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The cost of care for children hospitalized with respiratory syncytial virus (RSV) associated lower respiratory infection in Kenya

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Abstract

Background Respiratory syncytial virus (RSV) is one of the main causes of hospitalization for lower respiratory tract infection in children under five years of age globally. Maternal vaccines and monoclonal antibodies for RSV prevention among infants are approved for use in high income countries. However, data are limited on the economic burden of RSV disease from low- and middle-income countries (LMIC) to inform decision making on prioritization and introduction of such interventions. This study aimed to estimate household and health system costs associated with childhood RSV in Kenya.

Methods A structured questionnaire was administered to caregivers of children aged < 5 years admitted to referral hospitals in Kilifi (coastal Kenya) and Siaya (western Kenya) with symptoms of acute lower respiratory tract infection (LRTI) during the 2019–2021 RSV seasons. These children had been enrolled in ongoing in-patient surveillance for respiratory viruses. Household expenditures on direct and indirect medical costs were collected 10 days prior to, during, and two weeks post hospitalization. Aggregated health system costs were acquired from the hospital administration and were included to calculate the cost per episode of hospitalized RSV illness.

Results We enrolled a total of 241 and 184 participants from Kilifi and Siaya hospitals, respectively. Out of these, 79 (32.9%) in Kilifi and 21(11.4%) in Siaya, tested positive for RSV infection. The total (health system and household) mean costs per episode of severe RSV illness was USD 329 (95% confidence interval (95% CI): 251–408) in Kilifi and USD 527 (95% CI: 405– 649) in Siaya. Household costs were USD 67 (95% CI: 54–80) and USD 172 (95% CI: 131– 214) in Kilifi and Siaya, respectively. Mean direct medical costs to the household during hospitalization were USD 11 (95% CI: 10–12) and USD 67 (95% CI: 51–83) among Kilifi and Siaya participants, respectively. Observed costs were lower in Kilifi due to differences in healthcare administration.

Conclusions RSV-associated disease among young children leads to a substantial economic burden to both families and the health system in Kenya. This burden may differ between Counties in Kenya and similar multi-site studies are advised to support cost-effectiveness analyses.

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Keywords Respiratory syncytial virus, Hospitalization, Cost, Households, Health System

Background

Respiratory syncytial virus (RSV) is the main cause of lower respiratory tract infection (LRTI), requiring hospitalisation, among children under five years of age [1–4]. Global estimates show that RSV causes about 2.9 to 4.6 million hospitalizations and 84,500–125,200 deaths among children under 5 years [4], and up to 90% of the deaths occur in low- and middle-income countries (LMICs) [3–6]. Severe RSV disease was associated with 1.4 million hospital admissions and 13,300 in-hospital deaths of infants under 6 months of age in 2019 [4]. The prevalence of RSV among infants under 6 months, hospitalized with severe or very severe pneumonia in coastal Kenya has been estimated to be about 32% during epidemics [7]. Consequently, there is a need for better options for RSV prevention to protect young infants who are most at risk of severe RSV-associated LRTI.

There are three RSV prevention products approved for use in high income countries [8]. These three interventions targeting RSV associated disease in young infants include a maternal vaccine (MV) [9], a long-acting RSV-specific monoclonal antibody (mAb)-Nirsevimab [10], and another mAb (Palivizumab) with a short half-life [11]. Results from phase III MV candidate trial (NCT04424316-Registraterd at ClinicalTrials.gov on June, 3rd 2020) found an efficacy of 81.8%; (99.5% confidence interval [CI]: 40.6 to 96.3) in preventing medically attended infant RSV LRTI within the first 90 days of life [9]. In the phase III trial of Nirsevimab (-NCT03979313), the mAb averted 74.5%; (95% CI, 49.6 to 87.1) of medically attended RSV LRTI [10]. Optimal implementation of these interventions in LMICs will require accurate studies of disease costs to inform cost-effectiveness analyses and guide decision making on prioritization.

There is a paucity of data on cost of RSV illness from LMICs [12]. However, a recent study in Argentina found the mean cost of RSV hospitalization among infants in 2022 USD to be 588 (95% CI: 535– 640) [13]. In Vietnam, the median cost for a RSV-associated LRTI episode in 2022 USD was 165 (IQR 95–249) among infants hospitalized in the respiratory disease ward [14]. Very few studies on RSV costs have been conducted in sub-Saharan Africa, including Kenya. Estimates from Malawi have shown the cost per episode of RSV hospitalization for children aged < 5 years, in 2018 was USD 62.26 (95% confidence interval [CI]: USD 50.87-USD 73.66) [15]. A previous study in Kenya, estimated the mean cost of treating pneumonia in public regional hospitals in 2005 as USD 99.26 (Standard Deviation (SD), 71.14) [16]. Additionally, cost per episode of influenza hospitalization for Kenyan children aged < 5 years in 2014 was USD 137.45 (SD, 76.24) [17]. These costs per episode were approximately, 79, 262 and 166 in 2021 USD for the Malawi and two Kenya studies, respectively but there has been no known specific costs for RSV hospitalization published in Kenya. Also, interpretation of cost data in a country such as Kenya, requires knowledge of the structure of the health care system. For instance, in 2013, Kenya transitioned to a devolved system of government [18], during which the national government retained the responsibility of policy-making and regulatory oversight while delegating health service delivery and management of funds to the 47 county governments [19]. Financing of public hospitals is mainly through user fees, reimbursements of lost revenues by the national government, and donor funds [19]. As a result, planning and budgeting processes by hospitals are not standardized across counties and user fees vary by facility level [16, 19] and facility type (public, mission, or private hospital) [16]. Thus, costing estimates from a single site might not be representative of all counties in Kenya.

In this study, we aimed to generate data on the direct and indirect costs of taking care of a child hospitalized with RSV-associated illness from the households and the health system perspectives of two county referral hospitals in Kenya. Results from this study may guide recommendations for decision making towards implementation of RSV interventions by country policymakers and other global stakeholders.

Methods

Study site

Data were collected within the paediatric wards of two public health facilities: Kilifi County Hospital (KCH) situated within Kilifi township in Coastal Kenya, and Siaya County Referral Hospital (SCRH) which is situated in Western Kenya. The two sites were purposively selected because they had paediatric RSV surveillance activities [20]. Both Siaya and Kilifi hospitals are located within the semi-rural parts of Kenya but differ in financing of healthcare services. Unlike Siaya County Referral Hospital, which depends on user fees and support from the national government, Kilifi County Hospital receives additional support from KEMRI-Wellcome Trust Programme (KWTRP) in financing the delivery of medical services within the paediatric ward. The KWTRP provides clinical research staff who care for and manage the high-dependency paediatric ward patients, provides free laboratory services, and pays utility bills for the hospital.

Study population

The study population includes children aged 1 day to 59 months admitted to Kilifi County Hospital or Siaya County Referral Hospital paediatric wards with symptoms of acute LRTI in Kilifi or severe acute respiratory infection (SARI) in Siaya. The case definition of LRTI as used in the Kilifi site was a child with cough or difficulty in breathing and either chest wall in-drawing or any one or more of the following danger signs: hypoxia (<90% O2 saturation)/ prostrate / inability to feed/ unconsciousness. The case definition for SARI was cough and reported/documented fever within 10 days of symptom onset. The child should also have provided a nasopharyngeal or oropharyngeal (NP/OP) swab and the parent or guardian given a written consent for their child to participate in the study. All readmissions within 14 days following discharge were excluded.

Study design

The sample size estimation for this study was based on the desired precision to provide an estimated mean cost and followed methods outlined in World Health Organization (WHO) guidelines for estimating the economic burden of diarrheal disease [21]. We used the formula:

$$N = \left(\frac{precision^2}{Coefficient\ of\ Variation^2 \times\ Z^2} + \frac{1}{Annual\ cases} \right)^{-1}$$

Where:

Annual Cases = annual LRTI or SARI patients during RSV season (N=730 per site),

Coefficient of variation = 0.5,

Precision = 0.10 and Z-score = 1.96.

A minimum sample size of 85 LRTI/SARI cases from each site was found sufficient to provide the mean cost of an RSV LRTI episode within a precision of ±10%. The sample size estimation procedure further assumed that a total of 730 LRTI patients aged < 5 years will be admitted to each hospital during the 2019–2020 RSV season and approximately 30% of children admitted to the hospital with LRTI would test positive for RSV infection. The estimates of 730 LRTI patients were derived from admission numbers during RSV epidemics observed through the continuous long-term surveillance of respiratory virus pathogens among pediatric admissions to Kilifi County Hospital [7].

Sampling

As part of the ongoing respiratory pathogens surveillance, all patients admitted Monday through Friday fitting the case definition for LRTI (at Kilifi County Hospital) or SARI (at Siaya County Referral Hospital) were screened for eligibility and enrolled. Screening logs were kept (to estimate non-enrolment numbers) as well as a total admissions log (to estimate weekend cases). This then linked the individual to all laboratory tests and investigations including details from the Health Demographic Surveillance System (HDSS) through their Personal identification (PID), if available. An automated algorithm then established if the child was eligible for LRTI surveillance, and this was flagged for the ward or clinical research team. If eligible, a nasopharyngeal swab sample was collected and tested for RSV and other respiratory pathogens (including influenza viruses, parainfluenza viruses, human coronaviruses, human metapneumoviruses, rhinoviruses, adenoviruses, and SARS-CoV-2) using a multiplex real-time polymerase chain reaction (RT-PCR) assay [22–24], as part of the ongoing surveillance procedures.

After the LRTI/ SARI ward surveillance procedures were complete, caregivers of potential participants were approached by study fieldworkers for recruitment into the RSV costing study. All LRTI surveillance patients who gave a nasopharyngeal swab sample and had not yet been discharged were eligible to participate. The caregivers were given information about the study and asked to give consent for participation and if willing, a standardized questionnaire was administered to consenting caregivers. To reduce the burden on the patient and family, parents were approached and were asked for consent for the participation of their child after the standard admission review and care procedures were complete and the patient had been assigned a bed. Recruitment of participants was done prior to receipt of RT-PCR results to minimize time between admission and enrollment (and consequently minimize recall bias).

This study recruited participants during the 2019/2020 RSV epidemic at Kilifi County Hospital, which began in November 2019 and ended in April 2020, while in Siaya County Referral Hospital, recruitment of participants started in March 2020 but was interrupted in April 2020, due to the COVID-19 pandemic. Recruitment of participants resumed in Siaya in March 2021 and ended in August 2021, which was coincident with the RSV season in Western Kenya.

Data collection procedures

Upon agreeing to participate in the costing study, caregiver questionnaires were administered by a trained study fieldworker to collect cost data in three phases: (1) during admission, (2) at discharge, and (3) two weeks after discharge via telephone call or follow-up home visit. The household costs were categorized into direct medical costs, direct nonmedical costs, and indirect costs.

During the first day of hospitalization, questions about costs incurred 10 days from onset of illness to hospitalization, such as transport, medications purchased, and healthcare provider costs were asked. Any other

information on costs incurred during outpatient visits prior to hospitalization was extracted from hospital records if it was available in the patient's hospital card or booklet. The child was monitored during the length of stay at the hospital (until discharge or death), to estimate the number of days of income lost by caregivers and the total cost for treatment while the child was admitted using an expense tracking form.

On the day of discharge, a questionnaire was administered to collect all household-level costs incurred while caring for the child during the entire period of hospitalization. These included direct non-medical costs (travel to and from the hospital, meals, etc.), as well as indirect costs such as the employment status of the caregiver followed by loss of income due to the child's illness.

A phone call or home follow-up visit was made to the participant's parent or guardian to administer a follow-up cost questionnaire two weeks after discharge. This was done with all participants in the study to record any extra costs incurred and the status of the child after hospitalization. A follow-up questionnaire was not administered to parents/ guardians whose children died during hospitalization.

In addition, health systems costs in the form of an aggregated cost estimate for each ward type (general/ high dependency unit wards), personnel, administrative, and the cost of procedures for the year 2019, were acquired on a standardized data collection form from the hospital administration [25].

Ethical considerations

Written informed consent was obtained from the parents/guardians of all study participants before enrolment. Ethical approval to conduct this study was provided by the KEMRI Scientific and Ethical Review Unit Committee (SERU #3939). Ethical clearance for the respiratory viruses surveillance in Siaya was obtained from KEMRI SERU (SSC# 2558) and from CDC Institutional Review Board (IRB# 6543).

Statistical analysis

Descriptive statistics were used to summarize participants' characteristics and to estimate the mean (95% CI) costs from the household and the health system.

Cost data collected prior to, during, and after hospitalization were categorized into direct medical, direct non-medical, and indirect costs. Money spent on drugs, hospital consultation or registration fees, laboratory tests and other care procedures, medical supplies, and bed fees were classified as direct medical costs. Direct non-medical costs comprised of transportation costs to and from the hospital, lodging fees while seeking care, food purchased, and caretaker fees. Indirect costs were calculated as the sum of self-reported income lost recorded as the daily wage and lost productivity for the days spent taking care of the sick child [25]. For participants with missing data on income or with no formal employment, the minimum wage for a casual laborer in Kenya of KSHS 500 (2021 USD 4.56) was applied to the number of days lost and was used to compute lost productivity.

Health system costs were averaged across the estimated number of inpatient episodes of RSV disease associated hospitalization which occurred in 2019 to generate the unit cost per case of RSV. Since health system costs for personnel salaries were collected as an aggregate cost (including inpatient and outpatient), estimation of inpatient-specific costs for an episode of RSV illness followed methods in the literature [15, 26]. Assuming the out-patient visit takes one day and that, the median number length of hospital stay per episode was 5 days [16], we used the 1:5 ratio for allocating personnel costs to outpatient and inpatient care. The daily personnel costs for inpatients were multiplied by the patient's length of stay in days to generate mean personnel costs per RSV episode. Similarly, administrative costs were calculated by dividing the administrative cost for services by the total number of inpatients, and then multiplying by the patient's length of hospital stay [26].

Reported household and health system costs collected in 2019 and 2020 were adjusted for inflation to 2021 prices using the gross domestic product (GDP) implicit price deflator (https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS.AD?locations=KE). This was done following methods described previously by Turner and colleagues [27]. The deflator values used in this analysis for years 2019, 2020, and 2021 were 117.31, 123.3,9 and 129.40 respectively. All costs were converted from Kenya shillings to USD using mean conversion rates of 109.64 KSHS/USD for 2021 (https://www.centralbank.go.ke/statistics/exchange-rates/). All analysis was conducted using STATA version 15.0 [25].

Results

Characteristics of participants

We recruited and interviewed a total of 241 (79 RSV positive; 162 RSV negative) and 184 (21 RSV positive; 163 RSV negative) participants from Kilifi and Siaya County referral hospitals, respectively. Among the 162 RSV-negative participants from Kilifi, 61 (37.7%) had other respiratory viruses detected (parainfluenza viruses-3, adenoviruses-4, influenza viruses-8, human metapneumo viruses-8 and rhinoviruses-38). There were more participants 29/79 (36.7%) in the younger age group of 0–2 months who tested positive for RSV infection in Kilifi than in Siaya 2/21 (9.5%). Over 90% of participants from both sites were brought to the hospital by their mothers. The most common means of transport to the hospital

was a motorcycle or tricycle with over 50% of participants from both sites using this mode (Table 1).

The median length of stay in the hospital for participants with RSV infection was 4 days (Inter Quartile Range (IQR): 3–6) in Kilifi and 5 days (IQR: 4–9) in Siaya. The mean length of stay in hospital for infants aged less than six months was 8 days (SD:9.81), whereas, infants aged greater than 6 months had a mean length of hospital stay of 5 days (SD:5.07). Mortality between hospitalization to two weeks post discharge among Kilifi participants was 10.8% (26/241: 2 RSV positive and 24 RSV negative) and 11.4% (21/184: 1 RSV positive and 20 RSV negative) among Siaya participants. Of the 14 (10.9%) infants, under six months of age, who tested negative for RSV infection and were reported dead in this study, 2 had primary diagnosis as LRTI only, 1 had birth asphyxia, 3 had bronchiolitis, 1 had congenital abnormalities, 1 had heart disease-congenital, 1 had meningitis-not Tuberculous Menengitis (TBM), 1 infant had neonatal sepsis, 2 infants were preterm and 1 infant had septicaemia/sepsis (Additional File 1). About 86% (68/79) of children hospitalized with RSV-LRTI in Kilifi and 62% (13/21) in Siaya recovered within 4 days (IQR:2–7) after discharge. About 58% of households in Kilifi and 86% in Siaya taking care of a child with RSV-associated LRTI reported to have a monthly household income of USD 500 or less (Table 1).

Household costs for RSV and non-RSV LRTI treatment by category

Family finance was reported to have been affected among 86% of households in Siaya and among 95% of households in Kilifi (Table 1).

The overall mean household costs for participants with LRTI (both RSV positive and RSV negative) was USD 80.79 (95%CI, 67.26–94.33) in Kilifi and USD 150.17 (95%CI, 134.11-166.24) in Siaya (Table 2). These total mean costs incurred by a household were statistically not different between RSV-associated LRTI and non-RSV-associated LRTI at USD 66.52 (95% CI, 53.50–79.55) vs. 87.75 (95% CI, 68.64–106.87), $p=0.147$) for Kilifi while corresponding values for Siaya were USD 172.43 (95% CI, 130.46 −214.39) vs. 147.31 (95% CI, 129.91–164.71), $p=0.328$).

Household costs prior to hospitalisation

The overall mean costs incurred by a household for a child with RSV-associated LRTI prior to hospitalization were USD 17.83 (95% CI, 8.80-26.86) in Kilifi. While among Siaya participants, the overall mean costs were USD 34.68 (95% CI, 12.86–56.49). The mean direct medical, direct non-medical, and indirect costs prior to hospitalization to the households were USD 4.14 (95% CI, 2.63–5.65), 3.13 (95% CI, 1.84–4.43) and 35.53 (95% CI, 11.7-59.35) in Kilifi and USD 10.91 (95% CI, 1.44–20.38), USD 3.14 (95% CI, 0.82–5.46) and USD 38.81 (95% CI, 8.08–69.53) in Siaya respectively (Table 2). Costs prior to hospitalization were significantly associated with monthly household income in Kilifi (Chi2 $P=0.005$) but not in Siaya (Chi2 $P=0.195$).

Household costs during hospitalization

The total mean cost incurred by a household for taking care of a child with severe RSV-associated LRTI during hospitalization was USD 46.88 (95% CI, 37.69–56.07) in Kilifi and USD 138.51 (95% CI,106.54-170.48) in Siaya. Almost 50% of the costs incurred during hospitalization to the households were from direct medical costs in Siaya USD 66.88 (95% CI, 50.99–82.77) while in Kilifi, the direct medical cost was USD 11.23 (95% CI, 10.17–12.30) contributing to less than 25% of the total hospitalization cost (Table 2). In Kilifi, household costs incurred during hospitalization were significantly associated with patient's age (Chi2 $P=0.001$) while in Siaya costs incurred during hospitalization were significantly associated with household monthly income ((Chi2 $P=0.012$).

The mean hospitalization costs for all causes of LRTI were USD 58.83 (47.75–69.90) and USD 116.14 (100.4-127.72) among participants in Kilifi and Siaya respectively. Overall, hospitalisation costs were three times higher among participants in Siaya County Referral Hospital than those admitted to Kilifi County hospital (Table 3). The cost of purchasing drugs was higher in Siaya USD 10.57 (95% CI, 7.62–13.51) than in Kilifi (USD 1.46 (95% CI, 1.40–1.52) (Table 3).

Household costs after hospitalization

The mean cost incurred by households within two weeks after hospitalisation among children with RSV-LRTI was USD 17.91 (95% CI, 4.42–31.40) for Kilifi and 15.35 (95% CI, 0-34.46) for Siaya.

The direct medical, direct non-medical, and indirect mean costs post hospitalization for a child with RSV-associated LRTI were USD 9.63 (95% CI, 0-24.34), 5.06 (95% CI, 0-10.13) and 19.92 (95% CI, 0-43.93) in Kilifi and USD 1.28 (95% CI, 0.03–2.53), 3.47 (95% CI, 0.64–6.29) and 50.16 (95% CI, 0-224.0) in Siaya, respectively (Table 2).

Health system costs for taking care of a child with an episode of RSV illness

The cost for treating an episode of RSV-associated LRTI to the health system was USD 262.83(95% CI:191.75-333.92) in Kilifi and USD 354.10 (95% CI, 254.26-453.94) in Siaya County Referral Hospital (Table 4).

Costs for salaries were higher in Siaya Hospital at USD 249.10 (95% CI: 178.87– 319.34) than in Kilifi Hospital at USD 47.03 (95% CI: 34.31– 59.76) but were similar (USD

Table 1 Characteristics of patients presenting with acute lower respiratory tract infections from Kilifi and Siaya County hospitals

	KILIFI				SIAYA			
	All Patients		RSV positive patients		All Patients		RSV positive patients	
	N	(%)	*n*	(%)	*N*	(%)	*n*	(%)
Characteristic	**241**	**100**	**79**	**100**	**184**	**100**	**21**	**100**
Age in months								
< 6 months	97	40.25	43	54.43	10	5.43	2	9.52
6–11 months	69	28.63	25	31.65	21	11.41	3	14.29
12–23 months	51	21.16	10	12.66	44	23.91	7	33.33
24–35 months	13	5.39	0	0	41	22.28	2	9.52
> 36 months	11	4.56	1	1.27	68	36.96	7	33.33
Sex								
Female	113	46.89	38	48.1	85	46.45	8	38.10
Male	128	53.11	41	51.9	98	53.55	13	61.90
Person brought child to hospital								
Mother	226	93.78	75	94.94	166	90.22	17	80.95
Father	14	5.81	4	5.06	2	1.09	2	9.52
Grandmother	1	0.41	0	0	16	8.69	2	9.52
Mode of transport used to bring child to hospital								
Personal car/vehicle	3	1.24	0	0	0	0	0	0
Taxi	8	3.32	3	3.8	2	1.09	0	0
Matatu/bus	64	26.56	25	31.65	7	3.80	1	4.76
Ambulance	36	14.94	6	7.59	14	7.61	1	4.76
Motorbike/tricycle	122	50.62	43	54.43	154	84.78	18	85.71
Foot	8	3.32	2	2.53	5	2.72	1	4.76
Purchased medication for the child prior hospitalization								
Yes	48	19.92	13	16.46	61	33.15	10	47.62
No	133	55.19	51	64.56	53	23.81	5	23.81
Did not respond	60	24.9	15	18.99	70	38.04	6	28.57
Median length of stay in hospital, bed nights median (IQR)	4 (3–7)		4 (3–6)		5 (3–7)		5 (4–9)	
Outcome at discharge								
Alive	218	90.46	77	97.47	172	93.48	21	100
Dead	19	7.88	1	1.27	11	5.98	0	0
Transferred to another hospital	4	1.66	1	1.27	1	0.54	0	0
Days child back to normal after discharge								
1–2 day	105	43.57	35	44.3	57	30.98	9	42.86
3–4 days	80	33.2	33	41.77	22	11.96	0	0
5–6 days	6	2.49	0	0	28	15.22	4	19.05
7–14 days	7	2.9	2	2.53	11	5.98	3	14.29
Over 14 days	32	13.28	4	5.06	25	13.59	3	14.29
Did not respond	11	4.56	5	6.33	41	22.28	2	9.52
Outcome between hospitalization and follow-up								
Alive	215	89.21	77	97.47	163	88.59	20	95.24
Dead	26	10.79	2	2.53	21	11.41	1	4.76
Total household income from all sources/month								
USD < = 50	3	1.24	0	0	22	11.96	1	4.76
USD 51-100	10	4.15	1	1.27	62	33.7	6	28.57
USD 101-250	88	36.51	34	43.04	54	29.35	9	42.86
USD 251-500	29	12.03	11	13.92	15	8.15	2	9.52
USD 501-1000	1	0.41	0	0	3	1.63	0	0
>1000	1	0.41	0	0	0	0	0	0
Don't know	105	43.57	33	41.77	23	12.5	3	14.29
Refused to disclose	4	1.66	0	0	5	2.71	0	0
Family finance affected by illness								

Table 1 (continued)

	KILIFI				SIAYA			
	All Patients		RSV positive patients		All Patients		RSV positive patients	
	N	(%)	*n*	(%)	*N*	(%)	*n*	(%)
Characteristic	**241**	**100**	**79**	**100**	**184**	**100**	**21**	**100**
Yes	228	94.61	78	98.73	159	86.41	19	90.48
No	13	5.39	1	1.27	7	3.80	1	4.76
Did not respond					18	9.78	1	4.76

Table 2 Mean (95% confidence intervals) Household costs in USD for children hospitalised with RSV LRTI in Kilifi and Siaya

Cost Parameters	All patients		RSV Positive		RSV Negative	
(A) KILIFI	**mean cost (95% CI)**	***N*** **= 241**	**mean cost (95% CI)**	***n*** **= 79**	**mean cost (95% CI)**	***n*** **= 162**
Household Costs incurred prior to hospitalization	**20.18** (15.03–25.34)	241	**17.83** (8.80-26.86**)**	79	**21.33** (15.00-27.67**)**	162
Direct Medical Costs	*7.58 (5.41–10.65)*	*187*	4.14 (2.63–5.65)	66	9.45 (4.79–4.55)	121
Direct non-Medical Costs	*3.76 (2.63–4.88)*	*241*	3.13 (1.84–4.43)	79	4.06 (2.50–5.62)	162
Indirect costs	*29.23 (19.85–38.60)*	*87*	35.53 (11.70-59.35)	25	26.69 (17.20-36.17)	62
Household Costs incurred during hospitalization	**58.83** (47.75–69.90)	241	**46.88** (37.69–56.07**)**	79	**64.65** (48.81–80.49**)**	162
Direct Medical Costs	*11.02 (10.40-11.65)*	*240*	11.23 (10.17–12.30)	79	10.92 (10.15–11.69)	161
Direct non-Medical Costs	8.64 (6.95–10.34)	240	10.12 (5.83–14.41)	79	7.92 (6.48–9.36)	161
Indirect costs	*39.4 (28.81–49.99)*	*240*	25.52 (18.48–32.56)	79	46.21 (30.85–61.57)	161
Household Costs incurred after hospitalization	**13.03** (4.24–21.82)	33	**17.91** (4.42–31.40)	8	**11.47** (0.29–22.64)	25
Direct Medical Costs	9.27 (0-19.15)	*24*	9.63 (0-24.34)	5	9.18 (0-21.64)	19
Direct non-Medical Costs	3.31 (1.68–49.28)	23	5.06 (0-10.13)	7	2.54 (1.16–3.92)	16
Indirect costs	*26.3 (0-53.19)*	*5*	*19.92 (0-43.93)*	*3*	*35.87 (0-370.10)*	*2*
Total household costs (USD)	**80.79** (67.26–94.33)	241	**66.52** (53.50-79.55)	79	**87.75** (68.64-106.87)	162
(B) SIAYA	**mean cost (95% CI)**	*N* = 184	**mean cost (95% CI)**	*n* = 21	**mean cost (95% CI)**	*n* = 163
Household Costs incurred prior to hospitalization	**19.77**(15.07–24.47)	**141**	**34.68**(12.86–56.49)	**17**	**17.72**(13.24–22.21**)**	**124**
Direct Medical Costs	5.41(2.91–7.91)	109	10.91(1.44–20.38)	14	4.60(2.04–7.15)	95
Direct non-Medical Costs	*2.81(1.97–3.65)*	*115*	3.14(0.82–5.46)	15	2.76(1.85–3.68)	100
Indirect costs	*23.28(17.53–29.02)*	*80*	38.81(8.08–69.53)	*10*	21.06(15.82–26.30)	70
Household Costs incurred during hospitalization	**116.14**(104.56-127.72)	**184**	**138.51**(106.54-170.48)	**21**	**113.26**(100.81-125.71)	**163**
Direct Medical Costs	57.22(51.95–62.48)	184	66.88(50.99–82.77)	21	55.97(50.36–61.59)	163
Direct non-Medical Costs	19.54(12.95–26.13)	170	27.37(16.18–38.57)	19	18.55(11.25–25.86)	151
Indirect costs	40.87(35.08–46.66)	184	46.87(32.69–61.04)	21	40.10(33.79–46.40)	163
Household Costs incurred after hospitalization	**39.05**(26.00-52.09)	**89**	**15.35**(0-34.46)	**8**	**41.39**(27.21–55.56)	81
Direct Medical Costs	7.87(2.57–13.16)	39	1.28(0.03–2.53)	4	8.62(2.75–14.49)	35
Direct non-Medical Costs	4.25(2.76–5.74)	53	3.47(0.64–6.29)	5	4.33(2.70–5.97)	48
Indirect costs	66.89(44.57–89.20)	44	50.16(0-224.00)	2	67.68(44.31–91.06)	42
Total household costs (USD)	**150.17**(134.11-166.24**)**	**184**	**172.43**(130.46-214.39)	**21**	**147.31**(129.91-164.71)	**163**

250.94 (95% CI:183.07–318.80) in Kilifi vs. USD 249.10 in Siaya) after including costs for salaries of USD 62.79(95% CI: 45.81–79.77) paid by KEMRI-Wellcome Trust and of USD 141.12(95% CI:102.95-179.28) paid by the County government to staff managing the high-dependency paediatric ward patients, in Kilifi County Hospital (Table 4).

About 26% of the total health system costs (USD 69.24(95% CI: 50.51–87.96)) in Kilifi, were paid by KEMRI-Wellcome Trust, while 53% were paid by the County government (Table 5). Costs for other patient services as provided by the hospital administration were higher in Siaya compared to Kilifi [25].

Total costs to the health system and household for taking care of a child with an episode of RSV illness

The total (household and health system) cost for an episode of RSV illness was USD 329.36 (95% CI: 250.51–408.20) in Kilifi and USD 527 (95% CI: 405– 649) in Siaya

Table 3 Mean (95% confidence intervals) Household hospitalization costs in USD by categories for an episode of RSV LRTI in Kilifi and Siaya

Cost Parameters	RSV Positive patients			RSV Negative patients		
	mean cost(USD)	(95% CI)	*n* = 79	mean cost(USD)	(95% CI)	*n* = 162
(A) KILIFI						
Costs incurred during hospitalization	**46.88**	37.69–56.07	79	**64.65**	48.81–80.49	162
Direct Medical Costs						
Drugs	1.46	1.40–1.52	69	1.84	1.33–2.35	124
Lab/medical care procedures	0.86	0.25–1.47	79	1.49	0.6–2.37	161
hospital bed fees	2.45	1.82–3.08	70	2.72	2.36–3.08	127
consultation/registration fees	4.37	4.32–4.43	70	4.4	4.27–4.53	127
Others (medical supplies)	4.06	3.43-4,69	76	3.89	3.48–4.29	161
Direct non-Medical Costs						
Transportation cost by distance	7.41	0-15.84	*39*	3.11	1.86–4.36	54
Lodging	*0*		*79*	*0*		*162*
Food	6.6	4.98–8.22	*77*	6.74	5.35–8.13	158
Caretaker/Others	0.08	0-25.14	*29*	0.77	0.09–1.46	55
Indirect costs						
Lost income	19.75	11.72–27.79	20	64.57	17.67–11.49	49
lost productivity	26.58	17.73–35.43	61	33.64	26.22–41.05	122
(B) SIAYA	**mean cost(USD)**	**(95% CI)**	*n* = 21	**mean cost(USD)**	**(95% CI)**	*n* = 163
Costs incurred during hospitalization	**138.51**	106.54-170.48	**21**	**113.26**	100.81-125.71	**163**
Direct Medical Costs						
Drugs	10.57	7.62–13.51	21	8.77	7.36–10.17	158
Lab/medical care procedures	19.51	14.72–24.29	18	17.83	14.73–20.92	143
hospital bed fees	33.59	25.36–41.83	21	28.63	25.70-31.55	159
consultation/registration fees	1.37		21	1.33	1.30–1.37	158
Others (medical supplies)	5.71	3.82–7.61	17	3.59	2.68–4.49	119
Direct non-Medical Costs						
Transportation cost	17.40	8.12–26.67	*21*	13.67	6.89–20.44	162
Lodging	*0.00*		*0*	*10.95*		*1*
Food	6.57	3.44–9.70	*18*	3.84	3.36–4.32	140
Caretaker/Others	12.16	0-64.49	*3*	4.31	1.16–7.46	9
Indirect costs						
Lost income	25.91	2.99–48.8	10	22.11	14.91–29.31	88
Lost productivity	34.53	25.04–44.02	21	28.69	25.44–31.94	160

respectively (Table 5). Further details of this analysis and supplementary tables have been provided with the replication dataset [25].

Discussion

Through this study, we have generated estimates on the cost of care for a child with severe RSV-LRTI to both families and the health system in Kenya. We found that the mean cost to households of taking care of a child with severe RSV-LRTI in Kenya is high, ranging from a mean of USD 66.52 in Kilifi to USD 172.43 in Siaya. Additionally, most families reported this cost to have impacted their family finances, as 86% of the households in Siaya with participants in this study, earned a total monthly income of less than USD 500. For participants in Siaya, this implies, 86% of households would spend about 34% of their monthly household income if their child is hospitalised with RSV-associated LRTI at the County Referral Hospital. With this substantial economic burden to households, interventions that prevent against RSV LRTI will lead to reduction in hospitalization costs. A cost-effectiveness analysis of the two approved RSV interventions estimated a maternal vaccine would reduce RSV-associated hospitalisations by 18.5% (95% CI: 14.5–21.6) and RSV-associated deaths by 10.5% (95% CI: 7.9–13.3). With a dose price of 5 USD, the MV will have an ICER value of 180 (95% CI: 126–267) USD per DALY averted and thus will be more cost-effective in Kenya [28].

We report high costs per episode of RSV associated hospitalization incurred by households in Siaya (USD 138.51) than in Kilifi (USD 46.83). We found costs incurred prior to hospitalization were associated with monthly household income whereas, costs during hospitalization were associated with age of the patient in Kilifi but not in Siaya. We also observed that household costs

Table 4 Health system costs for an episode of RSV LRTI in Kilifi and Siaya, Kenya

Cost Parameters	Hospital costs to all patients		2019 to 2021 prices		
	(Outpatient and inpatient) in 2019 (KSHS)	Unit cost/ LRTI episode (KSHS)	Adjusted costs(KSHS)	Unit cost/ LRTI episode (USD)	Mean cost/RSV-LRTI episode (USD)
A. Kilifi County Hospital					*n* = 79
Laboratory/clinical procedures and supplies	3,377,305	240.41	265.19	2.42	2.58(1.88–3.27)
Staff costs	378,048,256	23,401.81	25,813.83	235.44	250.94(183.07–318.80)
Costs paid by KCH	73,949,400	4,386.71	4,838.85	44.13	47.03(34.31–59.76)
Costs paid by the County government	221,848,200	13,160.13	14,516.54	132.40	141.12(102.95-179.28)
Costs paid by KEMRI	82,250,656	5,854.97	6,458.44	58.91	62.79(45.81–79.77)
Administrative costs	14,643,151.00	868.64	958.17	8.74	9.32(6.79–11.84)
Costs paid by KCH	4,512,625	267.69	295.28	2.69	2.87(2.09–3.64)
Costs paid by KEMRI	10,130,526	600.95	662.89	6.05	6.45(4.70–81.9
Total costs	**396,068,712**	**24,510.86**	**27,037.19**	**246.60**	**262.83(191.75-333.92)**
B. Siaya County Hospital					*n* = 21
Laboratory/clinical procedures and supplies	17,112,166	1,401	1,545.18	14.09	19.73(14.16–25.29)
Staff costs	155,559,480	17,685	19,508.07	177.93	249.10(178.87-319.34)
Administrative costs	53,250,800	6,054	6,677.96	60.91	85.27(61.23-109.32)
Total costs	**225,922,446**	**25,140**	**27,731.21**	**252.93**	**354.10(254.26-453.94**

Table 5 Total household and health system mean (95% confidence intervals) costs in USD for an episode of RSV LRTI in Kilifi and Siaya

Cost Parameters	All patients	RSV Positive	RSV Negative
	mean cost(95%CI)	mean cost(95%CI)	mean cost(95%CI)
(A) KILIFI	**(*N* = 241)**	**(*n* = 79)**	**(*n* = 162)**
Total health system costs(USD)	**307.79(260.99-354.58)**	**262.83(191.75-333.92)**	**329.71(269.94-390.29)**
Health system costs paid by KEMRI	**81.08**(68.75–93.40)	**69.24**(50.51–87.96)	**86.85**(70.90-102.81)
KCH Health system costs paid by the County government	**165.25(140.13-190.38)**	**141.12(102.95-179.28)**	**177.02(144.50-209.54)**
Total Health system costs paid by Kilifi County Hospital (KCH)	**61.46**(52.12–70.80)	**52.48**(38.29–66.67)	**65.83**(53.74–77.93)
Clinical procedures/lab/Supplies	3.20(2.56–3.48)	2.58(1.88–3.27)	3.24(2.64–3.83)
Staff	55.08(46.71–63.45)	47.03(34.31–59.76)	59.00(48.16–69.84)
Administrative costs	3.36(2.85–3.87)	2.87(2.09–3.64)	3.60(2.94–4.26)
Total household costs (USD)	**80.79**(67.26–94.33)	**66.52**(53.50-79.55)	**87.75**(68.64-106.87)
Direct medical	17.78(15.05–20.51)	15.30(13.38–17.22)	18.99(15.03–22.95)
Direct nonmedical	12.68(10.56–14.80)	13.7(9.14–18.26)	12.18(9.91–14.46)
Indirect costs	50.33(37.89–62.78)	37.52(26.93–48.11)	56.58(38.80-74.37)
Total costs (Health system + household costs) (USD) paid by KCH, County government and KEMRI	**388.58(335.02-442.15)**	**329.36(250.51–408.20)**	**417.47(347.57-487.38)**
(B) SIAYA	(*N* = 184)	(*n* = 21)	(*n* = 163)
Total health system costs (USD)	**285.37**(256.09-314.65)	**354.10**(254.26-453.94)	**276.51**(245.91-307.12)
Clinical procedures/lab/Supplies	15.90(14.27–17.53)	19.73(14.16–25.29)	15.40(13.69–17.11)
Staff	200(180.15-221.35)	249.10(178.87-319.34)	194.52(172.99-216.05)
Administrative costs	68.72(61.67–75.77)	85.27(61.23-109.32)	66.59(59.22–73.96)
Total household costs (USD)	**150.17**(134.11-166.24)	**172.43**(130.46-214.39)	**147.31**(129.91-164.71)
Direct medical	62.09(56.49–67.68)	74.49(57.28–91.50)	60.50(54.56–66.44)
Direct nonmedical	21.03(14.81–27.26)	27.83(16.83–38.83)	20.16(13.26–27.06)
Indirect costs	66.98(55.16–78.81)	70.12(41.52–98.73)	66.58(53.66–79.50)
Total costs (Health system + household costs) (USD)	**435.54**(396.32-441.77)	**526.53**(404.54-648.52)	**423.82**(382.30-465.34)

incurred two weeks after hospitalization were slightly higher in Kilifi than Siaya. As previously described in a study to assess predictors of outpatient care in Kenya [29], we also think, families with high income are likely to seek outpatient care in private hospitals or buy over the counter drugs for their child before visiting the County referral hospital. Similarly, in Kilifi most patients were young, requiring specialized care and longer stay in hospital than

patients in Siaya which resulted to more costs even two weeks after discharge. Adherence to treatment protocols for pneumonia, with 24-hour monitoring of patients [30] by clinicians from KEMRI-Wellcome Trust in Kilifi hospital paediatric ward, could have improved the quality of inpatient care and prudent use of medications and as a result low hospital care costs by households. The effect of subsidy is evident among participants in Kilifi who are likely to have paid less than the required cost for hospital supplies and services, leading to the observed low direct medical costs during hospitalization.

We found the health system unit cost per episode of RSV illness in Kenya to vary between the two study hospitals. Similar variation in costs between hospitals was reported in a study conducted in Bangladesh where higher costs were found in private than in public hospitals [31]. We reason the lack of standardization in the financing of the healthcare system across the 47 counties in Kenya [19] and the availability of commodities across health facilities [16] might have contributed to the observed County differences in costs.

We did not find any difference in the cost of treatment for RSV-LRTI and non-RSV-LRTI. This relates to the syndromic management of patients with severe LRTI in public hospitals in Kenya which follow the World Health Organization guidelines [32]. However, we found more deaths reported two weeks after hospitalisation in Kilifi among non-RSV LRTI patients (6 (3.7%) children) than in RSV LRTI patients (1 (1.3%) child), and in Siaya nine of the ten children (5.4%) who died after hospitalization were non-RSV LRTI patients. Some studies have shown that, bacterial co-infection enhances severity of RSV-associated LRTI disease and the development of bacterial pneumonia among infants [33]. This may explain the reported deaths of under 6 months non-RSV LRTI patients who had other medical conditions like sepsis and meningitis in this study. Furthermore, infections by respiratory viruses have also been found to alter the microbiome in the respiratory airways, which impairs the immune system and consequently predisposing patients to secondary bacterial super-infections [34]. It is therefore possible that, introduction of interventions against RSV will have a significant impact on the health and economic burden of both RSV and non-RSV LRTI among these infants.

This study has some limitations. Data on total household income was collected as a range rather than a single point from which we could not directly estimate total expenditures as a percentage of total household income. The number of RSV positive LRTI patients in Siaya were very few (21/184) and 90% of these reported not to have incurred any indirect costs (i.e. no loss of income or productivity) resulting to zero values in the post hospitalization data which contributed to the wider confidence intervals observed in the cost estimates. The data in Siaya was collected during the COVID-19 pandemic where non-pharmaceutical interventions were enforced and therefore reduced RSV transmission which could have resulted in the few cases presenting in hospital during that period. Additionally, we conducted the study in County referral public hospitals where costs are different from those in private hospitals and dispensaries and other lower-level health facilities. The methods used to estimate some of the inpatient- specific costs were based on parent's/guardian's recall of actual expenditures. We included costs paid by other organizations to the Hospital such as the case of KEMRI-Wellcome Trust and Kilifi County Hospital in this analysis, but costs in Kilifi were still low compared to those of Siaya which we think this is a true reflection of the cost of care within these two Counties. Interpretation of these results, therefore, needs to consider these differences in Kenya.

Conclusions

RSV-associated disease is a cause of substantial economic burden to the majority of families in Kenya where over 50% of households earn USD 500 or less per month. These data will support cost-effectiveness modelling for RSV prevention strategies and provide Kenyan policy makers with robust data.

Abbreviations

RSV	Respiratory syncytial virus
KHDSS	Kilifi Health and Demographic Surveillance System
KEMRI	Kenya Medical Research Institute
KWTRP	KEMRI Wellcome Trust Research Programme
KCH	Kilifi County Hospital
LMICs	Low- and Middle -Income Countries
GDP	Gross Domestic Product

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-19875-y.

Supplementary Material 1

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Author contributions

JUN: Designed the study, supervised data collection, performed data analysis and wrote the main manuscript text. BN: Designed the study, supervised data collection, reviewed and edited the manuscript. DJN: Designed the study, reviewed and edited the manuscript.MM: Performed laboratory testing of samples, reviewed and edited the manuscriptCO: Designed the study, reviewed and edited the manuscript.NM: Designed the study, performed data analysis, reviewed and edited the manuscript.GB: Designed the study, reviewed and edited the manuscript.NAO: Designed the study, reviewed and edited the manuscript.SL: Designed the study, reviewed and edited the

manuscript.BM: Designed the study, reviewed and edited the manuscript.CC: Designed the study, reviewed and edited the manuscript.JM: Designed the study, reviewed and edited the manuscript.MJ: Designed the study, reviewed and edited the manuscript.CP: Designed the study, reviewed and edited the manuscript.RB: Designed the study, reviewed and edited the manuscript. PM: Designed the study, reviewed and edited the manuscript.EV: Designed the study, performed data analysis, reviewed and edited the manuscript.All authors have reviewed and approved the manuscript for publication.

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Data availability
The dataset used and analysis scripts generated for this manuscript are available in Harvard Dataverse at https://doi.org/10.7910/DVN/XIYHXF. The data is stored under restricted access and available from the authors upon request through submission of a request form for consideration by our Data Governance Committee (dgc@kemri-wellcome.org).

Declarations

Ethics approval and consent to participate
All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained in writing from all guardians and parents of eligible participants. This study was granted ethical approval by the KEMRI Scientific and Ethical Review Unit Committee (SERU #3939).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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