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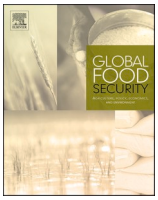

# The difficulty of meeting recommended nutrient intakes for adolescent girls

Indira Bose [a,*], Giulia Baldi [a], Lynnda Kiess [a], Janosch Klemm [a], Amy Deptford [a], Saskia de Pee [a,b,c]

[a] Nutrition Division, World Food Programme, Rome, Italy
[b] Friedman School of Nutrition Science and Policy, Tufts University, Boston, MA, USA
[c] Human Nutrition, Wageningen University, Wageningen, the Netherlands

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ABSTRACT

Adolescent girls have been recognised as a key group requiring nutritional support. This study compares the findings of Fill the Nutrient Gap (FNG) analyses in El Salvador, Ghana, Madagascar and Lao PDR, on the cost of meeting the nutrient needs of adolescent girls compared to other household members and investigates the drivers of these results. In all four countries, the cost of meeting the nutrient intake recommendations of the adolescent girl was one of the highest among all household members. In contexts with fewer affordable nutrient dense foods available, in particular iron-rich foods, the cost the diet of an adolescent girl was considerably higher than that of a boy of the same age, demonstrating the vulnerability of this group.

## 1. Introduction

Adolescence is a critical period for the development of girls and boys in terms of growth, sexual maturation and cognitive development. The behavioural patterns developed in this time can have substantial impacts on the health of this group and their risk of developing chronic diseases in the future (Lawrence et al., 2009). Healthy adolescents will likely become healthy adults and the driving force of future economic and social development. There are an estimated 1.2 billion adolescents worldwide (10–19 years old), making up 16% of the world's population, the largest generation of adolescents in human history (UNICEF, 2016). Ensuring the health and well-being of this group is crucial for their future and future generations. Despite this, adolescents are often neglected in national strategies, and in many countries nutrition programming for this group remains nascent.

In recent years adolescent girls have also been globally recognised as a key target group requiring nutrition support in order to ensure that women are well-nourished at the point of conception, thereby influencing the critical window of growth and development of the first 1000 days of their future offspring (Black et al., 2013). Adolescence is also 'the final chance' to intervene to try to improve growth and development, though it is not possible to catch up fully on vital cognitive development missed in the earlier years of life.

Adolescence is a second period of rapid growth after early childhood where it is possible to somewhat compensate for the failure to achieve full growth potential in childhood. Although most of the brain's development occurs before a child reaches the age of 2 (80% of brain size is usually reached by this point) the brain continues to develop until an individual is 18 years old, but at a much slower rate (Kretschmann et al., 1986; Casey et al., 2000). During adolescence approximately 45% of adult bone mass and 15% of adult height are gained (Spear, 2002). Some studies suggest that there is the possibility of catch-up growth during this period (Fink and Rockers, 2014; Martorell et al., 1994), but the evidence base for this assertion remains fairly limited. It is recognised, however, that in order to break the cycle of undernutrition it is crucial to ensure good nutrition among this group.

Prior to puberty there is no significant disparity in the nutrient needs of boys and girls. Due to the growth spurt that occurs during puberty the nutrient needs are in general high for both, but biological changes such as menarche result in gender-specific nutrient needs, with girls having higher iron requirements due to the iron losses incurred during menstruation (WHO, 2006). Boys tend to have higher energy needs in this period due to higher physical activity/greater lean body mass, so girls require foods of higher nutrient density compared with boys of the same age.

There is limited information on what adolescents actually consume, as dietary intake is primarily collected for households, young children and to a lesser extent on women of reproductive age during pregnancy and lactation. It is, therefore, difficult to assess how well they are able to meet their nutrient requirements. There is also limited data on the

* Corresponding author. World Food Programme, Via Cesare Giulio Viola 68, Parco dei Medici, 00148, Rome, Italy.
*E-mail addresses:* indira.bose@wfp.org, indiraellora@gmail.com (I. Bose).

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nutritional status of this group. Demographic and health surveys collect information of girls aged 15–19, but scarce information exists on 10–14 year old girls and boys aged 10–19. Analyses of the dietary intake of adolescents that exists in high-income countries, such as the US, indicate inadequate consumption of vitamins and minerals, a dietary gap which is much larger among girls than boys (Stang and Story, 2005). Invariably this is likely to be more pronounced in low- and middle-income countries (LMIC), where many households frequently cannot afford access to adequate nutritious diets and cultural practices and gender discrimination may also further restrict the ability of adolescent girls to meet their nutrient needs. In many LMIC countries, where many young children and women of reproductive age do not meet dietary diversity and nutrient intake recommendations, adolescents are also less likely to meet them, as is also indicated by findings of micronutrient deficiencies (Askeer et al., 2017). Country specific studies such as a study on girls aged 11–14 years old in Uganda, found a shortfall in their energy intake and in a number of nutrients including folate, iron, riboflavin, protein, and vitamin A (Barugahara et al., 2013). Studies in other regions, such as amongst urban adolescents in India similarly found a shortfall in the intake of a number of nutrients including energy, protein, fat, iron, and vitamins A and C (Deka et al., 2015). In addition to from micronutrient deficiencies, adolescents are at risk of becoming overweight or obese due to poor dietary practices. One driver of poor dietary practices is the inability to afford nutritious foods (Development Initiatives, 2018; Bose et al., 2018; Deptford et al., 2018), which makes it even more challenging for individuals within the household with elevated nutrient needs.

The objective of this paper is to explore the difficulty of meeting the nutrient needs of adolescent girls by comparing the findings of 'Fill the Nutrient Gap' systems-focused situation analyses for nutrition (Bose et al., 2019; WFP, 2020) in El Salvador (WFP, 2016), Ghana (MoH Ghana, MoA Ghana & WFP, 2016), Madagascar (ONN Madagascar, INSTAT Madagascar & WFP, 2017) and Laos PDR (MoH Lao PDR & WFP, 2017), on the cost of meeting the nutrient intake recommendations of adolescent girls compared to the cost of meeting the recommendations of other household members and to explore the drivers of these results.

## 2. Methodology

As a component of "Fill the Nutrient Gap" analyses (Bose et al., 2019; Untoro et al., 2017) linear programming, using the Cost of the Diet Software developed by Save the Children UK (Deptford et al., 2017), was used in El Salvador, Ghana, Madagascar and Laos PDR to model the affordability of nutritious diets when constraining for preferred staple consumption and food prohibitions. Staple foods were constrained by altering the parameters in the software to ensure that at least one portion of the main staples were included within the diets of each household member (except for the child under 2) and the parameters were also adjusted to make sure no widely prevalent prohibited foods, if any, were included within any of the diets modelled. This software calculates the combination of locally available foods that meet recommended intakes for energy (WHO/FAO, 2001), protein (WHO/FAO, 2007), fat (WHO/-FAO, 2008) and 13 micronutrients (WHO/FAO, 2004)- vitamin A, C, $B_1$, $B_2$, niacin, vitamin $B_6$, folic acid, vitamin $B_{12}$, calcium, iron, zinc, pantothenic acid, and magnesium-for each household member at the lowest cost (a minimum cost nutritious diet). The software applies an adjustable upper limit to energy, set by default at the Estimated Average Requirement (WHO and FAO, 2001) for each individual in the household. If the energy limit is met and it is not possible to meet the recommendations of the other nutrients, then the diet cannot be calculated. This occurs when there are not sufficient nutrient-dense foods in the model. The cost of the diet calculated is driven solely by the foods included within the software and the prices for that period of time.

These four countries were selected, as they show a diversity of contexts with El Salvador and Ghana, to different extents, experiencing a nutrition transition into the double burden of malnutrition. Whereas in Lao PDR, and to a greater extent Madagascar, poverty, food insecurity and undernutrition are of greater concern, but risk factors exist for a possible nutrition transition in the future (Development Initiatives, 2018). These countries were also amongst the first countries to conduct a Fill the Nutrient Gap analysis, that were selected based on their national processes and the potential for such an analysis to inform their national policies and programmes.

In El Salvador and Madagascar primary food price data collection was carried out at markets across the different livelihood zones in each country, 14 zones in Madagascar (August 2015) and 49 municipalities in 9 departments in El Salvador (September 2015). In Laos PDR primary price data collection was carried out in five provinces in February 2017: Vientiane Capital (VTE), Oudomxay (ODX), Phongsaly (PSL), Savannakhet (SVK) and Sekong (SKG). These provinces were selected based on their differing rates of stunting and livelihoods, in order to develop an understanding of the diversity of the national situation in respect to access to and availability of nutritious foods. In Ghana data collected by the Ministry of Agriculture in September 2015 were used, including prices on 42 key commodities in each of the 10 regions (as of 2015/16) except for Volta region, of which 39 were included in the analysis based on key informant discussions; the three excluded commodities were perfumed rice, both local and imported, and Apem plantains (Apentu plantains were included). These commodities were excluded as they are not commonly consumed by the local population. The drawback of the approach taken in Ghana (use of secondary data) is that a more limited list of commodities was assessed by comparison to El Salvador, Madagascar and Laos PDR, and only major markets in urban centres were assessed so prices might vary slightly in rural markets. In El Salvador data on 103 foods were collected, 133 foods were collected in Madagascar and 184 in Laos PDR. For the purposes of this study, however, these limitations should not drastically affect the relative cost of the diet of adolescent girls within the household, as within the model all household members would have access within the model to the same commodities. However, there was not enough price data for a diverse range of food items in the Upper West, Upper East, Eastern and Brong Ahafo regions of Ghana to calculate a nutritious diet, so these regions were not included in the analysis. The lack of adequate food price data for all of these regions is likely due to limitations in the data collected rather than indicative of a shortage of foods in these regions. The Upper West and Upper East regions are two of the most nutritionally vulnerable so the exclusion of these regions is a key limitation of the analysis for Ghana.

In all four countries Staple-adjusted Nutritious Diets (SNut) were calculated that took consideration of the key staples and food prohibitions found according to local data and verified by key informants. In Ghana information collected in a household survey in 2009 (WFP, 2009) was used to identify the key staples consumed in each region (these were foods that were consumed on a daily or close to daily basis), which was then cross-checked with local experts: Maize in Accra; Maize, Cassava and Plantain in Central; Cassava and Plantain in Western and Ashanti; and Maize and Cassava in Northern. In El Salvador rice, maize and red beans were included as daily staples, as identified by key informants. In Madagascar rice was included as the daily staple, as also identified by local experts, in all zones except for Altsimo Adrefana (in the South) where maize and cassava were included as the main staples. In Laos PDR the main staple included was glutinous rice, as supported by secondary data and confirmation by local experts.

Household size and expenditure was estimated using data from respective national household income and expenditure surveys (Ghana Statistical Service, 2014; DIGESTYC, 2013; InstitutNational de la Statistique (INSTAT), 2014; Lao Statistics Bureau, 2013) to calculate affordability of diets in each country. For Ghana and El Salvador 70% of total expenditure was estimated to be spent on food; in Lao PDR 65% of total expenditure was estimated to be spent on food and in Madagascar actual food expenditure was used for the analysis. These thresholds were

determined based on previous research conducted in each country and in consultation with local experts. For this analysis, households of five people were modelled composed of a lactating woman, a man, a breastfed child under 2, a primary-school (6–7 years) aged child and an adolescent girl (14–15 years). These household members were selected to represent a typical household and also include key members that might have different nutrient needs due to their different stage in the lifecycle. The proportional cost each household member contributes to the overall cost of this 5-person household are displayed for all geographic zones.

In addition to modelling the relative cost of household members, in each country an adolescent boy (aged 14–15 years) old was also modelled for comparison with the adolescent girl to see how biological sex might impact the cost of a nutritious diet.

In both Lao PDR and El Salvador there are high rates of adolescent pregnancy so a lactating and pregnant adolescent girl of the same age was also modelled to assess the additional impacts of pregnancy on the cost of a nutritious diet for an adolescent girl. Lao PDR has the highest adolescent pregnancy rate in South East Asia, with 40% of women pregnant or already having given birth to their first child by the age of 19 (Ministry of Health & Lao Statistics Bureau, 2012). El Salvador also has a very high adolescent pregnancy rate, with 1 in 3 pregnancies being to an adolescent mother (UNFPA, 2016). Adolescent pregnancy rates are also very high in Ghana and Madagascar, but this adjustment was not modelled for these countries.

Furthermore, nutritious diets including fortified foods -wheat flour (vitamin A, B1, B2, B3, B9, B12, iron and zinc) and vegetable oil (vitamin A)- made available on the market at market prices were modelled in Ghana to understand the potential impact the availability of affordable nutrient-dense foods could have on the cost distribution within the household.

## 3. Results

### 3.1. The relative cost of adolescent girls compared to other household members

Adolescent girls were usually found to have the most expensive diets within the household, or at least on par with the lactating woman. In each country adolescent girls were found to contribute approximately a third of the cost of the overall household nutritious diet (for households made up of 5 people). In El Salvador they made up 28–30% of the cost (see Fig. 1a), in Ghana it ranged from 42% to 48% (see Fig. 1b), in Madagascar it ranged from 27 to 29% (see Fig. 1c) and in Laos PDR it ranged from 24% to 31% (see Fig. 1d). This pattern was independent of geographic availability and access to foods and was found consistently across the countries. A discussion of which nutrients drive the cost of the adolescent girl's diet is outlined in the section on limiting nutrients below.

These results are indicative of the difficulty in meeting the high nutrient needs of adolescent girls. The FNG results found that a diet meeting nutrient needs was not affordable for many households in each of the countries. The percentage of household not being able to afford a nutritious diet ranged from 12 to 78% in Ghana, from 93% to 97% in rural areas in Madagascar, from 9 to 44% in El Salvador, and from 17% to 95% in Lao PDR. This range in affordability within each country is due to the respective expenditure patterns in each geographical zone, and the range of foods available and the prices within that zone. Thus, individuals requiring a more costly or specialised diet - such as adolescent girls - are even less likely to be able to meet their nutrient needs. It should be noted that affordability is likely to change throughout the year, as food prices fluctuate depending on the season, but for this analysis prices at only one point in the year were assessed.

### 3.2. The cost of the diet of adolescent girls compared to adolescent boys

As nutrient requirements vary across age and sex, an adolescent boy of the same age (14–15 years old) was modelled to determine the difference in cost according to sex. Results showed that in Ghana and El Salvador, the cost of the diet of an adolescent boy of the same age is lower than of an adolescent girl (see Fig. 2). In Ghana where prices on relatively few nutrient dense foods were available, a nutritious diet for adolescent girls was nearly three times more expensive than a nutritious diet for adolescent boys of the same age. The overall diet costs in Madagascar were much lower than other countries, but due to the high levels of poverty, non-affordability of nutritious diets were comparably much higher.

In Lao PDR and Madagascar, however, adolescent boys had a slightly higher cost of a nutritious diet than adolescent girls. In Lao PDR, largely due to the availability of cheap iron-rich foods, such as offal (in particular animal blood), the cost of the diet of an adolescent boy was 2% higher than an adolescent girl due to elevated energy needs. Whilst these foods are extremely good sources of nutrients they are unlikely widely consumed in sufficient quantities, as indicated by data found in the food balance sheets, and if these are removed from the diet then the cost of the diet of the adolescent girl becomes more expensive than that of the boy (see Fig. 3). Examples of nutrient-dense foods that were removed for this specific model are: blood, brains, lungs, liver, kidneys and tongues. It should be noted that the costs increase for both individuals overall, but that the cost of the diet of the adolescent girl

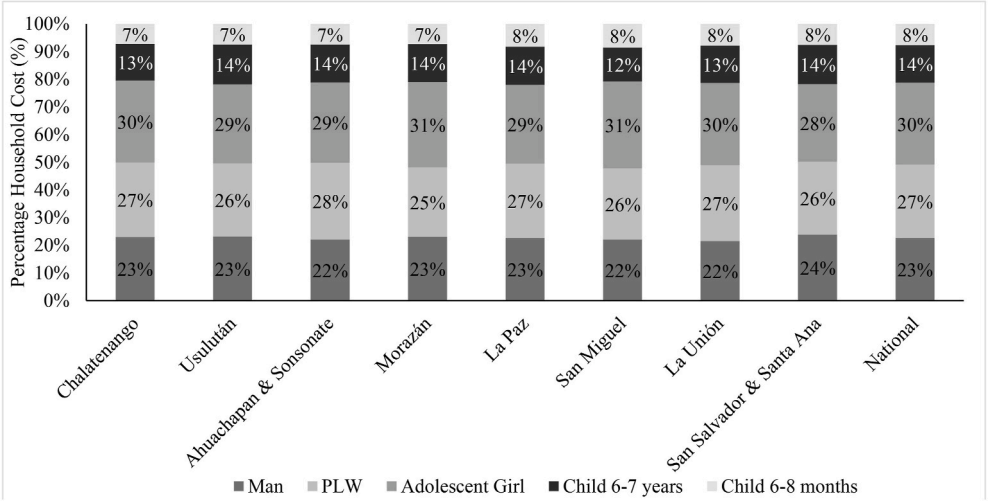


**Fig. 1a.** Contribution to overall household cost of each family member in each livelihood zone in El Salvador.

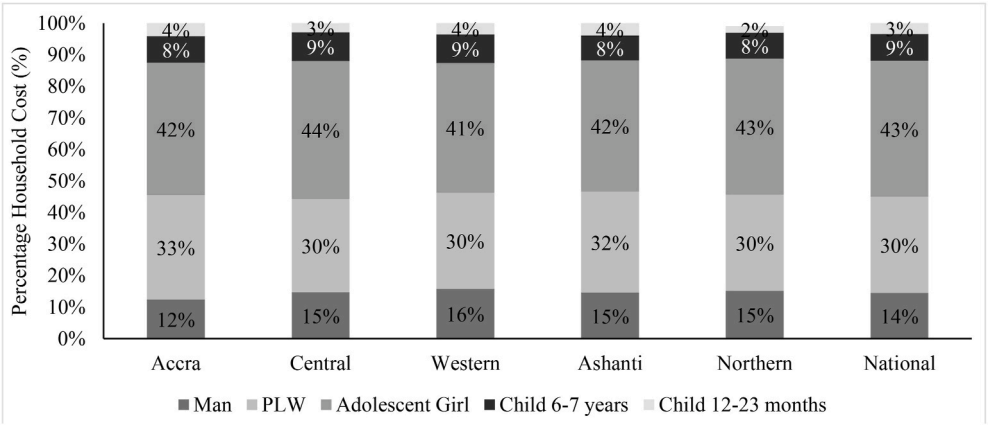


**Fig. 1b.** Contribution To Household Cost Of Each Family Member In Each Region Of Ghana.

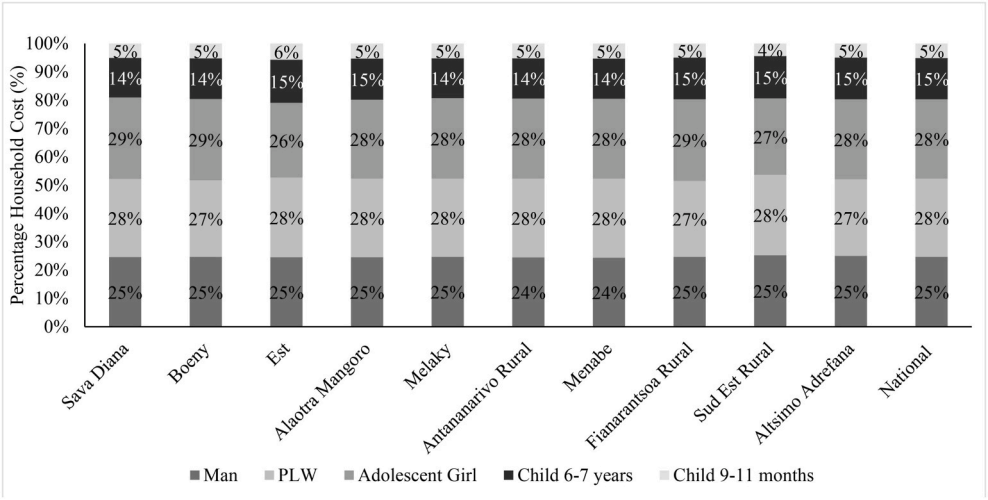


**Fig. 1c.** Contribution To Overall Household Cost Of Each Family Member In Each Rural Livelihood Zone In Madagascar.

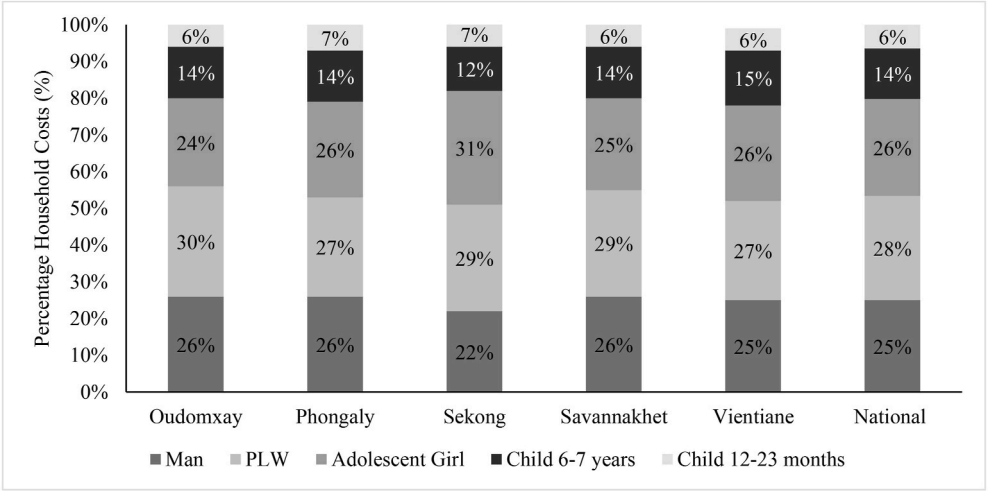


**Fig. 1d.** Contribution To Overall Household Cost Of Each Family Member In Each Province In Laos PDR.

increases by around 30% and the cost of the diet of the adolescent boy only by around 5%. Similarly, in Madagascar, the availability of cheap iron-rich foods, such as blood/offal, helps to drive down the modelled costs (cost of adolescent boys was 7% higher than of girls) but they are also unlikely to be consumed in sufficient quantities.

### 3.3. Limiting nutrients and drivers of cost for adolescent girls

In Ghana the extremely high proportional cost of the adolescent girl's diet within the household (see Fig. 1b) appears to be driven by the need to fill her vitamin A and iron recommendations. This is very

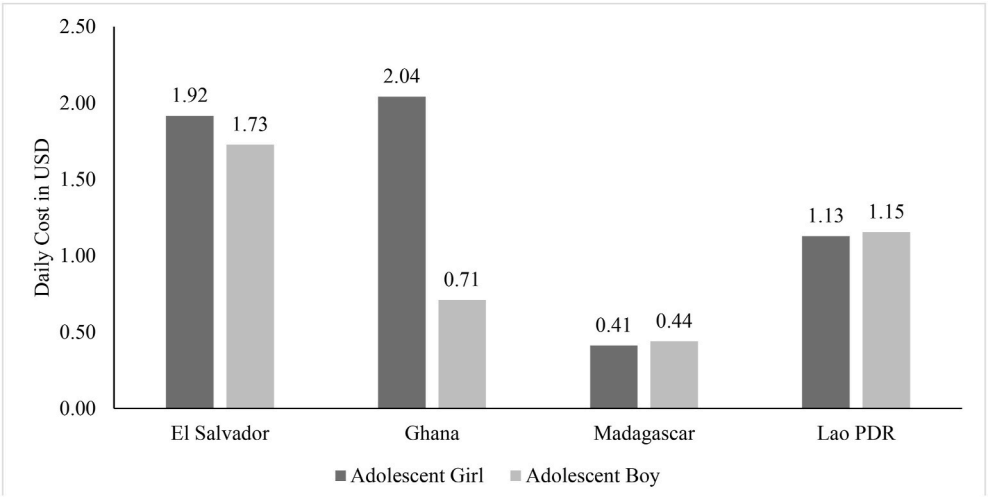


**Fig. 2.** The Cost Of The Diet Of An Adolescent Boy Aged 14–15 Years Old Compared To An Adolescent Girl Aged 14–15 Years Old In El Salvador, Ghana, Madagascar and Lao PDR.

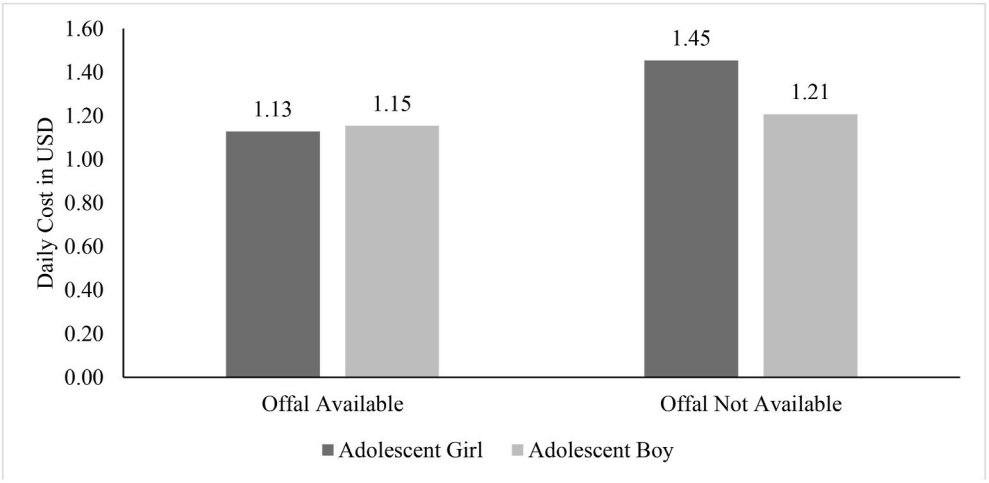


**Fig. 3.** The Cost Of The Nutritious Diet For An Adolescent Girl And Boy In Lao PDR With and Without Offal.

expensive to do using the commodities available for modelling. It should be noted, however, that these commodities did not include fortified foods such as wheat flour and vegetable oil, both of which are mandatorily fortified with vitamin A. Wheat flour is also fortified with other vitamins and minerals, including iron. When fortified foods were introduced into the model at market cost in most regions overall cost of

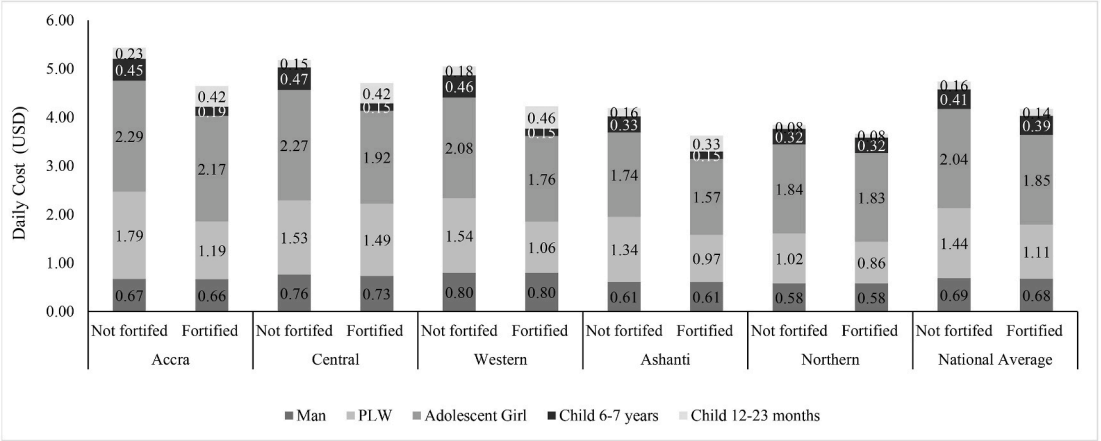


**Fig. 4.** The Cost Of A Nutritious Diet For All Household Members In Each Region Of Ghana With Fortified Staple Foods (Wheat and Oil) Available In The Market Compared With The Cost If No Fortified Staple Foods Are Available.

the diet for the household decreased substantially. However, this had a more dramatic impact on reducing the cost of the diet of the lactating woman than it did for the adolescent girl (as shown in Fig. 4). As a result, the proportional cost of the adolescent girl within the household increased, even though her absolute costs decreased.

In El Salvador adolescent girls also had the most expensive diet within the household, but their diet was only slightly more expensive than of the lactating women in relative terms (see Fig. 1a). The high costs of the girl's diet appear to be primarily driven by the need to fill the calcium requirement and to some extent her iron requirement. Although there are a number of other limiting nutrients, including fat, vitamin B6, pantothenic acid, folic acid and in some departments zinc. A limiting nutrient is defined as a nutrient whose requirements are met at exactly 100%, which indicates that is expensive to meet. The high price of foods rich in calcium, such as dairy products, substantially increases the costs to fulfil her calcium recommendations.

In Madagascar, similarly to El Salvador the high costs of meeting the nutrient intake recommendations of adolescent girls are driven primarily by calcium and iron. In the case of Madagascar dairy products are not widely available, so foods such as small dried fish are included to fulfil the requirement, which are relatively pricey. There is a smaller difference in costs between the lactating woman and the adolescent girl (as shown in Fig. 1c), due to the availability of cassava leaves at low prices in certain areas of Madagascar such as the East (Est). However, as the software considers the nutrient content of these leaves in their raw form and they would usually be boiled for consumption, the amount of calcium and iron that these leaves would actually provide is perhaps a little overestimated in these models.

In Lao PDR, the high costs of meeting the nutrient recommendations of adolescent girls are primarily driven by calcium, and in some areas iron and key B-vitamins (B-12, B-1 and Folic Acid). The cheap availability of blood and offal, which are rich in iron and B-vitamins help to drive down costs to a certain extent, but it is unlikely that these foods are consumed with sufficient frequency or in sufficient quantities, so it is likely that in reality these recommendations are much more difficult to meet than the model suggests.

### 3.4. The additional cost of adolescent pregnancy and lactation

The impact of pregnancy and lactation on the daily cost of the diet for the adolescent girl was modelled in each province in Laos PDR, the aggregate of all provinces is displayed in Fig. 5 by comparison to a woman of reproductive age (30–59 years). In all provinces, pregnancy and lactation were found to increase the cost of a nutritious diet. On average pregnancy during adolescence increased the cost of the diet for the adolescent girl by 12% and lactation increased it by 18%.

A similar, however, less drastic trend could be observed in El Salvador (see Fig. 5), where the daily cost changed by around 4% from the normal to increased nutrient intake recommendations.

## 4. Discussion

The findings of this study demonstrate the difficulty in meeting nutrient needs of adolescent girls from a cost perspective. On the whole, the proportional costs of the girl's diet tended to be similar within different parts of each country, though income/expenditure varies within countries, so affordability of these diets can vary drastically. In each country studied the diets of adolescent girls were one of the most expensive in the household. The diets of adolescent girls were typically a little more expensive or on par with a pregnant or lactating woman in each country as they have lower energy recommendations than an adult man or woman, but they have comparable recommendations for many of the other essential vitamins and minerals they require for healthy growth at this stage of the life cycle (WHO/FAO, 2004). Food that they consume must therefore be more nutrient dense to ensure they get the nutrients they need. Table 1 illustrates some of the nutrient intake recommendations of an adolescent girl, an adolescent boy, a lactating woman and a man. As shown in the table, the nutrient intake recommendations of the girl are usually equivalent or similar to other household members, while the energy requirement is much lower. The notable exception is iron, for which adolescent girls have a much higher requirement due to the iron losses in menstruation. This is reflected in the results where iron was a major limiting nutrient in many areas, driving up the cost. This high requirement of iron is likely to be a key driver of the high prevalence of anaemia frequently found in this group. Iron-deficiency anaemia is one of the top three ranked causes of disability-adjusted life years lost amongst adolescents (Nagata et al., 2016; Dick and Ferguson, 2015).

When compared to boys of the same age the diets of adolescent girls were found to be more expensive in places with a limited availability of relatively low-cost nutrient-dense foods. While some nutrient intake recommendations are increasing similarly during adolescence (such as calcium) and some nutrients are elevated for the boy (such as energy), the nutrient recommendations for iron are elevated for the adolescent girl but not the boy (cf. Table 1). As affordable sources of iron-rich foods are unavailable in different places this can mean that costs for the girl are elevated. Ghana, by contrast to the other countries studied, had substantial differences in the proportional cost of the diet of adolescent girls compared to boys of the same age, as well as to lactating women. The stark difference in Ghana can largely be attributed to the lower

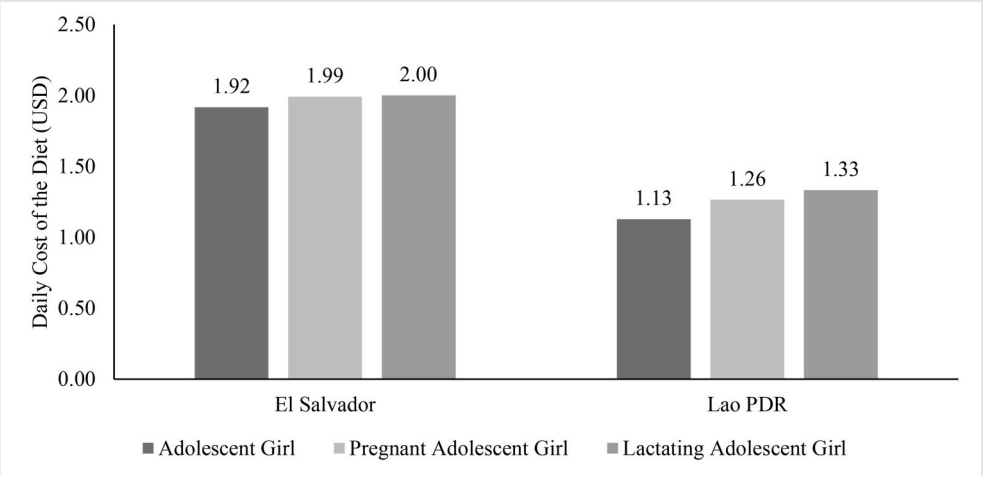


**Fig. 5.** The Change In The Daily Cost Of The Diet For An Adolescent Girl (14–15 Years) Who Becomes Pregnant Or Is Lactating, In EL Salvador And Laos PDR.

**Table 1**
Some of the key Nutrient Requirements of the household members modelled (Source: Nutrient Tables embedded in the Cost of the Diet Software) Note For iron bioavailability is applied to each food source according to factors stated in WHO/FAO, 2004.

| Household Member | Energy kcal | Absorbed Iron (mg) | Folate (ug DFE) | Calcium RNI (mg) | Vitamin B6 (Pyridoxine) (mg) | Vitamin B5 (Pantothenic Acid) (mg) | Zinc (moderate bioavailability) RNI (mg) | Vitamin A (ug RE) |
|---|---|---|---|---|---|---|---|---|
| **Female 14–15** | 2449 | 3.10 | 400 | 1300 | 1.20 | 5 | 7.2 | 600 |
| **Male 14–15** | 2990 | 1.46 | 400 | 1300 | 1.30 | 5 | 8.6 | 600 |
| **Lactating Woman 30–59 (average for lactation period)** | 2867.5 | 2.94 | 500 | 1000 | 1.30 | 7 | 4.9 | 850 |
| **Man 30–59** | 2750 | 1.05 | 400 | 1000 | 1.30 | 5 | 7.0 | 600 |

availability of cheap iron-rich foods. Whilst this might be indicative of the limitations of the secondary food price data available in Ghana, the sources of cheap iron-rich foods found in the markets in other countries, such as blood/offal are frequently not desirable or consumed in sufficient quantities. As shown by the analysis in Lao PDR, once these foods were removed from the model, the costs to meet the nutrient intake recommendations of an adolescent girl increased substantially. Animal-source food is one of the most nutrient dense sources of iron but require cold chain storage or to be purchased regularly for safe consumption. The low accessibility of many rural households to adequate cold chain for food storage, therefore, likely makes it even more difficult for iron recommendations to be met, but this cannot be adequately reflected in this model. These findings indicate why micronutrient deficiencies are likely amongst this group, as the high cost of the girl's diet and the overall low affordability at household level of a nutritious diet make it challenging for them to fill their nutrient requirements. This illustrates the importance of specifically targeting girls of this age with nutritional interventions (such as nutrient-dense foods or supplements), rather than this age group in general, though the needs of boys of this age should not be ignored as this is also a critical period of growth for them.

The findings also show that adolescent girls are particularly vulnerable during pregnancy and lactation, because of their high nutrient needs and consequently expensive diet. The extent to which her diet becomes more expensive is very dependent on context and access to nutritious foods. Given that in many countries, particularly in low middle-income countries, adolescent pregnancy rates are high, this further highlights the need to target adolescent girls with nutritional interventions and provides further impetus to promote delayed marriage and first pregnancy, family planning and sexual and reproductive health education for this group and reducing drop-out rates in secondary schools.

In low income settings many households struggle to afford diets that meet their nutrient needs, as found in El Salvador, Ghana, Madagascar and Lao PDR, as well as a number of studies and FNG analyses across Latin America, Asia and Africa (Bose et al., 2019; Development Initiatives, 2018; Bose et al., 2018; Deptford et al., 2018; Baldi et al., 2013; Frega et al., 2012; Geniez et al., 2014; WFP, n.d.). In such settings, it is likely that girls of this age group will not be able to access the nutritious diets that they need to achieve optimal growth and development. It should be noted that the role costs play as a barrier to consuming a nutritious diet is underestimated in these models, as they are optimal nutritious diets, which are not fully reflective of dietary choices or intra-household food distribution. Although some adjustments were made to include staple food preferences and exclude any food prohibitions, unhealthy dietary practices such as high staple- and snack-food consumption could cause the costs to meet nutrient needs to increase (Bose et al., 2018; Deptford et al., 2018). This situation is likely to be even worse in countries where gender dynamics make it highly likely that women and girls are not given equitable allocations of food (Haddad et al., 1996), let alone the larger allocations of nutrient dense food that they require. Integrating gender transformative programming with nutritional interventions are, therefore, essential to ensure that all household members have access to diets that meet their nutrient needs.

Beyond their own nutrient intake, adolescent girls also often play a critical role in ensuring household food and nutrition security (Anthrologica and the World Food Programme, 2018). They frequently act as caregivers to their younger siblings and are responsible for food preparation. Thus, improving the ability of adolescents to afford diets that meet their nutrient needs and make healthy choices, can have positive spill-over effects for the rest of the family. These results demonstrate that behaviour change communication needs to be accompanied by interventions addressing these economic constraints to enable adolescents and their caretakers to make healthy choices. The models in this analysis do not take into account 'time' as an opportunity cost, so it is likely that the economic constraints are higher in low income settings where work-loads are high, food preparation is time consuming, and cold storage is limited and/or markets are not easily accessible (Herforth and Ahmed, 2015). Interventions that help to strengthen the food system as a whole, such as improving access to food storage and reducing nutrient losses along the value chain, can help to make nutritious diets more affordable, available and desirable for the population as a whole. The inclusion of adolescents within social protection schemes could also help to alleviate the economic constraints of vulnerable households and raise awareness about her higher needs.

Food fortification of staple foods is another important intervention to help improve diet quality, but as the findings indicate, for some nutrients such as iron, fortification of staples alone will not fulfil the recommendations for an adolescent girl. Staple foods are fortified at levels suitable for consumption by the entire population, so will not alone be able to fill the nutrient needs of some groups with higher requirements. More targeted nutrition interventions such as the provision of Iron & Folic Acid supplements might help to fill this gap, such as Girls' Iron Folate Tablet Supplementation (GIFTS) programme launched in Ghana in 2017 to provide girls aged 10–19 both in and out of school with iron-folate tablets (WHO, 2018). These supplements, however, would not be sufficient to fill the requirements of other nutrients, such as B1 and B12, found to be limiting in some of the countries analysed. Multi-micronutrient supplementation offers a broader package of nutrients to address these needs and have shown to be effective in reducing anaemia (Lassi et al., 2017), but as of yet they are not provided widely. Increasing the market availability of affordable fortified foods specifically tailored for women at reproductive age, such as the recent example of the Obaasima initiative in Ghana (Gavin Smith and Amanquah, 2018), is another possible strategy to improve access to a nutritious diet for this age group. This should be coupled with effective demand creation strategies, as well as adequate price segmentation to also effectively reach the more vulnerable with these kind of commodities.

Whilst it is evident that adolescent girls require nutrition-related interventions, it is often challenging to select an appropriate platform that can reach adolescent girls. In many countries girls of this age are no longer in school, so it is difficult to reach this group through school-based platforms. Similarly, many adolescents may not frequent a health centre, so interventions delivered through the health system may also not be that effective. Pregnant adolescents might also not seek antenatal care for many reasons such as lack of money, not feeling

empowered in terms of their personal decision-making regarding health, or due to stigma. Adolescents also usually have more autonomy over their dietary choices than younger children, so traditional programming targeted to caregivers is unlikely to have the same impact. As a result, a holistic approach is required to make sure this group is effectively reached, and it may be necessary to use multiple platforms, including technological platforms, traditional platforms such as schools and health centres, and community-based platforms such as youth groups, to make sure no groups of adolescents are excluded (Bhutta et al., 2017). Recent ethnographic research conducted in Cambodia, Uganda, Kenya and Guatemala found that including adolescents in programme design is critical to help increase their buy-in and ensure that programming is designed appropriately (Anthrologica and the World Food Programme, 2018).

## 5. Conclusion

These Fill the Nutrient Gap studies conducted using linear optimization programming in El Salvador, Ghana, Madagascar and Laos PDR demonstrate the major financial constraints of meeting the nutrient intake recommendations of households and of adolescent girls and lactating women in particular. The results indicate a larger allocation of nutrient dense food is required for adolescent girls to ensure that this group have the nutrients they require for healthy growth and development, as well as for having a better chance of giving birth to well-nourished children. In low resource settings making sure adolescent girls received the requisite allocation of foods, and households can meet the needs of all household members, requires strengthening food systems to increase the availability and affordability of nutritious foods. Targeted food-based interventions, including through social protection schemes may also be required, in addition to social behaviour change communication to promote healthy dietary practices and to overcome some of the identified cultural barriers within households for this age group in specific contexts. Interventions targeted specifically at the child or the pregnant and lactating women are still crucial to ensure that nutrient needs are met in the first 1000 days, but these interventions alone are not enough especially given the high levels of unaffordability in many countries of minimum cost diets that meet nutritious needs (as found in these studies).

Adolescents are, however, a difficult group to target as many of the most vulnerable in low income settings are not in school and do not frequently visit health facilities. Other innovative ways of reaching this group, possibly through community-based platforms and technology, are thus also required to make sure their nutrient needs are met. Given the importance of ensuring adolescents are better nourished for their future and their families, a concerted effort must be made to make sure national policy and programming are developed to make nutritious diets for this group more available, affordable and convenient.

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