

Nutritional status and intestinal parasites among young children from pastoralist communities of the Ethiopian Somali region

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Abstract

Pastoralist children in the Ethiopian Somali Regional State (ESRS) are at high risk for undernutrition and intestinal parasitic infections (IPIs). We assessed the nutritional status and its association with IPIs in 500 children <5 years of age in a clustered cross-sectional study in Adadle district, ESRS. Stool samples were microscopically examined for IPIs and biomarkers for iron and vitamin A status, anthropometry, and food variety score (FVS) were assessed. Median (interquartile range [IQR]) FVS was 2.0 (2.0, 4.0), and 35% of children were exclusively breastfed up to age 6 months. Prevalence of stunting, wasting, underweight and mid-upper arm circumference (MUAC) <12.5 cm was 30, 34, 40, and 16%, respectively. Median (IQR) haemoglobin, ferritin, and retinol-binding protein concentrations were 9.5 g dL⁻¹ (8.2, 10.9), 6.2 µg L⁻¹ (4.0, 10.2), and 0.8 µmol L⁻¹ (0.67, 0.91), respectively. Prevalence of anaemia, iron, and vitamin A deficiency was 75, 91, and 30%, respectively. IPIs' prevalence was 47%; the most prevalent IPIs were *Giardia lamblia* (22%) and *Ascaris lumbricoides* (15%). *Giardial* infections but not *A. lumbricoides* increased the risk for MUAC <12.5 cm (adjusted odds ratio [aOR]: 3.50, 95% confidence interval [CI] [2.21, 5.54]). The odds for anaemia were 97% (aOR: 0.03, 95% CI [0.03, 0.07]) and 89% (aOR: 0.11, 95% CI [0.11, 0.23]) less for children with FVS >2 or with exclusive breastfeeding up to 6 months, respectively. Undernutrition and IPIs are alarmingly high in <5 years of age children in ESRS. *Giardial* infections and low nutritional adequacy of the diet seem to be major contributing factors to the precarious nutritional status and should be addressed by appropriate interventions.

KEYWORDS

Anaemia, children <5 years, Ethiopian Somali Regional State, intestinal parasitic infection, micronutrient deficiencies, pastoralist, undernutrition

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1 | INTRODUCTION

Although undernutrition in Ethiopian children <5 years of age has steadily decreased since 2000, it remains widespread, particularly in certain regions. In the Ethiopian Somali Regional State (ESRS), stunting and underweight have been reported to be 27 and 29%, respectively, and the wasting prevalence of 23% is countrywide the highest value and substantially higher than the country's average wasting prevalence of 10% (Central Statistical Agency/Ethiopia & ICF International, 2016). Undernutrition also includes micronutrient deficiencies. For children <5 years of age living in the ESRS, data on micronutrient deficiencies assessed by biomarkers are unavailable, except for anaemia. In the most recent demographic health survey, 83% of the children <5 years of age were anaemic, and the anaemia prevalence in ESRS increased by 14% from 2011 to 2016 (Central Statistical Agency/Ethiopia & ICF International, 2012, 2016). The aetiology of anaemia is multifactorial; it is estimated that half of the anaemia in sub-Saharan Africa is due to iron deficiency (ID; Kassebaum et al., 2014). Hence, a substantial number of children <5 years of age in ESRS is likely to be iron deficient, but no specific data is available. Similarly, data for vitamin A deficiency (VAD) in children from ESRS is missing. Nationwide data excluding ESRS indicates that VAD is a serious public health problem in Ethiopia with almost 40% of young children having deficient serum retinol levels (Demissie, Ali, Mekonen, Haider, & Umeta, 2010).

Undernutrition, which has been found to be an underlying cause in a third of deaths in children <5 years (Black et al., 2008), results from the interaction between inadequate diet and infectious disease. It is associated with intestinal parasitic infections (IPIs) of helminths and protozoa (Crompton & Nesheim, 2002; de Gier, Campos Ponce, van de Bor, Doak, & Polman, 2014; Hall, Hewitt, Tuffrey, & de Silva, 2008; Stanley, 2003), which are often a major public health problem in children <5 years in developing countries (Hotez, Fenwick, Savioli, & Molyneux, 2009). In various regions in Ethiopia, high IPIs prevalence ranging from 30–75% have been reported in preschool children <5 years of age (Asfaw & Goitom, 2000; Nyantekyi et al., 2010) and school children (Abdi, Nibret, & Munshea, 2017; Abera & Nibret, 2014; Alemayehu et al., 2017; Feleke, 2016; Gelaw et al., 2013; Nguyen et al., 2012). It is assumed that infections with soil-transmitted helminths and protozoa are as prevalent in ESRS as in other Ethiopian regions, but no data is available.

The arid to semiarid ESRS is widely inhabited by pastoralist. The amount and types of foods available to the pastoralists are strongly influenced by ecological and cultural factors as well as economic opportunities and constraints. Therefore, undernutrition is a concern in pastoralist populations, especially in young children (Galvin, 1992). In pastoralist communities, poor nutritional status of children due to inadequate diet is often exacerbated by lack of potable water and unsanitary conditions, which contribute to increased rates of IPIs (Bechir, Schelling, Hamit, Tanner, & Zinsstag, 2012). The preferred staple of pastoral populations is milk from livestock, and their diet has been reported to be generally low in energy and micronutrients but adequate in protein (Iannotti & Lesorogol, 2014; Sellen, 1996).

Key messages

- The burden of undernutrition (including wasting, stunting, underweight, anaemia, iron, and vitamin A deficiency) and intestinal parasitic infections is enormously high in children <5 years of age in the Ethiopian Somali Regional State and appropriate treatment and prevention measures are urgently needed.
- Undernutrition as indicated by low mid-upper arm circumference was strongly positively associated with *giardial* infections and age but negatively associated with milk consumption.
- Exclusive breastfeeding for 6 months and a higher food variety were associated with a massively reduced risk for anaemia.

Pastoralists, such as the ones in the ESRS, have been neglected in nutritional research, and detailed up-to-date data on nutritional status is missing. This study therefore aims to assess the nutritional status and its association with IPIs in children <5 years of age living in the Adadle district of the Somali region, Ethiopia. This study is part of the Jigjiga One Health Initiative, which aims to improve different aspects of human and animal health and of the environmental wellbeing among pastoralists in the ESRS. The data of this study will be important to design and target approaches to improve the nutritional status of young children in ESRS.

2 | MATERIALS AND METHODS

2.1 | Study setting

A clustered cross-sectional study was carried out in Adadle district in the Somali regional state, Eastern Ethiopia. Adadle is located in the lowlands of the Wabe Shabale River subbasin 17 km from the major town Gode. Most of the inhabitants in Adadle are Muslim pastoralists, who mainly depend on their own animal products for consumption and income generation. Altitude is 300–500 m; temperature is between 18–38°C, and rainfall approximately 300 mm per year (Gebre-Mariam, 2007).

2.2 | Sample size and household selection

To determine the sample size, we adjusted for clustering of households within sub-Kebeles or pastoralist camps (cluster unit), assuming an intraclass correlation coefficient of 0.2, a prevalence of underweight of 25%, and 10 eligible children per cluster (Bennett, Woods, Liyanage, & Smith, 1991). A total sample size of 500 children would allow to estimate the prevalence with a precision defined as one half

length of the 95% confidence interval of 6 percentage points (i.e., 3.2). As part of a three-level random selection process, first, out of the 15 Kebeles (lowest administrative unit) in the Adadle Woreda (district) in ESRS, six Kebeles (Buursaredo, Gabal, Boholoxagare, Higlo, Harsogand, and Malkasallax) were selected proportional to their size using an existing population list. Two Kebeles were excluded because of security reasons, and seven were excluded due to logistical reasons. As a second step, random geographical coordinates were generated for the selection of sub-Kebeles within each Kebele (Jean-Richard et al., 2015). Third, within a sub-Kebele, households were systematically selected by throwing a pencil. The data collectors then walked to the edge of the sub-Kebele into the direction to which the pencil pointed, numbering all the households on the way (Brogan, Flagg, Deming, & Waldman, 1994). A random number was chosen to identify one household as a starting household for the cluster of the pointed direction. Data collectors then continued to the right side until the targeted number of samples per cluster was reached. In household with two and more eligible children, all the children were enrolled. Camps were selected as a cluster, and all eligible children <5 years of age in the camp were enrolled. All children aged 1–5 years who started consumption of complementary foods were enrolled. Children whose mother/caregivers reported a severe illness within the last 2 weeks prior to the study were excluded.

2.3 | Data collection

Trained fieldworkers collected the data at the beginning of the dry season in 2016, locally named *xagaa*, using a previously tested questionnaire including sociodemographic status of the children's family, drinking water source and sanitation (toilet type and waste disposal), milk consumption in the family (milk source and consumption habit), breastfeeding practice, and a 24-hr food recall. As birth records rarely exist in pastoralist population, age of the children was assessed by the number of breastfeeding months for children <2 years of age and still receiving breast milk. For children ≥ 2 years of age, age was verified by the number of rainy seasons through which the child lived using a local pastoralist seasonal calendar. Breastfeeding practice were assessed by asking whether the child has been exclusively breastfed up to 6 months and whether the mother was aware of the World Health Organization (WHO) recommendation of exclusive breastfeeding up to 6 months of age. The 24-hr food recall embedded in the questionnaire recorded any food item or beverage consumed by the child the day before the interview but did not consider quantities of consumed foods and beverages. To assess nutritional adequacy of the diet, a food variety score (FVS) was calculated based on the number of different food items eaten during the day before the day of the interview as previously published (Hatloy, Torheim, & Oshaug, 1998). All food items were given the same weight. Beverages and condiments (e.g., salt or bouillon cubes) were not considered as food items and therefore not included in the calculation.

2.4 | Anthropometry measurements

Weight and height were measured in duplicate and recorded as the average of the two measurements using a digital balance scale and a wooden measuring board, respectively. For the weighing, children able and willing to stand alone were asked to stand in the middle of the scale without touching anything. For children, who were not willing to stand alone, first the weight of their mother/caregiver alone was measured then the mother/caregiver holding the child was measured. The weight of the mother/caregiver alone was then deducted from the weight of the mother/caregiver holding the child. Children were weighted with light clothes and without shoes to the nearest 0.5 kg. The accuracy of the weighing scale was monitored daily against known weights. The height of the children was measured without shoes, with heels together, arms to the sides, legs straight, shoulders relaxed, and the head looking straight ahead. The height was measured to the nearest 1.0 cm. Z scores for weight-for-age (WAZ), weight-for-height (WHZ), and height-for-age (HAZ) were calculated using WHO Anthro software (Version 3.2.2.1). Stunting, underweight, and wasting were defined as HAZ, WAZ, and WHZ, <-2 standard deviations, respectively. Mid-upper arm circumference (MUAC) was measured in duplicate using a measuring tape to the nearest 1 mm. Low/insufficient MUAC was defined as MUAC <12.5 cm (WHO, 2013) and used as the main indicator for undernutrition.

2.5 | Blood sampling, biochemical analysis, and applied cut-offs

Venous whole-blood samples from the study children were collected directly into trace element-free lithium heparin tubes (Sarstedt). In addition, capillary blood using a finger prick was collected to assess haemoglobin (Hb) with a portable HemoCue 301+ analyser (HemoCue AB). Samples were immediately stored in a refrigerated cool box and transported to the laboratory units in the Adadle Health Center. The samples were then centrifuged ($3,000 \times g$ for 10 min at room temperature) using a portable centrifuge (LW Scientific). Plasma aliquots were stored at -20°C until they were shipped on dry ice with an international courier to a laboratory in Germany for the analysis of plasma ferritin (PF), soluble transferrin receptor (sTfR), retinol-binding protein (RBP), C-reactive protein (CRP), and $\alpha 1$ -acid glycoprotein (AGP) using a sandwich enzyme-linked immunosorbent assay (Erhardt, Estes, Pfeiffer, Biesalski, & Craft, 2004). Liquicheck Trilevel (Bio-Rad Laboratories Inc.) was used as control material with each run of analysis, and measured values were within acceptable ranges as specified by the manufacturer. Severe, moderate, and mild anaemia was defined as; $\text{Hb} < 7.0$, $\text{Hb} = 7.0\text{--}9.9$, and $\text{Hb} = 10.0\text{--}10.9 \text{ g dl}^{-1}$, respectively. ID was defined as $\text{PF} < 12 \mu\text{g L}^{-1}$ or $\text{sTfR} > 8.3 \text{ mg L}^{-1}$. In the children who provided both a capillary and venous blood sample, ID anaemia was defined as $\text{Hb} < 11.0 \text{ g dl}^{-1}$ plus $\text{PF} < 12 \mu\text{g L}^{-1}$ and/or $\text{sTfR} > 8.3 \text{ mg L}^{-1}$ (Erhardt et al., 2004; WHO/UNICEF/UNU, 2001). Parents of the children with Hb levels $< 7.0 \text{ g dl}^{-1}$ were instructed to take the child to the health facility for follow-up care. VAD was defined as

RBP $<0.7 \mu\text{mol L}^{-1}$; children with $\geq 0.7 \mu\text{mol L}^{-1}$ but $<1.05 \mu\text{mol L}^{-1}$ were considered as at risk for VAD (WHO, 2011). AGP and CRP concentrations for healthy children were defined as $<1 \text{ g L}^{-1}$ and $<5 \text{ mg L}^{-1}$, respectively (Thurnham et al., 2010). Serum ferritin was corrected for inflammation based on CRP and AGP using the Thurnham et al., 2010 regression coefficients (Thurnham et al., 2010).

2.6 | Stool sample collection and processing

Stool samples were collected using coded plastic containers given to the mothers/caregivers of the children with detailed instructions of how to collect fresh stool samples. Qualitative single Kato–Katz thick smears were prepared from each stool sample and examined under a microscope for the presence of soil-transmitted helminth (*Ascaris lumbricoides*, hookworm, and *Trichuris trichiura*) and *Schistosoma mansoni* eggs (Katz, Chaves, & Pellegrino, 1972). In addition, stool smears based on sodium acetate–acetic acid–formalin (SAF)-fixed stool samples were examined to detect protozoal vegetative forms and cysts and helminth eggs and larvae (Utzinger et al., 2010). All enrolled children received Albendazole or Mebendazole for treatment.

2.7 | Ethical considerations

The study was conducted according to the declaration of Helsinki, and ethical clearance was obtained from the Review Committee of the University of Jigjiga in Ethiopia (JJU-RERC 002/2016) and the Swiss Ethics Committee of Northwest and Central Switzerland (Ethikkommission Nordwest- und Zentralschweiz; EKNZ BASEC UBE-req. 2016-00204) prior to initiation of the study. A material transfer agreement was established by the Food, Medicine and Health Care Authority of Ethiopia for the shipment of blood and faecal samples from Ethiopia to Switzerland. All the parents/caregivers of the participating children gave oral and written consent prior to the study enrollment of their children.

2.8 | Statistical analysis

Descriptive statistics were done with Stata (Intercooled Stata® Version 14, College Station, TX). The main anthropometric indicator for undernutrition was MUAC $<12.5 \text{ cm}$ (WHO, 2013) because other anthropometric indicators, such as stunting or underweight, were affected by the difficulty of recording the exact age of the children from their mothers due to the lack of a birth certificate, or by the weight measurements that was only measured to the nearest 0.5 kg. Also, in contrast to height, MUAC can be measured more easily and reliably in children <5 years old. Multivariable logistic regression analysis including the covariates age, sex, milk consumption, *Giardia lamblia*, *A. lumbricoides*, FVS, and exclusive breastfeeding up to 6 months of age (EBF) were conducted. Odds ratio were adjusted for clustering on a village level using generalized estimating equation

models for binary outcomes, logit link, and independent correlation structure. The generalized estimating equation models were fitted using the *geeglm* package of the statistical environment R (v 3.5.0).

3 | RESULTS

3.1 | Participant characteristics

A total of 500 children aged between 1–5 years were enrolled from six Kebeles of Adadle Woreda in ESRS (Figure S1). For eight children, no data was collected due to loss of follow-up after consent signing. The questionnaire and anthropometric measurements were therefore completed for 492 children. In total, 453 capillary blood samples, 404 venous blood samples, and 387 stool samples were collected and analysed. For 371 children, both capillary and venous blood samples were available. Gender was equally distributed, and approximately one-tenth of the children were <2 years of age whereas the remaining children were between 2 and 5 years of age (Table 1). All mothers, of whom the clear majority was illiterate, spoke Somali language. The main source of drinking water was river water. Households mainly used outdoor nature toilet facilities, and waste was dumped in the open space. Almost all households had milk from their own sources, and almost none of them did boil the milk before consumption.

3.2 | Food variety score and breastfeeding practices

Almost all children (96%) had eaten a type of staple food in the 24 hr recall. The staples were mainly cereals and included whole wheat or wheat flour (44%), maize (20%), rice (18%), potato (8%), sorghum (4%), and pasta (2%). Consumption of vegetables was low; only 14 and 26% of the children consumed tomato and onions, respectively. No fruits rich in vitamin C or A were consumed. Banana was the only fruit that was consumed by 2% of the children. Milk and milk products were consumed by 42% of the children; 37% and 5% consumed milk and yoghurt, respectively. Goat and sheep meat was consumed by 6% of the children, and 39% consumed oils and fats. Tea consumption with milk was reported in 51% of the children. The median (interquartile range) FVS was low with 2.0 (2.0, 4.0), and most of the children (34%) consumed only two food items (Figure 1). In total, $>50\%$ of the children consumed only one or two food item (Table 1). The percentage of EBF was only 35%. The other 65% received animal milk, tea with milk, or solid foods before the age of 6 months. Thirty-six (36) % of the mothers were aware of the WHO recommendation of exclusive breastfeeding during the first 6 months of life.

3.3 | Nutritional status and intestinal parasitic infections

Stunting, wasting, and underweight were 30, 34, and 40%, respectively, with median Z scores for HAZ, WHZ, and WAZ clearly

TABLE 1 Sociodemographic characteristics, food variety score, and breastfeeding pattern of children <5 years of age living in Adadle Woreda, Somali region, Ethiopia (data collected in the dry season 2016)

Characteristic	% (n = 492)
Age of the children	
<2 years	8.3
≥2 years	91.7
Sex	
Female	50.8
Male	49.2
Literacy of the mother^a	
Illiterate	97.6
First to eighth grade	2.4
Source of drinking water^b	
Dug well	16.5
River/bond	83.5
Types of household toilet^c	
Pit latrines	2.2
Outdoor in nature	97.8
Household waste disposal^d	
Dumped in the river	95.9
Burned	4.1
Source of milk^e	
Own source	96.5
Bought from market	3.5
Milk consumption habit	
Boiled	3.0
Raw	97.0
Food variety score	
≤2 food items	55.1
>2 food items	44.9
Exclusive breastfeeding	
Exclusively breastfed up to 6 months of life	35.0
Not exclusively breastfed up to 6 months of life	65.0

^aAnswer options in the questionnaire were: Illiterate, First to eighth grade, and above ninth grade.

^bAnswer options in the questionnaire were: Tap, tube well/borehole, dug well, spring water, river, tank truck, and rain water.

^cAnswer options in the questionnaire were: Pit latrines, composed latrines, bucket toilet, hanging toilet, and outdoor in nature.

^dAnswer options in the questionnaire were: Dumped in the compound, dumped in the open space, dumped in the river, and burned.

^eAnswer options in the questionnaire were: Own source, bought from market, relatives, and other sources.

below -1 (Table 2). The biomarker measurements for iron, vitamin A, and inflammation status were also shown in Table 2. Values indicate poor iron and vitamin A status, and very high prevalence of anaemia, ID, IDA, and VAD was observed. Anaemia (75%) was mainly moderate anaemia (51%) followed by mild (16%) and severe anaemia (8%). Overall, IDA prevalence was 73%. Looking only at the anaemic children

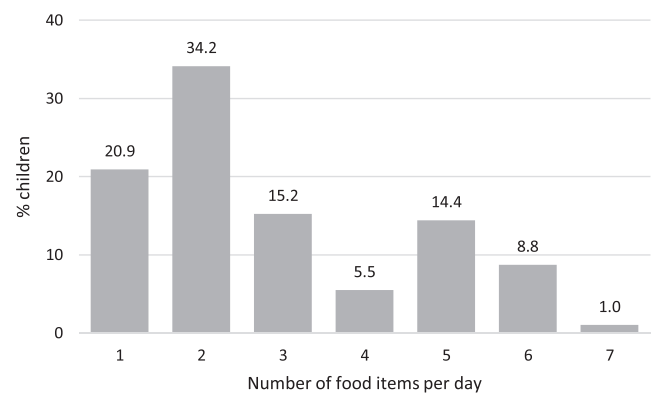


FIGURE 1 Number of food items consumed by children <5 years of age living in Adadle Woreda, Somali region, Ethiopia, derived from a 24-hr food recall in the dry season 2016 (n = 492). Food items include all foods consumed the day prior to the food recall but do not include beverages or condiments (e.g., salt or bouillon cubes)

who provided both capillary and venous blood samples, 97% had IDA. The median (interquartile range) for the inflammation markers CRP and AGP used to correct the PF values was 0.4 mg L⁻¹ (0.2, 1.3) and 0.7 g L⁻¹ (0.5, 0.9), respectively. VAD was found in 30% of the children (Table 2), and 58% of the children were at risk for VAD.

The prevalence of IPIs is summarized in Table 3. The overall prevalence of IPIs was high with 47% children having at least a single infection. The most prevalent IPIs were protozoan infections with *G. lamblia* (22%) followed by helminthic infections with *A. lumbricoides* (15%).

Children infected with *G. lamblia* were 3.5 times more likely to be undernourished as indicated by low MUAC compared with noninfected children (Table 4). Remarkably, ID was associated with a reduced risk of *G. lamblia* infection. No significant associations were found between *G. lamblia* infection and anaemia or VAD. For *A. lumbricoides*, we did not find any association with undernutrition. Low MUAC was associated with no milk consumption, children <2 years of age, and female children. The odds of having low MUAC was 49% less in children consuming milk than in children not consuming milk. Children who consumed more than two food groups had anaemia and ID odds that were 97% and 90% lower than children who consumed two or less than two food items (Table 4). The odds for anaemia in children who had EBF were 89% less than in children who were not EBF, and there was a tendency for lower odds for ID in EBF children. Furthermore, the odds of being anaemic were higher in the children <2 years of age. Children consuming more than two food items or consuming milk tended to have lower odds for VAD than their peers consuming one or two food items or not consuming milk, respectively.

4 | DISCUSSION

To our knowledge, this is the first study collecting detailed data about the nutritional status of children <5 years of age living in the ESRS

TABLE 2 Anthropometric, iron, vitamin A and inflammation status among children <5 years of age living in Adadle Woreda, Somali region, Ethiopia, overall and by gender (data collected in the dry season 2016)

Variable	All children	Boys	Girls
Height (cm) ¹	91 (84, 98)	91 (84, 98)	91 (84, 99)
Weight (kg) ¹	12 (10, 13)	12 (10, 13)	12 (10, 13)
HAZ ^a	-1.5 (-2.2, -1.0)	-1.7 (-2.3, -1.2)	-1.3 (-2.0, -0.9)
WAZ ^a	-1.8 (-2.7, -1.0)	-1.8 (-3.0, -1.0)	-1.6 (-2.6, -0.8)
WHZ ^a	-1.2 (-2.5, 0.0)	-1.4 (-2.9, -0.2)	-1.0 (-2.5, 0.1)
Insufficient MUAC < 12.5 cm ^a	15.9%	13.6%	18.0%
Hb (g dl ⁻¹) ^b	9.5 (8.2, 10.9)	9.4 (8.2, 10.9)	9.7 (8.2, 11.0)
Anaemia (Hb < 11.0 g dl ⁻¹) ^b	75.1%	76.2%	73.9%
PF (µg L ⁻¹) ³	6.2 (4.0, 10.2)	5.9 (4.0, 9.4)	6.4 (4.0, 10.5)
sTfR (mg L ⁻¹) ³	21.1 (13.2, 33.1)	21.5 (13.3, 34.3)	20.1 (13.1, 32.1)
Iron deficiency (PF < 12 µg L ⁻¹ and/or sTfR > 8.3 mg L ⁻¹) ³	91.1%	90.8%	91.4%
Iron deficiency anaemia (Hb < 11.0 g dl ⁻¹ + PF < 12 µg L ⁻¹ and/or sTfR > 8.3 mg L ⁻¹) ^d	72.8%	75.3%	70.3%
RBP (µmol L ⁻¹) ^c	0.8 (0.67, 0.91)	0.8 (0.67, 0.91)	0.8 (0.67, 0.92)
Vitamin A deficiency (RBP < 0.7 µmol) ^c	30.2%	29.7%	30.6%
Elevated CRP > 5 mg L ⁻¹ ^c	10.6%	10.3%	11.0%
Elevated AGP > 1 g L ⁻¹ ³	19.1%	17.4%	20.6%

Note. Values represent median (interquartile range), unless indicated otherwise.

Abbreviations: AGP, α-1-acid glycoprotein; CRP, C-reactive protein; HAZ, height-for-age z score; Hb, haemoglobin; MUAC, mid-upper arm circumference; PF, plasma ferritin; RBP, retinol-binding protein; sTfR, soluble transferrin receptor; WAZ, weight-for-age z score; WHZ, weight-for-height z score.

^an = 492.

^bn = 453.

^cn = 404.

^dn = 371.

TABLE 3 Prevalence of intestinal parasitic infections among children <5 years of age living in Adadle Woreda, Somali region, Ethiopia (data collected in the dry season 2016)

	% (n = 387)	95% CI
Overall		
Parasite-free	53.2	46.2, 60.1
Single-parasite	42.1	36.7, 47.7
Poly-parasite	4.7	2.5, 8.4
Protozoa		
<i>Giardia lamblia</i>	22.0	16.2, 29.1
<i>Entamoeba histolytica</i>	4.1	2.2, 7.8
<i>Entamoeba dispar</i>	0.3	0.0, 1.8
<i>Entamoeba coli</i>	1.0	0.3, 3.0
Helminths		
<i>Ascaris lumbricoides</i>	14.7	7.1, 28.0
<i>Trichuris trichiura</i>	0.5	0.1, 1.8
Hookworms	1.6	0.7, 3.3
<i>Hymenolepis nana</i>	3.1	1.3, 7.1
<i>Taenia</i> spp.	2.1	0.9, 4.8
<i>Enterobius vermicularis</i>	1.8	0.8, 3.9

including nutritional biomarkers, anthropometrics, and IPIs. In the present study, high prevalence of both undernutrition and IPIs were observed. This high prevalence of IPIs is not surprising as in our study area, systematic mass anti-helminthic drug administration or deworming programs are not implemented, and infected children are only occasionally treated based on clinical suspicion. Several previous studies have reported high prevalence of IPIs among Ethiopian preschool and school children (Abdi et al., 2017; Abera & Nibret, 2014; Alemayehu et al., 2017; Mahmud et al., 2013; Nguyen et al., 2012; Yami, Mamo, & Kebede, 2011); however, data on under five children in ESRS was not available. Depending on the area where the previous studies were conducted, the type of the most prevalent IPIs is different from our study as protozoa and helminths follow a focal distribution depending on climate and environment. For example, in a study conducted in the Tigray region, Northern Ethiopia, the prevalence of enteric parasites in children <5 years of age (48%) was comparable with our study (47%). In contrast to our study, the most prevalent parasites were *Entamoeba histolytica* and *Hymenolepis nana* (Asfaw & Goitom, 2000). In our study, low MUAC, used as a proxy for undernutrition, was significantly associated with *G. lamblia*. Similarly, *Giardial* infections but not helminthic infections were strongly associated with underweight, wasting, and stunting in a previous study in

TABLE 4 Logistic regression analysis of associations between mid-upper arm circumference, anaemia, iron and vitamin A deficiency and sociodemographic characteristics, food variety score, milk consumption, selected intestinal parasitic infections, and exclusive breastfeeding (data collected in the dry season 2016)

Variables	MUAC <12.5 cm		Anaemia (Hb <11.0 g dl ⁻¹)		Iron deficiency (PF <12 µg L ⁻¹ and/or sTfR >8.3 mg L ⁻¹)		Vitamin A deficiency (RBP <0.7 µmol)	
	% (n/N) ^b	aOR ^a	% (n/N) ^b	aOR ^a	% (n/N) ^b	aOR ^a	% (n/N) ^b	aOR ^a
Age								
<2 years	31.7 (13/41)		88.6 (31/35)		87.9 (29/33)		33.3 (11/33)	
≥2 years	14.4 (65/451)	0.41	73.9 (309/418)	0.24	91.4 (339/371)	1.08	29.9 (111/371)	0.92
Sex								
female	18.0 (45/250)		73.9 (164/222)		91.4 (191/209)		30.6 (64/209)	
Male	13.6 (33/242)	0.54	76.2 (176/231)	1.61	90.8 (177/195)	0.90	29.7 (58/195)	0.98
Food variety score								
≤2 food items	17.0 (46/271)		95.5 (231/242)		96.4 (216/224)		32.6 (73/224)	
>2 food items	14.5 (32/221)	0.96	51.7 (109/111)	0.03	84.4 (152/180)	0.10	27.2 (49/180)	0.68
Milk consumption								
No	18.9 (54/285)		74.3 (197/265)		90.1 (191/212)		34.4 (73/212)	
Yes	11.6 (24/207)	0.51	76.1 (143/188)	0.76	92.2 (177/192)	1.14	25.5 (49/192)	0.61
Giardia lamblia infection								
Negative	12.6 (38/302)		78.9 (221/280)		94.1 (239/254)		31.5 (80/254)	
Positive	32.9 (28/85)	3.50	75.9 (60/79)	0.93	86.4 (57/66)	0.45	30.3 (20/66)	0.91
Ascaris lumbricoides infection								
Negative	17.0 (56/330)		77.0 (238/309)		91.7 (244/266)		31.6 (84/266)	
Positive	17.5 (10/57)	1.38	86.0 (43/50)	0.79	96.3 (52/54)	1.35	29.6 (16/54)	0.87
EBF first six months of age								
No	16.2 (52/320)		91.9 (262/285)		95.2 (257/270)		33.0 (89/270)	
Yes	15.1 (26/172)	0.93	46.4 (78/168)	0.11	82.8 (111/134)	0.58	24.6 (33/134)	0.77

Abbreviations: aOR, adjusted odds ratio; aCI95, adjusted 95% confidence interval; EBF, exclusive breastfeeding; Hb, haemoglobin; PF, plasma ferritin; RBP, retinol-binding protein; sTfR, soluble transferrin receptor.

^aaOR were calculated by adjusting for clustering within households and administrative units (Kebeles) as a fixed effect.

^bn/N, n = number of children that are positive for the dependent variable in the respective category of the independent variable; N = total number of children in the category of the independent variable.

Zimbabwean school children (Loewenson, Mason, & Patterson, 1986). In another study in Chad, undernutrition in pastoralist children was significantly associated with IPIs (Bechir, Schelling, Hamit, et al., 2012).

We found an extremely high prevalence of ID (91%), as measured as low PF and/or elevated sTfR, suggesting a lack of iron in the diet of the children. Interestingly, ID was associated with a decreased risk of infections with *G. lamblia*. ID has been associated with protection against several infectious diseases including protection against *G. duodenalis* in Rwandan children (Danquah, Gahutu, Ignatius, Musemakweri, & Mockenhaupt, 2014; Prentice, 2008). For intestinal and extracellular parasites, such as *G. lamblia* and *G. duodenalis*, a low iron status of the host may generate an unfavourable environment and interfere with the parasite's metabolism and replication (Duncombe, Bolin, Davis, Fagan, & Davis, 1980) and could be considered as a host mechanism to withhold iron from the parasite (Prentice, 2008). Anaemia in our study was mainly IDA as indicated by the high prevalence of IDA (73%) almost equal to the anaemia prevalence (75%). To a limited extent, inflammation might have contributed to anaemia as well as indicated by elevated CRP and AGP levels in 11 and 19% of the children, respectively. We used both of the inflammation markers to correct the ferritin concentrations. However, due to the already very low ferritin concentration in almost all children, the effect of the correction on median ferritin concentration and prevalence of ID and IDA was negligible. The anaemia prevalence in our study (75%) was 8% lower than that reported in the most recent DHS for ESRS (Central Statistical Agency/Ethiopia & ICF International, 2016). This difference might be due to a general improvement in nutritional status in ESRS or due to seasonal differences in diet patterns influencing Hb levels. In pastoralist communities, meat consumption is increased during rainy season compared with the dry season as condition for animals are more favourable; hence, more livestock products are available; and particularly, milk yields are higher (Sadler & Catley, 2009). This leads to an increased consumption of milk but also an increased meat consumption as incomes are better from selling milk and milk products. On the other side, the dry season is characterized by a higher availability of staples and a decrease of livestock products, especially milk and milk products (Hassen, Ismail, Haile, & Legese, 2013). We conducted our study at the beginning of the dry season shortly after the rainy season. Therefore, we were likely to capture a slightly improved nutritional status influenced by the increased milk and meat consumption during the rainy season. In our study, children who were EBF up to 6 months of age were less likely to be anaemic. This has also been documented in other studies where EBF in the first 6 months of life was associated with reduced risk of anaemia and ID in infants (Marques, Taddei, Lopez, & Braga, 2014; Uyoga et al., 2016). This is likely because EBF reduces diarrheal disease (and other infections) that accompany early introduction of complementary foods, especially in resource-limited areas, such as ESRS, where water and sanitation facilities are inadequate. The iron concentration and bioavailability in the diet of young children from resource-poor areas is often inappropriate to meet their requirements (Gibson, Bailey, Gibbs, & Ferguson, 2010); therefore, children in ESRS

who become anaemic in infancy due to the early introduction of complementary foods will unlikely catch up their Hb levels during toddlerhood. Our findings support the recommendation for EBF up to 6 months in this setting. Most of our study children were not EBF up to 6 months of age (65%), and maternal knowledge about the importance of EBF was scarce; 36% of mothers were aware of the WHO recommendation of EBF. Programs on maternal nutrition education are therefore needed to promote EBF in our population.

The mean FVS was very low; most of the children consumed only one or two food items the day before the interview. The consumed foods were mostly staples, which are not a good source of iron or other micronutrients (Gibson et al., 2010). Meat, a good iron source, was rarely consumed because as mentioned before, during the dry season, availability of staples but not meat is high. Our results clearly stress that lack of micronutrient-dense foods and low nutritional adequacy of the diet are serious issues in pastoralists of the ESRS and a contributing factor to undernutrition. Anaemia was strongly negatively associated with FVS and the odds of anaemia in children who consumed more than two food items were 97% less than in children consuming one or two food items. Similarly to our study, a previous study on predictors of anaemia in Tanzanian children <5 years of age found that nonconsumption of meat, fruits, and vegetables is significantly associated with anaemia, indicating that a more diverse diet is beneficial for Hb levels (Kejo, Petrucka, Martin, Kimanya, & Moshia, 2018). Our measurement of RBP indicates that 30% of the children in the ESRS are vitamin A deficient. Milk and milk products are the main animal sources for vitamin A (Codjia, 2001) and frequently consumed by pastoralist communities particularly during the rainy season (Galvin, 1992). In children from nomadic Chadian pastoralists, serum retinol concentrations were higher than in children from settled pastoralists consuming less milk and milk products (Bechir et al., 2012). Goat and cow milk were reported to be important sources of vitamin A in Chadian pastoralist, and the retinol concentrations of milk significantly correlated with the human serum retinol concentration (Zinsstag et al., 2002). Our data was collected shortly after the rainy season characterized by high milk consumption; hence, prevalence of VAD might be higher at the end of the dry season when milk and milk products have been scarcely available for a longer period. A previous study in pastoralists not only showed a strong seasonal fluctuation of milk consumption but also of human retinol status as the retinol concentrations in blood were strongly associated with season (Crump et al., 2017). In our study, milk and milk products were consumed by 42% of the children, and there was a tendency (adjusted 95% confidence interval [0.35, 1.06]) that the odds of having VAD in children consuming milk were lower than those for children not consuming milk, indicating the importance of milk consumption for vitamin A status. Additionally, milk consumption was associated with less undernutrition as indicated by better MUAC. The vital nutritional profile of milk and dairy products providing protein, essential fatty acids, and critical micronutrients, such as vitamin A, vitamin B12 and calcium can help to prevent undernutrition (Murphy & Allen, 2003). In pastoralists in Samburu, Kenya, milk contributed to only 10% of the overall energy intake but to $\geq 50\%$ of the vitamin A, C, and B12 intake

(Iannotti & Lesorogol, 2014). Milk intake in low-income countries has been associated with improved growth indicators, micronutrient status, and cognitive performance in undernourished children (Dror & Allen, 2011).

The strengths of our study include the holistic approach using biomarkers, anthropometry, and IPIs analysis to gather the first comprehensive data on the nutritional status of children <5 years of age in ESRS and the factors influencing undernutrition. We had a large sample size covering several Kebeles and were able to collect and analyse biological samples in a challenging logistical and infrastructural setting. Although the number of enrolled children per cluster was higher than assumed for the sample size determination, we were able to estimate the prevalences with the anticipated precision as the estimated intracluster correlation coefficient was lower than expected (e.g., .024 for anaemia and .048 for VAD using analysis of variance estimates; for further intra cluster coefficients, see Table S1). Our approach was that parasitic infections increase the risk of undernutrition based on evidence where helminthic infections were strongly associated with undernutrition (Smith & Brooker, 2010). The relationship between infections and nutritional status is however complex, and it is also possible that undernutrition increases the susceptibility to infections: and hence the risk of infections. One limitation in our study was the difficult collection of accurate data on birth dates due to missing birth certificates and high illiteracy in mothers. This had an impact on the analysis of parameters that required a reliable age measurement. In our study, we therefore decided not to use MUAC-for-age Z scores as an indicator for undernutrition, and WAZ and HAZ in Table 2 need to be interpreted with caution. Due to constraints with the equipment, body weight was only measured to the nearest 0.5 kg. This affected WHZ, and therefore, we decided not to use WHZ as a key indicator for undernutrition and did not conduct a regression analysis on it. Between 10 to 20% of the children did not provide a blood or stool sample. This could have introduced bias. Consequently, we compared the sociodemographic characteristics of children with missing samples with those with complete data. We did not find noteworthy differences (see Table S2) indicating that our study was not affected by such a bias. Infrastructural constraints only allowed us to conduct qualitative analysis of IPIs using single Kato Katz and SAF smears, and food intake was based on a single 24-hr recall that did not allow us to capture day-to-day and seasonal variations, and which could be influenced by recall bias.

To conclude, our findings show that in pastoralist communities in ESRS, prevalence of undernutrition and IPIs is alarmingly high in children <5 years of age. Undernutrition defined as low MUAC was associated with *giardial* infections and milk consumption, and anaemia with exclusive breastfeeding and low nutritional adequacy of the diet. A holistic approach to improve nutrition, promote maternal education, as well as to reduce IPIs is therefore urgently needed in this region. Such an approach should include (a) education on breastfeeding practice, dietary diversification, and good hygiene; (b) enhanced infrastructure to provide safe drinking water, environmental sanitation, and healthcare access; (c) regular deworming and facilitated access to helminth and protozoa treatments; and 4)

nutritional interventions to provide adequate amounts of micronutrients, particularly during periods of food shortage, for example, seasonal droughts. The latter could include provision of micronutrient powders (e.g., to fortify milk) and capacity building on food conservation for animal source foods so that they can be stored for use during the dry season.

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CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

CONTRIBUTIONS

KO, JZ, ES, JH, and CIC designed the study; KO, RS, AU, and SA managed study sites and sample collection; KO, JZ, ES, JH, and CIC analysed study data, KO and CIC wrote the first draft; and all the authors reviewed and approved the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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