SUPPLEMENT ARTICLE

Geography, Population, Demography, Socioeconomic, Anthropometry, and Environmental Status in the MAL-ED Cohort and Case-Control Study Sites in Fortaleza, Ceará, Brazil

Aldo A. M. Lima,[1,2] Reinaldo B. Oriá,[1] Alberto M. Soares,[1] José Q. Filho,[1] Francisco de Sousa Jr,[1] Cláudia B. Abreu,[1] Alexandre Bindá,[1] Ila Lima,[1] Josiane Quetz,[1] Milena Moraes,[1] Bruna Maciel,[1] Hilda Costa,[1] Álvaro M. Leite,[3] Noélia L. Lima,[1] Francisco S. Mota,[3] Alessandra Di Moura,[3] Rebecca Scharf,[2] Leah Barrett,[2] and Richard L. Guerrant[1,2]

[1]Federal University of Ceará, Fortaleza, Brazil; [2]University of Virginia, Charlottesville; and [3]Institute for the Promotion of Nutrition and Human Development, Fortaleza, Ceará, Brazil

The Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development (MAL-ED) cohort in the study's Fortaleza, Brazil, catchment area has a population of approximately 82 300 inhabitants. Most of the households (87%) have access to clean water, 98% have electricity, and 69% have access to improved toilet/sanitation. Most childbirths occur at the hospital, and the under-5 mortality rate is 20 per 1000 live births. The MAL-ED case-control study population, identified through the Institute for the Promotion of Nutrition and Human Development (IPREDE), serves 600 000 inhabitants from areas totaling about 42% of the city of Fortaleza. IPREDE receives referrals from throughout the state of Ceará for infant nutrition, and provides services including teaching activities and the training of graduate students and health professionals, while supporting research projects on child nutrition and health. In this article, we describe the geographic, demographic, socioeconomic, anthropometric, and environmental status of the MAL-ED cohort and case-control study populations in Fortaleza, Brazil.

Keywords. demography; diarrheal diseases; malnutrition; nutrition; socioeconomic status.

The Etiology, Risk Factors, and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development (MAL-ED) network is conducting a multicountry, longitudinal prospective cohort study on the etiology, risk factors, and interactions of enteric infections and malnutrition, and the consequences of these factors on child growth, cognitive development, and vaccine response. The 8 study sites are epidemiologically and geographically diverse and comprised of low-income populations. The 8 MAL-ED cohort sites are located in Bangladesh, Brazil, India, Nepal, Pakistan, Peru, South Africa, and Tanzania. The Fortaleza, Brazil (BRF) site of the MAL-ED cohort study has participated in several cohort and intervention studies over the last 3 decades on enteric infectious diseases and malnutrition as well as the long-term effects on child development [1–6]. In this article, we describe the geographic, demographic, socioeconomic, anthropometric, and environmental status of the MAL-ED cohort and case-control study populations in Fortaleza, Ceará, Brazil.

Based on the 2010 census by the Instituto Brasileiro de Geografia e Estatística (IBGE), Brazil has a population of approximately 194 million people. Fortaleza is the capital of the state of Ceará and has a population of 2.5 million, making it the fifth most populated city,

Correspondence: Aldo A. M. Lima, MD, PhD, INCT-Biomedicine, Federal University of Ceará, R. Cel. Nunes de Melo, 1315, Rodolfo Teófilo, Fortaleza, CE, Brazil, CEP 60.430-270 (alima@ufc.br).

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after the cities of São Paulo (11.3 million), Rio de Janeiro (6.4 million), Salvador (2.7 million), and Brasília (2.6 million) [7]. Ceará is comprised of 189 counties, and Fortaleza and its 14 surrounding counties account for 43% of the total population of the state. Ceará is located in a semiarid region with low levels of precipitation throughout the year and a tendency for droughts, especially in the interior. After several years of drought in the 1980s, Fortaleza's population rose to become the fifth most crowded Brazilian city due to the migration of rural inhabitants seeking opportunities for employment and a better life [8]. Ceará is one of the poorest states in northeast Brazil.

The ancestry of Brazil, based on mitochondrial DNA sequencing, is 33% Amerindian, 28% African, and 39% European [9]. In Fortaleza, however, the ancestry of the population follows the pattern seen in northeastern Brazil, which is 22% Amerindian, 44% African, and 34% European. This increase in African ancestry is due to the transport of Africans from Central Africa (predominantly Angola) and West Africa to the ports in the northeast of the country. Based on Y chromosome studies, the European ancestry came mainly from Portugal.

METHODS

Study Location, Population, Demography, and Socioeconomic Status

For the geographic location and population, we used information from the Fortaleza administrative service and IBGE [7, 10]. Initial demographic data were collected from the study catchment area using a pilot demographic and socioeconomic status (SES) questionnaire developed for the MAL-ED study protocol [11]. For the case-control study, the demographic data were obtained using a case report form developed specifically for the MAL-ED study. The demographic information for Fortaleza, Ceará, and Brazil was abstracted from 2 official sources: Instituto Brasileiro de Geografia e Estatística and Departamento de Informática do Sistema Único de Saúde [12]. SES information was used to rank the study participants into low-, intermediate-, and high-SES categories. For example, we identified low-SES households as those who responded more frequently that their household did not have a mattress, television, chair or bench, or refrigerator, whereas high SES was identified as those who responded more frequently that their household had a cabinet with doors and open shelves, a watch or clock, an iron (charcoal or electric), a radio or transistor, a bicycle, a sofa, a bank account, and a computer. To assess food insecurity, we used a case report form adapted in 2006 by the Food and Nutrition Technical Assistance project for use in low-resource settings [13, 14].

Environmental Status

The cohort and case-control study developed specific case report forms for each study protocol. For this article, we used the initial baseline case report form as those were collected more than once during the study protocol. The environmental status parameters evaluated in the study protocols are described in the Results section.

Preparation, Training, Recruitment, and Study Enrollment Plan

In the BRF cohort study, the census of the community was obtained by field-workers (FWs) under the direct supervision of and trained by the principal investigator (A. A. M. L.), the study coordinator (C. B. A.), and a study nurse (A. D. M.). The census was conducted to collect data to inform and initiate the recruitment of potential study cohort participants (pregnant women). The FWs followed a daily schedule and went house to house obtaining information on all members of each household within the defined study area (Figure 1). The households were given a household number and the field-worker collected the following information on the census form: address, telephone number, the main source of drinking water, type of toilet facility that the members of the household usually used, first and last names and relationship between the members of the house to the household head, date of birth and sex of all household members, pregnancy status of women with the date of the last menstrual cycle, and weight and height for children 0–60 months of age. Prior to measuring the children, the FWs obtained informed consent from the parent or guardian and used a standard SchorrBoard to measure length (1–24 months) or height (25–60 months) to the nearest 0.1 cm. Digital scales were used to measure weight to the nearest 100 g. The weight-for-age, height-for-age, and weight-for-height z scores were calculated using the World Health Organization Multi-Country Growth Reference Study [15]. In addition to active surveillance in the community and word-of-mouth communication with pregnant participants, the FWs visited the antenatal clinic to obtain information about pregnant women living in the study community to recruit additional study participants.

The pregnant women identified by the initial MAL-ED census in BRF were visited 4 times by the FWs. The first visit occurred around the seventh month of the pregnancy to collect information on the expected delivery date. To monitor the delivery, the FWs would visit the pregnant woman 30 days and 10 days before the expected delivery date. A fourth visit would occur about 5 days after the expected delivery date. After the mother had delivered her baby, the FWs would explain the purpose of the MAL-ED study and obtain signed, informed consent for study enrollment. The FWs scheduled the start date for study participation when the infant was 17 days of age.

On the first day of observation of participants in the study, the FWs followed the study surveillance procedures [16]. Using an SES survey adapted from the initial pilot survey, data were collected at the time of enrollment. All children delivered in the study community within the bounds of both the

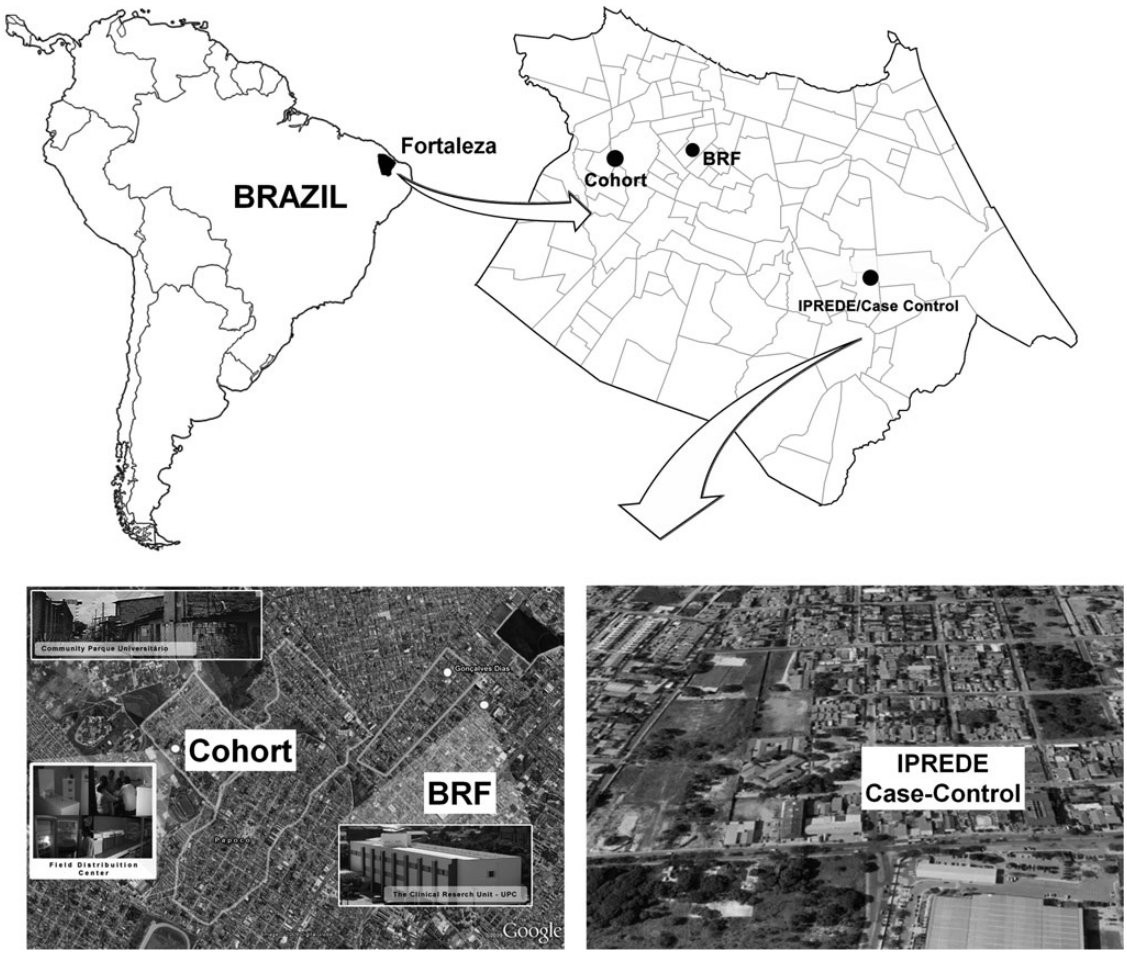

Figure 1. Geographic location of the Fortaleza, Brazil, site in the global network and Fortaleza satellite view. In addition, the figure illustrates the specific area of the cohort and case-control study areas. It also illustrates community activities such as healthcare worker activities and living and environmental conditions. Abbreviations: BRF, Fortaleza, Brazil; IPREDE, Institute for the Promotion of Nutrition and Human Development.

inclusion and exclusion criteria [11] were eligible and invited to enroll in the study. The expected average frequency of the recruitment was 8–12 subjects per month. Enrollment continued until 233 children were participating in the BRF site cohort study.

For the MAL-ED case-control study in the BRF site, the researchers and the study coordinator (C. B. A.) trained the clinic laboratory supervisor and health agents using the orientation course in Good Clinical Practice developed by the National Institute of Allergy and Infectious Diseases of the US National Institutes of Health [17], and the MAL-ED Manual of Procedures. The recruitment and enrollment for the case-control study differed from the community cohort study as the participants were children who attended the Institute for the Promotion of Nutrition and Human Development (IPREDE) clinic (Figure 1) for nutritional counseling. As collection of anthropometry measurements is the standard routine for the institution, the IPREDE nurses and health agents were able to locate children who met the entry criteria for the case-control study. The inclusion criteria were as follows: (1) 6–24 months of age; (2) weight-for-age z score < -2 for cases and > -1 for controls; (3) being healthy (ie, without any specific illness or fever); and (4) mother/primary caregiver present and have legal custody of the child. The exclusion criteria were as follows: (1) children who required prolonged hospitalization or had serious health issues, such as human immunodeficiency virus (HIV), tuberculosis, neonatal disease, kidney disease, chronic heart failure, liver disease, cystic fibrosis, congenital conditions, or enteropathy (eg, Crohn disease, celiac disease, ulcerative colitis, or malabsorption disease), diagnosed by a physician; or (2) a parent or primary caregiver with cognitive deficits or who was <16 years of age. For mothers aged 16–17 years, permission of their guardian or the child's father was required for enrollment in the case-control study. Signed, informed consent was

obtained by the health agent from the parents or guardians of children who met the entry criteria. If the parent/primary caregiver agreed to participate in the study, she/he received an identification code for the child to preserve their privacy. The child was then weighed and measured using the same method as described above and recorded on a data entry form. The mother/primary caregiver was interviewed about conditions of the birth and infant feeding practices. Nurses or health agents provided a paper card with the schedule for return visits to the IPREDE clinic as described in the MAL-ED study protocol [16, 18–24]. The first return visit was scheduled for 14 days after enrollment.

Statistical Analysis

The data were entered twice by 2 different persons using Microsoft Access software (Microsoft Corporation, Redmond, Washington), and validated by a third person by cross-matching the 2 databases. The data are presented as mean and standard deviation or when appropriate as proportion with their percentage. All parameters were compared using appropriate parametric or nonparametric tests such as Student t test, χ^2 test, or Fisher exact test using the Statistical Package for Social Sciences, version 18.0 (SPSS Inc, Chicago, Illinois). P values <.05 were considered statistically significant.

Ethics Approval

The MAL-ED cohort and case-control study protocols and consent forms were approved by the local institutional review board (IRB) at the Federal University of Ceará, the national IRB Conselho Nacional de Ética em Pesquisa, and the University of Virginia in the United States.

RESULTS

Study Geographical Location and Population

Fortaleza is divided into 6 regional areas and 1 central area for administrative purpose. The MAL-ED BRF cohort study site is located in the regional areas (Regional Executive Secretary [SER]) III and IV, and the case-control study is located in SER VI (Figure 1).

The SER III provides municipal services, identifying and articulating the needs of the population and promoting urban environmental and social development, with the purpose to provide better living conditions for the approximately 378 000 inhabitants spread across 17 neighborhoods. Two neighborhoods, Pici and Bela Vista, constitute our cohort study population. With a land area of 34.2 km², SER IV covers 19 neighborhoods, with one of the oldest and largest districts of the city, Parangaba, plus several commercial corridors, including Avenida Gomes de Matos, in Montese. There are 4 major neighborhoods in SER IV: Demócrito Rocha, Panamericano, Couto Fernandes, and part of Parangaba. The population of SER IV is approximately 305 000 inhabitants. Parangaba is the most populous district with about 32 840 inhabitants, and Dende is the least populous, with only 2480 inhabitants. The SER IV area includes 15 kindergartens and 28 schools from kindergarten and up to elementary. They are served by a health network with 12 primary care units, plus 3 Centers for Psychosocial Care and a Child Care Center. The SER IV also has the second largest emergency clinic in Ceará State, Frotinha of Parangaba, which provides for an average of 16 000 visits per month. The population in the catchment area for the cohort study is approximately 82 300 inhabitants, which included the 2 neighborhoods in the SER III and 4 major neighborhoods in SER IV.

The case-control study conducted at IPREDE is located at SER VI. The SER VI directly serves the residents of 29 neighborhoods with a population estimated of about 600 000 inhabitants. However, the population accessing IPREDE services is larger because it serves patients from other SERs and corresponding areas to cover >42% of the entire municipal area of Fortaleza. IPREDE is located in the Cidade dos Funcionários neighborhood. SER VI aims to ensure the improvement of life for residents and the preservation of the natural potential of the region. The children cared for at IPREDE are mainly from Fortaleza and smaller proportions of neighboring municipalities. IPREDE is a referral institution for infant nutrition and development in the state of Ceará, and provides relief services; teaching activities, including training of graduate students and health professionals; and research projects on child nutrition and health.

Demographics

Based on the last IBGE census in the cohort study area, we estimated a population of 44 000. The population density was 23 (national), 57 (Ceará state), 7785 (Fortaleza), and 4400 (cohort study area) inhabitants per square kilometer (Table 1). The percentage of females is 51% for Brazil and Ceará, and 54% for Fortaleza and the cohort study area. The average family size is 3 persons in Brazil, 3.5 in Ceará, 3.4 in Fortaleza, and 3.2 in the cohort study populations. The life expectancy ranges from 71 to 73.5 years for all of these populations cited.

Environmental and Socioeconomic Status

The major employment recorded for all populations described in the previous section was local work in the community. Unfortunately, there is also a problem of many inhabitants being involved in the selling of narcotics. The percentage of the population with access to clean water ranges from 87% to 97% for Fortaleza, Ceará, and Brazil (Table 1). Access to electricity was 96% for the cohort households, and 97% and 94% for Fortaleza and Ceará. Access to improved toilet/sanitation ranges from

Table 1. Health and Demographic Data for the MAL-ED Cohort Study Site, Urban Fortaleza, Ceará State, Brazil

Feature	Cohort Study Site	Year	Fortaleza (Urban Area)	Year	Ceará	Year	Brazil (National)	Year
Population density per km^2	4400	2009	7785	2010	57	2012	23	2012
Rural	0%	2009	0%	2010	6%	2012	13%	2011
Urban	100%	2009	100%	2010	21%	2012	87%	2011
Population in catchment area	44 000	2009	NA	NA	NA	NA	NA	NA
Female sex	54%	2009	54%	2012	51%	2010	51%	2011
Average family size	3.2	2009	3.4	2010	3.5	2010	3.0	2012
Life expectancy, y, mean	71	2010	71	2010	71	2010	73.5	2011
Major employment	Service	2009	Service	2009	Service	2009	Service	2009
Access to clean water	87%	2000	87%	2000	87%	2000	97%	2008
Access to electricity	97.5%	2012	97.5%	2012	94.1%	2012	NA	NA
Access to improved toilet/ sanitation	69%	2012	74%	2008	74%	2008	80%	2008
Home births	0%	2012	NA	NA	NA	NA	NA	NA
Antenatal and postnatal care								
Under-5 mortality rate per 1000 live births	18.9	2012	18.9	2012	18.9	2010	19	2010
Diarrhea episodes per year, mean ± SD	1.83 ± 0.588	2012	NA	NA	NA	NA	NA	NA
HIV positive	0.3%	2007	NA	NA	0.6%	2010	0.6%	2007
HIV incidence per 100 000	22.2	2010	22.2	2010	11.1	2010	17.9	2010
Tuberculosis rate per 100 000	71.1%	2010	71.1	2010	42.5	2010	37.6	2010
Per capita GDP, US$	NA	NA	8598	2009	5234	2009	12 486	2009

Abbreviations: GDP, Gross Domestic Product; HIV, human immunodeficiency virus; NA, not available; SD, standard deviation.

69% to 74% in these locations. In the cohort population, 100% of all women deliver in a hospital. The Gross Domestic Product per capita per year ranges from US$5234 to $8598.

Table 2 summarizes the SES pilot (in the study community) and baseline (survey of study participants at time of enrollment) data gathered on the cohort and case-control study populations. Initial pilot and baseline data for most of the measurements were very similar. The age of the mother and age at first pregnancy were 29 and 19.8 years, respectively, in the pilot data and 25.5 and 19 years, respectively, in the baseline data. The mean duration of the families living in their houses was 6.9 years in the pilot data and 7.1 years in the baseline data. The number of rooms and sleeping areas in the household were 3.9 and 1.7, respectively, for the pilot data and 4.1 and 1.7, respectively, for the baseline data. The number of people sleeping in the house was 4.5 and 4.8 for the pilot and baseline data, respectively. The main building material for the home's flooring material only was cement in both the pilot (58%) and baseline (55%) data. The cooking was done mostly inside their houses, and the main type of cooking fuel was gas, both in the pilot (86%) and baseline (91%) data. The main drinking water was piped into the dwelling (77% in the pilot data and 64% in the baseline data). The behavior of hand washing after helping the child was 60% (pilot) and 41% (baseline). The level of mother's education classified as secondary school completion or higher was 49% in the pilot data and 60% in the baseline data. The monthly household income of >US$185 was 83% (pilot) and 88% (baseline). Household food security access was 42% in the pilot data whereas cohort study homes (baseline data) were considered to be moderately food insecure at 55% (Table 2). The means and standard deviations of the nutritional *z* scores are summarized in Table 2.

The baseline data for the MAL-ED case-control study are summarized in Table 2. Because the data collected for the cases and controls were similar, averages of the combined results are described. The mean overall age of mother and at time of first pregnancy was 26.3 years and 18.4 years, respectively, and the mean number of live births was 2.8. The mean duration of the families living in their homes was 4.5 years. The mean numbers of rooms in the house, rooms for sleeping, and people usually sleeping in the house were 4.5, 1.7, and 5.1, respectively. The main building material for house roof was tile, and cement or concrete for the main building house floor as well as for house walls. Eighty-eight percent of the case and control houses had a separate room for the kitchen, and 99% did their cooking inside of their houses. The main type of cooking fuel was gas. Eighty-four percent had drinking water piped into the dwelling, and 68% treated it to make it safe. Twenty percent of the houses had water treatment using a water filter and the majority do not use water treatment in their

Table 2. Socioeconomic Data From the MAL-ED Socioeconomic Status Questionnaire in a Pilot Population (Community) and at Time of Enrollment (Baseline) of the MAL-ED Cohort and Case-Control Study Populations

Feature	Pilot SES (n = 100), Mean/Number	SD or %	Baseline SES of Cohort (n = 210), Mean/Number	SD or %	Baseline SES of Case (n = 83), Mean/Number	SD or %	Baseline SES of Control (n = 83), Mean/Number	SD or %
Age of mother, y	29.0	6.9	25.5	5.5	26.5	6.5	26.1	6.1
Age at first pregnancy, y	19.8	5.1	19.0	4.0	18.3	3.8	18.6	4.3
Live births	2.5	1.6	2.3	1.4	3.0	1.8	2.6	1.9
Duration of residence in home, y	6.9	4.8	7.1	4.9	6.8	5.0	6.8	5.0
Rooms in home	3.9	1.5	4.1	1.7	4.4	1.8	4.7	2.1
Rooms for sleeping	1.7	0.7	1.7	0.8	1.8	0.7	1.7	0.8
Persons sleeping in the home	4.5	1.6	4.8	1.9	5.2	2.2	5.0	2.2
Primary building material for roof								
Metal	1	1%	0	0%	0	0%	0	0%
Wood	0	0%	1	0.5%	0	0%	0	0%
Cement or concrete	2	2%	0	0%	0	0%	0	0%
Other	97	97%	209	99.5%	83	100%	83	100%
Primary building material for floor								
Earth/sand	0	0%	2	1%	4	5%	4	5%
Wood	0	0%	0	0%	0	0%	0	0%
Ceramic	39	39%	92	44%	20	24%	23	24%
Cement or concrete	58	58%	116	55%	59	71%	56	71%
Other	3	3%	0	0%	83	100%	83	100%
Primary building material for wall								
Bamboo/cane	0	0%	0	0%	0	0%	0	0%
Cement or concrete	12	12%	208	99%	76	92%	78	94%
Bricks	86	86%	0	0%	0	0%	0	0%
Metal	0	0%	0	0%	0	0%	0	0%
Other	2	2%	2	1%	7	8%	5	6%
Separate room for kitchen	86	86%	184	88%	69	83%	69	83%
Cooking done								
Inside house	99	99%	208	99%	82	99%	82	99%
Outside house	1	1%	2	1%	1	1%	0	0%
Inside and outside house	0	0%	0	0%	0	0%	0	0%
Type of cooking stove used								
Gas stove	86	86%	191	91%	81	98%	81	98%
Open fire	1	1%	2	1%	0	0%	1	1%
Electric heater	0	0%	0	0%	0	0%	0	0%
Kerosene stove	0	0%	4	2%	1	1%	0	0%
Other	13	13%	13	6%	1	1%	1	1%
Main source of drinking water								
Piped into dwelling	77	77%	135	64%	75	90%	65	78%
Piped to yard and plot	0	0%	0	0%	0	0%	2	2%
Public tap	0	0%	0	0%	0	0%	1	1%
Treat water to make it safe to drink	35	35%	32	15%	56	67%	57	69%
Water treatment at household								
Boil	1	1%	2	1%	6	7%	6	7%
Chlorine or bleaching powder	0	0%	1	0%	2	3%	1	1%
Water filter	20	20%	23	11%	20	24%	14	17%
Let it stand and settle	0	0%	1	0%	0	0%	0	0%
Other	79	79%	183	87%	55	66%	62	75%

Table 2 continued.

Feature	Pilot SES (n = 100), Mean/Number	SD or %	Baseline SES of Cohort (n = 210), Mean/Number	SD or %	Baseline SES of Case (n = 83), Mean/Number	SD or %	Baseline SES of Control (n = 83), Mean/Number	SD or %
Wash hands after helping child defecate								
Always	60	60%	86	41%	79	95%	80	96%
Sometimes	36	36%	87	41%	3	4%	3	4%
Rarely	4	4%	33	16%	1	1%	0	0%
Never	0	0%	4	2%	0	0%	0	0%
Education level of mother								
No schooling	4	4%	0	0%	1	1%	1	1%
Primary incomplete (1–5 y)	14	14%	17	8%	21	25%	9	11%
Primary completed (6–10 y)	37	37%	9	4%	43	52%	44	53%
Secondary completed or higher	49	49%	127	60%	18	22%	28	34%
Monthly household income, US$								
≤62	3	3%	6	3%	4	5%	1	1%
63–123	7	7%	12	6%	11	13%	11	13%
124–185	7	7%	7	3%	7	8%	6	7%
>186	83	83%	185	88%	61	73%	65	78%
Household food security access								
Food secure	42	42%	28	13%	29	41%	37	45%
Mildly food insecure	14	14%	37	18%	11	15%	18	22%
Moderately food insecure	30	30%	115	55%	18	25%	12	15%
Severely food insecure	14	14%	30	14%	13	18%	15	18%
Nutritional status, *z* scores								
Weight-for-height	NA	NA	0.98	1.22	−1597	0882	0596	1061
Height-for-age	NA	NA	0.08	1.09	−2737	1202	−0915	0998
Weight-for-age	NA	NA	0.72	1.16	−2614	0839	−0028	1017

Abbreviations: NA, not available; SD, standard deviation; SES, socioeconomic status.

houses. Ninety-six percent always washed hands after helping a child defecate. A majority of the mothers (80%) had primary school completion or a higher education level. Seventy percent of the monthly home income was >US$185. Forty-three percent of households in the case and control groups were food secure. The nutritional *z* scores are summarized in Table 2 for the case and control populations.

Disease Burden

The under-5 mortality rate is estimated to be 19 per 1000 live births for Brazil, Ceará, and Fortaleza, including the cohort area. The HIV incidence in Brazil, Ceará, and Fortaleza ranges from 11 to 22 per 100 000 and the incidence of tuberculosis ranged from 38 to 71 per 100 000.

DISCUSSION

Steady improvements in water, sanitation, nutritional status, and diarrhea rates in the study cohort area of Fortaleza have been well documented in previous cohort studies [25]. These improvements are likely due to increased access to healthcare that often accompanies intensive surveillance visits by community health workers and by a study nurse visiting each household at least twice weekly. These are the reasons we incorporated a case-control study population design to complement the cohort study. To support this view, the case-control study population across the city shows that moderate and severe stunting and undernutrition persists in many unstudied favela (shantytown) populations in Fortaleza. The relative proximity of the cohort field site (ie, within 5 km) to the research laboratories where study samples were processed, along with children in the case-control study being seen in the IPREDE clinic rather than in their homes, enabled better communication and improved quality of assay results.

Low SES in the BRF site was characterized by people who lived in households that had low frequencies of mattress, television, chair or bench, or refrigerators, whereas intermediate-SES homes had frequencies between the extremes of these items in their household plus cupboard with shutters and open shelves, watch or clock, iron (charcoal or electric), radio or transistor,

bicycle, sofa, or bank account. The high-SES homes had higher frequency of all items noted above or had a computer in the household. These SES parameter results were similar for the pilot SES data compared with the baseline SES data collected from the cohort and the case-control studies.

The long-standing rapport and trust in the cohort population enables long-term follow-up that is critical to understand the effects of early childhood enteric and other infections on cognitive and physical development occurring later in life.

Notes

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