Determinants of pneumonia among children attending public health facilities in Worabe town

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Childhood pneumonia is common in developing countries, with significant morbidity and mortality. Taking the significance of the problem and variability of risk factors into account, a study was needed to identify the potential determinants of pneumonia in under-five children. A facility-based unmatched case–control study was conducted among 435 children (145 cases and 290 controls) aged 2–59 months at public health facilities in Worabe town from December 28, 2016, to January 30, 2017. Data were collected using interviewer-administered questionnaire and analysed using SPSS version 22. Bivariable and multivariable binary logistic regression were used to determine association between dependent and independent variables. Among the factors assessed, stunting [AOR = 3.6, 95% CI: 1.9–6.9], carrying the child on the back during cooking [AOR = 2.0, 95% CI: 1.2–3.2], absence of chimney in the cooking room [AOR = 2.2, 95% CI: 1.3–3.7], having a history of asthma [AOR = 5.0, 95% CI: 2.0–12], and a previous acute upper respiratory tract infection [AOR = 3.7, 95% CI: 2.3–6.1] were significantly associated with pneumonia.

Abbreviations

AURT I  Acute upper respiratory tract infection
ICCM  Integrated community case management
IMNCI  Integrated management of neonatal and childhood illness
WCSH  Worabe comprehensive specialized hospital
WHO  World Health Organization

Pneumonia is a respiratory tract infection that affects children. *Streptococcus pneumoniae*, *Haemophilus influenzae* type b (Hib), and respiratory syncytial virus are among the common pathogens involved. *S. pneumoniae* is the most common cause of bacterial pneumonia during childhood in the developing countries. Microbes that are commonly found in upper respiratory tract can cause lower respiratory tract infection. They may also spread via air-borne droplets at the time of cough or sneeze or may spread through blood, especially during and shortly after birth. Pneumonia is the major killer of under-five children than any other disease known to affect children. Childhood pneumonia causes substantial mortality and morbidity among under-five children, with developing nations carrying the highest pneumonia burden.

Every year, nearly 1 million children die of pneumonia worldwide and approximately about 15% of all deaths occur in children under age of five. This means a loss of over 2500 children's lives every day or 100 children every hour. It is the most prevalent in sub-Saharan Africa and South Asia, Nigeria, Pakistan, the Democratic Republic of Congo, and Ethiopia, accounting for 50% of total deaths. In Ethiopia, pneumonia is the leading cause of death, accounting for 18% of all under-five mortality burdens. As a result, Ethiopia ranks fifth (62 deaths in 1000) among 15 countries in the world and has the highest death rate from clinical pneumonia in under five children. It also causes millions of morbidity and adds costs to the health services program; as health services are passed on to cure high pneumonia morbidity cases, with an estimated 3,370,000 children encountering pneumonia annually.

Ethiopia follows the same strategy and has adopted the World Health Organization (WHO) Integrated Management of Childhood Illness (IMNCI) guidelines since 2001. Moreover, with the objective of increasing access to life-saving interventions, Ethiopia made a policy breakthrough of introducing community-based treatment.
of pneumonia through health extension workers in 2010. Since then, 38,000 health extension workers from nearly 15,000 health posts have been equipped with the skills and supplies to treat pneumonia at the community level using the integrated community case management (ICCM) approach.

Previous studies indicated that some of most determinants for pneumonia include the educational status of parents, age of the mother, family child caring practice, family income, age and sex of the child, parental smoking or indoor air pollution from biomass fuel smoke, absence window in the kitchen, overcrowding, parental asthma, household history of pneumonia, malnutrition, lack exclusively breastfeeding, lack of zinc supplementation, comorbidity condition such as diarrhoea, measles, acute upper respiratory infection (AURTI), and previous history of asthma.

Contributing factors of pneumonia need to be studied to better inform health care providers and policymakers to consider pneumonia prevention strategies. Although there are studies conducted in Ethiopia, the risk factors for pneumonia differ in different societies and study populations. Taking the high burden of pneumonia and variability of risk factors into account, this study is envisaged to identify the potential determinants of pneumonia in under-five children. Above all, there was no previous study in the study area that could show the determinants of pneumonia.

**Methods**

**Study setting and study design.** An unmatched case–control study was conducted from December 28, 2016, to January 30, 2017, in public health facilities located in Worabe town, Silte zone, Southern Nation Nationalities, and People's Region. Worabe town is the capital town of Silte zone. The town has a total population of 29,600, of which 4618 are under-five children. There are two public health facilities in Worabe town and 6 private clinics.

**Study population.** Children who were 2–59 months old, and those who visited the selected health facilities during the study period.

Cases were children aged 2–59 months who visited pediatric units, registered and diagnosed with pneumonia as defined by the Federal Democratic Republic of Ethiopian Ministry of Health Integrated Management of Childhood Illness (IMNCI) guideline that is adapted from WHO.

The control group was defined as children aged 2–59 months without pneumonia and attended the public health facilities in Worabe town.

**Sample size determination and sampling technique.** A sample size of 435 (145 cases and 290 controls) was determined using Epi-Info version 3.5.4 statistical software assuming two side confidence level (CI) of 95%, power = 80%, ratio control to case 2:1, and taking a history of AURTI as a predictor of pneumonia with 22.4% prevalence among control group; 1.80 Odds ratio from a case–control study and an estimated non-response rate of 10%. All public health facilities in the town were purposively included based on patient load and the presence of accessible trained staff on IMNCI. The sample size was distributed to each health facility based on the average daily caseload. According to the zonal health bureau Health Management Information System report, the average daily pneumonia patients among under-five children at Worabe comprehensive specialized hospital (WCWH) was seven and it was two at Worabe Health Centre. Based on this, the sample size allocated for the Worabe health centre was one case and two controls on a daily basis with a total of 21 cases and 42 controls. The sample size allocated for WCWH was six cases and twelve controls on a daily basis with a total of 124 cases and 248 controls.

**Selection of cases.** All cases (diagnosed and recorded as pneumonia/severe pneumonia) were considered in the study until the required sample size was reached/fulfilled.

**Selection of controls.** As the control-to-case ratio was 2:1, two children who did not have pneumonia and visited selected health facilities for different services at the time of data collection were randomly selected by systematic random sampling after the cases were identified.

**Eligibility criteria.** The study included children who were between 2 and 59 months of age, those who were residents of Worabe town for a minimum of six months, and visited the pediatric unit of WCWH and Worabe Health Center during the study period.

Children with the following conditions were excluded from the study: cardiac disease, cough that lasted for >15 days (suspected of pulmonary tuberculosis), cough because of the recent history of aspiration of a liquid or a foreign body, and caregiver who did not have any information about the child at the time of data collection.

**Study variables.**

**Dependent variables.** Presence of pneumonia.

**Independent variables.** Socio-demographic factors: Parental factors such as educational and occupational status, parental cigarette smoking, age of the mother, family size, and family caring practice (parental/home maid, place of child during cooking, and family income).

Child factors: age and sex, immunization status, a pre-existing illness such as a history of diarrhoea, AURTI, and acute lower respiratory tract infection/pneumonia in the last 2 weeks and asthma.

Environmental factors: type of fuel used for cooking, crowding status, place of cooking, parental asthma, and household history of tuberculosis and pneumonia.
Nutritional condition of the child: undernutrition, breastfeeding status of the child for the first 6 months and duration of breastfeeding, age of complementary feeding started, and zinc supplementation.

**Operational definitions.**

**Pneumonia.** A child aged 2–59 months with cough and/or difficulty in breathing for less than two weeks of duration plus fast breathing and/or chest in drawing \(^{15–19}\). Fast breathing is defined as:

- For children in the age interval of 2–11 months, 50 breaths per minute or more
- For children in the age interval of 12 months to 5 years, 40 breaths per minute or more \(^{39–41}\).

History of acute upper respiratory tract infection (AURTI): a child who had a history of ear infection, common cold, tonsillitis, or pharyngitis in the last fifteen days prior to data collection \(^{42}\).

**Underweight:** Weight at the birth of less than 2500 g \(^{35,44}\).

**Stunting:** Chronic undernutrition condition in which a child is short for his or her age \(^{44}\).

**Wasting:** Unintended loss of weight which makes children too thin and weak \(^{46}\).

**Data collection tools and procedures.** A structured questionnaire was developed based on a review of previously published studies and adapted for the current study with certain modifications \(^{17–28}\). The questionnaires included information on the possible risk factors for pneumonia, including socio-demographic factors, environmental/home-based factors, nutritional factors, immunization status, pre-existing illness and child care practices. Data were collected by IMNCI-trained nurses working in under-five clinics who received two days of training regarding the research. After the study participants were identified as cases and controls, mothers/primary caretakers were interviewed based on the interviewer-administered pretested structured questionnaire.

**Anthropometric measurements.** The weight and height of the child were taken at the beginning of the interview by data collectors. A suspended scale of 25 kg capacity graduated at 0.1 kg was used for weighing infants and children. The reading was recorded to the nearest 0.1 kg. Length measurements in the lying position were taken for children less than two years of age, and height measurements were taken for children 2–5 years of age. The anthropometric data were analysed in terms of weight for age, length for age, and weight for length using WHO Anthrosoftware to prepare for SPSS. The WHO (2006) growth standard was used to report anthropometric measurements result by Z-score, and the global acute malnutrition standard was used to classify the child’s nutritional status as normal, stunted, wasted, or underweight.

**Data quality management.** The questionnaire was pretested on a 5% sample size at Kbit Primary Hospital to ensure the validity and reliability of the survey tools. After collecting the pre-test data, it was checked for potential problems related to the tool, such as any difficult question that was understandable or unclear to reply and corrective measures were taken.

**Data processing and analysis.** The collected data were checked for completeness, coded and entered into Epi Info version 7 and exported to the statistical package for social sciences (SPSS) version 22 for analysis. The entered data were cleaned and checked for consistency and extent of outliers. Different statistical assumptions and appropriate corrections were made prior to analysis. Descriptive analyses were carried out for each of the independent variables. Bivariable and multivariable binary logistic regression analysis was used to test the association between the independent and dependent variables. Bivariable analysis was performed for each of the independent variables with the outcome variable. Variables that had a \(p\)-value < 0.2 on bivariate analysis were taken as candidates for multivariable binary logistic regression model analysis to identify predictors of the outcome variables. Variables with a \(p\)-value less than 0.05 on multivariable logistic regression analysis were considered statically significant factors for the outcome variables. The strength of the association between the dependent variable and independent variables was expressed using adjusted odds ratio (AOR) with 95% confidence intervals.

**Ethical approval and consent to participant.** The study was ethically approved by the Institutional Review Board of Saint Paul’s Millennium Medical College Department of Public Health. An official permission letter was obtained from the study site. The objectives, expected outcomes, benefits, and risks of the study were explained to mothers/guardians/caregivers of the study participants. Data were collected after written informed consent was obtained. The study was conducted in accordance with the Declaration of Helsinki.

**Results**

**Socio-demographic characteristics.** A total of 435 (145 cases and 290 controls) children aged 2–59 months participated in the study, making the response rate 100% for both groups. The highest proportion of cases (57.2%) and controls (62.4%) were in the age group of 2–11 months, with mean ages of 14.6 (SD ± 12.8) and 12.6 months (SD ± 12.7) for cases and controls respectively. Approximately 52% of cases and 51% of controls were males (Table 1).

**Nutritional, pre-existing illness and vaccination status of the children.** The majority (79.3%) of cases and 85.5% of controls were exclusively breastfed for the first six months of life. Regarding the nutritional sta-
The study indicated that; variables such as Zinc supplementation \((p = 0.01)\), stunting \((p = 0.001)\), wasting \((p = 0.06)\), exclusive breastfeeding for the first 6 months \((p = 0.1)\), a child with the previous history of AURTI \((p < 0.001)\), and diarrhoea \((p = 0.06)\) in the past two weeks and history of asthma \((p < 0.001)\) were associated with the occurrence of pneumonia in the bivariate logistic regression at \(p < 0.2\) (Table 2).

Table 1. Socio-demographic characteristics of children aged 2–59 months attending public health facilities in Worabe town, Silte zone, 2017\((N = 145\) cases and 290 controls). COR crude odds ratio, CI confidence interval, 1 reference group.

| Variables                      | Cases Frequency | Cases Percent | Controls Frequency | Controls Percent | Total Frequency | Total Percent | P-value | COR(95% C.I) |
|-------------------------------|----------------|--------------|--------------------|------------------|----------------|--------------|---------|--------------|
| **Age of the child**          |                |              |                    |                  |                |              |         |              |
| 2–11 months                   | 83             | 57.2         | 181                | 62.4             | 264            | 60.7%        | 0.200   | 0.7 [0.4, 1.2] |
| 12–23 months                  | 31             | 21.4         | 61                 | 21               | 92             | 21.1%        | 0.500   | 0.8 [0.4, 1.5] |
| 24–59 months                  | 31             | 21.4         | 48                 | 16.6             | 79             | 18.2%        | 1       |              |
| **Sex of the child**          |                |              |                    |                  |                |              |         |              |
| Male                          | 76             | 52.4         | 148                | 51               | 224            | 51           | 0.800   | 1.2 [0.7, 1.6] |
| Female                        | 69             | 47.6         | 142                | 49               | 211            | 49           | 1       |              |
| **Age of the mother**         |                |              |                    |                  |                |              |         |              |
| 18–24                         | 38             | 26.2         | 95                 | 32.8             | 133            | 31           | 0.5     | 0.8 [0.5, 1.5] |
| 25–31                         | 79             | 54.5         | 138                | 47.6             | 217            | 50           | 0.6     | 1.2 [0.7, 1.9] |
| ≥32                           | 28             | 19.8         | 57                 | 19.7             | 85             | 19           | 1       |              |
| **Educational status of mother** |           |              |                    |                  |                |              |         |              |
| Not formal education          | 51             | 35.2         | 80                 | 27.6             | 131            | 30.1         | 0.7     | 1 [0.6, 2.2] |
| Primary school                | 51             | 35.2         | 130                | 44.8             | 181            | 41.6         | 0.29    | 0.7 [0.4, 1.3] |
| Secondary school              | 24             | 16.6         | 46                 | 15.9             | 70             | 16           | 0.86    | 0.9 [0.4, 1.9] |
| Higher education              | 19             | 13.1         | 34                 | 11.7             | 53             | 12.2         | 1       |              |
| **Educational status of father** |          |              |                    |                  |                |              |         |              |
| No formal education           | 44             | 30.3         | 71                 | 24.5             | 115            | 26.4         | 0.4     | 1.3 [0.7, 2.4] |
| Primary                      | 53             | 36.6         | 121                | 41.7             | 174            | 40           | 0.8     | 0.9 [0.5, 1.6] |
| Secondary                    | 21             | 14.5         | 41                 | 14.1             | 62             | 14.3         | 0.8     | 1 [0.5, 2.2] |
| Higher                       | 27             | 18.6         | 57                 | 19.6             | 84             | 19.3         | 1       |              |
| **Mother's occupation**       |                |              |                    |                  |                |              |         |              |
| House wife                    | 88             | 60.7         | 204                | 70.3             | 292            | 67.2         | 0.2     | 0.5 [0.2, 1.4] |
| Civil servant                 | 17             | 11.7         | 33                 | 11.4             | 50             | 11.5         | 0.4     | 0.6 [0.2, 1.9] |
| Merchant                      | 33             | 22.8         | 45                 | 15.5             | 78             | 17.9         | 0.7     | 0.8 [0.3, 2.5] |
| Others                        | 7              | 4.8          | 8                  | 2.8              | 15             | 3.4          | 1       |              |
| **Father’s occupation**       |                |              |                    |                  |                |              |         |              |
| Merchant                      | 51             | 35.2         | 124                | 42.8             | 175            | 40.3         | 0.9     | 0.9 [0.5, 1.9] |
| Daily labourers               | 44             | 30.3         | 71                 | 24.4             | 115            | 26.4         | 0.3     | 1.5 [0.7, 2.9] |
| Civil servant                 | 31             | 21.4         | 50                 | 17.2             | 81             | 18.6         | 0.3     | 1.5 [0.7, 2.9] |
| Others                        | 19             | 13.1         | 45                 | 15.5             | 64             | 14.7         | 1       |              |
| **Family monthly income in Ethiopian birr** |             |              |                    |                  |                |              |         |              |
| < 1000                        | 23             | 15.9         | 64                 | 22.1             | 87             | 20           | 0.4     | 0.8 [0.4, 1.4] |
| 1000–1500                     | 27             | 18.6         | 39                 | 13.4             | 66             | 15.2         | 0.2     | 1.4 [0.8, 2.7] |
| 1600–2500                     | 53             | 36.6         | 99                 | 34.1             | 152            | 34.9         | 0.7     | 1.1 [0.7, 1.8] |
| >2500                         | 42             | 29.0         | 88                 | 30.3             | 130            | 29.9         | 1       |              |
| **Family size**               |                |              |                    |                  |                |              |         |              |
| 2–3                           | 26             | 17.9         | 69                 | 23.8             | 95             | 21.8         | 0.1*    | 0.8 [0.5, 1.3] |
| 4–5                           | 67             | 46.2         | 135                | 46.6             | 202            | 46.5         | 0.4     | 0.6 [0.4, 1.1] |
| ≥6                            | 52             | 35.9         | 86                 | 29.7             | 138            | 31.7         | 1       |              |
| **Family child care practice** |                |              |                    |                  |                |              |         |              |
| Parental                      | 116            | 80           | 228                | 78.6             | 344            | 79           | 0.7     | 1 [0.7, 1.8] |
| Home maid                     | 29             | 20           | 62                 | 21.4             | 91             | 21           | 1       |              |

tus of the children, 11.9% cases and 9% controls, 26.9% cases and 18.6% controls were underweight and stunted respectively. More than 90% of cases and 95% of controls received pentavalent and pneumococcal conjugate vaccines.
Environmental factors associated with pneumonia. More than half of the cases (57.2%) and controls (54.8%) lived in households that used wood as a source of energy for cooking. The highest proportion of cases (63.4%) and controls (63.8%) had mothers cooking their food in the kitchen. Approximately 61% of cases and 44% of controls stayed near or on their mothers'/care takers back while she was cooking. The bivariate logistic regression analysis revealed that crowding \( (p = 0.04) \), type of energy source for cooking \( (p = 0.02) \), absence of chimneys in the cooking room \( (p < 0.01) \), and place of a child during cooking \( (p < 0.01) \) had significant associations with pneumonia among children (Table 3).

Factors associated with pneumonia among children aged 2–59 months. All variables analysed by bivariate binary logistic regression showed a \( p \)-value less than 0.2. Multivariable binary logistic regression analysis showed that stunting, previous history of asthma diagnosis in the child, place of the child during cooking, absence of chimney in the cooking room and history of AURTI in the last 2 weeks prior to data collection were determinants of pneumonia. The findings revealed that the odds of stunting were 3.6 times higher among children with pneumonia than controls \( (\text{AOR} = 3.6, 95\% \text{ CI}: 1.8, 7; p < 0.001) \). On the other hand, the odds of carrying the child on the back while cooking/beside the cooking mother were twice as high as those of compared to children outside of the cooking room among cases than controls \( (\text{AOR} = 2, 95\% \text{ CI}: 1.2, 3.3; p = 0.006) \).

| Variables                                      | Case Frequency | Case Percent | Control Frequency | Control Percent | Total Frequency | Total Percent | \( p \)-value | COR(95% CI) |
|-----------------------------------------------|----------------|--------------|-------------------|-----------------|----------------|---------------|--------------|-------------|
| Breast feeding status of the child during the first 6 months |                |              |                   |                 |                |               |              |             |
| Exclusive BF                                   | 115            | 79.3         | 247               | 85.2            | 362            | 83.2          | 0.1*         | 1.2 (0.9, 1.6) |
| Mixed feeding                                 | 30             | 20.7         | 43                | 14.8            | 73             | 16.8          |              | 1           |
| Zinc Supplementation                          |                |              |                   |                 |                |               |              |             |
| Supplemented                                  | 56             | 38.6         | 77                | 26.6            | 133            | 30.6          | 0.01*        | 1.7 [1.1, 2.7] |
| Not supplemented                              | 89             | 61.4         | 213               | 73.4            | 302            | 69.4          |              | 1           |
| Weight for age                                |                |              |                   |                 |                |               |              |             |
| Underweight                                   | 17             | 11.7         | 26                | 9               | 43             | 9.9           | 0.4          | 1.3 (0.7, 2.6) |
| Normal                                        | 128            | 88.3         | 264               | 91              | 392            | 90.1          |              | 1           |
| Height for age                                |                |              |                   |                 |                |               |              |             |
| Stunted                                       | 36             | 24.8         | 23                | 7.9             | 59             | 13.6          | 0.00*        | 3.8 (2.2, 6.8) |
| Not stunted                                   | 109            | 75.2         | 267               | 92.1            | 376            | 86.4          |              | 1           |
| Weight for height                             |                |              |                   |                 |                |               |              |             |
| Wasted                                        | 29             | 20           | 38                | 13.1            | 67             | 15.4          | 0.06*        | 1.7 (0.9, 2.8) |
| Not wasted                                    | 116            | 80           | 252               | 86.9            | 368            | 84.6          |              | 1           |
| Do the child received Pentavalents vaccine    |                |              |                   |                 |                |               |              |             |
| Yes                                           | 134            | 92.4         | 277               | 95.5            | 411            | 94.5          | 0.2          | 0.6 (0.3, 1.3) |
| No                                            | 11             | 7.6          | 13                | 4.5             | 24             | 5.5           |              | 1           |
| Get measles vaccine                           |                |              |                   |                 |                |               |              |             |
| Yes                                           | 76             | 52.4         | 128               | 44.1            | 203            | 46.7          | 0.70         | 1.5 (0.9, 2.3) |
| No                                            | 13             | 4.9          | 28                | 9.7             | 50             | 11.5          | 0.50         | 1.3 (0.7, 2.5) |
| N/A(age < 9 months)                           | 56             | 38.6         | 134               | 46.2            | 182            | 41.8          |              | 1           |
| Diarrhoea in last 2 weeks                     |                |              |                   |                 |                |               |              |             |
| Yes                                           | 44             | 30.3         | 54                | 18.6            | 98             | 22.5          | 0.06*        | 1.9 [1.2, 3]  |
| No                                            | 101            | 69.7         | 236               | 81.4            | 337            | 77.5          |              | 1           |
| AURTI in the last 2 weeks                     |                |              |                   |                 |                |               |              |             |
| Yes                                           | 68             | 46.9         | 51                | 17.6            | 119            | 27.4          | 0.00*        | 4 [2.7, 6.5]  |
| No                                            | 77             | 53.1         | 239               | 82.4            | 316            | 72.6          |              | 1           |
| Previous history of asthma in the child       |                |              |                   |                 |                |               |              |             |
| Yes                                           | 23             | 15.9         | 10                | 3.4             | 33             | 7.6           | 0.00*        | 5.3 [2.4, 11.4] |
| No                                            | 122            | 84.1         | 280               | 96.6            | 402            | 92.4          |              | 1           |
| Pneumonia among family in last 2 weeks        |                |              |                   |                 |                |               |              |             |
| Yes                                           | 34             | 23.4         | 61                | 21              | 95             | 21.8          | 0.6          | 1.2 (0.7, 1.9) |
| No                                            | 111            | 76.6         | 229               | 79              | 340            | 78.2          |              | 1           |
| Parental asthma                               |                |              |                   |                 |                |               |              |             |
| Yes                                           | 7              | 4.8          | 13                | 4.5             | 20             | 4.6           | 0.8          | 1.1 (0.4, 2.8) |
| No                                            | 138            | 95.2         | 277               | 95.5            | 415            | 95.4          |              | 1           |

Table 2: Nutritional status, vaccination status and pre-existing illness among children aged 2–59 months attending public health facilities in Worabe town, Silte zone, 2017 (N = 145 cases and 290 controls). BF breast feeding, COR crude odds ratio, CI confidence interval, 1 reference group.
Similarly, the odds of children living in households with no chimney in the cooking room were 2.2 times higher among cases than controls (AOR = 2, 95% CI: 1.3, 3.7; \(p = 0.003\)). The odds of having a previous history of asthma were fivefold higher among cases than controls (AOR = 5, 95% CI: 2, 12; \(p < 0.001\)). Likewise, the odds of having a history of AURIT in the last 2 weeks prior to data collection were 3.7 times higher among children with pneumonia than among children without pneumonia (AOR = 3.7, 95% CI: 2.3, 6.1; \(p < 0.001\)) (Table 4).

### Discussion

In this study, pre-existing respiratory illnesses, such as a history of asthma in the child and a previous history of AURTI, undernutrition (stunting), absence of chimney in the cooking room, and carrying the child on the back during cooking, were found to be significant risk factors associated with the occurrence of pneumonia among children aged 2–59 months.

The odds of carrying the child on the back while cooking was 2 times greater than that of children who pass outside of the cooking room among cases than controls. This could be due to indoor pollution as a result of unsafe energy sources such as charcoal, wood, and biomass. This result is consistent with a cross-sectional study conducted in northwest Ethiopia found that a child who was carried on the back of mother during cooking was five times more likely to develop pneumonia than their counterparts\(^{17}\). Similar findings were obtained in different countries that reported indoor air pollution as a risk factor for pneumonia\(^{15,25,28–30}\). However, two studies conducted in Ethiopia did not report a significant association between the place of the child during cooking and the occurrence of pneumonia in children\(^{18,23}\). The variation of the results could be due to differences in study setting and methodology used.

Stunting was another factor identified to be significantly associated with pneumonia, indicating that the odds of stunting were 3.6 times higher among children with pneumonia than controls, which is in line with a study conducted in Northwest Ethiopia and Bangladesh\(^{17,19}\). The possible reason might be that stunting shows long-term malnutrition, which weakens the child’s immunity and makes the child vulnerable to pneumonia. From different prospects of different studies, malnutrition (undernutrition) weakens the respiratory muscles needed to clear secretions in the respiratory tract, which intern predisposes to pneumonia\(^{1,24,41}\).

In this study, there was the strongest association between pneumonia and a history of asthma, indicating that children who had a previous history of asthma had approximately fivefold increased odds of developing pneumonia compared to their counterparts. According to the WHO 2008 bulletin report, concomitant diseases such as asthma were likely to be the risk factors for the occurrence of childhood pneumonia\(^{15}\). Several findings from

| Variables                        | Case Frequency | Case Percent | Control Frequency | Control Percent | Total Frequency | Total Percent | P-value | COR (95% CI) |
|----------------------------------|----------------|--------------|-------------------|-----------------|----------------|---------------|---------|-------------|
| Common source of energy used for cooking used the family |                |              |                   |                 |                |              |         |             |
| Wood                             | 83             | 57.2         | 159               | 54.8            | 242            | 55.6          | 0.40    | 1.4 (0.8, 2.3) |
| Charcoal                         | 21             | 14.5         | 41                | 14.1            | 62             | 14.2          | 0.20    | 1.4 (0.7, 2.6) |
| Kerosene                         | 10             | 6.9          | 8                 | 2.8             | 18             | 4.1           | 0.02*   | 3.3 (1.2, 9.1) |
| Electricity                      | 31             | 21.4         | 82                | 28.3            | 113            | 26            | 1       |             |
| Common place of cooking used by the family |                |              |                   |                 |                |              |         |             |
| In living room                   | 53             | 36.6         | 105               | 36.2            | 158            | 36.3          | 0.70    | 1.1 (0.7, 1.8) |
| In kitchen attached to the living room | 37             | 25.5         | 64                | 22.1            | 101            | 23.2          | 0.40    | 1.3 (0.8, 2.1) |
| In separate kitchen              | 55             | 37.9         | 121               | 41.7            | 176            | 40.5          | 1       |             |
| Chimney in the cooking room      |                |              |                   |                 |                |              |         |             |
| No                               | 101            | 69.7         | 140               | 48.3            | 241            | 55.4          | <0.01*  | 2.5 (1.6, 3.7) |
| Yes                              | 44             | 30.3         | 150               | 51.7            | 194            | 44.6          | 1       |             |
| Air flow in the living room      |                |              |                   |                 |                |              |         |             |
| Yes                              | 124            | 85.5         | 261               | 90              | 385            | 88.5          | 0.20    | 1.5 (0.8, 2.8) |
| No                               | 21             | 14.5         | 29                | 10              | 50             | 11.5          | 1       |             |
| Place of the child during cooking (usual location) |            |              |                   |                 |                |              |         |             |
| Near or carried on back          | 93             | 64.1         | 127               | 43.8            | 220            | 50.6          | <0.01*  | 2.3 (1.5, 3.5) |
| Outside of cooking room          | 52             | 35.9         | 163               | 56.2            | 215            | 49.4          | 1       |             |
| Cigarette smoker among household residents |         |              |                   |                 |                |              |         |             |
| Yes                              | 11             | 7.6          | 19                | 6.6             | 30             | 6.8           | 0.70    | 1.2 (0.5, 2.5) |
| No                               | 134            | 92.4         | 271               | 93.4            | 405            | 93.2          | 1       |             |
| Crowding status                  |                |              |                   |                 |                |              |         |             |
| Crowded                          | 60             | 41.4         | 91                | 31.4            | 151            | 35            | 0.04*   | 1.5 [1.1, 2.3] |
| Not crowded                      | 85             | 58.6         | 199               | 68.6            | 284            | 65            | 1       |             |

Table 3. Environmental characteristics of children aged 2–59 months attending public health facilities in Worabe town, Silte zone, 2017 (N = 145 cases and 290 controls). COR crude odds ratio, CI confidence interval, 1 reference group.
other areas also indicated the relationship between asthma and pneumonia episodes\(^{21,36}\). In a study conducted in the Philippines, 55.4% of children who developed consolidated pneumonia had asthma as an underlying illness\(^{27}\). In the current study, we are unable to conclude whether asthma or other asthmatic condition was a predisposing factor for pneumonia. Further study is needed to define a causal relationship between asthma and pneumonia.

A history of AURTIs in a child in the last two weeks preceding the current pneumonia was identified to put a child 3.7 times at risk of pneumonia compared to their counterpart. This is in line with the study conducted in southwest Ethiopia, which indicates that the risk of pneumonia is more than 5 times for children who had previous AURTIs\(^{23}\), and a similar finding in the Netherlands showed a strong relationship between the occurrences of community-acquired pneumonia and an increasing number of previous AURTIs\(^{21}\). However, a study conducted in Ethiopia reported no significant association between occurrences of pneumonia and preceding infection of AURTI in children\(^{22}\). A possible explanation might be that AURTI increases susceptibility to infections that subsequently predisposes patients to pneumonia or that there might be descending infection from the upper to lower respiratory tract.

### Table 4. Determinants of pneumonia among children aged 2–59 months in public health facilities in Worabe town, Southern Ethiopia, 2017\((N = 145 \text{ cases and } 290 \text{ controls})\). COR crude odds ratio, AOR adjusted odds ratio, CI confidence interval, I reference group.

| Variables                                | Cases No (%) | Controls No (%) | COR (95% C.I.) | AOR (95% C.I.) | P-value |
|------------------------------------------|--------------|-----------------|----------------|----------------|---------|
| Breast feeding status of the child during the first 6 months |              |                 |                |                |         |
| Exclusive BF                              | 115 (79.3%)  | 247 (85.2%)     | 1.5 (0.9, 1.6) | 0.8 (0.4, 1.5) | 0.4     |
| Mixed feeding                            | 30 (20.7%)   | 43 (14.8%)      | 1.0            | 1.0            |         |
| Zinc supplementation                      |              |                 |                |                |         |
| Supplemented                              | 56 (38.6%)   | 77 (26.6%)      | 1.7 (1.2, 2.7) | 1.4 (0.8, 2.3) | 0.2     |
| Not supplemented                         | 89 (61.4%)   | 213 (73.4%)     | 1.0            | 1.0            |         |
| Height for age                            |              |                 |                |                |         |
| Stunted                                  | 36 (24.8%)   | 23 (7.9%)       | 3.8 (2.2, 6.8) | 3.6 (1.8, 7)*  | <0.001  |
| Not stunted                              | 109 (75.2%)  | 267 (92.1%)     | 1.0            | 1.0            |         |
| Crowding status                          |              |                 |                |                |         |
| Crowded                                  | 60 (41.4%)   | 91 (31.4%)      | 1.5 [1.1, 2.3] | 1.2 (0.7, 2)   | 0.6     |
| Not crowded                              | 85 (58.6%)   | 199 (68.6%)     | 1.0            | 1.0            |         |
| Place of child during cooking             |              |                 |                |                |         |
| Near or carried on back                   | 93 (64.1%)   | 127 (43.8%)     | 2.3 [1.5, 3.5] | 2.0 [1.2, 3.3]* | 0.006   |
| Outside of cooking room                   | 52 (35.9%)   | 163 (56.2%)     | 1.0            | 1.0            |         |
| Type of cooking fuel mostly used the family |          |                 |                |                |         |
| Wood                                      | 83 (57.2%)   | 159 (54.8%)     | 1.4 (0.8, 2.3) | 1.3 (0.7, 2.4) | 0.500   |
| Charcoal                                  | 21 (14.5%)   | 41 (14.1%)      | 1.4 (0.7, 2.6) | 0.9 (0.4, 1.9) | 0.800   |
| Kerosene                                  | 10 (6.9%)    | 8 (2.8%)        | 3.3 (1.2, 9.1) | 2.3 (0.7, 7.3) | 0.200   |
| Electricity                               | 31 (21.4%)   | 82 (28.3%)      | 1.0            | 1.0            |         |
| Weight for height                         |              |                 |                |                |         |
| Wasted                                    | 29 (20%)     | 38 (13.1%)      | 1.7 (0.9, 2.8) | 1.4 (0.7, 2.7) | 0.300   |
| Not wasted                                | 116 (80%)    | 252 (86.9%)     | 1.0            | 1.0            |         |
| Family size                               |              |                 |                |                |         |
| 2–3                                      | 26 (17.9%)   | 69 (23.8%)      | 0.6 (0.4, 1.1) | 0.7 (0.3, 1.6) | 0.400   |
| 4–5                                      | 67 (46.2%)   | 135 (46.6%)     | 0.8 (0.5, 1.3) | 0.9 (0.5, 1.6) | 0.700   |
| 6 and above                              | 52 (35.9%)   | 86 (29.7%)      | 1.0            | 1.0            |         |
| Chimney in the cooking room               |              |                 |                |                |         |
| No                                       | 101 (69.7%)  | 140 (48.3%)     | 2.5 (1.6, 3.7) | 2.2 [1.3, 3.7] | 0.003*  |
| Yes                                      | 44 (30.3%)   | 150 (51.7%)     | 1.0            | 1.0            |         |
| History of diarrhoea in the last 2 weeks  |              |                 |                |                |         |
| Yes                                      | 44 (33.3%)   | 54 (18.6%)      | 1.9 [1.2, 3]   | 1.5 [0.9, 2.7] | 0.1     |
| No                                       | 101 (69.7%)  | 236 (81.4%)     | 1.0            | 1.0            |         |
| History of AURTI in the last 2 weeks      |              |                 |                |                |         |
| Yes                                      | 68 (46.9%)   | 51 (17.6%)      | 4 [2.7, 6.5]   | 3.7 [2.3, 6.1] | <0.001* |
| No                                       | 77 (53.1%)   | 239 (82.4%)     | 1.0            | 1.0            |         |
| History of asthma in the child            |              |                 |                |                |         |
| Yes                                      | 23 (15.9%)   | 19 (3.4%)       | 5.3 [2.4, 11.4] | 5.0 [2, 12]   | <0.001* |
| No                                       | 122 (84.1%)  | 280 (96.6%)     | 1.0            | 1.0            |         |
Limitations of the study. The diagnosis of pneumonia was based on the clinical WHO IMNCI classification guidelines, which introduced misclassification recall bias; the study did not consider privates health facilities and did not consider the complete population.

Conclusions
This study indicated stunting, a previous history of asthma and upper respiratory tract infection, the absence of chimney in the cooking room and carrying the child on the back during cooking are strongly associated with an increased risk of childhood pneumonia. Therefore, the zonal health bureau, in collaboration with the agricultural office needs to improve the nutritional status of children, and the town administrative health office, in collaboration with the health facilities may provide health education to the community about the health risk of child exposure to biomass fuel smoke and to have chimneys in the cooking room.

Data availability
All necessary raw data used for analysis in this study is available from corresponding author with reasonable request.

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Author contributions
R.K.S. Designed the study, was involved in data collection, data analysis and interpretation, wrote the paper and prepared the manuscript for publication. Y.A.W. & M.M.A. Data analysis; and interpretation and prepared the initial draft of the manuscript for publication. S.M.A. Had oversight of all the stages of the research, critically reviewed the final draft of the paper and the prepared manuscript for publication. The final manuscript was read and approved by all authors.

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