



## Review Article

# A scoping review of literature describing the nutritional status and diets of adolescents in Côte d'Ivoire

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Submitted 24 December 2019: Final revision received 18 June 2020: Accepted 2 July 2020: First published online 4 September 2020

### Abstract

**Objective:** Adolescents living in resource-limited settings remain a neglected population regarding their nutritional health. We reviewed what studies on nutrition have been conducted for adolescents living in Côte d'Ivoire.

**Design:** A scoping literature review, searching for any quantitative studies published from 1 January 2000 to 1 May 2019, referenced in PubMed and grey literature, related to adolescent nutritional status and diet, written in English or French.

**Setting:** Côte d'Ivoire, West Africa

**Subjects:** Adolescent girls and boys (aged 10–19 years).

**Results:** We used three search strategies to explore studies related to (1) diet and nutritional practices, (2) anthropometry and (3) micronutrient intakes/status. Each identified 285, 108 and 84 titles and abstracts, respectively, resulting in 384 full-text articles to review. Finally, after adding five relevant studies from the grey literature, thirty articles were included. Two-thirds were cross-sectional observation studies. The main topics were anaemia and parasitic diseases. Among seven intervention studies, most focused on micronutrient supplementation or deworming. No studies on macronutrients or food supplementation were found. Overall, studies showed a high prevalence of undernutrition, along with emerging overweight and obesity. Anaemia and Fe deficiency were highly prevalent, with Fe supplementation showing modest improvements. Malaria and gut parasite infections remain a major burden, affecting adolescents' nutritional status.

**Keywords**  
Adolescent  
Nutrition  
Côte d'Ivoire  
Review literature

This work is dedicated to the memory of Professor Laurence **Adonis-Koffy**, who passed away on 23 May 2020. She was the principal investigator in Côte d'Ivoire for the TALENT collaboration and was a pioneer in developing access to paediatric care in West Africa, with the creation of the first paediatric dialysis centre in Côte d'Ivoire in 2012. The TALENT collaboration comprises: **Ulka Banavalli**, BKL Walawalkar Hospital and Rural Medical College, Dervan, India; **Mary Barker**, MRC Lifecourse Epidemiology Unit, University of Southampton, UK; **Edna Bosire**, University of the Witwatersrand, Johannesburg, South Africa; **Harsha Chopra**, Centre for the Study of Social Change, Mumbai, India; **Meera Gandhi**, Centre for the Study of Social Change, Mumbai, India; **Abraham Haileamlak**, College of Public Health and Medical Sciences, Jimma University, Jimma, Ethiopia; **Polly Hardy-Johnson**, MRC Lifecourse Epidemiology Unit, University of Southampton, UK; **Ramatoulie E. Janha**, MRC Keneba, MRC Unit The Gambia; MRC Keneba, **Landing Jarjou**, MRC Unit The Gambia; **Shama Joseph**, Epidemiology Research Unit, CSI Holdsworth Memorial Hospital, Mysore, India; **Kejal Joshi Reddy**, Unit, KEM Hospital, Pune, India; **Sarah H. Kehoe**, MRC Lifecourse Epidemiology Unit, University of Southampton, UK; **Elizabeth Kimani-Murage**, African Population and Health Research Center (APHRC), Nairobi, Kenya; **GV Krishnaveni**, Epidemiology Research Unit, CSI Holdsworth Memorial Hospital, Mysore, India; **Mubarek Abera Mengistie**, Jimma University, Ethiopia; **Sophie Moore**, Kings College London, London, UK; **Shane A. Norris**, SAMRC Developmental Pathways Research Unit, University of the Witwatersrand, Johannesburg, South Africa; **Suvarna Patil**, BKL Walawalkar Hospital and Rural Medical College, Dervan, India; **Sirazul Ameen Sahariah**, Centre for the Study of Social Change, Mumbai, India; **Kate Ward**, MRC Lifecourse Epidemiology Unit, University of Southampton, UK; **Susie Weller**, Clinical Ethics and Law (CELS), University of Southampton, Southampton, UK; **Chittaranjan Yajnik**, Diabetes Research Unit, KEM Hospital, Pune, India; **Pallavi Yajnik**, Diabetes Research Unit, KEM Hospital, Pune, India.

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**Conclusions:** Few specific relevant studies have been published regarding adolescent nutrition in Côte d'Ivoire, and most studies being focused on younger children. There are knowledge gaps about many nutritional aspects in this population, which urgently need to be addressed.

Nutrition is a major determinant of physical, cognitive and socio-economic development during adolescence<sup>(1,2)</sup>. In low- and middle-income countries, a nutrition transition is ongoing. With economic development, populations are slowly shifting from traditional diets to 'Western' diets, rich in high-energy foods and are more likely to adopt sedentary lifestyles. This is leading to a double burden of malnutrition, with under-nutrition persisting as a major public health problem, and with concomitantly a rise in the prevalence of overweight and obesity, accompanied by a higher risk of non-communicable diseases such as diabetes and cardiovascular disorders<sup>(3)</sup>. The West African region is currently at the early stages of this nutrition transition. This manifests as a rapid increase in urbanisation (projection to 62% in 2050 *v.* 42% in 2010) associated with changes in diet quality and quantity, but with for now small moderate increases in average daily energy intake (from 2002 to 2699 kcal between 1985 and 2013) compared with other regions<sup>(4)</sup>.

With a population of 22 million, one-fifth living in the district of Abidjan, the economic capital, Côte d'Ivoire is a growing developing country. In 2014, 42% of its population was aged <15 years<sup>(5)</sup>. Among children under 5 years of age, the prevalence of wasting and stunting was, respectively, 21.6 and 6.1% in 2018, and 1.5% were overweight<sup>(6)</sup>. It is estimated that 15% of the population is living in moderate food insecurity, at a stressed level, where households have minimally adequate food consumption<sup>(7)</sup>. Micronutrient deficiencies such as Fe deficiency are also highly prevalent in Côte d'Ivoire, resulting from insufficient micronutrient intake and sometimes also from infections such as hookworm infestation, schistosomiasis or malaria<sup>(8)</sup>. In 2016, 16% of children aged 6–59 months and 66% women aged 15–48 years had anaemia in Côte d'Ivoire, with higher rates in regions with lower economic development<sup>(9)</sup>. Research into adolescent health in Côte d'Ivoire is relatively under-developed, focusing mainly on sexual and reproductive health and HIV/AIDS<sup>(10–12)</sup>. Adolescent nutrition is not currently a priority for the National Multisectoral Nutrition Plan 2016–2020, except for adolescent girls of childbearing age, who represent a target population for the reduction of under-nutrition, anaemia and Fe deficiency. The aim of targeting this population is mainly to break the inter-generational cycle of malnutrition<sup>(13)</sup>.

Adolescent nutritional care remains a neglected topic worldwide, whereas this is a crucial period of development, with high energetic energy and nutrient requirements. Poor nutrition and multiple micronutrient deficiencies can hinder their physical, cognitive and psychosocial development<sup>(14)</sup>. Worldwide, between 10 and 14 years of age, Fe deficiency

anaemia is responsible for 1161 and 1365 disability-adjusted life years lost per 100 000 female and male adolescent, respectively<sup>(15)</sup>. Other key micronutrients such as Zn, Ca and vitamin D play a role in the adolescent development, promoting adequate growth, ensuring lifelong bone health while also enhancing immunity and sexual maturation<sup>(16)</sup>. While transitioning to adulthood, adolescents may experience lifestyle and eating behaviour change that may increase the risk of food disorders and overweight and obesity<sup>(17)</sup>, but important research gaps persist and factors influencing this nutrition transition in adolescents are insufficiently addressed<sup>(18)</sup>.

The TALENT (Transforming Adolescent Lives through Nutrition) collaboration aims to conduct qualitative and quantitative nutritional research among adolescents in five low-and middle-income countries (India, The Gambia, Ethiopia, South Africa and Cote D'Ivoire) and to develop interventions to improve adolescent nutrition. This literature review sought to describe what is known from recent research about the nutritional status of adolescents in Cote D'Ivoire and identify knowledge gaps in order to plan the most relevant future research.

## Methods

### Search strategy

This review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (Supplement 1). As part of a multiregional initiative, the keywords of interest were defined by a working group within the TALENT collaboration (Table 1). Three aspects of nutrition were covered: diet and nutritional practices, anthropometry and micronutrients. The study population (adolescents) was defined using another group of keywords which was added to each search strategy, as well as the country setting (Côte d'Ivoire or Ivory Coast), combining each group using 'AND'. We implemented this search strategy in the PubMed database and also looked for grey literature, searching relevant studies from libraries in Abidjan and in other web-based sources such as Google Scholar.

Inclusion criteria were as follows: all quantitative studies conducted in Côte d'Ivoire, among girls and boys aged between 10 and 19 years, published in English or French from the 1 January 2000 to the 1 May 2019. Any quantitative study design was accepted (observational, analytical, interventions, clinical trials); qualitative studies were not

**Table 1** Keywords used for the search strategy to identify nutritional studies conducted among adolescents aged 10–19 years in Côte d'Ivoire between 2000 and 2019

Nutrition topic	Outcomes	AND	Population/participants	AND	Setting
Diet and nutritional practices	Intake OR consumption OR food OR diet OR nutrition OR food frequency questionnaire OR 24-hour recall OR food diary OR protein OR energy OR carbohydrate OR fat OR sugar		adolescent OR adolescents OR adolescence OR youth OR young OR teen OR teens OR teenager OR teenagers OR student OR students OR girl OR girls OR boy OR boys OR pupil OR pupils		Côte d'Ivoire OR Ivory Coast
Anthropometry	Anthropometry OR weight OR BMI OR BMI OR overweight OR obesity OR body composition OR body size OR skinfold OR skinfolds OR waist circumference OR fat mass OR lean mass OR fat-free mass OR stunting OR stunted OR height-for-age OR wasted OR wasting OR weight-for-height				
Micronutrients	Vitamin B1 OR thiamin OR vitamin B2 OR riboflavin OR vitamin B3 OR niacin OR vitamin B6 OR folate OR vitamin C OR vitamin A OR vitamin E OR calcium OR iron OR anaemia OR zinc OR vitamin D				

included, as these were the subject of a separate review (see Hardy-Johnson *et al.*, this issue).

### Literature selection, data extraction and synthesis

This narrative review was conducted in an exploratory way, without excluding papers due to poor quality in terms of methodology, sample size or results. We only excluded studies which did not allow us extracting specific data for adolescents aged 10–19 years. Two independent reviewers (J.J. and K.K.) conducted the search and discussed discrepancies before agreeing on the final papers to be included. Each of the three search strategies (diet and nutritional practices, anthropometry and micronutrients) was carried out in PubMed, and duplicates were removed. Potentially relevant titles and abstracts were then screened; the full text articles were obtained and reviewed to finalise the selection. Main reasons for exclusion of articles were documented. The reference lists of included articles were manually searched for potential additional articles.

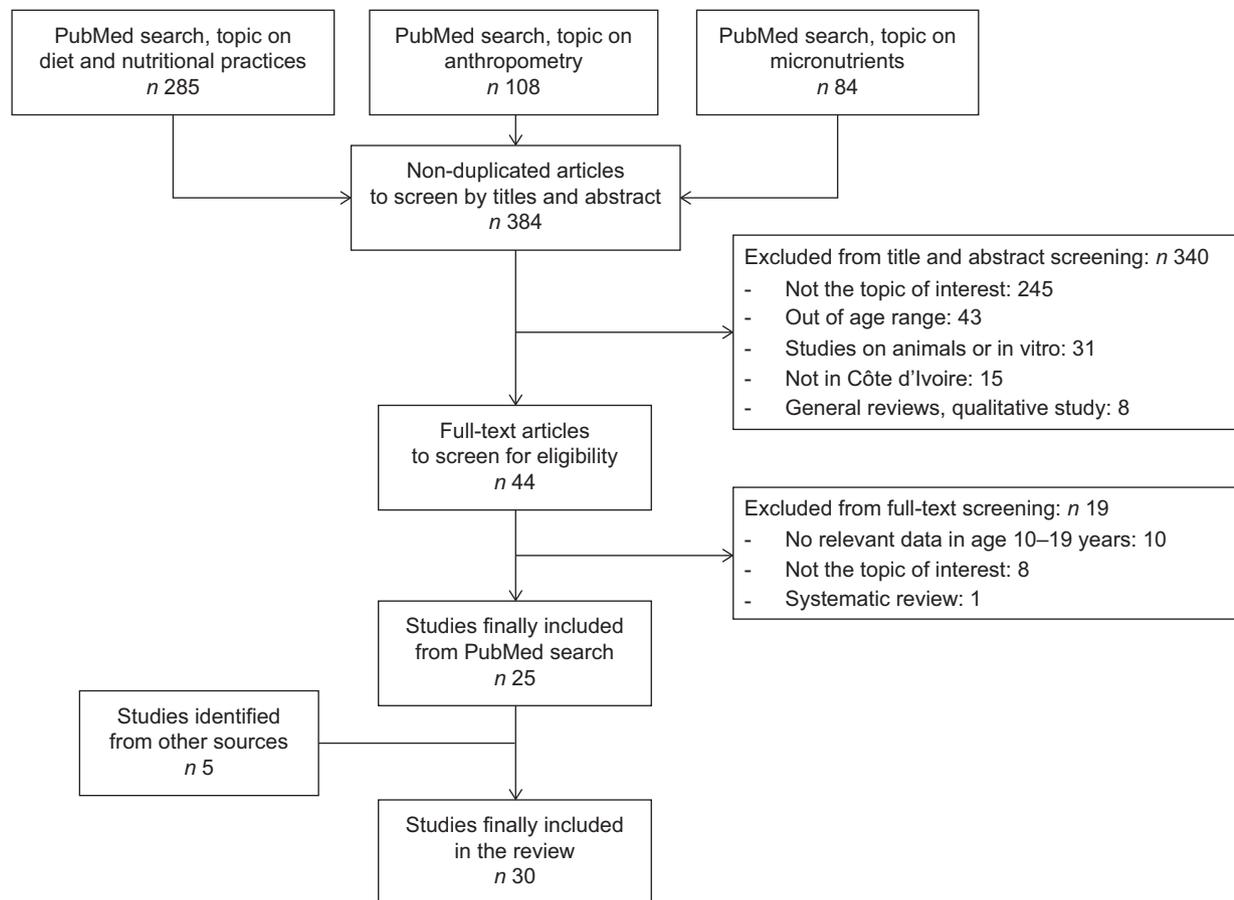
Data extraction was done using a standardised form that collected the following from each article: the first author and year of publication, main study objectives, study design and study period, sample size (specifically for the study population aged between 10 and 19 years if provided, as well as for Côte d'Ivoire only in the case of multi-regional studies), setting (rural/urban), age range, percentage of girls, main results and a final column reporting limitations and remarks of the person in charge of the data extraction (J.J.). Articles were ordered in the data extraction table by topic and then by year of publication. A narrative summary was presented for each selected study and a thematic synthesis described consecutively descriptive, analytical and interventional results related to nutritional status.

## Results

### Literature search and study characteristics

The three search strategies identified 285 potentially relevant articles regarding the topic of diet and nutritional practices, 108 on anthropometry and eighty four on micronutrients (Fig. 1). After deleting duplicates, 384 articles were obtained; screening their titles and abstracts resulted in forty four full-text articles to review. The main reason for exclusion on title and abstract screening was that the topic of the study was unrelated to nutrition or showed no applicable data. After carefully reading the remaining articles, twenty five were selected. The main reason of exclusion at this step was that the article did not describe relevant data on adolescents. Additionally, five studies from the grey literature search<sup>(3)</sup> and Google Scholar<sup>(2)</sup> were included. No additional articles were obtained from screening the references of the selected articles. Finally, thirty articles were analysed for this review.

Among the thirty articles selected<sup>(19–48)</sup>, twenty were cross-sectional observational studies<sup>(19–22,25,28–30,33,38–48)</sup>, seven were intervention studies<sup>(23,24,31,32,34,35,37)</sup> with three of them being randomised controlled trials<sup>(23,24,34)</sup> and three were longitudinal observational studies<sup>(26,27,36)</sup>. A third were conducted before 2010 and another third after 2013. Thirteen were conducted partially or exclusively in the city of Abidjan and fifteen exclusively in rural regions of Côte d'Ivoire, while three studies took place in multiple countries<sup>(20,38,44)</sup>. Overall, 12 279 children and adolescents were included, more than half of them being involved in studies assessing anaemia and/or parasitic diseases. The age range was wider than the 10–19-year interval for twenty six of the studies, most of them enrolling younger children, and disaggregated data by age group were not always provided for every outcome. Gender-stratified data



**Fig. 1** Flow-chart of the literature selection process to identify nutritional studies conducted among adolescents aged 10–19 years in Côte d'Ivoire between 2000 and 2019, TALENT collaboration

were also lacking in seven studies<sup>(19,22,33,35,37,43,46)</sup>. Three studies were conducted exclusively among girls; one among pregnant adolescent girls<sup>(26)</sup> and the other two among young non-pregnant women aged 15–25 years<sup>(25,27)</sup>. For the remaining studies, the percentage of girls included ranged from 30 to 62%. The main topics of interest addressed in these articles were anaemia and Fe deficiency in nine studies<sup>(19–27)</sup> (Table 2), parasitosis in six studies<sup>(26–33)</sup> (Table 3) and iodisation and salt fortification in four studies<sup>(34–37)</sup> (Table 4). Three studies focused on food intake and nutritional practices<sup>(38–40)</sup>, two on diabetes and overweight and obesity<sup>(41,42)</sup> (Table 5) and the last six studies were on different topics including the impact of nutritional status on immunity and inflammation<sup>(43)</sup>, prevalence of malnutrition in children and adolescents living with HIV<sup>(44)</sup>, associations between nutritional status and school performance<sup>(45)</sup> and living conditions, associations between body image/perception and eating behaviours and the association between sleep duration and nutritional status<sup>(46–48)</sup> (Table 6).

### Description of adolescent nutritional status

#### Prevalence of malnutrition

Anthropometric data were provided in eleven studies<sup>(21,28,29,31,33,40,42–46)</sup>. The prevalence of stunting

ranged between 8<sup>(21)</sup> and 27%<sup>(28)</sup>, with variations both in rural and urban settings. Among adolescents living with HIV, the prevalence of stunting was higher at 27%<sup>(44)</sup>. The prevalence of underweight ranged from 11<sup>(21)</sup> to 25%<sup>(28)</sup> and wasting from 23 to 30%, except for one study in Abidjan, where 65% of children and adolescents attending school were thin or extremely thin<sup>(42)</sup>. Four studies measured overweight and obesity (0.8% overweight<sup>(28)</sup>, 8% overweight or obese<sup>(40)</sup>, 4% overweight and 5% obese<sup>(42)</sup>, 5.9% overweight or obese<sup>(45)</sup>). The prevalence of malnutrition varied greatly between studies, with no clear differences between rural and urban settings.

#### Micronutrients

Fourteen studies provided data on anaemia and Fe deficiency, defined using the international red cell parameter cut-offs from WHO (Table 1). Rates of anaemia were very high, from 32<sup>(33)</sup> to 87%<sup>(29)</sup>. Fe deficiency with anaemia was also very common ranging from 9.3<sup>(23)</sup> to 43%<sup>(22)</sup>, and Fe deficiency without anaemia from 11<sup>(37)</sup> to 59%<sup>(21)</sup>. Fe intakes were measured in three studies using 3-day weighed food records, and 21% of participants had intakes below estimated average requirements (EAR)<sup>(21,37)</sup>. Although absolute intakes of Fe in boys and girls were similar, 94% of boys but only 44% of girls reached the EAR<sup>(24)</sup>.

**Table 2** Summary table of studies included in the present scoping review related to anaemia and iron deficiency in adolescents living in Côte d'Ivoire

First author (year)	Main objective(s)	Study design	Study period	N	Country and setting	Age (years)*	Sex (% girls)	Results	Remarks
<b>Anaemia</b>									
Asobayire (2001) <sup>(19)</sup>	To estimate prevalence of Fe deficiency and evaluate influence of infectious and inflammatory disorders on Fe status.	Cross-sectional observational study	1996	531	Côte d'Ivoire, Urban + Rural	6–15 years	No data	Data were not disaggregated by rural v. urban residence. Prevalence of anaemia 46%. Fe deficiency and IDA were obscured by high prevalence of inflammatory disorders (21%)	
Zimmerman (2005) <sup>(20)</sup>	To determine if transferrin receptor and Zn protoporphyrin predict Fe deficiency in Africa.	Cross-sectional observational study	2003	1016	Côte d'Ivoire, Morocco Urban + Rural	5–15 years	43 %	Data were not disaggregated by sex, but the following data were specific to Cote d'Ivoire. Prevalence of anaemia 39.4 %, Fe deficiency 19.7 %, Fe deficiency with anaemia 11 % (measured with serum transferrin receptor and erythrocyte Zn protoporphyrin tests)	Children with elevated CRP were excluded.
Rohner (2007) <sup>(21)</sup>	To determine prevalence of riboflavin deficiency; to estimate riboflavin content of diet; to investigate if riboflavin status contributes to anaemia or Fe deficiency.	Cross-sectional observational study	2004–2005	281	Côte d'Ivoire, Rural	5–15 years	44 %	<ul style="list-style-type: none"> <li>• Stunting 8 %, Underweight 11 %.</li> <li>• IDA 36 %, Fe deficiency without anaemia 59 %, vitamin A deficiency 1 %, plasmodium parasitaemia 49 %, mild riboflavin deficiency 65 %.</li> <li>• Daily intakes of riboflavin: median 0.42 mg (47 % of EAR), range 0.17 to 1.16 mg); 21 % had Fe intakes below EAR.</li> </ul>	
Yapi (2009) <sup>(22)</sup>	To assess associations of Fe deficiency with immunologic profile and nutritional status.	Cross-sectional observational study	2008	186	Côte d'Ivoire, Rural	5–15 years	No data	43 % had Fe deficiency. No differences on Fe deficiency according to malnutrition.	Excluded if likely to have parasitoses.
Rohner (2010) <sup>(23)</sup>	To assess effect of Fe fortified biscuits, IPT for malaria and anthelmintic treatment on Hb and anaemia.	RCT, double-blind, 6 months	2006–2007	554	Côte d'Ivoire, Rural	6–14 years	45 %	<ul style="list-style-type: none"> <li>• Prevalence of anaemia, Fe deficiency, malaria parasitaemia and helminth infection was 70.4, 9.3, 57.7 and 54.8 %, respectively. Hb: +2.4 g/l (<math>P &lt; 0.01</math>) with anthelmintics.</li> <li>• Fe fortification biscuits and IPT had no effects on Hb.</li> </ul>	

Table 2 Continued

First author (year)	Main objective(s)	Study design	Study period	N	Country and setting	Age (years)*	Sex (% girls)	Results	Remarks
Zimmermann (2010) <sup>(24)</sup>	To determine the effect of Fe fortification on gut microbiota and gut inflammation (sub-study of Rohner 2010)	RCT, double-blind, 6-month	2006–2007	139	Côte d'Ivoire, Rural	6–14 years	42 %	<ul style="list-style-type: none"> <li>At baseline, 73 % anaemia, 54 % infected by hookworm, estimated daily mean (SD) Fe intakes 14.5 ± 3.5 mg (94 % of EAR) in boys &gt;10 years, and 13.7 ± 2.9 mg (44 % of EAR) in girls &gt;10 years. These equate to 94 % and 44 % of EAR for absorbed Fe.</li> <li>Fe fortified biscuits was ineffective; no differences in Fe status, anaemia or hookworm prevalence at 6 months.</li> <li>Fe fortification increased number of enterobacteria, decreased lactobacilli and increased gut inflammation (measured by fecal calprotectin concentration)</li> </ul>	
Righetti (2012) <sup>(25)</sup>	To determine prevalence of anaemia and risk factors	Cross-sectional observational study	2010	89	Côte d'Ivoire, Rural	15–25 years	100 %	<ul style="list-style-type: none"> <li>Anaemia 47.9 %, riboflavin deficiency 68 %.</li> <li>Prevalence of <i>Plasmodium falciparum</i> 30 %.</li> <li>Associated factors to anaemia were cellular Fe deficiency and chronic inflammation.</li> </ul>	
Bleyere (2013) <sup>(26)</sup>	To evaluate changes in Fe metabolism in adolescents during pregnancy.	Prospective observational cohort	2006–2008	112	Côte d'Ivoire, Urban	15–19 years	100 %	<ul style="list-style-type: none"> <li>Anaemia 77.7 % in third trimester of pregnancy.</li> <li>Fe stores and all evaluation parameters of Fe metabolism were altered, especially a decrease of haematological parameters in the third trimester.</li> </ul>	Excluded if hypertension, diabetes, rheumatism.
Righetti (2013) <sup>(27)</sup>	To assess Hb dynamics in relation to parasitic infections, micronutrient status and age.	14-month prospective observational study	2010–2011	94	Côte d'Ivoire, Rural	15–25 years	100 %	No significant change in Hb during the study period. Parasitic status was not associated with anaemia.	

EAR, estimated average requirements; IDA, Fe deficiency anaemia; IPT, intermittent preventive treatment; RCT, randomised controlled trial.

\*Unless age sub-groups are specified, results are given for the whole age group.



**Table 3** Summary table of studies included in the present scoping review related to parasitic diseases and nutrition in adolescents living in Côte d'Ivoire

First author (year)	Main objective(s)	Study design	Study period	N	Country and setting	Age (years)*	Sex (% Girls)	Results	Remarks
<b>Parasitic diseases</b>									
Dancesco (2005) <sup>(28)</sup>	To assess the effect of intestinal parasites on physical, physiological development and nutritional status	Cross-sectional observational study	2004	129	Côte d'Ivoire, Rural	4–15 years	43 %	<ul style="list-style-type: none"> <li>10–15 years group: Stunting 27.3 %; Underweight 24.8 %; Overweight 0.8 %</li> <li>Pubertal delay for girls: pre-adolescent stage: 73 % at 10 years, 20 % at 11 years, 15.8 % at 12 years. After 13 years: 14.9 % Tanner stage 3, 56.8 % Tanner stage 4, 0 % stage 5. 61.7 % of 11–15 years (N 94) had <i>Ascaris Lumbricoides</i> infestation.</li> </ul>	Selected if assessed by their family as being in good health.
Yapi (2005) <sup>(29)</sup>	To assess relationships between anthropometry, Hb and parasitic infestation.	Cross-sectional observational study	2010	262	Côte d'Ivoire, Rural	7–15 years	43 %	<ul style="list-style-type: none"> <li>Stunting 27 %, Wasting 30 %.</li> <li>87 % were anaemic and these had lower mean weight and height values.</li> <li>47.7 % had monoparasitism, 16.7 % biparasitism, 3.8 % triparasitism. No relationship between anthropometry and intestinal parasite carriage.</li> </ul>	
Muller (2011) <sup>(30)</sup>	To investigate the relationship between helminth infection status and physical fitness among school-aged children.	Cross-sectional observational study	2010	156	Côte d'Ivoire, Rural	7–15 years	42 %	<p>Mean VO<sub>2</sub> max values, girls: 50.4 ml/kg/min (95 % CI: 49.4–51.3 ml/kg/min), and boys: 54.4 ml/kg/min (95 % CI: 53.5–55.2 ml/kg/min), decreasing with age. Prevalence of <i>Schistosoma haematobium</i>, <i>Plasmodium</i> species, <i>Schistosoma mansoni</i>, hookworm and <i>Ascaris lumbricoides</i> were 85.3 %, 71.2 %, 53.8 %, 13.5 % and 1.3 %, respectively. No differences in the VO<sub>2</sub> max values of helminth-infected and non-infected children.</p>	Excluded if dyspnoea, malaria, anaemia or asthma.

Table 3 Continued

First author (year)	Main objective(s)	Study design	Study period	N	Country and setting	Age (years)*	Sex (% Girls)	Results	Remarks
Hürlimann (2014) <sup>(31)</sup>	To determine the effect of deworming (albendazole and praziquantel at baseline and 2 months later) against soil-transmitted helminthiasis and schistosomiasis on children's physical fitness, cognition and clinical parameters.	Intervention study, 5-month follow-up	2012–13	257 (10–14 years: 192)	Côte d'Ivoire, Rural	5–14 years	50 % (10–14 years)	<ul style="list-style-type: none"> <li>• Stunting 13.6 %, Wasting 23 %, Underweight 14 %.</li> <li>• Anaemia 35 %. No effect of deworming on Hb levels and anaemia.</li> <li>• At baseline: 91 % of children infected with <i>Plasmodium falciparum</i> 8.2 %, <i>Plasmodium malariae</i> 35 %, <i>Schistosoma mansoni</i> 9.7 %, soil-transmitted helminth co-infection 38 %. 53 % low performance in the memory test.</li> <li>• Stunting and wasting were associated with lower scores in strength tests.</li> <li>• Post-intervention: Children with soil-transmitted helminth or <i>Schistosoma</i> infection at baseline performed better in the sustained attention test than their non-infected counterparts at the 5-month follow-up. Children performed better in the digit span test at 5 months compared to baseline. Standing broad jump and grip strength tests performance improved over the study period by 12 cm (95 % CI: 10, 14 cm) and 1.07 kg (95 % CI: 0.49, 1.65 kg).</li> </ul>	
Glinz (2015) <sup>(32)</sup>	To measure inflammation biomarkers, Fe absorption and utilisation pre- and post-treatment (Fe fortification + anti-parasitic) in children with afebrile malaria, hookworm, or <i>Schistosoma haematobium</i> infection.	Intervention study, single-arm	2010–11	41	Côte d'Ivoire, Rural	11–17 years	32 %	Hookworm infection did not produce inflammation and did not influence Fe utilisation (i.e. erythrocyte incorporation of <sup>58</sup> Fe from an intravenous dose) or absorption (i.e. intravenous incorporation + erythrocyte incorporation of <sup>57</sup> Fe from an orally administered syrup). In contrast, afebrile malaria caused inflammation and reduced Fe absorption, but not utilisation.	Little, specific study.
Hürlimann (2019) <sup>(33)</sup>	To study interactions between <i>Plasmodium</i> and helminth co-infections on anaemia and splenomegaly	Cross-sectional observational study	2013	4938	Côte d'Ivoire, Urban + Rural	5–18 years	No data	<ul style="list-style-type: none"> <li>• Malnutrition (either stunting, wasting or underweight): 28 %.</li> <li>• Anaemia prevalence 32 %.</li> <li>• No evidence that co-infection with <i>Plasmodium</i> and helminths was associated with worse anaemia</li> </ul>	

\*Unless age sub-groups are specified, results are given for the whole-age group.



**Table 4** Summary table of studies included in the present scoping review related to iodisation and salt fortification in adolescents living in Côte d'Ivoire

First author (year)	Main objective(s)	Study design	Study period	N	Country and setting	Age (years)*	Sex (% girls)	Results	Remarks
<b>Iodisation</b>									
Hess (2002) <sup>(34)</sup>	To determine if Fe supplementation in goitrous, Fe-deficient children improves response to iodised salt (IS)	Cross-sectional observational study + RCT, 20 weeks	1999–00	1014 (survey), 166 (RCT)	Côte d'Ivoire, Rural	5–14 years	30 %	<ul style="list-style-type: none"> <li>In the survey: Prevalence of Fe deficiency 38 %, IDA: 19 %, Fe deficiency + goitre 23 %.</li> <li>In the RCT: Fe deficiency at 20 weeks: 39 % in the intervention group v. 52 % in the placebo group, <math>P &lt; 0.05</math>. participants with goitre at 20 weeks: 43 % v. 62 %, <math>P &lt; 0.02</math></li> </ul>	Studies carried out before iodised salt introduced.
Zimmermann (2002) <sup>(35)</sup>	To assess response to oral iodine supplementation among goitrous children with IDA; to assess if Fe supplementation improves response to oral iodised oil and salt.	Intervention studies	1997–00	1433	Côte d'Ivoire, Rural	6–14 years	No data	Among goitrous children with anaemia, therapeutic response to iodised oil (Fe and iodine status) was impaired; supplemental Fe improved response.	
Zimmermann (2003) <sup>(36)</sup>	To describe the time course and pattern of changes in thyroid size and goitre rate in response to iodised salt introduction in an endemic area.	5-y prospective cohort starting 6 months before iodised salt	1997–01	419 before, 507 2 years after	Côte d'Ivoire, Rural	5–14 years	37 %	In the 4 years after the introduction of iodised salt and normalisation of median urinary iodine, mean thyroid size decreased by 56 % ( $P < 0.0001$ ). 29 % of children remained goitrous (v. 40 % at baseline). At 2, 3 and 4 years after salt iodisation, goitre rate was significantly higher in children aged 10–14 years v. 5–9 years (at 4 years: 52 % compared with 19 %), and the difference increased with time ( $P < 0.0001$ ).	Children attending school + same remark as above.
Wegmuller (2006) <sup>(37)</sup>	To assess stability, organoleptic qualities in traditional meals, and acceptability and efficacy of a dual-fortified salt (DFS, iodised salt with micronised FePP) to improve Fe status in Fe-deficient school children.	Cross-sectional observational study + intervention trial, 6 months: DFS v. IS.	2004–05	605 (survey), 123 (trial)	Côte d'Ivoire, Rural	6–15 years	No data	<ul style="list-style-type: none"> <li>At baseline: anaemia 50 %, Fe deficiency without anaemia 11 %, vitamin A deficiency 7 %, riboflavin deficiency 66 %.</li> <li>After 6 month intervention: serum ferritin, transferrin receptor concentration and body Fe stores (transferrin receptor: serum ferritin ratio) improved in the DFS but not IS group. Body Fe increased from <math>4.6 \pm 2.7</math> to <math>5.9 \pm 2.7</math> mg/kg (mean <math>\pm</math> sd) in the DFS group; equivalent values for the IS group were <math>5.5 \pm 2.9</math> and <math>5.6 \pm 3.1</math> mg/kg. There was no increase in Hb.</li> <li>Dietary nutrient intakes: % below EAR (6–15 years, <math>n</math> 71): 21 % for Fe, 37 % for vitamin A, 99 % for riboflavin, 83 % for ascorbic acid. Median salt intake 2.8 (0–10.9) g/day. Malaria infection 55 %, helminth infestation 14 %.</li> </ul>	

DFS, dual-fortified salt; EAR, estimated average requirements; IDA, Fe deficiency anaemia; IS, iodised salt; RCT, randomised control trial; suppl, supplementation.

\*Unless age sub-groups are specified, results are given for the whole age group.

**Table 5** Summary table of studies included in the present scoping review related to food intake and nutritional practices, diabetes, overweight and obesity in adolescents living in Côte d'Ivoire

First author (year)	Main objective(s)	Study design	Study period	N	Country and setting	Age (years)	Sex (% Girls)	Results	Remarks
<b>Food intake and nutritional practices</b>									
Peltzer and Pengpid (2015) <sup>(38)</sup>	To assess fruit and vegetable consumption and associated factors among university students from 26 low-, middle- and high-income countries.	Cross-sectional observational study	2013	745	26 countries across Asia, Africa, the Americas Urban	16–30 years	59 %	In Ivory Coast, mean daily servings of fruits and vegetables = 3.9 (1.3 for fruits and 2.6 for vegetables). 64.4 % (61.0–67.9) had <5 servings of fruits and vegetables.	No specific data for Ivory Coast except daily serving (one of the highest of study countries)
Inghels (2017) <sup>(39)</sup>	To describe health provision, needs and barriers when seeking medical care, for 1st-y students.	Cross-sectional observational study	2015	543	Côte d'Ivoire, Urban	Median 22 years	41 %	No information or support regarding nutrition available at the University healthcare centre, need for information campaigns on nutrition.	Not adolescents but young adults, interesting to describe in our context.
Gbogouri (2018) <sup>(40)</sup>	To describe dietary habits and socio-demographic features of University students.	Cross-sectional observational study	2015	156	Côte d'Ivoire, Urban	18–34 years	47 %	<ul style="list-style-type: none"> <li>• 18 % underweight and 8 % overweight or obese.</li> <li>• 10 % reported diabetes, 12 % arterial high blood pressure.</li> <li>• 88 % not regularly having breakfast, while 88 % and 95 % have lunch and dinner, respectively, 33 % claimed financial problems as a reason for skipping meals. Rice and 'Attiéké' (cassava semolina) were the favourite foods during the three daily meals, 26 % never consume fruits, 82 % do daily physical activity for a minimum of 30 min three times a week.</li> </ul>	
<b>Diabetes, overweight and obesity</b>									
Agbre-Yace (2016) <sup>(41)</sup>	To determine the prevalence of the diabetes mellitus.	Cross-sectional study	2013	813	Côte d'Ivoire, Urban + Rural	2–19 years	62 %	<ul style="list-style-type: none"> <li>• 0.4 % had diabetes mellitus (fasting glucose <math>\geq</math> 7 mmol/l), 17.2 % had impaired fasting glycaemia (5.6–6.9 mmol/l). 4.9 % had at least one diabetic parent.</li> <li>• No difference in terms of ethnicity/nationality, genders. More subjects with hyperglycemia from rural areas.</li> </ul>	

\*Unless age sub-groups are specified, results are given for the whole age group.



**Table 6** Summary table of studies included in the present scoping review related to nutrition in adolescents living in Côte d'Ivoire, covering specific populations, topics and grey literature

First author (year)	Main objective(s)	Study design	Study period	N	Country and setting	Age (years)*	Sex (% Girls)	Results	Remarks
<b>Specific population and other topics</b>									
Houphouët (2010) <sup>(43)</sup>	To determine the alteration of immunity, inflammatory and nutritional proteins according to malnutrition.	Cross-sectional study	No data	142	Côte d'Ivoire, Semi-urban	5–15 years	No data	<ul style="list-style-type: none"> <li>• 30 % wasting.</li> <li>• Albumin was lower and CRP higher in undernourished children. The prognostic nutritional and inflammatory index assessing both inflammatory and nutritional state also increased. Immunity proteins (IgA, IgG, IgM) remain unchanged.</li> </ul>	
Jesson (2015) <sup>(44)</sup>	To assess the prevalence of malnutrition among HIV-infected children in West and Central Africa.	Cross-sectional study	2011	110	Côte d'Ivoire, Semi-urban	2–19 years	46 %	<ul style="list-style-type: none"> <li>• Wasting only 12.5 %, stunting only 31.7 %, wasting + stunting 16.4 %.</li> <li>• Among those malnourished, more than half did not receive any nutritional support. Male gender and severe immunodeficiency were associated with undernutrition, but not orphanhood or Cotrimoxazole prophylaxis</li> </ul>	HIV-infected population
Zahe (2016) <sup>(45)</sup>	To evaluate the impact of nutritional status on the academic performance.	Cross-sectional study	2015–16	237	Côte d'Ivoire, Urban	8–14 years	50 %	<ul style="list-style-type: none"> <li>• Underweight 20.3 %, overweight or obesity 5.9 %</li> <li>• For underweight, no difference between boys and girls; mainly girls were overweight or obese. No effect of nutrition status on school performance.</li> </ul>	
<b>Grey literature review</b>									
Beda (2016) <sup>(46)</sup>	To compare nutritional status by life conditions (family environment, specialised institution and centre).	Cross-sectional study	2016	273	Côte d'Ivoire, Urban	10–13 years	40 %	<ul style="list-style-type: none"> <li>• Specialised centres v. family: wasting 3.3 % v. 26.1 %, stunting 11.1 % v. 30.4 %</li> <li>• Children living in family environment had significantly higher rates of wasting and stunting than those living in specialised centre or institution.</li> </ul>	
Ouattara (2017) <sup>(47)</sup>	To describe the influence of body perception on eating behaviour.	Cross-sectional study	2017	403	Côte d'Ivoire, Urban	12–17 years	51 %	Body perception is not significantly associated with eating behaviours.	Few data available on these reports
Tiehi (2017) <sup>(48)</sup>	To describe the influence of sleep duration on risk of overweight.	Cross-sectional study	2017	320	Côte d'Ivoire, Urban	5–12 years	50 %	Those who sleep <9 h had a higher weight than those who sleep >9 h: +3.5 kg in females and +2.5 kg in males. No differences for height.	

CRP, C-reactive protein.

\*Unless age sub-groups are specified, results are given for the whole age group.



Three studies assessed the status and/or intake of other micronutrients. The prevalence of vitamin A deficiency was 1 % [21] and 7 % [37] in two studies. Two-thirds of participants were estimated to be riboflavin (B<sub>2</sub>) deficient in three studies<sup>(21,25,37)</sup>. In the study from Rohner *et al.* 2007<sup>(21)</sup>, median riboflavin intake was only 47 % of the EAR, and this was attributed to infrequent consumption of animal foods except smoked fish, and the negligible riboflavin content of cassava, the dietary staple. In another rural setting, 99 % were below the EAR for riboflavin and only 37 % achieved the EAR for vitamin A. Authors explained that this may be due to rare consumption of fresh fruit and the fact that vegetables are simmered for several hours, causing extensive losses of vitamin C<sup>(37)</sup>.

In children aged 2–19 years, the prevalence of diabetes was reported to be 0.4 % (fasting glucose  $\geq$  7 mmol/l) and 17.2 % for impaired fasting glycaemia (between 5.6 and 6.9 mmol/l)<sup>(41)</sup>. The prevalence of diabetes was 10 % among young adults attending University; 12 % also having high arterial blood pressure<sup>(40)</sup>. Pubertal development was described in only one study<sup>(28)</sup>.

#### *Food intakes and nutritional practices*

One study measured the consumption of fruits and vegetables among those aged 16–30 years. The mean number of servings per day of fruit and vegetables was 3.9, with 64 % having less than five servings per day<sup>(38)</sup>. In another survey among university students, 26 % reported never consuming fruit<sup>(40)</sup>. This study was the only one to document further diet practices, showing that 88 % did not regularly have breakfast and that financial problem was a reason for skipping meals in 33 % of cases. Another survey among a similar population highlighted the need for information campaigns on nutrition within the University Healthcare Center<sup>(39)</sup>.

#### *Parasitosis infections*

Twelve studies documented infections with parasites, especially in rural areas, which could affect nutritional status (Table 1). Children and adolescents were infected with several types of parasitosis. The prevalence of malaria ranged from 30<sup>(25)</sup> to 58 %<sup>(23)</sup>, infections with hookworm from 13<sup>(30)</sup> to 54 %<sup>(24)</sup> and with *Ascaris Lumbricoides* from <2<sup>(30)</sup> to 65 %<sup>(28)</sup>. Soil-transmitted helminths were also commonly found from 14<sup>(37)</sup> to 55 %<sup>(23)</sup>.

#### **Factors associated with nutritional status among adolescents**

Overall, most studies were descriptive. Among children living with HIV, being male and having advanced disease increased the odds of being undernourished<sup>(44)</sup>. Children living in a family environment had significantly higher rates of wasting and stunting than those living in specialised centres or institutions for orphans<sup>(46)</sup>. Sleeping <9 h per day was associated with a higher weight (+3.5 kg in females and +2.5 kg in males)<sup>(48)</sup>. Obesity was found to

be more common in girls than in boys<sup>(42,45)</sup> and was related to high blood pressure but not physical activity<sup>(42)</sup>. Nutritional status was not related to school performance<sup>(45)</sup> and was not associated with mono- or multi-parasitism<sup>(29)</sup>. Finally, a report stated that body perception was not associated with eating behaviours<sup>(47)</sup>.

Regarding micronutrients, no correlation was found between riboflavin intake and anaemia<sup>(21)</sup>. Fe absorption (measuring erythrocyte incorporation of <sup>57</sup>Fe) was reduced by afebrile malaria due to inflammation but was not affected by hookworm infection<sup>(32)</sup>. Parasitic infection was also not associated with anaemia<sup>(27)</sup>, and helminth-infected children had similar VO<sub>2</sub> max values to non-infected children<sup>(30)</sup>.

#### **Interventions to modify nutritional status in adolescents**

Most of the interventions were micronutrient supplementation or deworming. Three studies conducted in the early 2000s focused on goitrous children and young adolescents (<15 years of age), implementing Fe supplementation and salt fortification (iodised salt) (Table 1). Fe supplementation alone<sup>(34)</sup> or combined with iodised salt<sup>(35)</sup> reduced Fe deficiency and the proportion of goitrous children. In a 5-year prospective cohort following the introduction of iodised salt in Côte d'Ivoire in the 2000s, there was a significant reduction in mean thyroid size<sup>(36)</sup>. Following these studies, dual-fortified salt (with Fe and iodine) was compared with iodised salt and showed better improvement in Fe status, but no difference in Hb concentration<sup>(37)</sup>.

A randomised controlled trial involving Fe-fortified biscuits resulted in two articles<sup>(23,24)</sup>; this intervention did not reduce anaemia or hookworm prevalence<sup>(24)</sup> and did not increase Hb concentration, even when combined with malaria treatment<sup>(23)</sup>. Finally, a study assessing deworming treatment showed no effect on Hb levels and anaemia but improved performance in physical fitness tests<sup>(31)</sup>.

#### **Discussion**

This scoping review gives an overview of recent research into the nutrition of adolescents living in Côte d'Ivoire. Overall, some studies have been conducted specifically in this population, and most were cross-sectional observational studies. Nutrition-related topics covered were mostly anaemia and Fe deficiency as well as parasitosis; other studies were on diverse subjects with few results on food intakes, diabetes, overweight and obesity.

Studies assessing anthropometry showed that undernutrition is still highly prevalent in this country, in rural as well as in urban settings. Stunting rates found in adolescents were similar to the estimated prevalence among children under 5 years of age (21.6 % in 2018)<sup>(6)</sup>. However, there were higher rates of underweight and wasting found in



adolescents (at least 11 %) *v.* a 6.1 % estimated prevalence of wasting in under fives<sup>(6)</sup>. Higher or similar rates of underweight for adolescents compared with children have been found in multiregional surveys<sup>(49)</sup>. Because no national estimate of malnutrition exists beyond 5 years of age in Côte d'Ivoire, it is not possible to compare these results within the adolescent population which justifies the need to advocate for further data and adolescent research. As adolescents have higher absolute energetic needs than during any other life period<sup>(50,51)</sup>, a poor-quality diet cannot cover these and may result in higher rates of undernutrition than during childhood. Also, overweight and obesity are an emerging public health problem, which could worsen in the coming years, due to increasing consumption of sweets and saturated fat-rich food<sup>(2,3)</sup>. Indeed, a rising prevalence of overweight and obesity is observed worldwide, even in West Africa<sup>(52)</sup>. Among adults in Côte d'Ivoire, higher rates of overweight and obesity are associated with higher socioeconomic level. This has been attributed to more sedentary lifestyles and changes in dietary patterns, influenced by the introduction of fast foods and other westernised foods at the expense of the traditional diet<sup>(13)</sup>. The prevalence of diabetes in Côte d'Ivoire estimated by the non-communicable disease Risk Factor Collaboration was 6.3 % for women and 7.3 % for men in 2014 and continues to increase<sup>(53)</sup>. Although studies on diabetes and hyperglycaemia were not included in our search strategy initially, we reported two studies that show a prevalence of between 10 and 20 % for impaired glycaemia or diabetes in adolescents. No further data are available among adolescents in Côte d'Ivoire regarding diabetes.

Anaemia and Fe deficiency are a major public health concern, widely documented in different age groups. Our review indicates that the prevalence of anaemia among adolescents remains high and could be explained by several factors, such as persistently high rates of infectious disease (malaria and other parasitosis), nutritional deficiencies (Fe, vitamin B<sub>12</sub>, folic acid, vitamin A) and low dietary Fe intakes<sup>(54)</sup>. Reducing the prevalence of anaemia is a priority of the current National Multisectoral Nutrition Plan in Côte d'Ivoire and the government aims to reduce it from 75 to 60 % in children and from 54 to 42 % in women of childbearing age between 2016 and 2020, promoting essential nutrition actions such as good nutritional practices and consumption of micronutrient-rich foods<sup>(13)</sup>. However, studies of Fe fortification in our review showed only modest effects, whereas it has been effective in improving Hb and reducing anaemia in other contexts<sup>(55)</sup>. As the burden of Fe deficiency anaemia has been shown to be detrimental in terms of economic losses and health impact, increasing disability-adjusted life years, food fortification and infectious disease prevention and control are urgently needed in Côte d'Ivoire<sup>(56)</sup>.

Other micronutrient deficiencies such as vitamin A and vitamin B<sub>2</sub> were explained by insufficient nutritional intakes, due to a lack of dietary diversity and limited

consumption of fruit and vegetables. Other sources of vitamin A or vitamin B<sub>2</sub>, such as red meat, eggs, fish or dairy intakes, were not explored. Iodine deficiency and associated thyroid dysfunction have been reduced since the introduction of iodised salt<sup>(13)</sup> (the iodine studies included in the literature review pre-dated the introduction of iodised salt). Overall, results on micronutrients were limited to Fe, vitamin A and vitamin B<sub>2</sub>. Other micronutrient deficiencies such as Zn, Ca and Mg have been insufficiently explored in Côte d'Ivoire, to our knowledge, constituting a major gap in research data.

High rates of parasitic infection were another important concern (malaria, helminths, hookworm). Deworming interventions did not show significant effects on nutritional status in adolescents<sup>(31)</sup>, which is in line with a systematic literature review conducted in children aged 16 years or less<sup>(57)</sup>. Parasitism may, however, lead to multiple comorbidities requiring treatment<sup>(58)</sup>. A cost-effectiveness modelling study based in Côte d'Ivoire demonstrated that expanded community-wide deworming interventions were highly cost effective in terms disability-adjusted life years averted<sup>(59)</sup>. Deworming campaigns are part of the National Multisectoral Nutrition Plan in the country, targeting pregnant women and children aged 1–12 years, but largely missing the adolescent age group<sup>(13)</sup>.

### Study limitations

The main limitation of this review was that only one bibliographic database was used. As our aim was to scope research already conducted into adolescent nutrition, we did not use other databases; our hypothesis being that most of the relevant studies would be referenced on PubMed. Few reports from the grey literature were found. Indeed, the searching process for grey literature was difficult, as listing of reports in university libraries was lacking. This may have under-estimated existing literature, especially that done by students or as part of national programmes. The search strategy was limited to quantitative studies. Qualitative studies were not included as they required specific key words for the search strategy, and because the results obtained have to be summarised in a different way. A specific literature review on this topic looking at qualitative studies conducted in TALENT participating countries has been done for this themed issue.

The literature review resulted in a small number of studies, with considerable heterogeneity regarding topics of interest, and data and outcomes collected, making it impossible to conduct meta-analyses. Quality assessment was not conducted, because the aim was to document what has been done and what kind of nutritional studies have included adolescents. However, this is to our knowledge the first literature review exploring adolescent nutrition in Côte d'Ivoire, including articles published in English and French, allowing us to identify gaps and plan future research.

Whereas it might have been interesting to extend the scope of this review to West Africa as a whole and not to a single country, we felt that our results provide a comprehensive description of adolescent nutrition research studies in Côte d'Ivoire that would not have been possible in a regional review, this topic remaining highly neglected and under-studied so far. This review can be seen as a preliminary step to support further research, in order to get a better picture of the adolescent nutrition situation in West Africa in the coming years.

### Implication of the results and perspectives

The main lesson of this review is that more research is needed into adolescent nutritional health in Côte d'Ivoire. Most of the studies identified were not focused on adolescents aged 10–19 years or did not provide disaggregated data by age. Research to understand the causes of Fe deficiency and anaemia and into the reasons for a poor response to supplementation or fortification are required. Data on micronutrient status going beyond Fe, vitamins A and B<sub>2</sub> are markedly lacking. There is also a lack of information on dietary intakes and potential determinants of diet and nutritional status.

With the sub-region experiencing a nutritional transition, with greater access to unhealthy foods and the development of non-communicable diseases<sup>(60)</sup>, leading to a double burden of malnutrition<sup>(61)</sup>, new research documenting this transition and how it impacts adolescent health is needed. Availability and access to healthy food may become a systemic challenge in this region that will have to be addressed. Innovative interventional research is needed, including prevention messages on good nutritional practices and physical activity, as well as nutritional education and food/nutrient supplementation.

### Acknowledgements

**Acknowledgements:** The authors would like to thank our partners from Abidjan who help us to conduct this study and the TALENT collaboration for its support. **Financial support:** The TALENT collaboration was funded by a Global Challenges Research Fund/Medical Research Council pump priming grant (grant number: MC\_PC\_MR/R018545/1). The funding agency was not involved in the study design, data analysis or writing of this article. **Conflict of interest:** None. **Authorship:** J.J. wrote the manuscript which has been reviewed by all co-authors. J.J. and K.K. conducted the literature search independently and then discuss the discrepancies. E.K.V.K. conducted the grey literature search. S.V.W. established the initial literature search strategy, which has been revised and approved by the TALENT literature review working group. C.F. was the main investigator of the project, and L.A. and V.L. were the local investigators in Côte d'Ivoire. All authors

approved the final version of the manuscript. *Ethics of human subject participation:* Not applicable.

### Supplementary material

For supplementary material accompanying this paper visit <https://doi.org/10.1017/S1368980020002621>

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