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RESEARCH ARTICLE

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Nutritional status of Ugandan school-children: The effect of age imprecision

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Abstract

Objectives: To analyze the nutritional status of Ugandan school-children in a cross-sectional and longitudinal perspective, considering the effect of age imprecision.

Materials and methods: Anthropometric measurements of 831 school-children (381 males and 450 females) were analyzed. A subsample of 246 children was measured in July 2014 and 2015. Stunting (based on height-for-age *Z*-scores), underweight (weight-for-age), and thinness (body mass index-for-age) prevalence were calculated. Three different ages were used: declared (from schools registers), attributed (based on multiple information sources), and bootstrap (from 10,000 replicates). Significant differences among malnutrition prevalence calculated with different ages and in different groups were assessed by means of bootstrap analysis. Longitudinal analysis was conducted using a paired *t* test.

Results: The mean prevalence of malnutrition calculated with declared, attributed, or bootstrap ages were very similar: stunting (11.9–12.7); underweight (5.4–5.9); thinness (3.3–3.7); and obesity (0.7). Undernutrition was more prevalent among older children, while obesity was mostly associated with young age. Obesity was equally distributed among sexes, while undernutrition was more prevalent among females of up to 10 years of age and males above 10 years.

The longitudinal analysis indicated a reduction in underweight and thinness, and an increase in stunting, especially among older children.

Discussion: Age imprecision did not significantly affect malnutrition estimates. Despite the decline in the prevalence of thinness and underweight observed over a 1-year period, undernutrition persists, with an observed rise in stunting. On the other hand, obesity is starting to appear. Public health efforts are required to eliminate stunting and address the emerging burden of obesity.

KEYWORDS

age error, malnutrition, school-children, Uganda

1 | INTRODUCTION

Despite a decreasing prevalence in undernutrition, millions of children are still stunted, underweight or wasted, mainly in sub-Saharan Africa (SSA) and South-East Asia (UNICEF, World Health Organization, & The World Bank, 2018). In Africa, modest progress has been observed and, due to population growth, the absolute frequency of undernourished children is on the rise (de Onis & Branca, 2016; NCD-RisC, 2017; UNICEF et al., 2018). Furthermore, childhood obesity is a health issue starting to affect this region (NCD-RisC, 2017; Ng et al., 2014; UNICEF et al., 2018).

Most research on child nutritional status in SSA focuses on children under the age of five, frequently using data retrieved from the internationally coordinated Demographic and Health Surveys (DHS) on households (ICF, 2018) or the Unicef-supported Multiple Indicators Clusters Surveys (MICS) (UNICEF, 2017). Information on the nutrition status of school-children is quite lacking. Available data mainly refer to particular groups of children, such as adolescents living in foster homes (Vogt, Rukooko, Iversen, & Eide, 2016), or children infected or affected by HIV (Nalwoga et al., 2010). Furthermore, even the comprehensive analysis on global trends in malnutrition among 128.9 million children, adolescents, and adults (NCD-RisC, 2017) is mainly based on information retrieved from DHS, and focused on children 0–5 years, or individuals within the reproductive age (15–49 years), mainly females. For sub-Saharan Africa, children aged 6–14 years are strongly underrepresented.

That said, malnutrition actually affects over 21% of school-children in Africa (Best, Neufingerl, van Geel, van den Briel, & Osendarp, 2010) and leads to immediate and long term consequences on their physical health and cognition (Best et al., 2010; Fink & Rockers, 2014; Turyashemererwa, Kikafunda, Annan, & Tumuhimbise, 2013). Those withstanding, malnourished adolescent mothers have higher chances of giving birth to malnourished new-born babies, thus generating a negative vicious circle that exacerbates the burden of malnutrition (de Onis & Branca, 2016).

One of the methodological challenges faced during nutritional assessment in sub-Saharan Africa is the insufficient and imprecise information on child age (Comandini, Cabras, & Marini, 2016; Comandini, Cabras, & Marini, 2017; Finaret & Hutchinson, 2018; Jeong, Bhatia, & Fink, 2018; Larsen, Headey, & Masters, 2019). In fact, without reliable information about a child's age, the indicators stunting, underweight, and obesity (defined in relation to sex and age), according to standard criteria (WHO, 1995) cannot be accurately calculated. For this, Bairagi, Edmonston, and Khan (1987) recommended the use of age-independent indices, such as weight-for-height or mid-upper-arm circumference, to overcome the problem of age error. However, these indices are suitable for use among children of-up to 59 months. Hence, in most cases, particularly in older children, nutritional analyses can be affected by coverage biases toward children with a valid date of birth, and information error in children whose knowledge of age is imprecise. Both selection bias and imprecision have an effect on malnutrition prevalence estimates (Comandini et al., 2016, 2017; Grellety & Golden, 2016). Particularly, Grellety and Golden (2016) estimated that even small errors in age can change the estimates of malnutrition prevalence substantially.

Although rich in natural resources, favorable conditions for agriculture, and is realizing steady health, economic and social transformation, Uganda is still deeply affected by malnutrition, poor access to health care, poverty, and disease (Government of Uganda, 2011; UBOS & ICF, 2018; Vogt et al., 2016). According to the 2016 Uganda Demographic and Health Survey (UBOS & ICF, 2018), 28.9% of children under five are stunted, 3.5% are wasted, 10.5% are underweight, and 3.7% are overweight (based on weight for height). Further, a substantial percentage (14%) of Ugandan children is orphans, thus stretching the Ugandan child protection structures and hindering the improvement of children's nutritional status (MGLSD, 2004; Vogt et al., 2016).

Relatedly, almost one out of four Ugandan girls 15–19 years old are already mothers, and they are also likely malnourished (Vogt et al., 2016). It is estimated that malnutrition is responsible for about 35% of deaths among children under five (Agaba, Pomeroy-Stevens, Ghosh, & Griffiths, 2016) and that it will cost Uganda about 7.7 billion US$ in lost productivity between 2013 and 2025 (Pomeroy-Stevens et al., 2016).

Just like other African countries, Uganda's response to the malnutrition challenge has mainly focused on children under 5 years. Further, the relationship between malnutrition and age imprecision has not been faced. Yet, the lack or uncertainness of birth data is common in Uganda (registration of children soon after their birth is 32.2%; UBOS & ICF, 2018), further reducing the possibility of evaluating and tracking childhood nutritional status (Comandini et al., 2016; Comandini et al., 2017).

The aim of this article was twofold: (a) To analyze the effect of age imprecision on nutritional estimates using data from a real context; and (b) to analyze the nutritional status of Ugandan school-children in a cross-sectional and longitudinal perspective, considering the effect of awareness actions.

2 | METHODS

Two surveys were carried out in July 2014 and July 2015 in four private primary schools located in the central region of Uganda. The research was linked to a collaborative project with a humanitarian non-governmental organization (NGO), the Bhalobasa association (www.Bhalobasa.it), which mainly supports child schooling. The project on nutritional status was planned with the Bhalobasa association, in consultation with the association of Ugandan schools "Kwagala" (Kampala, Uganda), a local non-governmental organization.

The study was approved by The Uganda AIDS Support Organization (TASO) independent ethics committee (TASOREC/020/18-UG-REC-009), head teachers of schools who are the legal custodians of the children while at school gave their informed consent to the study. The children also verbally assented to a nutritional assessment and general body examination

2.1 | The schools

The primary schools included in the research were selected based on social and geographical backgrounds: two of them are located in Kampala and two in a rural setting; within the two contexts, schools differ in internal organization (boarding children, feeding practice) and family characteristics of the students. Briefly, we provide details about each school below.

1. Nakinyuguzi Parent's School is located in the Kampala District, 5 km from the city center. Children attending the school come mainly from the middle socio economic class. However, children from lower socio economic class families are also present and supported by Bhalobasa. As for family characteristics, the presence of both parents is very high (about 95%) and the mean number of siblings for family is 3.7 (maximum 10). About 45% of the parents have had no formal education. All children have lunch at school, whose menu is mainly posho (corn flour) and beans. Children in the Baby and Middle classes (3–4 years) have also a snack (porridge) in the morning, on top of lunch. The school has no boarding section.
2. In Need Home School (INH) is a not-for-profit organization, located close to the Namuwongo slum, one of the biggest informal settlement areas in Kampala. The school aims at providing home support, care, protection, and education to orphans and other vulnerable children staying within the vicinities. As for family data, only 27.5% have fathers living in the household, while 58.8% of the mothers live with their children. Nearly 40% of children are total orphans (have no father or mother). All children attending the school have breakfast and lunch at school. Meals are offered based on a weekly schedule and include posho, and beans on a daily basis, and meat once a week.
3. Marengoni Primary School is located in Luweero, Nakaseke District, in Kikkumango Community, a rural setup 60 km north of the capital. Children attending the school mainly come from families within the low social economic status. A very high presence of both parents in the households (99.2%) was recorded. The mean number of siblings is 5.5. All the children have lunch at school. The teachers try to ensure that children get meals rich in carbohydrates (matoke, posho) and proteins (beans). A small group of students (30 children) is in the boarding section.
4. Gossace Primary School is located in Mukono District, Golomolo Community, an agricultural area 35 km south-east of the capital. All the children have lunch at school, and half of them are in the boarding section. These children mainly come from low socio economic settings, and most of them are orphans. The meals mainly consist of daily rations of beans with posho and weekly portions of chicken and potatoes. The school also has big fields where previously corn has been cultivated, however, in the last 2 years other edible plants (some of them rich in proteins) have been grown and are part of the current student's meals.

Majority of children, in all schools, belonged to the Bantu ethnic-linguistic group.

2.2 | The sample

We examined all children (*n* = 1,056; 3–16 years of age) that were found at the fore mentioned schools during the data collection period, representing more than 90% of all children attending each school. Of the study sample, 225 children (21.3%) were excluded from the analysis due to lack of reliable information on their age, or because of its high level of imprecision. The final sample of 831 children is described in Table 1. Age groups were defined considering stages in human growth (Bogin, 2001). However, we slightly modified the groups splitting the childhood stage into 3–5 and >5–7 years, in order to be consistent with a great body of the literature on child malnutrition (all DHS and MICS surveys, indeed) referring to children until 5 years of age. We have also extended the juvenile stage of girls (7–11 instead of 7–10) in order to account for the slower sexual maturation rates of girls living in worse socioeconomic conditions. The final groups considered were: childhood (two groups: ≥3 years ≤ 5 years and >5 years ≤ 7 years; juvenile: >7 years and ≤11 years (females) and >7 years and ≤12 years (males); adolescence: >11 years and ≤16 years (females) and >12 years and ≤16 years (males).

Longitudinal analysis was carried out in a subsample of 246 children, who were measured in both 2014 and 2015.

2.3 | Measurements

For all children, personal data and anthropometric measurements were collected. Information on the child's age, sex, and class level were obtained from different sources. In particular, child's date of birth has been collected at different intervals (2012, 2013, and 2014) mainly from school registers, seeking confirmations from teachers, nurses, or social workers registers. In most cases, birth data had been declared orally, without the exhibition of any birth certificate.

Anthropometric (height, cm; weight, kg) measurements were taken following standard international criteria (Lohman, Roche, & Martorell, 1988).

Data have been deposited in the University of Cagliari repository under an open access policy: http://hdl.handle.net/11584/265673.

2.4 | Nutritional status assessment

Body mass index (BMI) was calculated by dividing weight (in kg) by the square of height (in m). According to WHO criteria (, 1995) and to WHO Child Growth Standards (WHO, 2006), anthropometric indices of nutritional status (weight-for-age *Z*-scores: WAZ; height-for-age *Z*-scores: HAZ; body mass index-for-age *Z*-scores: BAZ) expressed in standard deviation units (*SD*) from the median of the reference population were calculated. Undernutrition was defined as an index below −2 *SD*: stunting (HAZ <−2), underweight (WAZ <−2), and thinness (BAZ <−2). Obesity was diagnosed when BAZ was above 2 *SD*. The WHZ index (Weight-for-Height/Length *Z* score) was calculated, but not included in the present analysis, because the WHO standards for WHZ are available only for children under five and hence only usable with a too few children of in the present sample.

TABLE 1 Sample composition of the 831 children examined for nutritional status

	Gossace		Marengoni		Parent's		In Need Home		Total	
Age group	M	F	M	F	M	F	M	F	M	F
≥2.9–≤5 years	1	2	3	6	10	19	6	11	20	38
>5 and ≤7 years	5	4	11	14	20	28	11	11	47	57
F: >7–≤11 years M: >7–≤12 years	47	25	61	57	41	49	29	37	178	168
F: >11–≤16 years M: >12–≤16 years	54	54	41	47	32	59	9	27	136	187
Total	107	85	116	124	103	155	55	86	381	450

Abbreviations: F = females; M = males.

2.5 | Awareness actions

In collaboration with the local public and religious organizations, and with the Bhalobasa NGO, awareness actions have been performed in all the schools. Training sessions have been organized in order to practice with teachers and nurses on methods for assessing children nutritional status. Moreover, health education sessions to families on the importance of hygiene and nutrition for proper child growth were carried out, with the contribution of school teachers and nurses.

2.6 | Statistical analysis

All the statistical analyses have been carried out using the free software R (https://www.R-project.org/; R Core Team, 2018).

2.7 | Effect of age imprecision

Nutritional indices and malnutrition prevalence were calculated considering the statistical effect of age imprecision, that is, taking into account the multiple information on the date of birth, in order to overcome the effect of age error. Three different variables describing age were defined as follows:

- Age declared: the age registered at the moment of the measurement (in most cases, the one available from school archives).
- Age attributed: an age arbitrarily assigned on the basis of different sources of information, and according to the following criteria. When only the child's age in years, or just the year of birth was declared, the date of birth as July 1st (middle of the year) was assigned. When the different ages declared did not coincide, the mean age was assigned. However, when one of the different declared ages was evidently more accurate than the others (such as when one date was complete of day, month, and year, and the other ones reported only the year), this was the age attributed. When the difference between dates from various sources was higher than 2 years, the case was excluded from the analysis.
- Age bootstrap: the age derived from randomly assigning 10,000 times to each child each supposed ages and thus obtaining 10,000 different samples of children with their age supposed to be known exactly. This implies a mean bootstrap age for each child and a joint probability for the ages of all children in the sample. It also implies that all the sources of birth data were considered equally reliable.

A Student's t test was applied to compare the mean values of declared, attributed, and bootstrap ages. A Pearson's chi-squared test with approximated p-value (by simulating 10,000 replicates of the contingency table) was applied to compare age distribution within schools. Malnutrition prevalence calculated using different ages (declared, attributed, and bootstrap) were compared with the bootstrap analysis.

2.8 | Nutritional status

Malnutrition prevalence in the two sexes (based on HAZ, WAZ, BAZ), among age groups and among schools (considering age groups) were compared using bootstrap analysis.

Longitudinal analysis was performed using attributed ages and comparing malnutrition indices calculated in 2014 and 2015 with a paired t test. Two-factor ANOVA was applied to compare the change in nutritional status (as indicated by the difference between nutritional indexes calculated in 2015 and 2014) among children of different schools and with different age groups.

3 | RESULTS

Mean differences among declared, attributed, and bootstrap ages did not reach the significance level, with high standard deviation values, related to both interchildren and intrachild, that is, age imprecision—variability (Table 2).

Bootstrap analysis showed that age imprecision did not significantly affect mean malnutrition estimates. In fact, for all the indicators, the prevalence calculated with declared, attributed, or bootstrap ages were very similar: stunting (11.9–12.7); underweight (5.4–5.9); thinness (3.3–3.7); and obesity (0.7–0.7) (Table 3, Figure 1; Table S1 with more detailed information). The prevalence of severe undernutrition calculated with three different ages was similar too (stunting: 1.2–1.4; underweight: 0.2–0.3; thinness: 0.6–0.7) (Table 3). The variability of the prevalence estimated with bootstrap due to age imprecision had a magnitude of 1% (prevalence standard deviation) for stunting and underweight, 0.6% for thinness, and 0.3% for obesity.

TABLE 2 Statistical comparisons of the three age estimates

	Declared		Attributed		Bootstrap	
Age group	Mean	ds	Mean	ds	Mean	ds
≥2.9–≤5 years	46.4	8.4	47.3	8.3	46.9	8.5
>5 and ≤7 years	70.4	7.3	71.5	6.9	70.6	7.2
F: >7–≤11 years M: >7–≤12 years	110.5	14.2	109.2	14.1	109.7	14.4
F: >11–≤16 years M: >12–≤16 years	158.8	18.5	158.5	18.5	157.5	18.0
Total	121.2	40.1	119.3	38.9	121.1	38.2

Abbreviations: F = females; M = males.

TABLE 3 Prevalence of malnutrition calculated with the three different ages

	Age declared	Age attributed	Age bootstrap
HAZ			
Mean	−0.67	−0.70	−0.69
SD	1.18	1.15	1.16
<−2 (%)	11.9	12.7	12.5
<−3 (%)	1.4	1.4	1.2
WAZ			
Mean	−0.43	−0.48	−0.46
SD	1.02	1.01	1.00
<−2 (%)	5.4	5.8	5.9
<−3 (%)	0.3	0.2	0.2
BAZ			
Mean	−0.43	−0.40	−0.40
SD	0.89	0.88	0.88
<−2 (%)	3.7	3.3	3.3
<−3 (%)	0.7	0.6	0.6
>2 (%)	0.7	0.7	0.7

Abbreviations: BAZ = body mass index-for-age *Z*-score; HAZ = height-for-age *Z*-score; WAZ = weight-for-age *Z*-score.

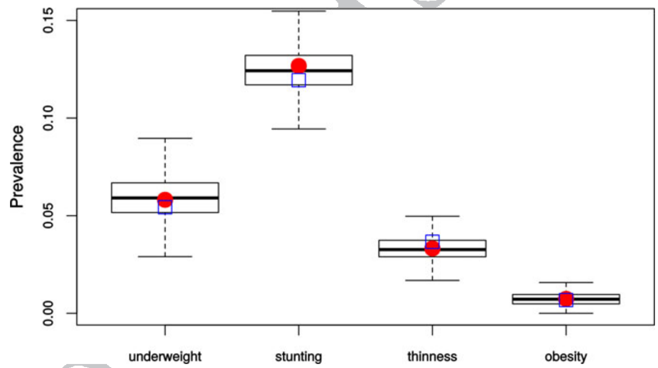

FIGURE 1 Prevalence of malnutrition calculated with bootstrap analysis (box-plots) and based on age attributed (red) or age declared (blue)

Undernutrition increased with children's age, while obesity was more prevalent among younger children (Figure 2). Obesity was equally distributed between the two sexes, while undernutrition differed with sex, depending on children's age. In fact, among children under 10 years, females showed a higher prevalence of underweight, and, to a lesser degree, of stunting and thinness, whereas above 10 years of age males showed a significantly higher prevalence of stunting and thinness (Figure 2).

The differences among age groups were also evaluated considering school variability, as age distribution was different in the four schools examined (χ-squared = 130.1, *p*-value ≈ .000). Undernutrition was more prevalent in children belonging to Groups 3 and 4 (the older ones) in all schools, and also in younger children from In Need Home School, while obesity was more frequent among younger children in the two schools from Kampala (Figure 3).

The longitudinal analysis over the 2014–2015 period showed, in both sexes, a general increase of BAZ (t = 2.7, p = .007), a tendency to the increase of WAZ (t = 1.6, p = .114), and a decrease of HAZ scores (t = −5.2, p ≈ .000). The prevalence of malnutrition changed accordingly, thus showing a reduction of underweight and thinness, and an increase of stunting (Table 4). The longitudinal change of HAZ scores was significantly influenced by age (F = 4.8; p = .003), as younger children showed a decrease of stunting, whereas the older ones showed an increase. The longitudinal change was also significantly affected by the school (WAZ: F = 6.8; p = .001); in fact, children from Nakinyuguzi Parent's School showed a decrease in underweight, while those from Marengoni Primary School showed an increase.

4 | DISCUSSION

4.1 | Age imprecision

Among the sample of Ugandan children analyzed in this research, despite the attention given to collect age data, information on age remained affected by systematic and random error. In fact, we excluded 225 children (21.3%) from the total sample, due to their lack or incorrect dates of birth. Such exclusion represents an unintentional selection bias that likely caused the underestimation of undernutrition, according to the results of Comandini et al. (2016) and Jeong et al. (2018). Indeed, children whose births are more accurate generally belong to the better-educated and also better-nourished segments of the population (Comandini et al., 2016). Moreover, for most

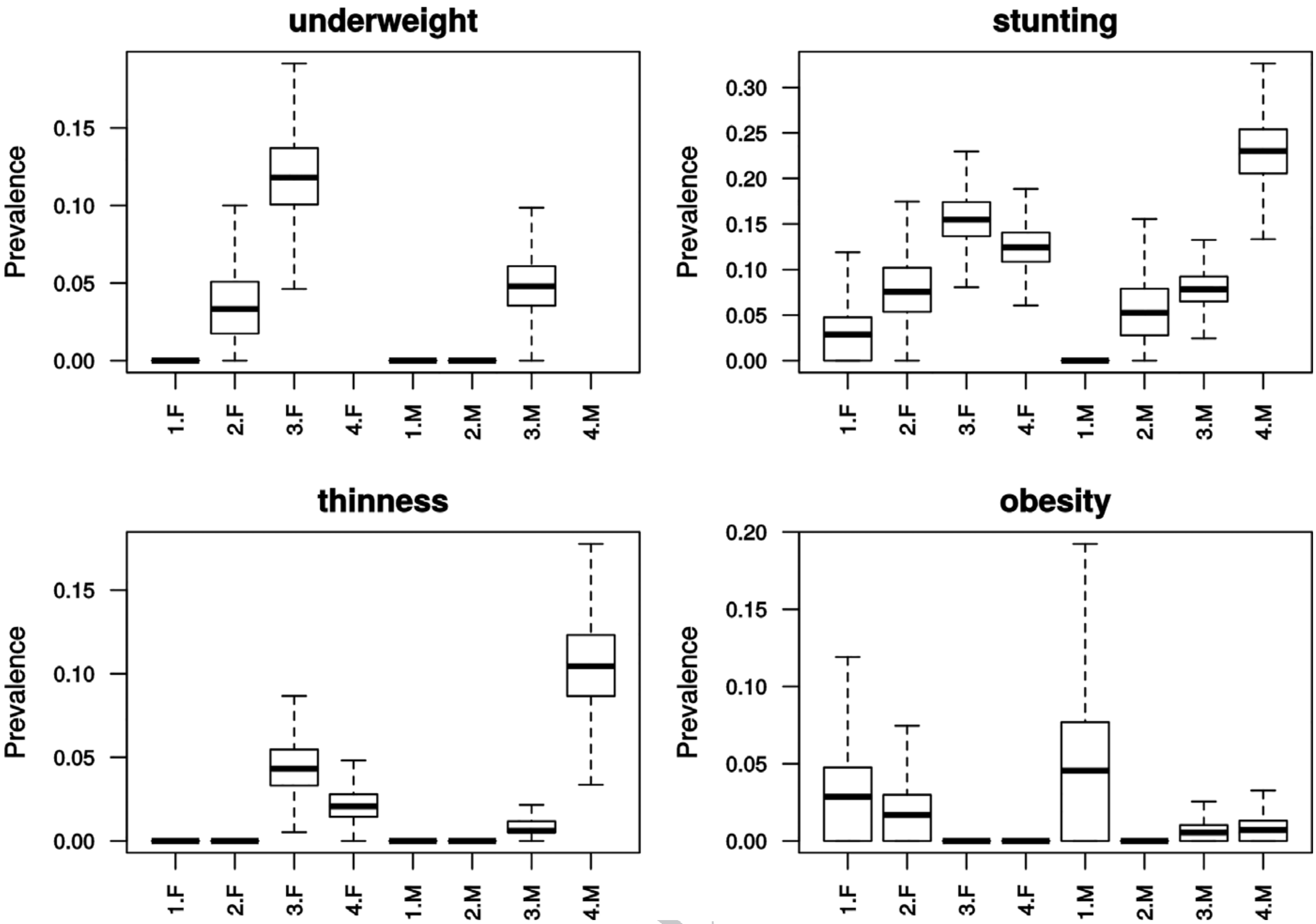

FIGURE 2 Conditional distributions of malnutrition in age classes and sexes (females: F; males: M). Age group 1: ≥2.9 and ≤5 years; age group 2: >5 and ≤7 years; age group 3: >7 and ≤11 years in females, >7 and ≤12 years in males; age group 4: >11 and ≤16 years in females, >12 and ≤16 years in males

children with age data, we detected high levels of imprecision. In fact, as shown in more details elsewhere (Comandini et al., 2017), the mean range of age from two different sources was equal to 7.5 (±8.8) months.

The existing differences due to age imprecision compensated each other and did not cause a significant difference between the mean of different ages, even contributing to increase the variability of the distributions. As discussed by Comandini et al. (2016) and Grellety and Golden (2016), under the assumption of equal probability of deviations in excess and in deficit, age imprecision has no effect on the mean age, but can strongly affect malnutrition estimates, producing an overestimation of malnutrition, especially of stunting. However, in our sample, bootstrap analysis, that allowed us to estimate the potential error of the variability linked to the imprecision of age data, showed that the mean prevalence of malnutrition was not significantly affected by age imprecision. To be noted, however, that the previous studies (Comandini et al., 2016; Grellety & Golden, 2016) were based on DHS datasets, that is, on children under five, and that the magnitude of the observed effect is related to the child's age, being greater in younger children (Bairagi, 1986; Comandini et al., 2016; Gorstein, 1989). Thus, it is likely that school-children are less, not strongly, affected by age imprecision.

Bootstrap analysis also allowed us to investigate differences of nutritional status among subsamples, considering the imprecision of age data. This was done without assuming any specific sampling distribution of ages in a nonparametric statistical fashion. In this way, we detected a different pattern of malnutrition in the two sexes, in different age groups and in the four schools.

4.2 | Age differences

In our study, children from higher age groups displayed a higher prevalence of undernutrition, especially of stunting, and lower prevalence of overnutrition. Such results remained unchanged when considering environmental variability, that is, despite schools' differences in terms of organization, environment, and social context. This finding is in agreement with the literature on school-aged children in sub-Saharan Africa, that consistently report an accruing of nutritional status with age (Acham, Kikafunda, Tylleskar, & Malde, 2012 [for underweight and thinness, but not for stunting]; Chesire, Orago, Oteba, & Echoka,

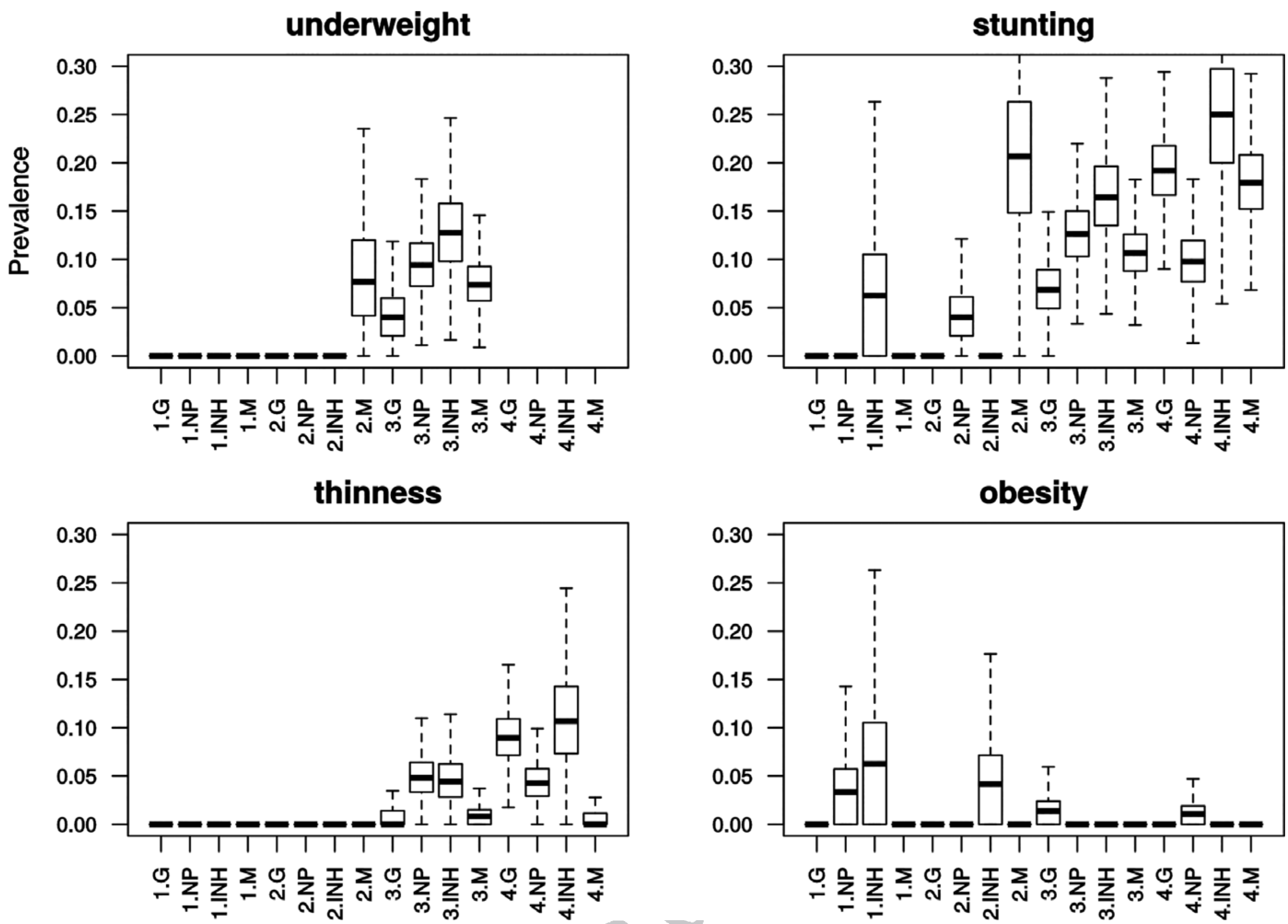

FIGURE 3 Conditional distributions of malnutrition in age classes and schools. 1G, 2G, 3G, age classes 1, 2, 3, respectively at Gossace; 1NP, 2NP, 3NP, age classes 1, 2, 3, respectively at Nakinyuguzi Parent's School; 1INH, 2INH, 3INH, age classes 1, 2, 3, respectively at In Need Home School; 1M, 2M, 3M, age classes 1, 2, 3, respectively at Marengoni School. Age group 1: ≥2.9 and ≤5 years; age group 2: >5 and ≤7 years; age group 3: >7 and ≤11 years in females, >7 and ≤12 years in males; age group 4: >11 and ≤16 years in females, >12 and ≤16 years in males

TABLE 4 Malnutrition prevalence (%) in the total sample, according to attributed ages

HAZ <−2 (*n* = 246)		WAZ <−2 (*n* = 171)		BAZ <−2 (*n* = 246)		BAZ > 2 (*n* = 246)	
2014	2015	2014	2015	2014	2015	2014	2015
15.2	17.5	7.9	4.4	4.8	3.0	0.0	0.0

Abbreviations: BAZ = body mass index-for-age *Z*-score; HAZ = height-for-age *Z*-score; WAZ = weight-for-age *Z*-score.

2008; Comandini et al., 2018; Fiorentino et al., 2013; Friedman et al., 2005; Lwanga, Kirunda, & Orach, 2012; Saltzman et al., 2017; Turyashemererwa et al., 2013). Indeed, school-children, especially the older ones, may not assume a sufficient intake of micronutrients or macronutrients to satisfy the *greatest demands* during the adolescent growth spurt, or to experience a catch-up (Fink & Rockers, 2014; Fiorentino et al., 2016).

We also detected an incipient increase in obesity, especially among younger children from urban schools. Due to their smaller dimensions and slower height growth velocity, younger children are likely more sensitive to the effects of the reduced breastfeeding period and the earlier use of junk foods (Ramírez-Vélez, 2012). Furthermore, urban children have different lifestyle and greater opportunity to consume energy-dense foods as compared to colleagues from rural schools. Relatedly, literature shows a rise in prevalence of obesity, affecting both industrialized and low-middle-income countries, including Sub-Saharan Africa (NCD-RisC, 2017; Ng et al., 2014; Steyn & McHiza, 2014; UNICEF et al., 2018).

4.3 | Sex differences

The pattern of sex differences in malnutrition changed with children's age, except for obesity prevalence, that was similar in the two sexes in all age groups. Until the age of 10 years, females were more underweight than males, afterward males appear more stunted and thinner. This period precedes the puberty: a phase of critical anthropometric and body composition changes, leading to adult sexual dimorphism. The literature on the rates of maturation and growth in SSA adolescents is quite scanty. Only rarely, to the best of our knowledge, studies on malnutrition in SSA school-children include information on pubertal ages, and, when it happens, only give data for females (Leenstra et al., 2005). However, the trend of growth is different in malnourished adolescents with respect to a reference population of well-nourished adolescents (WHO, 1995); hence, it should be better investigated in future studies.

The results of other researches on sex differences in malnutrition among SSA school-children are quite heterogeneous. Researches among Ugandan school-children showed no sex differences (Zhao, 2015), or a higher risk of undernutrition among males (Acham et al., 2012; Lwanga et al., 2012). Further, Uganda's national data on children under five reported a slightly poorer nutritional status among males (UBOS & ICF, 2018). Considering studies on school-children in other SSA, a similar inconsistent scenario of sex differences has been reported, with males showing lower (Comandini et al., 2018; Chesire et al., 2008, relative to wasting), similar (Fiorentino et al., 2013), or higher risk of malnutrition (Chesire et al., 2008, relative to stunting; Saltzman et al., 2017).

4.4 | External comparisons

The nutritional status of study children appears to be tangentially better than that of other children of similar age from other parts of Uganda. In fact, the prevalence of malnutrition obtained using attributed, declared, and bootstrap ages were inside or toward the lower edge of the range of values reported in the literature. In fact, the prevalence of malnutrition of school-children in Central (Lwanga et al., 2012; Turyashemererwa et al., 2013) and eastern Uganda (Acham et al., 2012) ranged between 6.6 and 22.5 for stunting, 5.3 and 13.0 for underweight, and 3.3 and 10.1 for thinness. This situation could be a result of the attention and care of all the schools in feeding their students, proposing them meals that can offer the best nutrient intake possible. On the other hand, research on overweight and obesity among 12–15 year adolescents in Uganda and Ghana (Peltzer & Pengpid, 2011) reported a prevalence of obesity of 0.9% in girls and 0.5% in boys, which was higher with respect to our study population of similar age (0.3–0.4; Table S1), and similar to those observed in the whole sample of students aged 3 to 17 years (0.7%; Table S1), but lower to those of children under 7 years (4.3% and 1.2%; Table S1). These results indicate that the global increase in obesity is starting to affect Ugandan children, especially the youngest ones.

4.5 | Longitudinal analysis

Longitudinal analysis over a 1-year period showed an increase in stunting, stable values for underweight and a general decline in thinness. The only school (Marengoni) where an increase of thinness was observed is located in the Nakaseke District, where in 2014–2015 several floods occurred, destroying crops and generating a food emergency (personal communication).

The increasing trend of stunting was significantly affected by age, with older children more affected. These findings are consistent with the results of other longitudinal studies on the nutritional status of older children and early adolescents in SSA (Comandini et al., 2018; Friedman et al., 2005).

The different longitudinal trend of the three nutritional indicators is likely related to their different properties, with stunting that mainly reflects long-term malnutrition and requires time and a high quality diet to be recovered, whereas underweight and, especially, thinness are more sensitive to environmental changes and less dependent on the uptake of particular nutrients, or micronutrients. Similar arguments explain why underweight and thinness are sensitive to policies, programs, and awareness actions on health and nutrition, while there is poor evidence on the beneficial effects of health and nutrition interventions on stunting (Bhutta et al., 2013; Dangour et al., 2013; Nabwera, Fulford, Moore, & Prentice, 2017). In this research, awareness actions that promote hygienic rules and diet at schools have started to show their benefits. Schools are moving in the right direction; however, more time is needed to verify if these efforts can lead to a reduction of stunting, besides of thinness and underweight.

4.6 | Strengths and limitations

This study has demonstrated several points of strength. First, this is one of the very few nutritional researches where the quality of age data has been checked, the coverage bias mentioned, and age imprecision analyzed to evaluate the error on malnutrition estimates. Second, the design of the study is based on a cross-sectional plus longitudinal analysis in different schools and refers to school-aged children, who are poorly represented in the literature on child nutrition. Third, the research was associated with awareness actions aimed to sensitize teachers, nurses, and parents on the relevance of nutrition and hygiene for the proper growth of children. Last but not least, the collaboration with an NGO represented a useful approach for affording the public health issue of malnutrition, improving on the validity and utilization of findings, hence adding concreteness to scientific results.

However, the study has also some limitations. First, we could not elude the bias due to the lack of birth data, interesting a large proportion (21.3%) of the initial sample, hence probably leading to underestimating undernutrition. Second, we were not able to analyze the effect of family characteristics. In fact, children had very different kinds of relationships with their families (if present) and different family structures; further, schools had different kinds of the organization (boarding children, number and type of meals distributed), and parent's characteristics have a different impact in each school. Third, a 1-year of observation is a time frame too short for detecting a clear trend, especially for stunting, whose recovery is difficult and gradual.

5 | CONCLUSION

This study showed that age imprecision did not affect significantly malnutrition estimates in the analyzed sample of Ugandan school-children.

However, malnutrition is still prevalent among children from both urban and rural Uganda. Despite the slight, albeit clear, decrease of thinness and underweight observed in a 1-year period, undernutrition persists in all the schools, and stunting is even accruing, especially in older children. On the other side, obesity is starting to appear and is on the rise more so among children under 5 years.

These results indicate that factors like children's diet and food quality may be an issue of public health importance. Well as several efficient awareness actions have been realized, greater cooperative efforts, particularly stronger Water, Sanitation and Hygiene (WASH) interventions and public health actions focused on school-children as well as their mothers, are required to significantly improve children's nutrition, health and environments, in order to eliminate stunting, and avert obesity.

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CONFLICT OF INTEREST

All authors declare no competing conflicts of interest.

AUTHOR CONTRIBUTIONS

C.O. and M.E. conceptualized the study developed the proposal, led data collection and analysis, wrote the manuscript. S.J.T., C.Ga., and C. Gi. supported data collection. S.J.T. sought study approval. C.S. designed the statistical analysis and analyzed study data. All the authors reviewed the proposal and participated in reviewing the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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