mosquito breeding has little impact particularly on the affected individuals. It can be inferred that possibly due to the implementation of a 5-year vector control program in the study area (Rajagopalan et al. 1989; Subramanian et al. 1989) during the period 1981–1985, the individuals gained a high level of knowledge on prevention aspects of the disease (Table 2). However, due to lack of knowledge on disease transmission, the individuals seem to do little practical measures against mosquito breeding. Further, people are likely to be of the view that prevention of mosquito breeding falls in the jurisdiction of health authorities and individuals do not have a role to play in this aspect. Therefore, by increasing awareness on disease transmission and local practices against mosquito breeding, the prevention aspects of disease and practices, against mosquito biting are likely to increase. A similar view was expressed in a study carried out in Sri Lanka; that risk communities need to be educated on the causes and transmission of LF that would motivate the target communities to keep a clean environment and participate actively in vector control (Wijesinghe et al. 2007).

Among the non-infected individuals, there is a positive effect of 'income' on mosquito aspects of the disease implying that those who have higher income are likely to spend more for personal protection measures. Even though the affected individuals have a higher level of knowledge on all aspects of the disease, due to inability they appear to spend less on personal protective measures. Though non-infected individuals are with higher standard of living, its effect on the various dimensions of knowledge and practice measures is not prominent. However, among the affected individuals, the 'standard of living' has a positive effect on all aspects of the disease. It may be explained that with widespread access to mass media such as radio, television

Table 3 Parameters estimate of structural equation model by maximum likelihood method for affected individuals

Parameter	Estimate	SE	Standardized value	Comments
Λ_y	1.00	–	0.22	Loading of KNDISSPD on AWARE
	0.86	0.18	0.33	Loading of KNDISTRT on AWARE
	1.00	–	0.63	Loading of KNDIAG on PREVENT
	0.68	0.10	0.56	Loading of KNDISPVT on PREVENT
	0.46	0.11	0.32	Loading of KNDISTRT on PREVENT
	−0.22	0.07	−0.31	Loading of PRACTMBI on PREVENT
	0.12	0.05	0.22	Loading of PREVENTM on PREVENT
	1.00	–	0.61	Loading of KNMOSBC on MOSQUITO
	0.43	0.07	0.63	Loading of PRACTMBI on MOSQUITO
	0.15	0.05	0.28	Loading of PREVENTM on MOSQUITO
Γ	0.14	0.04	0.70	Path coefficient from STDLIV to AWARE
	−0.83	0.22	−0.74	Path coefficient from GENDER to AWARE
	−0.01	0.002	−0.53	Path coefficient from INCOME to PREVENT
	0.19	0.03	0.50	Path coefficient from STDLIV to PREVENT
	0.94	0.21	0.46	Path coefficient from GENDER to PREVENT
	−0.02	0.01	−0.32	Path coefficient from AGE to PREVENT
	0.17	0.03	0.43	Path coefficient from STDLIV to MOSQUITO
	−0.02	0.005	−0.28	Path coefficient from AGE to MOSQUITO
Ψ	0.45	0.15	0.80	Residual covariance of AWARE and PREVENT
	0.43	0.16	0.42	Residual variance in PREVENT
	0.78	0.17	1.34	Residual covariance of AWARE and MOSQUITO
	0.39	0.11	0.36	Residual covariance of PREVENT and MOSQUITO
	0.84	0.19	0.76	Residual variance in MOSQUITO
E	6.20	0.51	0.95	Error in KNDISSPD
	1.36	0.15	0.66	Error in KNDISTRT
	1.54	0.19	0.60	Error in KNDIAG
	1.04	0.11	0.69	Error in KNDISPVT
	1.84	0.20	0.62	Error in KNMOSBC
	0.38	0.04	0.73	Error in PRACTMBI
	0.25	0.02	0.80	Error in PREVENTM
Θ_{ε}	−0.52	0.17	−0.17	Error covariance of KNDISSPD and KNDISPVT
	−0.60	0.08	−0.42	Error covariance of KNDISSPD and PREVENTM
	0.13	0.04	0.18	Error covariance of KNDISPVT and PREVENTM
$\Theta_{\delta\varepsilon}$	0.45	0.14	0.14	Error covariance of EDUCTN and PRACTMBI
	0.48	0.10	0.24	Error covariance of STDLIV and PRACTMBI
	−0.16	0.05	−0.20	Error covariance of GENDER and KNDIAG
	0.03	0.01	0.10	Error covariance of GENDER and PREVENTM
	6.30	2.07	0.14	Error covariance of AGE and KNDISSPD

– Parameter is constrained to "1", *SE* standard error

and cable television, the affected individuals are likely to be concerned to learn more about the various aspects of the disease. Since the literacy rate of females among the affected group was significantly ($P < 0.05$) lower than that of females in the non-infected group (Vanamail and Gunasekaran 2008), the gender effect is not remarkable among the affected individuals. Similarly the effect of age in the affected individuals is not seen clearly and it may be due to the fact that the majority (70%) of the affected individuals is above 30 years of age.

In view of our findings, it seems that a strong and committed health education program concentrating on preventive aspects related to disease causation, spread, mosquito breeding and control, especially for those who have a low level of formal schooling, is a prerequisite for any effective control strategy. However, the gestation

Table 4 Parameters estimates of structural equation model by maximum likelihood method for non-infected individuals

Parameter	Estimate	SE	Standardized value	Comments
Λ_y	1.00	–	0.45	Loading of KNDISSPD on AWARE
	1.00	0.15	0.61	Loading of KNDISTRT on AWARE
	1.00	–	0.58	Loading of KNDIAG on PREVENT
	0.63	0.09	0.59	Loading of KNDISPVT on PREVENT
	1.00	–	0.56	Loading of KNMOSBC on MOSQUITO
	0.06	0.03	0.10	Loading of PRACTMBI on MOSQUITO
	0.24	0.04	0.50	Loading of PREVENTM on MOSQUITO
Γ	0.12	0.02	0.55	Path coefficient from EDUCTN to AWARE
	0.08	0.02	0.39	Path coefficient from EDUCTN to PREVENT
	0.01	0.004	0.37	Path coefficient from INCOME to MOSQUITO
	0.05	0.02	0.15	Path coefficient from STDLIV to PREVENT
	0.64	0.18	0.30	Path coefficient from GENDER to AWARE
	0.79	0.19	0.34	Path coefficient from GENDER to MOSQUITO
	0.02	0.01	0.36	Path coefficient from AGE to AWARE
	−0.01	0.01	−0.19	Path coefficient from AGE to MOSQUITO
Ψ	0.56	0.24	0.51	Residual variance in AWARE
	0.96	0.17	0.90	Residual covariance of AWARE and PREVENT
	1.07	0.20	0.89	Residual covariance of AWARE and MOSQUITO
	0.79	0.20	0.76	Residual variance in PREVENT
	1.10	0.18	0.94	Residual covariance of PREVENT and MOSQUITO
	0.87	0.28	0.66	Residual variance in MOSQUITO
E	4.25	0.42	0.79	Error in KNDISSPD
	1.89	0.24	0.63	Error in KNDISTRT
	2.00	0.22	0.66	Error in KNDIAG
	0.79	0.09	0.66	Error in KNDISPVT
	2.87	0.32	0.69	Error in KNMOSBC
	0.51	0.05	0.99	Error in PRACTMBI
	0.22	0.02	0.75	Error in PREVENTM
Θ_ε	−0.31	0.07	−0.25	Error covariance of KNDISSPD and PREVENTM
	0.23	0.07	0.18	Error covariance of KNDIAG and PRACTMBI
	−0.09	0.03	−0.15	Error covariance of KNDISPVT and PREVENTM
$\Theta_{\delta\varepsilon}$	0.08	0.03	0.15	Error covariance of GENDER and KNDISPVT

– Parameter is constrained to "1", $\chi^2 = 97.9$, $df = 92$, $P = 0.318$, AGFI = 0.96, *SE* standard error

period to see the impact of education will be a long-term affair. Therefore, non-formal education through widespread mass media at community level is expected to have greater impact on the prevention of disease transmission in a short span of time. Realizing the importance of non-formal education a comic book was designed to improve knowledge and attitudes of Egyptian school children, which included messages on the acceptability of mass drug administration and stigma reduction (el-Setouhy and Rio 2003). The study claimed that the comic book administration significantly reduced the fear of the studied children that LF is a killer disease. The knowledge about the ability of treating and preventing LF was also significantly increased among the children after reading the comic book. A similar view was expressed in an earlier study (Suma et al. 2003) that in endemic countries, health education programs should be targeted at school level by introducing health education program in the school curriculum. India is the largest LF endemic country in the world, and has signed a resolution of the World Health Assembly (1997) calling for the elimination of LF as a public health problem globally. However, the prospects of global elimination will very much depend on the success in the Indian sub-continent. Further, LF does not get due priority of the planners and policy makers owing to the fact that it is not a direct cause to mortality (Cox 2000). Therefore, considering the goal of elimination, it can

Table 5 Total and standardized (Std) effects of exogenous on endogenous variables

Observed endogenous variables	EDUCTN		INCOME		STDLIV		GENDER		AGE	
	Total	Std	Total	Std	Total	Std	Total	Std	Total	Std
Among affected individuals										
KNDISSPD	0.00	0.00	0.00	0.00	0.14	0.15	−0.83	−0.16	0.00	0.00
KNDISTRT	0.00	0.00	−0.001	−0.17	0.21	0.40	−0.27	−0.09	−0.01	−0.10
KNDIAG	0.00	0.00	−0.001	−0.33	0.19	0.32	0.94	0.29	−0.02	−0.20
KNDISPVT	0.00	0.00	−0.001	−0.29	0.13	0.28	0.64	0.26	−0.01	−0.18
KNMOSBC	0.00	0.00	0.00	0.00	0.17	0.27	0.00	0.00	−0.02	−0.17
PRACTMBI	0.00	0.00	0.001	0.16	0.03	0.12	−0.21	−0.14	−0.001	−0.08
PREVENTM	0.00	0.00	−0.001	−0.12	0.05	0.23	0.12	0.10	0.001	−0.15
Among non-infected individuals										
KNDISSPD	0.12	0.25	0.00	0.00	0.00	0.00	0.64	0.14	0.02	0.16
KNDISTRT	0.12	0.33	0.00	0.00	0.00	0.00	0.64	0.18	0.02	0.22
KNDIAG	0.08	0.23	0.00	0.00	0.05	0.09	0.00	0.00	0.00	0.00
KNDISPVT	0.05	0.23	0.00	0.00	0.03	0.09	0.00	0.00	0.00	0.00
KNMOSBC	0.00	0.00	0.001	0.21	0.00	0.00	0.79	0.19	−0.01	−0.10
PRACTMBI	0.00	0.00	0.001	0.04	0.00	0.00	0.05	0.03	−0.001	−0.02
PREVENTM	0.00	0.00	0.001	0.19	0.00	0.00	0.19	0.17	−0.001	−0.09

very well be stated that, if planned properly, keeping in view of socio-economic characteristics and other logistics, LF elimination could be achieved in India at least in the target year of 2015 if not earlier.

The limitation of the present study is that each person's data were from one time point so there was no temporal sequence, which would enable causality to be inferred with more confidence. Further, the model developed here is not a predictive one, but it is a theory testing concept. Therefore, taking this lacuna into consideration, it can be concluded that applying this kind of cause-effect model to the major vector-borne diseases would pave way to plan an efficient control strategy towards their elimination.

Acknowledgments The authors are grateful to Drs. M. Kalyanasundaram, Officer-in-Charge and S. Sabesan, Scientist "F", Vector Control Research Centre, Pondicherry for their help and encouragement during the study. They acknowledge the health authorities of Pondicherry Government for their help and cooperation during the study. The authors are also grateful to the reviewers for their critical review and editing work.

Appendix

The transformation of the likelihood function that is often used in maximum likelihood estimation (MLE) is given by

$$H = \log[\det(Z)] + \text{tr.}\left[SZ^{-1}\right] - \log[\det(S)] - U,$$

where "log" means natural logarithm, "det" means determinant, "tr." means trace (sum of main diagonal), U total number of measured exogenous (q) and endogenous (p) indicators, S unbiased sample estimate of covariance matrix of observed indicators, Z estimate of covariance matrix of measured indicators based on estimates of model parameters, and Z^{-1} inverse of Z matrix.

Minimization of this function is used to obtain estimates of model parameters from the sample data. As the sample size increases, the sample estimates become closer to the population values. The minimum value of H can be used to compute a likelihood ratio χ^2 statistic that allows us to test the degree of congruence of the covariance structure implies by the theory and that observed by empirical data. This χ^2 statistics is given by

$$\chi^2 = \min(H)(N/2),$$

with $df = [(p + q)(p + q - 1)/2 + (p + q)] - f$, where N sample size, and f number of free parameters estimated.

The emphasis was on understanding the causal sequence of relationships implies by the theory. In SEM for sound statistical reasons, it is usual to analyze covariance matrix and not correlation matrix. Therefore, observed variance covariance matrix between exogenous and endogenous variables was used as input data for fitting the full structural LISREL model. Initially, the measurement errors of exogenous and endogenous variables were assumed to be uncorrelated. Therefore, the corresponding covariance matrices of Θ_δ and Θ_ε (Table 1) were presumed to be diagonal. Accordingly, the model with the following matrix specifications was fitted.

Model (a)

Matrix	Form	Fixed elements	Value
Λ_y	Rectangular	(1,1), (3,2), (5,3)	1.00
B	Rectangular	All	0.00
Γ	Rectangular	Nil	–
Φ	Symmetric	All	–
Ψ	Symmetric	Nil	–
Θ_ε	Symmetric	Off-diagonal	–
Θ_δ	Diagonal	All	0.00
$\Theta_{\delta\varepsilon}$	Rectangular	All	0.00

The coefficients involved in this model were estimated and the model yielded a very high χ^2 value (310.7; $P < 0.001$ for 92 *df*) indicating that the fit was unacceptable. If the fit of a model is not adequate, it has been common practice to modify the model, by deleting parameters that are not significant and adding parameters that improves the fit. Therefore, statistical significance of individual parameter estimation was tested based on a null hypothesis that a parameter in a measurement model is zero. To reject this null hypothesis, a test criterion that the ratio of parameter estimation to its standard error approximately equals to 2 (fixing the confidence probability of 95%) was used. Accordingly, 14 parameter estimates of exogenous path coefficients in both affected and non-infected groups were not statistically significant. Therefore, a constraint was imposed that these 14 exogenous path coefficients were zero. While the model was fitted again the χ^2 value was 317.3 for 106 *df* The difference in χ^2 (317.3–310.7) between the two models was not statistically significant at 14 *df* confirming that these path coefficients are zero. Further, to improve the model fit, modification indices of all the fixed parameters were examined and the maximum modification index was 51.5 for Θ_ε (7, 1) in affected group and this parameter was set free. While the model was fitted again, as expected the χ^2 value was reduced to 248.9 for 105 *df* indicating that the parameter is significant for the refinement of the model.

Model (b)

At each step the parameter that showed maximum modification index was freed to obtain the largest improvement in the fit. This process is shown below until an adequate fit was reached.

Group	Fixed parameter	Maximum modification index	Action taken	Model χ^2	Reduction in χ^2
Non-infected	Θ_ε (7, 1)	15.62	Freed	226.3	22.6
Affected	$\Theta_{\delta\varepsilon}$ (3,6)	14.41	Freed	217.4	8.9
Affected	$\Lambda_{y\ (6,2)}$	14.02	Freed	197.4	20.0
Non-infected	Θ_ε (6, 3)	11.25	Freed	187.3	10.1
Affected	$\Theta_{\delta\varepsilon}$ (1,6)	11.07	Freed	174.2	13.1
Affected	$\Theta_{\delta\varepsilon}$ (4,7)	9.53	Freed	162.7	11.5
Affected	$\Lambda_{y\ (2,2)}$	10.79	Freed	151.2	11.5
Affected	$\Lambda_{y\ (7,2)}$	9.37	Freed	141.9	9.3
Affected	$\Theta_{\delta\varepsilon}$ (5,1)	8.76	Freed	133.2	8.7
Non-infected	$\Theta_{\delta\varepsilon}$ (4,4)	8.71	Freed	123.9	9.4
Non-infected	Θ_ε (7, 4)	6.61	Freed	115.3	8.6
Affected	$\Theta_{\delta\varepsilon}$ (4,3)	5.54	Freed	109.7	5.6
Affected	Θ_ε (7, 4)	6.83	Freed	103.7	6.0
Affected	Θ_ε (4, 1)	7.82	Freed	96.8	6.9
Non-infected	$\Theta_{\delta\varepsilon}$ (1,5)	5.22			

Since the maximum modification index 5.22 for the element $\Theta_{\delta\varepsilon}$ (1,5) was in the tolerable level of 5.0, further refinement of model was felt redundant. However, the parameter estimate for Ψ (1,1) was not statistically significant. Therefore, it was fixed to be zero and the resultant model χ^2 was 97.9 for 92 *df*. The good fit of the model and its assessment indices are presented in the result part.

References

Babu BU, Kar SK (2004) Coverage, compliance and some operational issues of mass drug administration during the programme to eliminate lymphatic filariasis in Orissa, India. Trop Med Int Health 9:702–709

Cox FEG (2000) Elimination of lymphatic filariasis as a public health problem. Parasitol Today 16(4):135

Das PK, Manoharan A, Subramanian S, Ramaiah KD, Pani SP, Rajavel AR, Rajagopalan PK (1992) Bancroftian filariasis in Pondicherry, South India: epidemiological impact of recovery of vector population. Epidemiol Infect 108:483–493

El-Setouhy MA, Rio F (2003) Stigma reduction and improved knowledge and attitudes towards filariasis using a comic book for children. J Egypt Soc Parasitol 33:55–65

Esterre P, Plichart C, Sechan Y, Nguyen NL (2001) The impact of 34 years of massive DEC chemotherapy on *Wuchereria bancrofti* infection and transmission: the Maupiti cohort. Trop Med Int Health 6:190–195

Hoyle RH, Smith GT (1994) Formulating clinical research hypotheses as structural equation models: a conceptual overview. J Consult Clin Psychol 62:429–440

Joreskog KG (1973) A general method of estimating a linear equation system. In: Goldberger AS, Duncan OD (eds) Structural equation models in the social sciences. Seminar Press, New York, pp 85–112

Joreskog KG (1977) Structural equation models in the social sciences. Specification, estimation, and testing. In: Krishnaiah PR (ed) Application of statistics. North-Holland, Amsterdam, pp 265–287

Joreskog KG, Sorbom D (1978) LISREL IV: analysis of linear structural relations by the method of maximum likelihood. National Educational Resources, Chicago

Joreskog KG, Sorbom D (1984) LISREL VI: analysis of linear structural relationships by maximum likelihood, instrumental variables, and least square methods, 3rd edn. Scientific Software, Mooresville. ISBN 0-8949-8024-6

Kahn HA, Sempos CT (1989) Sample size calculation using odds ratio. In**:** Statistical methods in epidemiology. Oxford University Press, New York, pp 64–71

Manoharan A, Das PK, Keerthiseelan VB, Ramaiah KD (1997) Trend in *Wuchereria bancrofti* infection in Pondicherry urban agglomeration after withdrawal of a five-year vector control programme. J Commun Dis 29:255–261

Mathieu E, Lammie PJ, Radday J, Beach MJ, Streit T, Wendt J, Addiss DG (2004) Factors associated with participation in a campaign of mass treatment against lymphatic filariasis, in Leogane, Haiti. Ann Trop Med Parasitol 98:703–714

Michael E, Bundy DAP, Grenfell BT (1996) Re-assessing the global prevalence and distribution of lymphatic filariasis. Parasitology 112:409–428

Ottesen EA (2000) The global programme to eliminate lymphatic filariasis. Trop Med Int Health 5:591–594

Rajagopalan PK, Das PK, Subramanian S, Vanamail P, Ramaiah KD (1989) Bancroftian filariasis in Pondicherry, south India. 1. Pre-control epidemiological observations. Epidemiol Infect 103: 685–692

Ramaiah KD, Vijay Kumar KN, Ravi R, Das PK (2005) Situation analysis in a large urban area of India, prior to launching a programme of mass drug administration to eliminate lymphatic filariasis. Ann Trop Med Parasitol 99:243–252

Richards FO Jr, Pam DD, Kal A, Gerlong GY, Onyeka J, Sambo Y, Danboyi J, brahim B, Terranella A, Kumbak D, Dakul A, Lenhart A, Rakers L, Umaru J, Amadiegwu S, Withers PC Jr, Mafuyai H, Jinadu MY, Miri ES, Eigege A (2005) Significant decrease in the prevalence of *Wuchereria bancrofti* infection in anopheline mosquitoes following the addition of albendazole to annual, ivermectin-based, mass treatments in Nigeria. Ann Trop Med Parasitol 99(2):155–164

Subramanian S, Pani SP, Das PK, Rajagopalan PK (1989) Bancroftian filariasis in Pondicherry, South India: 2. Epidemiological evaluation of the effect of vector control. Epidemiol Infect 103:693–702

Suma TK, Shenoy RK, Kumaraswami V (2003) A qualitative study of the perceptions, practices and socio-psychological suffering related to chronic brugian filariasis in Kerala, southern India. Ann Trop Med Parasitol 97:839–845

Sunish IP, Rajendran R, Mani TR, Munirathinam A, Tewari SC, Hiriyan J, Gajanana A, Satyanarayana K (2002) Resurgence in filarial transmission after withdrawal of mass drug administration and the relationship between antigenaemia and microfilaraemia—a longitudinal study. Trop Med Int Health 7:59–69

Surendran K, Pani SP, Soudarssanane MB, Srinivasa DK, Bordolai PC, Subramanian S (1996) Natural history, trend of prevalence and spectrum of manifestations of Bancroftian filarial disease in Pondicherry (South India). Acta Trop 61:9–18

Vanamail P, Gunasekaran S (2006) A study on risk factors of *Wuchereria bancroftian* filarial disease in Pondicherry. Demogr India 35:159–171

Vanamail P, Gunasekaran S (2008) A quantitative analysis of the socio-economic determinants of health seeking behaviour related to bancroftian filariasis and its impact on elimination: a case–control study in Pondicherry, India. J Public Health 16:339–346

Wijesinghe RS, Ekanayake S, Perera MS, Wickremasinghe AR (2007) Knowledge and perceptions of filariasis in Colombo, Sri Lanka, among patients with chronic filarial lymphoedema. Ann Trop Med Parasitol 101:215–223

World Health Assembly (1997) Elimination of lymphatic filariasis as a public health problem. A 50.29