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ORIGINAL ARTICLE

Are overweight and obesity in children risk factors for anemia in early childhood? Results from a national nutrition survey in Tajikistan

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Abstract

Objectives To assess the association between overweight/obesity and anemia in early childhood in Tajikistan.

Methods Using a two-stage-cluster sampling, a representative sample of 1342 children (48.7% girls) aged 25–60 months was included in a nationwide survey in Tajikistan in 2009. Weight status was defined by age- and gender-specific body mass index, anemia by hemoglobin < 11 g/dl, according to WHO cut-off values for children, adjusted for altitude. Gender-stratified association of anemia and overweight/obesity was estimated by mixed models, controlling for age, parental education, and location type and region.

Results In the study population, the prevalence of anemia was 20.0%, overweight 13.0%, and obesity 9.5%. In multi-variable analyses, obesity and overweight were not associated with anemia. Lower age and living in the remote region of Gorno-Badakhshan Autonomous Oblast were associated with a higher prevalence of anemia.

Conclusions In Tajikistan, anemia is at a moderate level, affecting every fifth child aged 25–60 months. Around every fifth child is overweight or obese. Interventions should focus on preventing anemia and overweight/obesity.

Keywords Children · Overweight · Obesity · Anemia · Tajikistan

Introduction

Whether overweight and obesity are associated with anemia in children is of relevance on the background of the recent obesity epidemic in developed and developing countries and of the burden of anemia in developing countries. The combined impact of anemia and obesity could be more detrimental to health than either one of these conditions separately (Cepeda-Lopez et al. 2011). The Center for Disease Control and Prevention (CDC) and the American Academy of Pediatrics recommend screening for iron deficiency anemia (IDA) among vulnerable populations, including infants aged 9–12 months and high-risk toddlers (Centers for Disease Control and Prevention 1998), whereas the U.S. Preventive Services Task Force recommends routine supplementation in asymptomatic children who are at risk for iron deficiency anemia (McDonagh et al. 2015); no indication is given regarding obesity.

In children, iron deficiency anemia (IDA) is reported to be around 47% worldwide, ranging from 10% in Europe to around 46% in Africa and 57% in South-East Asia (Ahmed et al. 2012), affecting child development in terms of cognitive, motor, and mental development (Grantham-McGregor and Ani 2001). The main causes of anemia are dietary iron deficiency (ID), and infectious diseases and deficiency of further key micronutrients (folate, vitamin B12, vitamin A, iodine, and zinc) (Saloojee and Pettifor 2001).

Obesity has significant health consequences, starting already in childhood, such as hypertension, dyslipidemias, orthopedic disorders, sleep disorders, gall bladder disease, insulin resistance, and cognitive impairment (Barlow and Dietz 1998; Black et al. 2013; Farr et al. 2008; Li et al. 2005). Worldwide, an increase from about 4 to 15% has been reported among children and adolescents (Kleinert

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and Horton 2015), making obesity one of the greatest public health challenges of the 21st century, and interventions for preventing obesity in childhood have gained increasingly interest (Waters et al. 2011).

Obesity was consistently associated with low serum iron concentrations and with higher rates of ID in obese children and adolescents (Cepeda-Lopez et al. 2011; Nead et al. 2004; Pinhas-Hamiel et al. 2003). Already in the early 1960s, two epidemiological studies noted a correlation between overweight and obesity and low serum iron, the one in preadolescents and adolescents aged 11–16 years (Wenzel et al. 1962), the other in 11–21 years old (Seltzer and Mayer 1963). A more recent large study demonstrated an approximately threefold higher prevalence of ID in overweight children and adolescents (aged 2–16 years) than in normal-weight subjects (Nead et al. 2004). A significantly greater proportion of IDA was found among overweight and obese than among normal-weight children aged 5–12 years (Cepeda-Lopez et al. 2011; Pinhas-Hamiel et al. 2003). Weight reduction was associated with an improvement of the iron status in obese children with IDA in an intervention study in obese children aged 9–16 years (Amato et al. 2010).

Whether obese young children are also at risk of anemia is reported only in very few studies with conflictive findings. An early study investigating whether Hb criteria should be adjusted to obesity among children aged 6–14 years (Scheer and Guthrie 1981) suggested that no clear distinction can be made between the distributions of Hb concentrations in obese and non-obese children and that ID but not anemia was significantly more prevalent among obese infants. In contrast, a more recent study reported a dose–response relationship between BMI percentiles and iron deficiency (Nead et al. 2004).

Tajikistan, the poorest of the five Central Asian Republics, has experienced economic collapse and civil conflict since the dissolution of the Soviet Union in 1991. Several years of drought in the region resulted in significantly reduced yields and production of basic food crops and near exhaustion of normal coping strategies (World Health Organization 2000), directly affecting the nutritional status of vulnerable population groups (State Committee on Statistics of the Republic of Tajikistan 2007). National nutrition surveys conducted in 2003 and 2009 had revealed persistently high rates of acute and chronic malnutrition and a high prevalence of IDA in children [Ministry of Health (Tajikistan) and United Nations Children's Fund 2010]. These conditions may indirectly be caused by household poverty, improperly balanced diets, weak public management and promotion of nutrition, including poor public education, and inadequate food fortification and micronutrient supplementation programs. Moreover, a food price crisis in 2007 has threatened the population of Tajikistan, resulting in poor diet for a high number of people (Clifford et al. 2010).

Malnutrition in Tajikistan is still widespread and related to poor diets. A dietary diversity study in Tajikistan (Food and Agriculture Organization of the United Nations 2015) showed that current diets are high in sugars and saturated fats, and poor in mineral-rich fruits and vegetables, resulting in an increasing prevalence of diet-related problems such as obesity, hypertension, heart disease, and persistent under-nutrition. Therefore, the aim of this study was to investigate the association between overweight/obesity and anemia, making use of data from a representative population sample of children aged 25–60 months who were included in a national nutrition survey in Tajikistan and to assess whether overweight/obesity is a risk factor for anemia.

Methods

The study was conducted within the frame of a Nutritional National Survey in Tajikistan in 2009. Tajikistan is divided into five oblasts, or regions, Sughd in the northeast, Dushanbe in the west, Khatlon in the southwest, Rayon of Republican Subordination (or Direct Rule District, DRD) in the center, and Gorno-Badakhshan Autonomous Oblast (GBAO) in the east. Oblasts are divided into rayons (districts). Rayons are further subdivided into mahallas (committees) in urban areas and jamoats (villages) in rural areas. According to the statistical office of Tajikistan, the population of all cities and urban settlement with more than 10,000 inhabitants are categorized as urban. Tajikistan's population is concentrated in the geographic lowlands, and 90% of its inhabitants live in valleys, often in densely concentrated urban centers.

Study population

The study population consisted of children whose mothers/caregivers were included in the Nutritional National Survey in Tajikistan in 2009. A two-stage-cluster sampling design was used to include a representative sample. At a first stage, primary sampling units were selected, i.e., the clusters (usually villages in rural areas or mahallas in urban areas) with a probability proportional to the population size of the primary sampling unit. At a second stage, a random sample of a fixed number (as revealed in the first stage) of individuals in each village or mahalla was drawn. The analysis was limited to children aged 25–60 months for whom data were available on Hb, as a biochemical indicator of anemia, and on weight and height for BMI calculations. This information was available for 99% of the sampled children [Ministry of Health (Tajikistan) and United Nations Children's Fund 2010].

Collection of information

For all children, a questionnaire was filled in by fieldworkers who interviewed the mothers/caregivers who provided relevant indicators of the health and nutritional status of children. Information on anthropometric measurements was taken by fieldworkers and laboratory examinations were conducted from blood samples taken at the site of the survey.

Measurements and definition of anemia

Hemoglobin measures relied on on-site measurements conducted by the field Hb analyzer (Hemocue^{TM}) (Burger and June 2002). Blood was collected from each subject by pricking the middle finger with a sterile lancet. The first drop of blood was removed and the second one was collected by capillarity in a cuvette containing dry Drabkin's reagent for Hb analysis. Anemia was defined according to the WHO cut-off value for Hb for children (Hb $<$ 11 g/dl) (United Nations Children's Fund, United Nations University and World Health Organization 2001). To estimate correctly the prevalence of anemia at higher altitudes of the survey sites in Tajikistan, the Hb cutoffs were adjusted to the respective altitudes (Sullivan et al. 2008). Hb values measured in the field were recorded as uncorrected values. The altitude for each cluster was obtained using Google Earth Programme and detailed Tajikistan maps provided from the Swiss Development Cooperation in Dushanbe, and Hb values were corrected accordingly.

Ferritin measurements were also conducted, but for technical reasons, these measurements seemed very unreliable and were thus not used for analyses.

Measurement of height and weight and definition of weight status

Every child was weighted using a standardized electronic scale provided by UNICEF and measured barefoot in upright position. Fieldworkers were trained and quality control was assured by the Non-Governmental Organization Zerkalo as well as the supervisor in charge of the respective teams. Anthropometric measurement procedures were standardized on the basis of guidelines published by the UN (United Nations 1986) and the WHO (World Health Organization 1995).

Weight status was defined using the WHO Child Growth Standards sex-specific weight-for-height extended tables and cross-checked with BMI-for-age tables (for 2–5 years old) (World Health Organization 2006). Children classified under the respective 5th percentile were considered as underweight, from the 5th to $<$ 85th percentile as normal weight, from 85th to $<$ 95th percentile as overweight, and from 95th percentile and over as obese.

Ethical considerations

During the study, high value was given to the respect of ethical considerations related to study design and implementation. The Ministry of Health of Tajikistan provided written approval of the survey, including approval of the survey's ethical aspects. Ethical clearance was also granted from the institutional board of Swiss Tropical and Public Health Institute and UNICEF. Written informed consent was obtained from all parents/legal guardians of children below the age of 5 years.

Statistical analyses

Comparison of anthropometric measurements with the WHO standard growth curve and calculation of z scores were conducted with the program ENA (ENA for SMART—Software for Emergency Nutrition Assessment, version 2007). Descriptive analyses were conducted for the prevalence of anemia and obesity. The subjects were grouped into the age categories of 25–36, 37–48, and 49–60 months to include an approximately equal proportion of children. To test for differences in prevalence across the strata, the Chi-square test or the Fisher's exact test was used. The last was applied when the count size was small (not all expected frequencies were $\geq$ 2, or if more than 20% of the cells had an expected frequency of $\leq$ 5) (Lydersen et al. 2007; McDonald 2009). Generalized linear-mixed models (for binary distribution and logit link) were conducted to assess the independent association of weight status with anemia, adjusting for social demographic characteristics: children's age (grouped into 25–36, 37–48, and 49–60 months) and sex (male, female), parental education (categorized as none, grades 9–11 as secondary education, and $\geq$ 12 grades as higher education), location (categorized as urban if cities and urban settlement with more than 10,000 inhabitants, as rural otherwise), and region [Dushanbe, Khatlon, Sughd, Direct Rule District (DRD), Gorno-Badakhshan Autonomous Oblast (GBAO)]. Interactions of sex with other covariates were checked. The effects of cluster and household were introduced in the model as random effects. Because gender differences in malnutrition and in treatment of infectious diseases have been documented, particularly in poor settings (Santosh 2006), the analyses were performed stratified by sex even if interactions were statistically non-significant.

Data entry was performed using EpiInfo version 3.5.1 [Center for Disease Control and Prevention (CDC), Atlanta]. Statistical analyses were conducted with SAS version 9.4 (2002–2012, SAS Institute Inc., Carey, NC, USA. P values < 0.05 were considered statistically significant.

Results

The study population consisted of 1342 children (48.7% female) aged 25 through 60 months (Table 1). About half of the parents had none or primary education, about a fourth a higher education. Overall, two-thirds were living in urban areas. According to the study design, the distribution of the study population across regions was largely uniform.

The overall prevalence of anemia among children aged 25–60 months was 20.0% (Table 1). It was most prevalent in the youngest age group (31.7%) and in the geographical region of GBAO (28.1%). No significant differences were seen by sex and location (rural versus urban). A somewhat lower prevalence of anemia was observed among children whose parents had a higher educational level, but the differences were statistically not significant.

Out of 1342 children, 175 were overweight (13.0%) and 128 (9.5%) were obese (Table 2). The highest prevalence of overweight and obesity was seen in the youngest age groups in both sexes. The largest sex differences were seen for obesity in the group aged 49–60 months (3.6% in girls compared to 8.9% in boys) (Table 2).

The prevalence of anemia decreased with age in all three weight categories and in both sexes (Table 3), being somewhat more pronounced in normal-weight girls than in normal-weight boys (from 35.1 to 7.0% in girls compared to 32.4 to 12.7% in boys). The decrease with increasing age seems also present in overweight and obese girls and boys; however, numbers are very low, particularly in the obese category.

In the bivariate analysis (data not shown), the associations between overweight and obesity with anemia were not significant (OR for overweight: 1.13 [0.75–1.70], OR for obesity: 1.15 [0.72–1.85] compared to normal weight).

In the multivariable analyses, conducted separately for boys and girls and adjusting simultaneously for age,

Table 1 Study population and prevalence of anemia by demographic and socioeconomic characteristics, National Micronutrient Status Survey, Tajikistan, 2009

	Study population		Anemia (Hb < 11 g/dl)		P value (χ^2 test)
	N	%	*N*	%	
Total	1342	100.0	269	20.0	
Age (months)					< 0.001
25–36	473	35.3	150	31.7	
37–48	446	33.2	78	17.5	
49–60	423	31.5	41	9.7	
Gender					0.796
Male	689	51.3	140	20.3	
Female	653	48.7	129	19.8	
Parental education[a]					0.342
None	191	14.2	41	21.5	
Primary (grades 1–9)	483	36.0	107	22.2	
Secondary (grades 9–11)	316	23.5	56	17.7	
Higher education	330	24.6	60	18.2	
Location					0.729
Urban	886	66.0	180	20.3	
Rural	456	34.0	89	19.5	
Region					0.007
Dushanbe	276	20.6	52	18.8	
Khatlon	291	21.7	57	19.6	
Sughd	246	18.3	39	15.9	
DRD (Direct Rule District)	269	20.0	48	17.8	
GBAO (Gorno-Badakhshan Autonomous Oblast)	260	19.4	73	28.1	

[a]Missing information: $n = 22$ (1.6%)

Table 2 Prevalence of overweight and obesity among children, stratified by age and gender, National Micronutrient Status Survey, Tajikistan, 2009

Age (months)	Gender	N_{Total}	Weight status				P value[a]
			Underweight N (%)	Normal N (%)	Overweight N (%)	Obese N (%)	
25–36	Female	211	8 (3.8)	154 (73.0)	27 (12.8)	22 (10.4)	0.405
	Male	262	15 (5.7)	173 (66.0)	39 (14.9)	35 (13.4)	
	Total	473	23 (4.9)	327 (69.1)	66 (13.9)	57 (12.1)	
37–48	Female	222	9 (4.0)	162 (73.0)	31 (14.0)	20 (9.0)	0.720
	Male	224	8 (3.6)	154 (68.7)	37 (16.5)	25 (11.1)	
	Total	446	17 (3.8)	316 (70.9)	68 (15.2)	45 (10.1)	
49–60	Female	220	6 (2.7)	185 (84.1)	21 (9.6)	8 (3.6)	0.123
	Male	203	8 (3.9)	157 (77.3)	20 (9.9)	18 (8.9)	
	Total	423	14 (3.3)	342 (80.8)	41 (9.7)	26 (6.2)	
Total	Female	653	23 (3.5)	501 (76.7)	79 (12.1)	50 (7.7)	0.040
	Male	689	31 (4.5)	484 (70.3)	96 (13.9)	78 (11.3)	
	Total	1342	54 (4.0)	985 (73.4)	175 (13.0)	128 (9.5)	

[a] χ^2 test or Fisher's exact test as applicable

Table 3 Prevalence of anemia by weight status, age, and gender, National Micronutrient Status Survey, Tajikistan, 2009

Age (months)	Gender	Anemia (Hb < 11 g/dl)					
		N_{total} (%)	Weight status				P value[a]
			Underweight N (%)	Normal N (%)	Overweight N (%)	Obese N (%)	
25–36	Female (n = 211)	70 (33.2)	4 (50.0)	54 (35.1)	6 (22.2)	6 (27.3)	0.400
	Male (n = 262)	80 (30.5)	5 (33.3)	56 (32.4)	10 (25.6)	9 (25.7)	0.788
	Total (n = 473)	150 (31.7)	9 (39.1)	110 (33.6)	16 (24.2)	15 (26.3)	0.307
37–48	Female (n = 222)	43 (19.4)	2 (22.2)	31 (19.1)	7 (22.6)	3 (15.0)	0.884
	Male (n = 224)	35 (15.6)	1 (12.5)	19 (12.3)	10 (27.0)	5 (20.0)	0.128
	Total (n = 446)	78 (17.5)	3 (17.7)	50 (15.8)	17 (25.0)	8 (17.8)	0.340
49–60	Female (n = 220)	16 (7.3)	0 (0.0)	13 (7.0)	2 (9.5)	1 (12.5)	0.709
	Male (n = 203)	25 (12.3)	1 (12.5)	20 (12.7)	2 (10.0)	2 (11.1)	0.999
	Total (n = 423)	41 (9.7)	1 (7.1)	33 (9.7)	4 (9.7)	3 (11.5)	0.956
Total	Female (n = 653)	129 (19.8)	6 (26.1)	98 (19.6)	15 (19.0)	10 (20.0)	0.891
	Male (n = 689)	140 (20.3)	7 (22.6)	95 (19.6)	22 (22.9)	16 (20.5)	0.887
	Total (n = 1342)	269 (20.0)	13 (24.1)	193 (19.6)	37 (13.0)	26 (20.3)	0.847

[a] χ^2 test or Fisher's exact test as applicable

parental education, BMI, and urban versus rural area and region (Table 4), the pattern for overweight did not change for boys (OR of anemia of 1.22 [0.68–2.18]) but slightly decreased in girls (0.94 [0.48–1.84]). The direction of the association of obesity and anemia also differed for boys and girls (OR 1.05 [0.55–2.02] for boys, OR 0.85 [0.38–1.86] for girls); however, they did not reach statistical significance. The association was neither significant when the categories of overweight and obesity were collapsed into one category (data not shown). To see whether the pattern of associations would differ for children living in GBAO, a remote mountain area with high levels of poverty, the analyses were restricted to the children living in this region. Neither the association of anemia with weight status nor with sex was statistically significant. Nevertheless, the effect size of comparisons within weight status categories was lower than those in the main sample (OR anemia 0.17 [0.02–1.70], OR 1.19 [0.44–3.23], and OR 0.35 [0.09–1.44], respectively, for underweight, overweight, and obese compared to normal weight).

Table 4 Predictors of anemia in children 25–60 months of age in a multivariable regression (n = 1320) stratified by sex, National Micronutrient Status Survey, Tajikistan, 2009

Factor	Value	Male			Female		
		OR (95% CI)	*P* value	*P* value (overall factor effect)	OR (95% CI)	*P* value	*P* value (overall factor effect)
Weight status	Underweight	1.07 (0.41–2.83)	0.883	0.937	1.49 (0.52–4.31)	0.455	0.842
	Normal	1.00 (reference)			1.00 (reference)		
	Overweight	1.22 (0.68–2.18)	0.503		0.94 (0.48–1.84)	0.858	
	Obese	1.05 (0.55–2.02)	0.874		0.85 (0.38–1.86)	0.675	
Age (months)	25–36	3.23 (1.90–5.49)	< 0.001	< 0.001	6.42 (3.47–11.89)	< 0.001	< 0.001
	37–48	1.23 (0.68–2.22)	0.482		2.99 (1.58–5.67)	0.001	
	49–60	1.00 (reference)			1.00 (reference)		
Parental (there should be ONE field, up to the category of higher	education)	None	1.35	(0.70–2.63)	0.370	0.357	1.12 (0.50–2.48)
0.788	0.902						
	Primary (Grades 1–9)	1.33 (0.77–2.29)	0.307		1.25 (0.69–2.26)	0.458	
	Secondary (Grades 9–11)	0.84 (0.45–1.57)	0.588		1.17 (0.60–2.26)	0.641	
	Higher Education	1.00 (reference)			1.00 (reference)		
Location	Rural	0.99 (0.53–1.87)	0.975	0.975	0.89 (0.44–1.80)	0.746	0.746
	Urban	1.00 (reference)			1.00 (Reference)		
Region	Dushanbe	1.38 (0.51–3.26)	0.465	0.039	1.38 (0.52–3.67)	0.514	0.207
	Khatlon	1.95 (0.95–4.00)	0.067		1.26 (0.57–2.77)	0.567	
	Sughd	1.00 (reference)			1.00 (reference)		
	DRD (Direct Rule District)	1.32 (0.64–2.72)	0.451		1.36 (0.61–3.02)	0.451	
	GBAO (Gorno-Badakhshan Autonomous Oblast)	2.88 (1.41–5.88)	0.004		2.34 (1.10–4.96)	0.027	

Generalized linear-mixed models for binomially distributed data were used. The effects of cluster and household were included as random effects in the models

OR odds ratio, *CI* confidence interval

P value < 0.001 for the intercept in both models

Discussion

In a large nationally representative sample of children aged 25–60 months in Tajikistan, an overall prevalence of anemia of 20.3% was observed in boys and 19.8% in girls which decreased with increasing age. One region, GBAO, a poor and remote mountain area with extremely difficult living conditions, emerged with a particularly high prevalence of 28%. The prevalence of overweight and obesity was 13.0 and 9.5%, respectively, and decreased as well with increasing age (overweight from 14.6% in those aged 25–36 months to 9.7% in those aged 49–60 months, and obesity from 12.1 to 6.2%). In multivariable analyses, obesity and overweight were not associated with anemia in this sample.

The overall prevalence of anemia in children aged 25–48 months of 20% is lower than in a previous survey when it was at 37% [Ministry of Health (Tajikistan) and United Nations Children's Fund (UNICEF) 2010]. It is considered a moderate level compared to rates found in other developing countries in Asia and Africa (McLean et al. 2009). More than every fifth child was overweight or obese. Obesity seems to be more prevalent in boys than girls, especially in those aged 49–60 months (8.9% compared to 3.6%). For the studied age group, overweight/obesity is reported to be increasing worldwide (Black et al. 2013). The prevalence rates of overweight and obesity among the population below 20 years in Tajikistan were reported to belong to the lowest in Central Asia (Ng et al. 2014). Because no national data were available for the studied age group, it remains unclear whether there was an increase of obesity in the early childhood in recent years.

Only one other study reported on the association of BMI and IDA for children aged 25–60 months and has found a dose–response relationship, with an increasing prevalence of ID with increasing BMI categories (Nead et al. 2004). Their findings were, however, based not only on Hb but also on the assessment of iron status (measurement of transferrin saturation, free erythrocyte protoporphyrin level, and serum ferritin levels). This may have increased the power of detecting an association between IDA and obesity. Further studies have investigated the association between overweight and ID in children of 5–12 years (Cepeda-Lopez et al. 2011) and in adolescents aged 11–15 years (Nead et al. 2004; Seltzer and Mayer 1963; Wenzel et al. 1962; Zimmermann et al. 2008), and reported a significantly increased risk of ID in overweight/obese children. Data obtained in children from transitional countries, such as Morocco and India, have suggested that the prevalence of ID increased as BMI increases from normal weight to obesity (Nead et al. 2004; Ng et al. 2014). Our findings rely on measurements of hemoglobin only, and the number of anemic obese children was very low in our sample, lowering the power to detect an eventual association.

There were no significant differences in sex-stratified analyses. In the youngest age group, anemia was more frequent in normal than overweight boys, but the reverse was true in those aged 37–48 months. However, these differences were statistically not significant. The proportion of anemia was almost identical in normal and overweight girls of both age groups. In sex-stratified multivariable analyses, the ORs for obesity were discrepant for boys and girls (but again, statistically not significant). A significant association was neither observed when collapsing overweight and obesity into one category. Larger samples are needed to substantiate whether the association of obesity and anemia is modified by sex. The only other study addressing BMI and IDA in children aged 25–60 months did not report on gender differences (Nead et al. 2004). To the best of our knowledge, this is the first study to address this association separately in boys and girls of 25–60 months of age.

The finding of a somewhat higher rate of anemia in normal than overweight boys and girls aged 25–36 months needs consideration. It can be only speculated that more physical activity among normal compared to overweight boys of this age might lead to higher environmental exposures associated with anemia (e.g., helminths). Breastfeeding seems unlikely to explain this pattern, as only 2% of mothers in our study reported to continue breastfeeding into the second year [Ministry of Health (Tajikistan) and United Nations Children's Fund (UNICEF) 2010]. Other nutritional infant feeding pattern may play a role, but this cannot be substantiated in our data.

The association between obesity and poor iron status has been attributed to erroneous nutrition habits with limited intake of iron-rich foods, as already suggested in the 1960s (Wenzel et al. 1962). Only more recently, it was suggested that hypoferremia in obesity is not associated with dietary factors but with a functional iron deficiency which is possibly related to insufficient iron stores or to diminished iron availability related to inflammation-induced iron sequestration (Cepeda-Lopez et al. 2011; Saloojee and Pettifor 2001). In this analysis, we did not evaluate if children had an iron deficient diet.

Adiposity in children aged 9–13 years predicted not only lower iron absorption but also reduced response to iron supplementation (Zimmermann et al. 2008). Thus, ID in overweight children may be due to adiposity-related inflammation reducing iron absorption (Baumgartner et al. 2013). The findings of a placebo controlled trial of iron supplementation in ID children aged 6–11 years supported the assumption that overweight children had a higher risk of persisting ID after oral iron supplementation(Baumgartner et al. 2013). Thus, lowering BMI would, indeed, improve the iron status and iron absorption (Amato et al. 2010). Research points to adverse effects of non-anemic iron deficiency, including impaired physical and cognitive conditions, and several studies observed that obese children had a higher rate of ID (Cepeda-Lopez et al. 2011). Where IDA is prevalent, effective control programs may yield benefits to human health [United Nations Children's Fund (UNICEF); United Nations University (UNU); World Health Organization (WHO) 2001].

There are some potential limitations to be reported. First, the findings of this study are based on the comparison between BMI and Hb levels and not on ferritin values which is used as biochemical evidence for ID (World Health Organization 2007), although this was actually the prior hypothesis. However, ID could not be used, because there was evidence of measurement problems for serum Ferritin. This concern was substantiated by a higher prevalence of anemia compared to the prevalence of ID (20% for Hb < 11 g/dl and 16% for Ferritin < 12 ng/l). IDA occurs when iron stores are exhausted and the supply of iron to the tissues is compromised. It would have been expected to observe more children having ID than anemia, whereas children with ID do not necessarily have a level of Hb < 11 g/dl (Burger and June 2002). Inaccuracies may have occurred during the procedures between sampling and laboratory analysis. Hb values were obtained on site by trained field workers using the validated field Hb analyzer (Hemocue^{TM}) (Burger and June 2002), and therefore, the margin of error should be minimal.

Although the study sample was large, the prevalence of obesity in children in Tajikistan was possibly too low to detect an association of anemia with obesity and eventual sex differences. Measurement errors regarding the anthropometric measures done by field workers cannot be excluded, although they all had undergone training, performed a quality control exercise, and were closely supervised on site. A further limitation is that residual confounding by factors not assessed in this study cannot be ruled out, in particular, effects of dietary patterns, deficiency of key micronutrients, or infectious diseases could not be taken into account.

In conclusion, on the background of the known negative consequences of ID, an association between obesity and ID may have important public health and clinical implications. In Tajikistan, an association of obesity and anemia could not be substantiated for children aged 25–60 months. It thus remains open whether in this age group, BMI reduction should be considered before iron substitution, and whether obese children of this age group should be routinely screened for ID and not only for anemia. However, the level of anemia in the early childhood—although improved when compared to a previous survey in Tajikistan—remains a relevant Public Health concern in this country, and interventions should continue to focus on the prevention of anemia. Further studies should assess iron status in addition to Hb in large study samples, with thorough control of measurement issues in the field.

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Compliance with ethical standards

Conflict of interest None of the authors have any conflicts of interest.

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