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Household Fuel Use and Acute Respiratory Infections in Children Under Five Years of Age in Gondar city of Ethiopia

Mekuriaw Alemayehu[1], Kassahun Alemu[1], Hardeep R. Sharma[2*], Zemicheal Gizaw[1], Abera Shibru[1]
1.Department of Environmental and Occupational Health and Safety, College of Medicine and Health Science University of Gondar, Post Box No. 196, Ethiopia
2.Institute of Environmental Studies, Kurukshetra University, Kurukshetra, Haryana, PIN 136119, India
*Email of the Corresponding author: hrsharma74@yahoo.co.in
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Abstract
Acute respiratory infections (ARI) are the leading cause of childhood illness and death worldwide, accounting for an estimated 6.5% of the entire global burden of disease. This study investigated the association between household use of biomass fuels for cooking and acute respiratory infections in preschool age children (< 5 years) in Gondar city of Ethiopia. This cross sectional study was based on 715 children age 0–59 months included in three clusters randomly selected from 12 administrative areas of Gondar city. Children who suffered from cough accompanied by short, rapid breathing during the two weeks preceding the survey were defined as having suffered from ARI. Logistic regression was used to estimate the odds of suffering from ARI among children from households using biomass fuels (wood, dung or straw) relative to children from households using cleaner fuels (liquid petroleum gas (LPG), or electricity) after controlling for potentially confounding factors. More than half of the children (54.7%) lived in households using biomass fuels from which 26.3% suffered from ARI during the 2 weeks preceding the survey interview. Children in households using wood, dung, or straw for cooking were 3.89 times more likely to have suffered from ARI as compared to children from households using LPG or electricity (OR = 3.89; 95% CI: 1.54, 28.25). Household's use of high pollution biomass fuels is significantly associated with ARI in preschool age children in Gondar city, Ethiopia. The relationship needs to be further investigated using more direct measures of smoke exposure and clinical measures of ARI.
Keywords: Acute respiratory illness, Indoor air pollution, Biomass combustion, Gondar city

1. Introduction

Acute respiratory infection (ARI) is the most common cause of illness in children and a major cause of death in the world. Among children under five years of age, three to five million deaths annually have been attributed to ARI, of which 75% are from pneumonia (Stansfield and Shepard, 1993). The World Health Organization (WHO) estimates that approximately over 6% of the global disease burden and 7% of all deaths is due to ARI (WHO, 2002). A number of studies have suggested that exposure to domestic smoke from biomass fuels (e.g., charcoal, wood, dung, and crop residues) increases the risk of respiratory problems such as persistent cough in adults (Bruce *et al.* 1998) and acute lower respiratory infections in young children (Ezzati and Kammen, 2001; Mishra, 2003).

This study examines the association between household use of high pollution biomass fuels (wood, dung, or straw) and ARI prevalence in children using data collected from Gondar city community. Biomass fuels are at the low end of the energy ladder in terms of combustion efficiency and cleanliness (Smith and Liu, 1994) and cause high pollution. Exposure to pollution from wood burning stoves for indoor heating is associated with severe respiratory symptoms and mortality (Johnson and Aderele, 1992).

Biomass smoke contains hundreds of chemical compounds (Smith and Liu 1994). Some of the components present in biomass smoke that are of concern for health include particulate matter, carbon monoxide (CO), nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), polycyclic aromatic hydrocarbons (PAH) and other volatile organic compounds (Samet *et al.* 1987; Smith *et al.* 2000). In developing countries, large proportions of households rely on biomass fuels for cooking and space heating, concentrations of these air pollutants tend to be highest indoors (Bruce *et al.* 2000).

Earlier researches in Butajira and Shebedino towns of Ethiopia showed the predominance of acute ARI among under-five children (Desalegn *et al.* 2011; Lulu *et al.* 1997). Among the more commonly suspected risk factors, exposure to smoke from unvented cooking fires indoor has ranked high, whether described as indoor air pollution or as smoke from biomass fuels (Chretien *et al.* 1984; Desalegn *et al.* 2011; Mishra, 2003; Zhang and Smith, 2003).

Since the household energy use and the epidemiology of ARI vary from country to country and from place to place in the same country, indoor air pollution from biomass combustion and ARI in preschool age children in the study area was carried out. The main objective the study is to investigate the prevalence of ARI and associated risk factors for ARI in children less than 5 year age in the study area.

2. Materials and Methods

The cross – sectional study design, which employed an exposure assessment approach, collected detail primary data through questionnaires from 715 households regarding exposure level indicators (cooking fuel type, kitchen type, housing type, ventilation, children's proximity to the cooking stove etc.).

The study was conducted in Gondar city which is located about 750 kilometers northwest from the capital Addis Ababa, and about 180 kilometers from BahirDar town, the capital of the Amhara region. The city has an altitude 12°36′N 37°28′E and longitude of 12.6^{0}N 37.467'E with an elevation of 2133 meters above sea level and is divided into 12 administrative areas according to the recent administration structure. Gondar is among one of the ancient and largely populated cities in the country. The city has an estimated total population of 206,987 of whom 98,085 are men and 108,902 are women (CSA, 2007).

The 12 administrative areas of the city were used as clusters with an assumption of being homogeneous. Three clusters were selected randomly from the 12 administrative clusters and all eligible study participants present in the selected clusters were included in the study. During the identification process some houses were missing and some were business centers (non-residential) and were not included in the survey. Repeated attempts were made to get the selected respondents and were successful. During the survey, where more than one pre–school child was available in household, all of them were included in the study. For each selected child under age 5, the mother was enquired if the child had been ill with a cough in the 2-week period preceding the survey interview. For children who had been ill with cough in the last 2 weeks, the mother was further asked about the time span of cough, faster breathe than usual with short, rapid breaths. Children found to suffer from cough accompanied by short and rapid breathing at any time during the last 2 weeks were categorized in acute respiratory infection, a response variable of the analysis.

Exposure to cooking smoke was ascertained indirectly by type of fuel used for cooking. The survey used an eightfold classification of main cooking fuel—wood, cow dung, straw, charcoal, kerosene, and electricity, liquid petroleum gas (LPG), and a residual category of other fuels. Based on the fuel types, the households were grouped into three categories representing the extent of exposure to cooking smoke i.e. high pollution fuels (wood, dung, or straw), medium pollution fuels (kerosene or charcoal), and low pollution fuels (LPG or electricity).

2.1. Operational definitions

Household standard of living index (SLI) was calculated by adding the following scores: 3 for a car or tractor; 2 each for the motorcycle, TV, telephone, refrigerator, piped/public tap water, flush toilet, electricity, wood/vinyl/asphalt/ ceramic/cement/carpet of main floor material; 1 each for a bicycle. Index scores ranged from 0–2, 3–8, and 9–21 were considered as low, medium, and high SLI, respectively (Mishra, 2003).

Housing condition: Mud houses were constructed from mud, thatch or low-quality materials. Concrete or brick houses were made using high quality materials such as bricks, tiles, cement, and concrete throughout, including roof, walls, and floor whereas, semi-mud and semi-concrete houses are made partly from both low-quality and high-quality materials.

Nutritional status: was calculated by the height-for-age index. It is an indicator of linear growth retardation and cumulative growth deficits. Children whose height-for-age Z-score is below minus two standard deviations (-2 SD) from the median of the reference population were considered short for their age (stunted) and are chronically malnourished. Children who scored below minus three standard deviations (-3 SD) from the median of the reference population were considered severely stunted. Stunting reflects failure to receive adequate nutrition over a long period of time and is also affected by recurrent and chronic illness. Height-forage, therefore, represents the long-term effects of malnutrition in a population and does not vary according to recent dietary intake.

The data were collected by interviewing mothers using a structured and pre-tested questionnaire. The questionnaire was prepared in English and translated to Amharic (native language) and then back to English to verify its consistency and contents. To ensure data quality, data collection was performed by B. Sc. Environmental Health students of University of Gondar for each selected administrative area. In addition, one supervisor was assigned for each data collection sites. Training was given both to data collectors and supervisors before data collection and the principal investigators regularly monitored and followed the data collection process. Questionnaire was checked for completeness on a daily basis by immediate supervisors. After checking all questionnaires for consistency and completeness the supervisors submitted the filled questionnaire to principal investigator. Incorrectly filled or missed ones were sent back to respective data collector for correction. The investigator made supervision of the data collection sites throughout stay. In order to crosscheck the collected data and to maintain the quality of data the principal investigator also randomly rechecked five percent of the completed questionnaires daily. Data clean up and cross–checking was done before analysis. Ethical clearance was obtained from the Institutional Review Board of School of Public Health, College of Medicine and Health Sciences, University of Gondar. The purpose of the study was clearly explained to the study subjects and their verbal consent was obtained. Confidentiality of the data was strictly maintained throughout the study period.

The data were entered and analyzed by SPSS version 15.0 statistical software (SPSS Inc. Chicago, 2007). Bivariate and multivariate logistic regression analyses were used to indentify factors associated with biomass use for cooking and ARI. The unadjusted (crude) (COR) and adjusted odds ratios (AOR) together with their corresponding 95% confidence intervals (CI) were computed. A *p*–value ≤ 0.05 was considered statistically significant in this study. Efforts were made to assess whether the necessary assumptions for the application of multiple logistic regression were fulfilled. In this regard, the Hoshmer and Lemeshow's goodness– of –fit test was considered where a good fit will yield a large *p* – value (Mehta *et al.* 2002).

3. Results

A total of 715 pre–school age children's were included in the study with an overall response rate of 100%. The majority of the study participants (51.3%) were males and the rest (48.7%) were females. The mean age of the study participant was 29.17±16.01 months. The mean age of mothers during first child birth was 25.6±5.6 years. Ninety six percent of the mothers were Amhara by ethnicity and 67% were orthodox Christians by religion. About 35.7% of the mothers were literate to level of secondary school. Regarding marital status of the mother, 77.9% of them were married, 11.3% of them were divorced and 5.6% of them were single. The proportion of children in the sample decreases by birth order from 47.6% at birth order 1 to 27.6% at birth order 2, and 12.9% at birth order 3. About 19.7% of the children lived in low standard households whereas 39.7% lived in high standard households. Thirty eight percent of the children were severely stunted, 23.6% were mild stunted and the rest 36.1% were not stunted. The largest proportion of children (68.7%) live in mud houses, 20.4% live in concrete/brick houses and the remaining 9.7% live in semi concrete and semi mud houses. Regarding employment status about 21 % was employed, 10% were merchants and remaining 63% of the mothers were housewives. More than half (54.7%) of the children found to live in households that rely primarily on high pollution biomass fuels (wood, dung or straw) for cooking, 39.2% live in households using medium pollution fuels (charcoal or kerosene) and the remaining 6.2% live in households using low pollution fuels (LPG or electricity) (Table 1).

About twenty six percent of children under age 5 were found to suffer from ARI during the 2 weeks preceding the survey. The prevalence of ARI was much higher (32.7%) among children living in households using biomass as fuel than among 6.8% who lived in households using comparatively less pollution fuels. Children aged 6 – 11 (28%) and 12 – 23 (29.3%) months were more likely suffered from ARI than children < 6 months. Children from high standard of living households were considerably less likely to had ARI (20.4%) than those from low (34%) and medium (28.6%) standard. The prevalence of ARI is much lower in children living in concrete/brick house (17.9%) than those from mud house (27%). Children living in a single room household were suffered from high ARI (29%) compared to those children living in house with ≥ 2 rooms (21.9%). The prevalence of ARI is much higher in households (67.6%) where smoking cigarette was reported inside homes than the households (24%) where it was not reported. Thirty five percent of children under age 5 who were often carried or lap during cooking suffered from an ARI during the 2 weeks preceding the survey. The reported prevalence also higher for children staying with their mother during cooking (33.3%) as compared to those does not. Children playing nearby during cooking (30.7%) have got higher prevalence compared to those does not (Table 1).

The unadjusted odds of having suffered from ARI were 5.86 times higher among children living in the households using high pollution biomass fuels than among those living in households using low pollution fuels LPG/ natural gas or electricity for cooking (OR = 5.86, 95% CI: 1.46, 23.53) (Table 2). As expected children from households using medium pollution charcoal or kerosene also had higher ARI prevalence (OR = 2.71, 95% CI: 0.66, 11.01) than those from households using LPG or electricity. As in the case of unadjusted odds of ARI (Table 2) with variables that have statistically significant effects are standard living index (SLI), number of rooms, separate kitchen in the household, windows in the house, windows in the kitchen, child staying with you while cooking, child playing nearby cooking area during cooking and children carried or lap during cooking.

Controlling for variables like cooking fuel, child age (months) and sex, birth order, nutritional status, mothers age at child birth (years), educational level and religion of the mother, SLI, number of rooms in house, availability of separate kitchen, having windows in house and kitchen, child staying with mother while cooking, child playing nearby while cooking and carry the child while cooking were considered in the model (Table 2). Both the condensed model and bivariate analysis showed cooking fuel type, window in the kitchen, child playing nearby while cooking and carry the child on back or in lap while cooking are significant and independent predictor variables in determining ARI prevalence in preschool age children.

4. Discussion

ARI is a serious problem among preschool age children in the Gondar city. ARI prevalence of the study area (26.3%) was found to be higher as compared to the study carried out in Shebedino region of Ethiopia (Desalegn *et al.* 2011) and the national figure of 24%. However, it is amazingly too high when compared with that to Butajira, area of Ethiopia (Muhe *et al.* 1997), where the prevalence was 2.8%. It is partly explained that factors

like household setup, socio-economic characteristics, residence and study period may contribute for the inconsistency. In consistent with the Zimbabwean study (Mishra, 2003) on preschool age children the present study suggested that cooking smoke exposure from biomass combustion was significantly associated with ARI prevalence in preschool age children, independent of child's age, nutritional status, maternal education, household living standard, and other factors (OR = 5.86, 95% CI: 1.46, 23.53).

Those children from households having kitchen without windows were 3.53 times more likely to have suffered from ARI as compared to children from households having windows in the kitchen (OR = 3.53; 95% CI: 1.49, 8.32). This could be because of limited ventilation and this increases exposure of smoke, particularly for women and young children who spend much of their time in the kitchen for cooking. Children playing nearby cooking area during cooking were 7 times more likely to have suffered from ARI than those who do not play nearby cooking area during cooking (OR = 7.08; 95% CI: 2.59, 19.35). The practice of carry young children or keep them nearby area while cooking by mothers or guardians is common in Ethiopia. Mothers are more likely to carry a sick child, continue carrying a child during cooking until the next birth or the child's becomes too heavy to carry. Due to which the children's become more proximal to cooking stoves/exhaust and they became exposed for the pollutants that are risk factors for acute respiratory infections. Those children's often carried or in lap during cooking were 2.68 times more likely to suffered from ARI than their counterparts (OR = 2.68; 95% CI: 1.12, 6.48). An increased risk from ALRI associated with the child being carried on the mothers back has been noted in other studies (Armstrong and Campbell, 1991; Kilabuko *et al.* 2007).

Exposure to biomass smoke has been associated with compromised pulmonary immune defense mechanisms (Green 1977; Thomas and Zelikoff, 1999). Exposure to respirable particulate matter (PM_{10}) in biomass smoke can induce systemic inflammatory response that includes bone marrow stimulation, which can contribute to the pathogenesis of the cardiorespiratory morbidity (Fujii *et al.* 2001; Mukae *et al.* 2001). Other evidence indicates that exposure to polycyclic aromatic hydrocarbons (PAH) – especially benzo [a] pyrene (B[a]P), which is found in large quantities in biomass smoke – can cause immune suppression and can increase the risk of infection and disease (Kong *et al.* 1994). Moreover, acute and long term exposures to oxides of nitrogen, commonly found in biomass smoke, can increase bronchial reactivity and susceptibility to bacterial and viral infection (Samet and Utell, 1990). Tobacco smoke also has been shown to cause depressed immune system responses (Chang *et al.* 1990; Heresy *et al.* 1983; Sopori *et al.* 1989). It is, therefore, possible that extended exposure to high levels of cooking smoke can impair the pulmonary defense mechanism, compromise lung function, and render children more susceptible to ARI.

The information on tobacco smoking by the household members in current study was unable to control in our logistic regression model for environmental tobacco smoke (ETS), which is a known risk factor for ARI in children (Li *et al.* 1999). The possible reason for this was having small number of households (5.2%) with ETS in our study area resulting wider confidence interval. The prevalence of ARI in households with having tobacco smoking members (67.6%) who smoke inside home is higher as compared to households without tobacco smoking members (24%). Maternal smoking is not a significant confounding factor because women rarely smoke in Ethiopia especially in Gondar city.

The current research had some measurement constraints like many households in Ethiopia typically use combination of cooking fuels, whereas we restrict our study from the households mainly use primary cooking fuel. Our estimated effects are attenuated to the extent that a mix of biomass fuels and cleaner fuels is actually used by many households instead of biomass fuels alone. Also direct control for crowding in the households was not done. Indoor crowding tends to be correlated with biomass fuel use and may affect the risk of ARI. However, indoor crowding is controlled in our analysis to the extent it is correlated with birth order of child and number of rooms in the household included in our logistic regression model. Further, underreporting of ARI due to lack of awareness that the child had the disease during the study period can be possible. Here 58.6% answered yes for the question 'is the child had been ill with cough in the last two weeks?' but among those only 26.3% of our study participants suffer by ARI. To the extent that underreporting due to lack of awareness is greater among those living in the households using biomass fuels, it would contribute to under estimation of the effect of cooking smoke on the prevalence of ARI. As mentioned earlier, information on ARI is based on mothers report and no clinical measurements undertaken and smoke exposure was ascertained from type of fuel used for cooking. Although the symptomatic definition used here is intended to measure acute lower respiratory infections (ALRI) in children, some acute upper respiratory infection may have been included in the reported prevalence. Because it is not possible to separate ALRI from these data, we use the term ARI in this study, not ALRI. In developing countries such as Ethiopia, where clinical data on ARI are usually not available or very week, the symptomatic definition of illness used here has been shown to provide a fairly accurate assessment of ARI in the population (Cabaraban, 1993). Moreover, indoor air pollution measurements in several developing countries have shown fuel type to be the best single indirect indicator of household pollution level (Mehta, 2002). Despite these problems in the measurement of smoke exposure and ARI, the consistency in the size of crude and adjusted effects of biomass fuel use on childhood ARI suggests a possible 'exposure - response' relationship. To

validate this relationship, our research needs to be followed by carefully designed epidemiological studies, with direct measurement of smoke exposure and clinical measures of ARI.

Overall, this study revealed heavy reliance on biomass fuels for household energy for cooking in the study area which resulted into high prevalence of ARI in preschool age children. Apart from fuel type, other factors that may associated with ARI incidence are house ventilation, children playing nearby during cooking and mother carrying children on back or in lap during cooking. The exposure to indoor air pollution can be reduced by promoting the use of cleaner fuels like LPG and electricity. Indoor air pollutants level can be further reduced through improvements in kitchen and cooking stove design and ventilation. Environmental awareness and health education should be provided to sensitize the women/mothers about the health problems associated with ARI and biomass combustion within the house.

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Ethical approval

Ethical clearance was obtained from the Institute Review Board of School of Public Health, College of Medicine and Health Sciences, University of Gondar. The purpose of the study was clearly explained to the study subjects and their verbal consent was obtained.

Competing Interest

None declared.

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Table 1

Socio–demographic characteristics of pre–school children and their mothers in Gondar city.

Variable	Frequency	percent
Sex		
Male	367	51.3%
Female	348	48.7%
Age child (months)		
0 – 5	57	8.0%
6 – 11	50	7.0%
12 – 23	164	22.9%
24 – 35	149	20.8%
36 – 60	295	41.3%
Age of mother's (years)		
15 -24	323	45.2%
25 -34	334	46.7%
35 -49	58	8.1%
Religion of mother		
Orthodox	479	67.0%

Muslim	234	32.7%
Protestant	2	3.0%
Ethnicity of the mother		
Amhara	687	96.1%
Tigrie	26	3.6%
Others	2	0.3%
Education level of the mother		
Illiterate	167	23.4%
Read and write	23	3.2%
Primary	209	29.2%
Secondary	255	35.7%
Graduate from vocational	15	2.1%
Diploma and above	46	6.4%
Marital status of the mother		
Married	557	77.9%
Single	40	5.6%
Divorced	81	11.3%
Widowed	18	2.5%
Separated	19	2.7%
Employment of the mother		
Employed	148	20.7%
Merchant	72	10.1%
Housewife	455	63.6%
Others	40	5.6%
Standard Living Index [SLI]		
Low SLI	141	19.7%
Medium SLI	280	39.2%
High SLI	284	39.7%
Housing condition		
Mud house	491	68.7%
Concrete/ brick house	146	20.4%
Semi concrete and semi mud house	69	9.7%
Nutritional status		
Mild stunted	169	23.6%
Severely stunted	273	38.2%
Not stunted	258	36.1%
Birth order		
1	340	47.6%
2	197	27.6%
3	92	12.9%
4+	86	12.0%
Cooking fuel type		
High pollution fuel	391	54.7%
Medium pollution fuel	280	39.2%
Low pollution fuel	44	6.2%

Table 2
Factors affecting ARI prevalence among children under age five in Gondar city,Ethiopia.

Variables	ARI		COR (CI)	AOR (CI)
	YES	NO		
Cooking fuel type				
High pollution fuel	128	51	5.86 (1.46–23.53)*	3.89 (1.54–28.25)*
Medium pollution fuel	57	49	2.71 (0.66–11.01)	1.14 (0.15–8.85)
Low pollution fuel	3	7	r	r
Age of child (months)				
0 – 5	7	7	r	
6 – 11	14	8	1.75 (0.45–6.83)	-
12 – 23	48	21	2.29 (0.71–7.34)	-
24 – 35	41	18	2.28 (0.69–7.45)	-
36 – 59	78	53	1.47 (0.49–4.44)	-
Sex of the child				
Male	102	54	r	
Female	86	53	0.86 (0.53–1.38)	-
Birth order				
1	90	53	r	
2	52	28	1.09 (0.62–1.94)	-
3	24	11	1.28 (0.58–2.83)	-
4+	22	15	0.86 (0.41–1.8)	-
Nutritional status				
Mild stunted	44	25	0.83 (0.44–1.57)	-
Severely stunted	70	46	0.72 (0.41–1.25)	-
Not stunted	72	34	r	
Mother's age at childbirth [years]				
15 -24	90	52	r	
25 -34	85	49	1.01 (0.61–1.64)	-
35 -49	13	6	1.25 (0.45–3.49)	-
Education level of the mother				
Illiterate	62	19	r	r
Read and write	7	6	0.36 (0.1–1.19)	0.13 (0.02–0.84)
Primary	49	27	0.56 (0.28–1.12)	0.38 (0.12–1.16)
Secondary	62	42	0.45 (0.24–0.86)	0.48 (0.16–1.41)
Graduate from vocational	2	4	0.15 (0.03–0.9)	0.06 (0.01–1.38)
Diploma and above	6	9	0.2 (0.06–0.65)	0.23 (0.05–1.13)
Religion of mother				
Orthodox	126	75	r	
Muslim	62	32	1.15 (0.69–1.93)	-
Standard Living Index [SLI]				
Low SLI	48	16	2.68 (1.36–5.3)*	0.48 (0.13–1.7)
Medium SLI	80	36	1.99 (1.56–3.43)*	1.21 (0.48–3.04)
High SLI	58	52	r	r
Number of rooms				
1	126	51	2.23 (1.37–3.63)*	-
2+	62	56	r	
Is there a separate kitchen in the house?				
Yes	110	85	r	
No	78	22	2.74 (1.56–4.76)*	-
Are there window in the house?				
Yes	121	86	r	r
No	67	21	2.27 (1.29–3.98)*	1.69 (0.63–4.53)

Is there window in the kitchen?				
Yes	27	39	r	r
No	83	46	2.6 (1.42–4.79)*	3.53 (1.49–8.32)*
Is the child staying while cooking?				
Yes	143	53	3.24 (1.95–5.37)*	2.0 (0.86–4.67)
No	45	54	r	r
Is your child play nearby you while cooking?				
Yes	153	74	1.95 (1.12–3.38)*	7.08 (2.59–19.35)*
No	35	33	r	r
Do you often carry your child or in lap while you are cooking?				
Yes	103	33	2.68 (1.62–4.43)*	2.68 (1.12–6.48)*
No	85	73	r	r

*statistically significant r = reference

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