Nutrition for the Next Generation: Older Children and Adolescents

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Key Messages

- It is critical to ensure adequate nutrition for children and adolescents as this is intrinsically linked to the health of future generations.
- There is a need to make specific guidelines for nutrition requirements and interventions for older children and adolescents across various contexts, including low- and middle-income countries (LMICs).
- There is a need for more evidence around determining the most effective strategies to tackle the rising burden of overweight and obesity, especially from LMICs.

Keywords

Adolescents · Older children · Nutrition · Undernutrition · Overweight · Obesity · Nutrition interventions

Abstract

This paper reviews information on why the nutrition of older children (5–9 years) and adolescents (10–19 years) is important and the consequences that it can have over generations. Developing countries still face a high burden of undernutrition and anemia, while the burden of overweight and

obesity is on the rise in both developing and developed countries. There are evidence-based interventions which can improve the nutritional status and these include interventions for a balanced and diverse diet and micronutrient supplementation, especially iron and multiple micronutrient supplementation where there is sufficient evidence to reduce anemia. There is mixed evidence for the effective strategies to prevent and control obesity and a dearth of evidence from developing countries. Adolescent pregnancy also poses greater challenges to the health of mother and child, and advocacy should be rampant to delay the age of marriage and pregnancy. Interventions targeted to improving the nutritional status among “pregnant adolescents” have shown improvement in birth weight and a reduction in low birth weight and preterm delivery. Traditional platforms including school-based and community-based approaches offer a mixed picture of effectiveness, but emerging avenues of mHealth and social media could also be channelized to reach this population. The population of this age group is on the rise globally, and failure to invest in improving the nutrition of older children and adolescents will further increase the number of dependents in coming generations and negatively influence the health of future generations and progress of nations.

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Fig. 1. Intergenerational effects of malnutrition. Adapted from the ACC/SCN-appointed Commission on the Nutrition Challenges of the 21st Century.

Background

Malnutrition encompassing both under- and overnutrition is a major public health crisis for children and adults across the world [1]. Developing countries are now facing the “double burden” of undernutrition and overweight and obesity [2], as the prevalence of overweight and obesity in children and adolescents has increased from 8.1% (7.7–8.6) in 1980 to 12.9% (12.3–13.5) in 2013 for boys and from 8.4% (8.1–8.8) to 13.4% (13.0–13.9) in girls [3]. And during the same period, the prevalence of overweight and obesity has increased remarkably in developed countries: from 16.9% (16.1–17.7) in boys and 16.2% (15.5–17.1) in girls in 1980 to 23.8% (22.9–24.7) in boys and 22.6% (21.7–23.6) in girls in 2013 [3]. There is also a high burden of undernutrition in developing countries and protein-energy malnutrition is responsible for 225,906 deaths (uncertainty level: 168,497–280,129) in children and adolescents aged 0–19 years [4]. Iron deficiency anemia is the leading cause of years lived with disability among children and adolescents, accounting for 619 million (uncertainty level: 618–621 million) prevalent cases in 2013 [4].

Pregnancy in adolescence poses additional risks to the mother and newborn, as adolescent girls are not physically mature enough, and undernutrition further exacerbates these risks. The common risks during adolescent pregnancy include anemia, stillbirth, prematurity, and mortality. It is estimated that around 10% of the global total births occur to adolescent girls between the age of 15

and 19 years [5]. And around three-quarters of these adolescent pregnancies occur in developing countries [5]. Stunted adolescents have further risks of obstetric complications, including obstructed labor and weakened physical capacity [6].

The major global focus of health has been on children under the age of 5 years and pregnant women, while older children (aged 6–9 years) and adolescents (aged 10–19 years) have not received the due attention until lately. Alleviating malnutrition in this age group requires a complex, multifactorial approach and thus addresses a major public health concern.

Consequences of Undernutrition across the Life Course

The nutritional issues of undernutrition and overnutrition among children and adolescents in developing countries are intricately woven together in an intergenerational cycle of malnutrition.

It is essential that women, particularly girls, are nourished well at all stages of growth and development because the risk of malnutrition in women spans a life cycle and also across generations, termed as intergenerational effects of malnutrition [7]. Any nutritional deficiency experienced during this critical period of life can have an effect on the future health of the individual and their offspring (Fig. 1).

Addressing nutritional deficiencies in women and girls via life cycle approach can improve their nutritional status. Nutritional deficiencies experienced early on such as in utero, infancy, and childhood have consequences into the adult life. Stunting is often rooted from inadequate fetal growth [8] and it also influences the childhood cognitive tests and educational achievement [9]. Changes in in utero nutritional environment are associated with hampered growth and development and increased risk of developing cardiovascular and metabolic disorders in adult life [10]. The same vicious cycle of malnutrition is repeated in children of mothers who were malnourished.

Women, in general, are more likely to suffer from nutritional deficiencies than men because of their reproductive biology. However, children and adolescents in developing countries suffer the most with additional underlying factors including poverty, illiteracy, poor social status, and disparity in society. Today, approximately 468 million nonpregnant women in low- and middle-income countries (LMICs) and half of all the pregnant women are anemic [11, 12]. Poor nutritional status increases the risks for morbidity and mortality. For women, anemia is an underlying cause in approximately 20% of maternal deaths [13] and being underweight increases the chances of being stunted and that increases the risk for obstetric complications such as obstructed childbirth [14, 15]. At a macro-level, malnourishment hinders work capacity and leads to further economic disadvantages.

Physiology and Metabolism

Malnutrition is the single most common reason for growth retardation. Inadequate nutrition in the early life of a child can delay sexual maturation and physical growth, which is necessary to reach the full development potential as an adult. For a girl, this is also important to prepare for her nutritional demands during pregnancy and lactation in adulthood. There are no standardized anthropometric measures for adolescents [16], and consequently various definitions are used by different studies to measure the burden of underweight and overweight in adolescents, thus hampering the determination of the actual burden of adolescent malnutrition.

The nutritional status has a significant contributing effect on the timing of adolescent sexual maturation, and it is well documented that undernutrition is associated with delayed age of menarche [17]. The growth spurt in adolescence requires rapid tissue expansion with special nutrient requirements, thus it is necessary to ensure that energy and nutrition requirements match the adolescent

needs. Approximately half of an adult's ideal body weight is gained during adolescence, and approximately 20% of adult height is gained during the adolescent age period and most of this is gained rapidly 1–2 years preceding the early stages of sexual maturation [16]. Malnutrition prevents individuals from attaining normal bone structure, strength, and development, and the onset of puberty is delayed in adolescents who are undernourished. This can allow for a longer time to catch up on growth, although there are deliberations on whether young adolescents who are stunted can catch up to their optimal height.

Older children and adolescents are particularly at risk of malnutrition because they experience the growth spurt and need all essential macro- and micronutrients to support the increased demand of the body for attaining puberty and development. Therefore, it is important that children and adolescents, particularly girls, are fed properly and are given all required micronutrients. Young girls who become pregnant during this phase are at greater risk of various complications since their body is supporting their own growth and that of the growing fetus; and the still-growing adolescent mother and her baby may compete for nutrients and increase the infant's risk of low birth weight and early death [18].

This age group also needs iron for their increased physiologic requirements for growth. Infectious diseases, such as malaria and hookworm, and menstruation in females can also affect iron absorption, use, and loss in adolescents and frequently contributes to iron deficiency. Malaria-related inflammation also reduces iron absorption and incorporation into red blood cells [19].

There is an increase in appetite in this age group and individuals with a sedentary lifestyle have a greater chance to accumulate fat, which contributes greatly to overweight and obesity, especially if they consume high-energy food. The caloric requirement of adolescent males is higher than that of adolescent females, owing to greater increases in height, weight, and lean body mass. Table 1 shows the Dietary Reference Intakes (DRIs) and Adequate Intakes (AIs) for adolescents as recommended by the Institute of Medicine and includes recommendations on energy requirements and requirements for various macro- and micronutrients [20].

Long-Term Health Impacts of Malnutrition

Malnutrition in women contributes to the growing burden of cardiovascular and other noncommunicable diseases. Undernutrition leads to numerous physiological and social alterations and is partly due to epigenetic

Table 1. Examples of population reference nutrient intakes (vitamins and minerals): Dietary Reference Intakes (DRIs) and Adequate Intakes (AIs) for adolescents in the USA [20]

	Females			Males		
	9–13 years	14–18 years	19–30 years	9–13 years	14–18 years	19–30 years
Energy, kcal/day	2,071	2,368	2,403 ^a	2,279	3,152	3,067
Carbohydrates, g/day	130	30	130	130	130	130
Total fiber, g/day	26	28	25	31	38	38
n-6 polyunsaturated fat, g/day	10	11	12	12	16	17
n-3 polyunsaturated fat, g/day	1.0	1.1	1.1	1.2	1.6	1.6
Protein, g/day	34	46	46	34	52	56
<i>Vitamins</i>						
Vitamin A, µg/day	600	700	700	600	900	900
Vitamin C, mg/day	45	65	75	45	75	90
Vitamin D, µg/day	5	5	5	5	5	5
Vitamin E, mg/day	11	15	15	11	15	15
Vitamin K, µg/day	60	75	90	60	75	120
Thiamin, mg/day	0.9	1.0	1.1	0.9	1.2	1.2
Riboflavin, mg/day	0.9	1.0	1.1	0.9	1.3	1.3
Niacin, mg/day	12	14	14	12	16	16
Vitamin B ₆ , µg/day	1.0	1.2	1.3	1.0	1.3	1.3
Folate, µg/day	300	400	400	300	400	400
Vitamin B ₁₂ , µg/day	1.8	2.4	2.4	1.8	2.4	2.4
Pantothenic acid, mg/day	4	5	5	4	5	5
Biotin, µg/day	20	25	30	20	25	30
Choline, mg/d ay	375	400	425	375	550	550
<i>Elements</i>						
Calcium, mg/day	1,300	1,300	1,000	1,300	1,300	1,000
Chromium, µg/day	21	24	25	25	35	35
Copper, µg/day	700	890	900	700	890	900
Fluoride, mg/day	2	3	3	2	3	4
Iodine, µg/day	120	150	150	120	150	150
Iron, mg/day	8	15	18	8	11	8
Magnesium, mg/day	240	360	310	240	410	400
Manganese, mg/day	1.6	1.6	1.8	1.9	2.2	2.3
Molybdenum, µg/day	34	43	45	34	43	45
Phosphorus, mg/day	1,250	1,250	700	1,250	1,250	700
Selenium, µg/day	40	55	55	40	55	55
Zinc, mg/day	8	9	8	8	11	11

Source: data from reports from the Institute of Medicine, Food and Nutrition Board, Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, copyright by the National Academy of Sciences, courtesy of the National Academies Press, Washington, DC, USA (<http://www.nap.edu/>).

changes [21]. Undernutrition provokes stress in the body and stimulates the release of adrenaline and noradrenaline and the production of cortisol. The chronic physiological stress due to undernutrition over time weakens the body and leads to fatigue and unproductivity and also poses multiple-fold risks of getting an infection [22]. A study on malnourished children found a higher resting heart rate [23] and an association of nutritional stunting

with increased rates of arterial hypertension [24, 25]. Short maternal stature is associated with obesity and type 2 diabetes [26], low birth weight, and stunting in children [27]. Undernutrition is also linked with hyperinsulinemia and reduced sensitivity to insulin, which is responsible for an increased BMI in adult life [28]. Animal studies have also proven that changes in in utero kidney development can occur due to maternal malnutrition and sug-

gested delays in intrauterine growth and a reduced number of nephrons [29]. This phenomenon determines poor renal function and increased blood pressure. Studies have also shown the association of pancreatic function with undernutrition in early life [30]. Undernutrition and ensuing anemia can also effect cognitive development, the ability to learn, and hence compromise the standard of living throughout the life cycle [31].

Evidence suggests that a poor maternal BMI before and during pregnancy has significant impacts on adverse pregnancy outcomes. A recent review reported that maternal prepregnancy underweight is significantly associated with preterm births, small-for-gestational-age babies and low birth weight [32]. On the other hand, maternal pre-pregnancy overweight is associated with increased risk of hypertensive disorders, pre-eclampsia, and gestational diabetes. The risk of adverse pregnancy outcomes increases multifold if the mother is obese [32].

Similarly, overweight and obesity among children and adolescents pose an increased risk for cardiovascular and other noncommunicable diseases. There is considerable evidence to show that childhood obesity is a risk factor for type 2 diabetes, hypertension, coronary heart disease, and stroke in adulthood (hazard ratios ranging from 1.1 to 5.4) [33, 34]. A systematic review of 23 studies reported that childhood obesity is significantly associated with adult systolic and diastolic blood pressure and triglycerides and inversely associated with high-density lipoprotein [35]. And hypertension is the leading cause of other noncommunicable diseases, such as high serum cholesterol, diabetes, etc. These also lead to direct (medical) and indirect (nonmedical) costs related to obesity that impose a significant economic burden to individuals and health care infrastructure.

Nutrition Interventions for Older Children and Adolescents

Intervening in infancy and early childhood is paramount to improving the nutritional status and achieving long-lasting impacts as this is an age group which responds well to the interventions not only to improve physical growth but also cognitive development and attainment of complete physical capacity. Various interventions including optimal breastfeeding, complementary feeding, and micronutrient supplementation have been recommended for infants and young infants. Apart from nutrition-specific interventions, water, sanitation, hygiene, and prevention of infection also play an important role [36]. Although older children and adolescents

Table 2. Evidence of impact of interventions in older children

Outcome	Impact
<i>School feeding programs</i>	
Weight gain	
Over 19 months	MD: 0.39 kg (95% CI: 0.11 to 0.67)
Over 11.3 months	MD: 0.71 kg (95% CI: 0.48 to 0.95)
Height gain	MD: 0.38 cm (95% CI: -0.32 to 1.08)
<i>Micronutrient powders</i>	
Anemia	RR: 0.53 (95% CI: 0.25 to 1.12)
Hemoglobin	MD: 7.86 g/L (95% CI: -0.76 to 16.49)
<i>Intermittent iron supplementation</i>	
Anemia	RR: 0.54 (95% CI: 0.33 to 0.90)
Hemoglobin	MD: 4.04 g/L (95% CI: 0.30 to 7.78)
<i>Iron fortification</i>	
Hemoglobin	SMD: 0.46 (95% CI: 0.24 to 0.67)
Anemia	RR: 0.60 (95% CI: 0.43 to 0.84)
<i>MMN-fortified beverages</i>	
Hemoglobin	MD: 2.76 g/L (95% CI: 1.19 to 4.33)
Anemia	RR: 0.58 (95% CI: 0.29 to 0.88)
Iron deficiency anemia	RR: 0.17 (95% CI: 0.06 to 0.53)

MD, mean difference; MMN, multiple micronutrient; RR, risk ratio; SMD, standard mean difference.

often do not receive intervention and policy priority, intervening in this age is also vital for improving nutrition and achieving long-term health. A balanced, nutritious diet is the key to promote healthy growth and development of children and adolescents [37], leading to a healthier and productive generation. Below we discuss the evidence-based nutrition-specific interventions for older children (Table 2) and adolescents. Younger adolescents (10–13 years) act as a special group, as they transition from older school-aged children to adolescents.

Older Children

The interventions range from addressing under- to overnutrition. A systematic review on school feeding programs reported that balanced school meals provided in LMICs had a significant impact on weight but not on height [38]. Multiple micronutrient supplementation through fortified beverages has shown a significant impact on improving serum hemoglobin level and reducing the risk of anemia in school-aged children in low-resource settings [39]. A systematic review on micronutrient powders suggested an impact on improving serum hemoglobin and reducing the prevalence of anemia in

children under the age of 5 years but not in older children [40]. A systematic review on intermittent iron supplementation in children aged 5–10 years showed a statistically significant increase in serum hemoglobin but no effect on anemia, and this review also suggested no difference when intermittent iron supplementation was compared to daily supplementation [41]. A review on iron fortification also suggested improvement in serum hemoglobin levels and reduction in anemia in preschool- and school-aged children [42]. There is some evidence suggesting that iodine supplementation in children aged 10–12 years leads to improvement in cognitive functioning and fine motor skills [43].

A review on interventions to prevent obesity in older children through altering dietary or physical activity-related factors, or both suggested a reduction in BMI with interventions predominantly based on behavior change theories and implemented in education

settings [44]. There is some evidence that school-based physical activity interventions lead to an improvement in engagement in moderate to vigorous physical activity during school hours (odds ratio: 2.74, 95% confidence interval [CI]: 2.01 to 3.75) and children spend less time watching television [45]. A recent systematic review reported that school-based interventions moderately improved fruit intake (mean difference [MD]: 0.24 portions, 95% CI: 0.05 to 0.43) but had a minimal impact on vegetable intake (MD: 0.07 portions, 95% CI: –0.03 to 0.16) [46]. Targeted interventions that work on consumption of sweetened beverages in children reported a modest reduction in the number of carbonated drinks consumed, which also led to a reduction in the prevalence of overweight and obese children [47]. The results for obesity prevention and management interventions in children are inconsistent and mostly from developed countries.

Adolescents

The World Health Organization (WHO) recommends that 3 months of preventative iron supplementation of 60 mg iron per day be given to adolescents living in areas where the population prevalence of anemia is greater than 40% [48]. Folic acid supplementation in the preconception period has been recommended to reduce the incidence of neural tube defects [49]. Calcium supplementation in girls aged 10–18 years has been essential for achieving optimum bone mineral density and hence preventing osteoporosis [50].

A recent systematic review of nutrition interventions in adolescents suggested that iron/iron folic acid supplementation alone or in combination with other micronutrients leads to a reduction in anemia (risk ratio: 0.69, 95% CI: 0.62 to 0.76) and was associated with improved serum hemoglobin (MD: 1.94 g/dL; 95% CI: 1.48 to 2.41), ferritin (MD: 3.80 µg/L; 95% CI: 2.00 to 5.59), and iron (MD: 6.97 mmol/L; 95% CI: 0.19 to 13.76) [51]. Zinc supplementation led to improved serum zinc concentrations (MD: 0.96 µg/dL; 95% CI: 0.81 to 1.12), while calcium and vitamin D supplementation did not have a clear impact on vitamin D levels or parathyroid hormone [51].

The nutritional effect of large-scale urbanization, often coined the “nutrition transition,” is that as people assume a more sedentary lifestyle, have more ready access to snack or street foods, and reduce the consumption of more traditional foods, the prevalence of overweight and

obesity increases substantially. As increased caloric input is one of the key mechanisms for weight gain, nutritional interventions are a key for preventing and managing obesity in adolescents. Interventions targeted to adoles-

cents to improve fruit and vegetable consumption behaviors suggest that these behaviors are dependent on home availability of fruits/vegetables and taste preferences [52]. A positive correlation between milk consumption and bone mineral density has also been reported in young girls [53]. Dietary interventions for obesity management in adolescents include caloric restriction [54] and/or traffic light diet (low added sugar and increased fiber intake) [55], which have shown to have significant reductions in BMI and waist circumference [56]. The NEAT (Nutrition and Enjoyable Activities in Teen Girls) trial to prevent obesity in girls from a low socioeconomic background reported an insignificant effect on body composition but may still have potential clinical importance [57].

Intervention Delivery

Several platforms have been used to deliver nutrition interventions to older children and adolescents. These include schools, community groups, youth organizations, health centers, and mass media [58]. Schools have been the main medium that has been used and has been effective to deliver nutrition interventions. Electronic and social media platforms have gained much popularity over the years as a way to reach a vast number of youth. Mass media campaigns using television and radio have the po-

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tential to improve dietary quality in youth [59]. mHealth technology has also been studied to promote a healthy diet and other lifestyle behaviors in children [60]. A recent systematic review reported that compliance to treatment and self-monitoring has been shown to improve with the use of this technology; however, the effect on outcomes such as BMI was limited [60]. A combination of various platforms such as schools, community, and media has been successful in implementing healthy dietary patterns in elementary-school children [61]. The combination of various settings can be proposed as one of the solutions to effectively address nutritional interventions in older children and adolescents.

Conclusion

Adolescent and older children health care is challenging compared to that of children under the age of 5 years and adults, and this is due to various factors mostly related to the ever-evolving physical and mental development. There is still a high burden of malnutrition in older children and adolescents globally, with developed countries facing a huge load of overweight and obesity,

while developing countries are engulfed with a traditionally high prevalence of undernutrition and the threats of recent hike in overweight and obesity. There is a greater need to focus exclusively on this population, as improving the nutritional status of adolescents can help break the vicious cycle of intergenerational malnutrition. National governments together with development partners need to make specific guidelines and recommendations to tackle malnutrition in this age group, albeit this may require more evidence especially around determining strategies to combat obesity. This focus would not only improve the nutritional status of older children and adolescents but may also escalate the mental and cognitive growth and help individuals reach their true potential, which may have far-reaching repercussions by not only increasing the quality of life but influence the growth and productivity of generations to come and countries at large.

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