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The relationship between residential altitude and stunting: evidence from >26 000 children living in highlands and lowlands of Ethiopia

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Abstract

Little information is known about the influence of altitude on child growth in Ethiopia, where most people live in highlands. We investigated the relation of residential altitude with growth faltering (stunting) of infants and young children in Ethiopia. We also examined whether the altitude–growth relationship was independent of the influence of the dietary and non-dietary determinants of growth. We used the data of 26 976 under-5-year-old children included in the Ethiopian Demographic and Health Surveys, conducted from 2005 to 2016. The samples were recruited following a two-stage cluster sampling strategy. Stunting was defined by height-for-age <−2 *z*-scores. The relationship between residential altitude and stunting was examined by running multiple logistic regression analysis, controlling the effect of covariate dietary and non-dietary variables. The residential altitude of the study participants ranged from −116 to 4500 m above sea level (masl). There was a significant and progressive increase in the prevalence and odds of stunting with increasing altitude ($P < 0.001$), irrespective of the dietary and non-dietary predictors of stunting. The prevalence of stunting was lowest in lowlands (39 %) and highest in highlands (47 %). Compared with altitude <1000 masl, the odds of stunting was 1·41 times higher at altitude ≥2500 masl (OR 1·41, 95 % CI 1·16, 1·71) and 1·29 times higher at altitude 2000–2499 masl (OR 1·29, 95 % CI 1·11, 1·49). Children living in highlands might be at a higher risk of poor growth. Further studies are warranted to understand the mechanism behind the observed altitude–stunting link and identify strategies to compensate for the growth-faltering effect of living in highlands.

Key words: Child growth: Stunting: Nutritional status: Residential altitude

Child stunting is still a major public health nutrition problem in developing countries. Height-for-age measures the linear growth status of children. It is also widely considered as the best anthropometric indicator for assessing the overall health and well-being of children[1,2]. Stunting is defined when a child fails to achieve a height appropriate for its age, that is, when a child's length-for-age (for children younger than 2 years) or height-for-age (for children older than 2 years) is below two standard units (<−2 *z*-scores) from the reference[3]. In 2018, 18 % of under-5-year-old children were stunted globally[4]. Children become stunted often as a consequence of chronic malnutrition[2,5,6]. However, epidemiological studies have shown that stunting is more prevalent in highlands than in lowlands. This altitudinal variation in stunting has been demonstrated by studies done in Tibet, Peru, Bolivia, Switzerland and Argentina[7–12]. The effect of altitude is not limited to only the growth of children. It also negatively, or positively, influences other health and nutritional outcomes[13]. The rise of Hb concentration with increasing altitude is an established phenomenon[14–16]. Child morbidity and mortality rates also vary by residential altitude[13,17,18].

Ethiopia bears one of the largest global stunting burdens, with 38 % of under-5-year-old children being stunted in 2016.

Abbreviations: DHS, Demographic and Health Survey; EA, enumeration areas; HFA, height-for-age; masl, metres above sea level.

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Besides, there is a wide geographical variation in the prevalence of stunting in Ethiopia[19]. Altitude in Ethiopia ranges from as low as −125 m below sea level in the Afar region to as high as 4600 m above sea level (masl) in the Amhara region. Most people in Ethiopia live in highlands, about 70 million people currently living at altitude >2000 masl[20]. Despite the geographical feature of Ethiopia is suitable to study the influence of altitude on health, only limited studies have been done in the country on the influence of altitude on children's growth[21]. Whether the growth pattern of Ethiopian children varies by residential altitude remains largely unknown. Thus, in the present study, we aimed to assess the relationship between residential altitude and the growth status of under-5-year-old children in Ethiopia. We determined the prevalence of stunting at different altitudes and the association of altitude with stunting. We also investigated whether the altitude–stunting link was influenced by the dietary and non-dietary predictors of growth.

Methods

Study population and data source

We used the data of a nationally representative sample of under-5-year-old children, included in the Ethiopian Demographic and Health Surveys (DHS), conducted in 2005, 2011 and 2016. The surveys were conducted by the United States Agency for International Development and ICF International in collaboration with the Ministry of Health of Ethiopia. United States Agency for International Development, through its international DHS programme, has also been conducting similar surveys in over 90 low- and middle-income countries since 1984. In each survey, data were collected on a wide range of variables of public health importance, including on the status and determinants of child health and nutritional status indicators[22]. All the datasets used in the present study are publicly available on the website of the international DHS programme: https://www.dhsprogram.com/data/available-datasets.cfm.

Sampling strategy and sample size

The samples of the study were obtained following a two-stage cluster sampling strategy. The primary and secondary sampling units of the surveys were census enumeration areas (EA) and households, respectively. In each survey, an average of 645 EA was randomly selected from the list of all EA in the country. Then, a fixed number of twenty-eight households per cluster, that is, twenty-eight households/EA, were randomly selected from the selected EA. Thus, a total of 18 060 households were included in each survey. All under-5-year-old children found in the selected households were eligible for inclusion in the surveys, and data were collected on various variables, including anthropometric measures. The data collection was done by trained interviewers and using the DHS questionnaire that was standardised across the 90 DHS member countries[19]. In the three datasets, we found a total of 26 976 under-5-year-old children, with complete information on the variables of interest for the present study.

Variables

Outcome variable. The primary outcome variable was stunting, which indicates that a child fails to achieve the height appropriate to its age[23]. In all DHS surveys, the length and height of children were measured (in cm). Length (only for children <2 years of age) was measured in a recumbent position, and height (for those ≥ 2 years of age) was measured in a standing position. The length and height measuring tools were produced under UNICEF supervision[19]. Using the anthropometric, sex and age data, height-for-age (HFA) z-scores for children ≥2 years of age and length-for-age for those < 2 years of age were calculated, based on the WHO 2006 child growth standards. Stunting was defined when the child's HFA or length-for-age was more than two standard deviations below the standard (<−2 z-scores)[3]. Because of its more familiarity in the literature, in this report, we used HFA to refer to both HFA and length-for-age.

Exposure variable. Residential altitude was the primary exposure variable of interest in the present study and measured using global positioning system which provides records of both elevation and location of places. There is no uniform altitude classification approach in the literature. We followed the most commonly used approach and categorised the residential altitudes into five groups: <1000, 1000–1499, 1500–1999, 2000–2499 and ≥2500 masl.

Covariates. In addition to the main exposure and outcome variables, we included other variables with the potential to influence the altitude–stunting relationship. The variables were selected based on theoretical relevance, reports of previous studies and availability in the datasets used. These include child factors (age, sex, birth size, breast-feeding and dietary practices), maternal factors (educational status and antenatal care utilisation) and household factors (source of water supply, type of toilet facility and household wealth statuses). A detailed description of the definition and measurement of the covariates is presented below.

(a) Age: measured in months and categorised into three groups: <12, 12–23 and >23 months.
(b) Sex: boys and girls.
(c) Birth size: assessed by the subjective reporting of the mother of the size of the child at the time of birth and categorised into three groups: low, average and large birth sizes.
(d) Early initiation of breast-feeding: assessed by whether the child was breastfed within the first hour after birth and dichotomised into yes and no.
(e) Duration of breast-feeding: measured by the number of months the child was breastfed.
(f) Dietary practice: data on dietary practice were collected by 24-h dietary recall method, following the multiple pass approach. Besides, the frequency of complementary food feeding was collected. The food items collected by the 24-h recall method were reduced into seven groups: (i) grains, tubers and roots, (ii) meat, (iii) milk, (iv) egg, (v) vitamin-A rich fruits and vegetables, (vi) other fruits and vegetables and (vii) nuts and legumes. Following the

WHO infant and young child feeding practice guidelines[23], the dietary recall data were used to develop dietary diversity and meal frequency scores, which were further used to assess whether the child's feeding fulfilled the minimum dietary diversity and minimum meal frequency. The minimum dietary diversity was assessed by whether the child's diet was composed of at least four of the seven food groups mentioned above and dichotomised into yes (≥4) and no (<4)[23]. The minimum meal frequency was assessed by whether the child was fed at least three times in the last 24 h and dichotomised into yes (≥3) and no (<3) for breast-feeding children. For non-breast-feeding children, the frequency of feeding should be at least four times a day[23].

(g) History of morbidity: assessed by whether the child had any one of fever, diarrhoea or cough in the last 2 weeks prior to the data collection date and dichotomised into yes and no.

(h) Antenatal care: assessed by the number of antenatal care visits attended by the mother during the pregnancy of the indexed child and categorised into three groups: none, 1–3 visits and ≥4 visits.

(i) Maternal stature: the height of the mother, measured objectively in cm and categorised into three groups: <150·0 cm (short stature), 150·0–154·9 cm and ≥155·0 cm (tall stature, reference group). The height categories were adapted from similar earlier studies[24,25].

(j) Maternal weight: the weight of the mother, measured objectively in kg and categorised into three groups: <50 kg, 50–59·9 kg and ≥ 60 kg (reference group).

(k) Maternal education status: assessed by the highest education level completed by the mother of the child and categorised into illiterate/none, primary and secondary and above.

(l) Household water sources: assessed by the type of water source used by the household and dichotomised into improved and unimproved. As per the WHO guideline, piped water and protected wells were classified as improved water sources and springs, lakes, ponds, unprotected wells, rivers and dams as unimproved sources.

(m) Household toilet facility: assessed by the type of toilet facility used by the household and dichotomised into improved and unimproved. Flush toilets or ventilated improved pit latrines were classified as improved toilet facilities and traditional pit latrines as unimproved facilities.

(n) Household wealth category: assessed by developing household wealth index, using the assets variables in the dataset and following the method of principal component analysis. The wealth index was used to classify the households into quantiles of wealth categories: poorest, poorer, middle, richer and richest.

(o) Residence place: assessed by the dejure place of residence and dichotomised into urban and rural.

(p) Survey time: the year in which the data were collected. The surveys were conducted in the years 2005, 2011 and 2016.

Statistical analysis

In all analyses, the complex design of the surveys was taken into consideration; such that, all estimates provided in this work were based on the weighted sample and taking into account the stratification and the sampling schemes used in recruiting the study participants[19,22]. The sample weighting was done to ensure that no region is over-represented or under-represented so that the sample resembles the actual population distribution of the country. The samples were obtained following a cluster sampling strategy. Adjustment for the cluster study design was done using the census EA as primary sampling units (clusters) and the regions (sub-national and urban-rural divisions) as strata. Descriptive statistics, like frequency distribution of stunting by residential altitude and covariates, were estimated and presented. To test the relation of residential altitude with stunting, first χ^2 test of association was run, and then multi-variable logistic regression analysis was run controlling for the effect of dietary and non-dietary covariates. The covariates included in the multi-variable regression analysis were selected based on theoretical relevance and statistical significance. Variables that demonstrated $P < 0·25$ during the bi-variable analyses, that is, between the covariates and stunting, were also included in the multi-variable model. All data analyses were conducted using STATA 16, with statistical significance determined at $P < 0·05$.

Ethical consideration

The study protocols of the surveys included in this analysis were approved by the Institutional Review Boards of Ethiopian Public Health Institute and ICF International to ensure the survey procedure and tools complied with the Ethiopian protocol for study participants handling and the USA Department of Health and Human Services regulations for the protection of human subjects. The data analysed in the present study are publicly available on the website of the International DHS programme (Georgia, Atlanta): https://www.dhsprogram.com/data/available-datasets.cfm. We obtained approval to use the Ethiopian DHS datasets from the international DHS programme, through a project entitled 'trends and determinants of malnutrition in Ethiopia'.

Results

The final analysis consisted of a total sample of 26 976 under-5-year-old children, whose mean age was 28·9 (SD 17·5) months. Almost three-fifths of the samples were in the age group 24–59 months. Most of the study participants (68 %) were living at altitude <2000 masl, 23 % at 2000–2499 masl and 9 % at ≥2500 masl. The average stunting (HFA < −2 z-scores) prevalence for the whole period (2005–2016) was 42 %. The year-specific stunting prevalence rates were 48, 44 and 38 % in 2005, 2011 and 2016, respectively. More information on the distribution of stunting as well as other covariates by different categories of altitudes is presented in Table 1.

The results of the bi-variable analyses on the relation of altitude with stunting as well as with other covariates are presented in Table 1. The prevalence of stunting among the lowlanders (altitude <1000 masl) and the highlanders (altitude >2500 masl) was 39 and 47 %, respectively. Fig. 1 shows the prevalence of stunting by categories of residential altitude. The prevalence of stunting increased progressively with increasing altitude.

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Table 1. Prevalence (%) of stunting by residential altitude and determinants of stunting (*n* 26 976)

Variables	Residential altitude (metres above sea level) <1000	1000–1499	1500–1999	2000–2499	≥2500	*P**
Stunting						
Yes	39·4	39·3	40·6	41·9	46·5	<0·001
No	60·6	60·7	59·4	58·1	53·5	
Sex						
Boys	52·7	51·7	51·0	50·3	51·4	0·098
Girls	47·3	48·3	49·0	49·7	48·6	
Age (months)						
<12	22·0	21·3	21·5	21·0	21·8	0·520
12–23	17·9	19·4	18·7	19·7	19·2	
≥24	60·1	59·2	59·8	59·3	59·0	
Infection						
Yes	28·2	29·1	31·2	29·3	29·8	0·002
No	71·8	70·9	68·8	70·7	70·2	
Dietary diversity						
<4	95·4	93·1	92·1	92·0	93·8	<0·001
≥4	4·6	6·9	7·9	8·0	6·2	
Feeding frequency						
<3	70·0	56·5	53·2	48·1	51·1	<0·001
≥3	30·0	43·5	46·8	51·9	48·9	
Place						
Rural	84·6	81·3	86·7	78·5	87·0	<0·001
Urban	15·4	18·7	13·3	21·5	13·0	
Toilet facility						
Unimproved	89·0	83·6	89·2	83·5	89·5	<0·001
Improved	11·0	16·4	10·8	16·5	10·5	
Water source						
Unimproved	33·2	37·5	37·8	34·4	37·8	<0·001
Improved	66·8	62·5	62·2	65·6	62·2	
Breast-feeding duration						
<12 months	44·8	40·5	38·6	35·2	34·7	<0·001
12–23 months	32·5	32·2	33·8	33·3	32·1	
≥24 months	22·7	24·3	27·6	31·5	33·2	
Birth size						
Small	35·0	29·0	25·8	28·0	29·2	<0·001
Average	39·6	40·3	40·7	42·0	42·3	
Large	25·4	30·8	33·6	30·1	28·6	
Maternal education						
Illiterate	71·9	73·7	71·2	63·3	73·4	<0·001
Primary	21·3	20·9	22·9	24·5	19·1	
Secondary+	6·8	5·4	5·9	12·2	7·6	
Maternal stature						
<150·0 cm	71·4	65·4	63·2	60·3	59·6	<0·001
150·0–154·9 cm	19·1	22·7	25·2	26·7	26·9	
≥155 cm	9·6	11·9	11·6	13·0	13·6	
Maternal weight						
<50 kg	51·6	49·0	52·1	53·3	51·1	<0·001
50–59·9 kg	35·0	39·2	39·7	38·4	41·0	
≥60 kg	13·4	11·8	8·2	8·3	7·9	
Wealth category						
Poorest	63·5	36·4	25·5	15·8	19·6	<0·001
Poorer	11·2	16·5	20·8	18·2	21·7	
Middle	7·1	12·9	19·3	19·0	21·9	
Richer	7·9	12·5	16·5	18·9	19·5	
Richest	10·4	21·6	18·0	28·1	17·3	
Survey year						
2005	49·2	43·5	33·5	35·5	43·0	<0·001
2011	34·6	20·7	37·5	34·2	27·0	
2016	29·9	35·7	29·0	30·4	16·1	

* *P* value derived from χ^2 test of association.

The statistical significance of the altitude–stunting link was examined by χ^2 test of association, which showed that residential altitude was significantly associated with stunting ($P<0·001$). Maternal height and weight were also significantly lower in the highlands than in the lowlands ($P<0·001$). As shown in Table 1, some of the determinants of stunting also varied by altitude. There was a significantly longer duration of breast-feeding in highlands, compared with lowlands ($P<0·001$). The frequency of child complementary feeding was also significantly higher in highlands than in lowlands ($P<0·001$). Other variables that varied significantly by altitude were dietary diversity, birth size, water source, toilet facility, history of infection,

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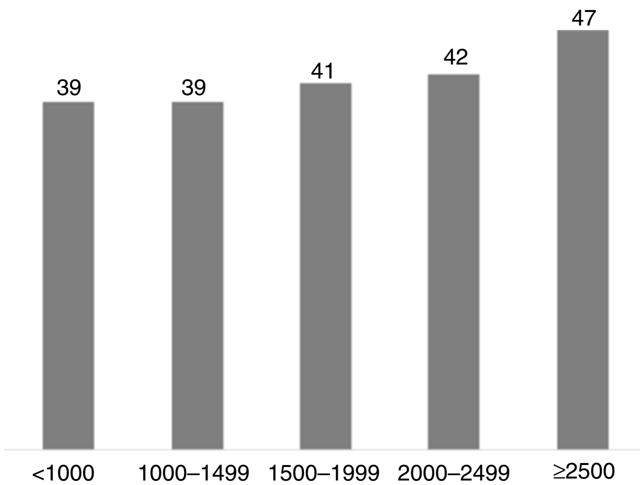

Fig. 1. Distribution of stunting by categories of altitude, given in metres above sea level.

maternal educational status and household wealth statuses ($P < 0·05$). Child sex ($P = 0·098$) and age ($P = 0·520$) did not vary significantly by residential altitude. These results are, however, less informative for they were not based on adjusted analyses, and the possibility of confounding by third factors needs to be ruled out.

To rule out whether the altitude–stunting link was confounded by a third variable, multiple logistic regression analysis was run adjusting for the dietary and non-dietary factors (covariates) which also varied by altitude. The covariates included in the model are shown in Table 2. Altitude demonstrated an independent and significant link with stunting ($P_{\text{for trend}} < 0·001$) after adjusting for the dietary and non-dietary determinants of stunting. There was a progressive increment in the odds of stunting with increasing residential altitude. The odds of stunting at altitude ≥2500 masl was 41 % higher than the odds of stunting at altitude <1000 masl (adjusted OR = 1·41, 95 % CI 1·16, 1·71, $P < 0·001$). The odds of stunting at altitude 2000–2499 masl was 29 % higher than the odds of stunting at altitude <1000 masl (adjusted OR = 1·29, 95 % CI 1·11, 1·49, $P < 0·001$). The odds of stunting at altitudes 1500–1999 and 1000–1499 masl was not significantly different from the odds of stunting at altitude <1000 masl ($P > 0·05$). Though not the primary aim of the present study, history of childhood illness, dietary diversity, meal frequency, breast-feeding duration, birth size, maternal educational status, maternal stature, maternal weight, survey year and household wealth category were also found significantly associated with stunting ($P < 0·05$).

Table 2. Relation of altitude with stunting (multi-variable adjusted) (*n* 26 976)
(Adjusted odds ratios (AOR) and 95 % confidence intervals)

Variables	AOR	95 % CI	*P**
Altitude (masl)			
<1000		Reference	
1000–1499	1·01	0·80, 1·26	0·933
1500–1999	1·03	0·92, 1·15	0·604
2000–2499	1·29	1·11, 1·49	<0·001
≥2500	1·41	1·16, 1·71	<0·001
Dietary diversity			
<4	1·38	1·09, 1·75	0·008
≥4		Reference	
Meal frequency			
<3	1·31	1·13, 1·50	<0·001
≥3		Reference	
Breast-feeding duration (months)			
<12	3·39	2·92, 3·94	<0·001
12–23	2·85	2·28, 3·56	<0·001
≥24		Reference	
Birth size			
Small	1·34	1·15, 1·56	<0·001
Average	1·09	0·87, 1·36	0·454
Large		Reference	
Infection history			
Yes	1·02	0·89, 1·17	0·755
No		Reference	
Water source			
Improved		Reference	
Unimproved	1·09	0·95, 1·25	0·234
Toilet facility			
Improved		Reference	
Unimproved	1·58	1·25, 1·99	<0·001
Maternal education			
Illiterate	1·75	1·50, 2·03	<0·001
Primary	1·42	1·22, 1·66	<0·001
Secondary+		Reference	
Maternal height (cm)			
<150·0	1·76	1·54, 2·02	<0·001
150·0–154·9	1·55	1·40, 1·72	
≥155		Reference	
Maternal weight (kg)			
<50	1·54	1·26, 1·88	<0·001
50–59·9	1·36	1·11, 1·65	0·003
≥60·0		Reference	
Antenatal care			
None	1·31	1·20, 1·44	<0·001
1–3	1·14	1·03, 1·25	0·011
≥4		Reference	
Residence place			
Rural	2·75	2·18, 3·46	<0·001
Urban		Reference	
Wealth category			
Poorest	1·68	1·46, 1·84	<0·001
Poorer	1·53	1·36, 1·71	<0·001
Middle	1·37	1·21, 1·55	<0·001
Richer	1·32	1·17, 1·49	<0·001
Richest		Reference	
Survey year			
2005	1·30	1·13, 1·50	<0·001
2011	1·08	0·98, 1·19	0·129
2016		Reference	

masl, Metres above sea level.
* *P* value derived from multiple logistic regression analysis.

Discussion

We aimed to investigate whether residential altitude was linked to the growth status of infants and young children in Ethiopia. We found that residential altitude was significantly associated with stunting, independent of the dietary and non-dietary determinants of stunting. There was a progressive increase in the prevalence as well as the odds of stunting with increasing altitude. The highest prevalence and odds of stunting were found among those who reside in highlands (altitude >2500 masl). The lowest prevalence and odds of stunting were found among those who reside in lowlands (altitude <1000 masl).

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Evidence is scarce on the influence altitude on the growth of children in Ethiopia, albeit it bears one of the largest global highland populations as well as a great variation in residential altitude[20]. Other countries with a large highland population and varying residential altitude include Tibet (China), Nepal, Colombia, Bolivia, Peru, Kazakhstan, Bolivia, Argentina, Bhutan and Switzerland[7,8,13]. Our finding of high growth faltering at high altitude was consistent with the findings of previous studies done in these highland countries. The risk of stunting among Tibetan children residing in highlands was two to six times higher, compared with those residing in lowlands[9]. In Bolivia, the prevalence of stunting was six times higher in highlands than in lowlands[7,26]. In Argentina, the risk of stunting was twice higher in highlands than in lowlands[8]. Studies conducted in Nepal[27], Switzerland[11] and Andean nations[21] had also shown a consistently higher risk of growth faltering among highlanders, compared with lowlanders.

Despite the evidence on the altitude–growth link is apparently consistent, the mechanism underlying the link remains largely unclear. The literature indicates that chronic exposure to hypoxia in highlands might negatively influence some phenotypic features, including children's growth pattern[13,21]. Hypoxic environment influences not only physical growth but also physiological states like respiration, metabolism and blood circulation rates[13,21]. A good example is the rise of Hb concentration in highlands, a phenomenon considered as a normal adaptive response to the decrease in O_2 tension at high altitude areas[14,15,28–30]. Likewise, the slow growth rate in highlands might be in part due to the hypoxic environment, acting on its own or most probably interacting with other highland-specific ecological, socio-cultural and genetic characters. Unique genes and polymorphisms have been identified among highland populations, including Ethiopians[20,21,31–34]. However, none of these hypotheses is well explored, and no conclusive evidence is available on the exact mechanism through which altitude influences growth negatively.

Specific to Ethiopia, the epidemiology of stunting in the country might be in part explained by our finding of altitude–growth linkage. Ethiopia bears one of the highest global stunting burdens. In 2016, 38 % of children were stunted in Ethiopia. Various stunting prevention and control measures have been instituted with the aim of meeting the WHO goal of a 40 % reduction in the proportion of stunted children by 2022[19,35]. However, stunting reduction has been less promising in Ethiopia over the last two decades, reducing only by 7 % during the period 2010–2018. In addition to the high national stunting burden, there is also a large geographical discrepancy in the prevalence of stunting in Ethiopia. The highest prevalence of stunting in Ethiopia has been in Amhara state, a mainly highland region, and the lowest prevalence has been in Somali state, a mainly lowland region[19]. This geographical variation in stunting, as well as the consistently high magnitude of stunting, might in part be explained by the fact that most Ethiopians live in highlands and consequently have a high risk of stunting.

Our finding of a significant altitude–stunting link after controlling the effect of dietary and non-dietary determinants of stunting might imply that altitude influences growth independently. Specific to Ethiopia, the main implication of the present study is that the high burden of stunting, particularly in the Amhara region, might be due to the growth-faltering effect of high residential altitude. However, as growth is of multiple influences and genetic factors like polymorphism were not taken into account in our analysis, our proposition of altitude influencing growth independently needs to be further corroborated by studies with better designs. Longitudinally designed and comprehensive studies might provide better information. Further studies are also warranted to know the mechanism(s) through which high altitude influences growth negatively. We are also of the opinion that the slow growth, and consequently the short stature, of children living in highlands needs to be viewed as an adaptive response to the hypoxic environment like the case of Hb, which is considered normal[13–15,28–30]. Recently, the WHO has established a task force to investigate the validity of the existing Hb cut-off points for highland communities[15,16]. Likewise, it would be timely and important to investigate the suitability and validity of the WHO growth standards for highland populations and develop a mechanism to adjust for the effect of altitude during growth assessment and stunting classification. Here, worthy of note to the reader is that the altitude–stunting association should not be misunderstood and divert attention from the need for improving health and nutrition services for highland populations. The effect of altitude on growth, if a true one, could be modified by compensatory education, health and nutrition interventions[36]. Thus, we recommend scaling up the implementation of nutrition-enhancing measures for all under-5-year-old children in general, and for highland children in particular[23,37].

Our findings are subject to the limitations of cross-sectional design, including its observational nature and the possibility of unmeasured confounding. The analysis did not take into account the effect of genetic factors and duration of residence on the altitude–growth link. Thus, we could not rule out the role of genetic factors like polymorphism and duration of stay on the observed altitude–stunting link. In spite of these limitations, the study has important strengths, including the use of large and nationally representative samples, the inclusion of individuals residing at a wide range of altitudes and the adjustment for various dietary and non-dietary determinants of stunting. The fact that the study was undertaken in a previously less explored setup (Ethiopia) would also be a strength as it would contribute to filling the gap in the literature.

Conclusion

We found that residential altitude was significantly and independently associated with the growth status of infants and young children in Ethiopia. The odds of stunting in children residing at altitude >2500 masl was 41 % higher than the odds of stunting in those residing at altitude <1000 masl. Living in high altitude areas might be contributing to the high burden as well as the wide regional variation of stunting in Ethiopia. Further studies are warranted to understand the mechanism behind the observed altitude–stunting link, identify strategies to compensate the growth-faltering effect of high altitude and evaluate the validity of the existing growth monitoring tools for highland communities. Meanwhile, presuming children living in highlands as more vulnerable to stunting and prioritising them for preventive interventions stand worthy of consideration.

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