Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review

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Abstract

Background: Prevalence of childhood overweight/obesity has increased considerably in recent years. The transition to higher rates of overweight/obesity has been well documented in high income countries; however, consistent or representative data from lower income countries is scarce. It is therefore pertinent to assess if rates of overweight/obesity are also increasing in lower income countries, to inform public health efforts.

Objective: This systematic review aimed to investigate the evidence for an overweight/obesity transition occurring in school-aged children and youth in Sub Saharan Africa.

Methods: Studies were identified by searching the MEDLINE, Embase, Africa Index Medicus, Global Health, Geobase, and EPI-Centre electronic databases. Studies that used subjective or objective metrics to assess body composition in apparently healthy or population-based samples of children and youth aged 5 to 17 years were included.

Results: A total of 283 articles met the inclusion criteria, and of these, 68 were used for quantitative synthesis. The four regions (West, Central, East, and South) of Sub Saharan Africa were well represented, though only 11 (3.9%) studies were nationally representative. Quantitative synthesis revealed a trend towards increasing proportions of overweight/obesity over time in school-aged children in this region, as well as a persistent problem of underweight. Weighted averages of overweight/obesity and obesity for the entire time period captured were 10.6% and 2.5% respectively. Body composition measures were found to be higher in girls than boys, and higher in urban living and higher socioeconomic status children compared to rural populations or those of lower socioeconomic status.

Conclusions: This review provides evidence for an overweight/obesity transition in school-aged children in Sub Saharan Africa. The findings of this review serve to describe the region with respect to the growing concern of childhood overweight/obesity, highlight research gaps, and inform interventions.

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Introduction

Worldwide populations are facing “modern” health risks due to increasing prevalence of overweight and obesity (overweight/obesity), physical inactivity, and sedentary behaviours, which are associated with obesogenic environments. This has caused a shift in the major causes of death from “traditional” health risks associated with poverty such as undernutrition, unsafe water, and poor sanitation, to a growing burden of modifiable non-communicable diseases (NCDs) [1]. The World Health Organization (WHO) classifies overweight/obesity as the fifth leading cause of global mortality, and one of the greatest health challenges and determinants for various chronic diseases such as heart disease, hypertension, diabetes, and psychosocial problems, in the 21st century [1,2–6]. This growing population health threat has garnered much attention in view of the declaration and global campaign on the prevention and control of NCDs signed by the United Nations in 2011 [7].

While the health benefits of maintaining healthy body weights and an active lifestyle are well established [6], consumption of calorie-dense foods, declines in habitual physical activity, and increases in sedentary behaviour have been on the rise across developing nations [8]. Traditional practices such as walking long distances, and habitual physical labour have been replaced by motorized transport, and sedentary activities, particularly in urban settings [9]. Furthermore, in many Sub Saharan Africa (SSA) countries, an increased level of body fat is associated with beauty,
prosperity, health, and prestige, while in contrast, thinness is perceived to be a sign of ill health or poverty [9]. These factors are now leading to increases in the occurrence of overweight/obesity and related risk factors for NCDS in SSA’s children and youth [1,9].

The health risks associated with overweight/obesity are particularly problematic in children due to the potential for long-term health concerns. A growing body of evidence has shown that overweight/obesity in childhood is significantly associated with increased risk of obesity, physical morbidity, and premature mortality in adulthood [10,11,12]. Fortunately, children who are able to attain a normal weight by adolescence have better cardiovascular disease risk factor profiles when compared to those that remain overweight [10]. Childhood is therefore a crucial time to learn basic life skills, including proper nutrition, and how to accumulate sufficient levels of activity in order to attain healthy body weights.

While we must recognize the diversity of populations in SSA, there are certain long-term developmental problems in this region that tend to adversely affect most or all of its countries and peoples [13]. Being the poorest continent in the world, with the highest population growth rate, the concern for an immense double burden of disease due to persistent infectious diseases and modern risks such as an overweight/obesity transition is troubling. The need for population wide interventions to reduce or prevent the adoption of less healthy lifestyles and body weights, particularly for children in SSA has never been greater [9,14].

The objective of this systematic review was to determine if SSA is indeed undergoing an overweight/obesity transition. Specifically, this review aimed to examine time trends in the proportions of overweight/obesity in school-aged children and youth in SSA, thereby highlighting any research gaps and identifying areas of need for healthy active living interventions.

Methods

Study inclusion criteria

Studies were included if they reported using either subjective (e.g., parent or self-report questionnaires) or objective (e.g., directly measured) measures of body composition (weight, height, body mass index, waist/hip circumference, skin-folds, or body image assessment) in children aged 5–17 years. No date or language limits were set, but due to feasibility, only studies presented in either English or French were included. In addition, only studies of populations from SSA countries were included.

Study exclusion criteria

All published, peer-reviewed studies were eligible for inclusion; however, in order to obtain information on a general population living under ordinary conditions, intervention programs and studies were excluded unless they conducted baseline assessments. Studies done on children with chronic conditions were excluded.

Search strategy

Studies were identified using the following electronic databases: Ovid MEDLINE (1948 to May, Week 4, 2013), Ovid Embase (1974 to Week 21, 2013), Africa Index Medicus (database dates not available, latest search on June 3, 2013), Global Health (1973 to June 3, 2013, through the CAB direct interface), Geobase (1804-June 3, 2013 through the Engineering Village interface), and EPPI-Centre database of health promotion research (Bibliomap) (dates of coverage not available, latest search on June 3, 2013). In addition, several open access journals relevant to SSA were identified and those journal web sites were searched for additional relevant papers. The search strategy for this systematic review was completed in tandem with a sister publication examining the evidence for a physical activity, sedentary behaviour, and physical fitness transition among school-age children and youth in SSA; hence, the inclusion of these terms in the search strategy. The search strategy was created and run by MS. The complete search strategy used for MEDLINE is presented in table 1. The PRISMA flow chart in figure 1 accounts for the number of articles included to inform this systematic review. References were exported, de-duplicated and reviewed using Reference Manager Software (Version 11, Thompson Reuters, San Francisco, CA). Titles and abstracts of potentially relevant articles were screened by two independent reviewers (SKM and one of CEF or LJW), and full text copies were obtained for articles meeting initial screening criteria. Full text articles were screened in duplicate for inclusion in the review (SKM and one of CEF or LJW), and any discrepancies were discussed and resolved by the reviewers. This review is registered with the international prospective register of systematic reviews PROSPERO network (registration number: CRD42013004399); available at http://www.crd.york.ac.uk/prospero/.

Data extraction, quality assessment, and synthesis

Data extraction was completed using a standardized data extraction template (SKM, CEF, AGL, and LJW). Study quality was assessed by SKM and CEF using a modified Downs and Black instrument [15]. Due to limitations in study design, questions selected from the Downs and Black quality assessment instrument excluded any questions that referred to intervention and trial study methodology. Ten out of the possible 27 questions were used for quality assessment as represented in table 2. Table 3 provides the score out of ten for all studies included in this systematic review. Due to heterogeneity in study methodology and cut-points used to categorize samples into under, healthy, overweight, and obese, we were unable to carry out a meta-analysis in this review. However, quantitative syntheses were conducted by calculating the weighted averages (by sample size) of the prevalence of overweight/obesity. Our goal was to examine time trends and therefore compute an overall prevalence of overweight/obesity in the region, by comparing the crude rates or prevalence of overweight/obesity in the individual populations or samples. As such, we attempted to standardize the crude rates by acknowledging and adjusting with respect to the sample sizes in each of the included studies, and indicating graphically the sample size upon which a particular data point was based. Findings from the quantitative synthesis were also complemented with narrative syntheses of the included studies.

Results

Figure 1 shows the PRISMA flow chart with numbers of included and excluded articles at each step of the review process, while table 3 provides a summary of all studies that met the inclusion criteria. A total of 2657 records were identified through database searches and other sources. Following de-duplication, 2242 articles were screened for eligibility, and 663 articles were selected for a full-text review. Of these, 283 articles met the inclusion criteria, and 68 of the studies (comprising 190,149 participants) were used in quantitative synthesis. Reasons for exclusion included: ineligible population (e.g., studies that did not involve children 5–17 years of age with no pre-existing condition) (n = 181); ineligible country (e.g., population living in a country/region outside of SSA) (10); ineligible outcome (n = 122); or ineligible study design (n = 67). It is important to note that all the studies included in this review were
found to have used objective methods of collecting body composition data.

Regional representation

As shown in Table 3, which includes a summary of the 283 studies included in the review, the four regions of SSA were well represented, with 91 (32.1%) from West African countries - with Nigeria represented in 60 of these records; 7 (2.5%) from Central African countries; 75 (26.5%) from East African countries - with Kenya represented in 28 of these records; 108 (38.2%) from South African countries - with South Africa represented in 102 of these records; and 2 (0.7%) that were East and West combined. In total, 27 countries were captured in this review.

Publication rate

The earliest relevant record captured was published in 1964. There was a marked increase in the publishing rate from the earliest to the current studies: 5 articles between 1960 and 1969, 15 from 1970–1979, 32 from 1980–1989, 31 from 1990–1999, 92 from 2000–2009, and 108 articles from 2010 to May/June 2013.

Data quality assessment

The average modified Downs and Black score out of ten for all studies included in this systematic review was 7.4; indicative that data quality was fairly high among the included records, within the prescribed limitations of study designs included in this review. The majority of studies used in the quantitative synthesis scored 7 or higher. As presented in Table 3, the scoring process further revealed that only 38 (13.4%) of 283 included articles targeted a sample that was representative of their population of interest, and 31 (11.0%) recruited a sample that was representative of their population of interest. Only 11 (3.9%) articles explicitly mentioned using a nationally representative sample, one of which used the same study sample as that of another already included study.
Body composition measures

Of the 283 included studies, 88 (31.1%) articles [16–103] reported on mean BMI, BMI-z-score, and/or weight z-scores of the sample population, 50 (17.7%) articles [104–153] reported on body fat percentage, waist circumference, skin fold measures, and/or weight and height measures, and a total of 30 (10.6%) articles [154–183] reported finding no prevalence of overweight/obesity in their study samples. Of the remaining 115 (40.6%) records, 82
articles [184–265] used the more widely accepted international cut-points (namely, the International Obesity Task Force (IOTF), the Centers for Disease Control and Prevention (CDC), and the most recent WHO cut-points) to further categorize their samples into underweight, normal-weight, and overweight/obese. The other 33 articles [266–298] mentioned using one of a number of other cut-points and reference standard groups including but not limited to Tanner et al., 1966, Seoane & Latham, 1971, Frisancho 1990, Rosner et al., 1998, Harvard Standards, Waterlow 1972/77, and various US and UK reference samples. Of the 30 studies reporting no prevalence of overweight/obesity, a majority had not used the more widely accepted international cut-points, while the reminder did not provide the required prevalence estimates to be included in the quantitative synthesis.

Quantitative synthesis

Of the 82 articles that used more widely accepted international cut-points, 11 studies [187,191,192,198,206,215,224,225,234,246,265] were removed due to having an identical study sample as an already included study, and 3 studies [214,218,264] were removed for having not indicated the sample sizes in the age range of interest. As represented in table 4, the remaining 68 (24.0%) articles [184–186,188–190,193–197,199–205,207–213,216,217,219–223,226–233,235–245,247–263] were used in quantitative synthesis. Of these, the largest proportion (44.1%) used the IOTF cut-points [299], 30.9% used CDC cut-points [300], and 25.0% used the most recent WHO cut-points [301] for weight status. Briefly, the IOTF methodology involved obtaining the body mass index for children from six large nationally representative cross sectional surveys on growth from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. Thereafter, centile curves for body mass index were constructed for each dataset by sex, and passed though the widely used cut off points of 25 and 30 kg/m2 for adult overweight and obesity at age 18 years. The resulting curves were averaged to provide age and sex specific cut off points for children 2–18 years of age [299]. In the case of the CDC cut-points, growth charts were developed based on data from five national health examination surveys conducted in the United States, including limited supplemental data. Smoothed percentile curves were created by first smoothing selected empirical percentiles, then creating parameters obtain the final curves, additional percentiles, and z-scores [300]. Finally, the

| Table 2. Modified Downs and Black checklist (Downs & Black, 1998). |
|---------------------------------------------------------------|
| **Reporting**                                                   |
| Objective Clearly Stated                                       | Question 1 from full checklist (Y = 1/N = 0) |
| Main Outcomes Clearly Described                                | Question 2 (Y = 1/N = 0)                      |
| Patient Characteristics Clearly Defined                        | Question 3 (Y = 1/N = 0)                      |
| Main Findings Clearly Defined                                  | Question 6 (Y = 1/N = 0)                      |
| Random Variability in Estimates Provided                       | Question 7 (Y = 1/N = 0)                      |
| Actual Probability Values Reported                              | Question 10 (Y = 1/N = 0)                     |
| **External Validity**                                          |                                               |
| Sample Targeted Representative of Population                   | Question 11 (Y = 1/N = 0)                     |
| Sample Recruited Representative of Population                  | Question 12 (Y = 1/N = 0)                     |
| **Internal Validity/Bias**                                     |                                               |
| Statistical Tests Used Appropriately                           | Question 18 (Y = 1/N = 0)                     |
| Primary Outcomes Valid/Reliable                                | Question 20 (Y = 1/N = 0)                     |

The weighted averages (for the entire time period and all studies included in the quantitative analysis) of overweight/obesity proportions in boys and girls were calculated as 7.6% and 15.4% respectively. Weighted averages of obesity alone for boys and girls were 2.0% and 3.9% respectively. Weighted averages of overweight/obesity and obesity proportions for boys and girls combined were 10.6% and 2.5%. Weighted proportion of overweight was calculated as 25.0% for boys, 8.3% for girls, and 17.6% for boys and girls combined.

**Narrative synthesis**

Narrative descriptions of the relationship between body composition and age, sex, socioeconomic status (SES), and urban/rural differences are discussed below based largely on the studies not included in the quantitative synthesis:

Figure 2 shows a distinctive time trend towards increasing proportions of overweight/obesity in school-aged children in SSA. The figure also shows a similar but less prominent trend towards increasing proportions of obesity over time. Figure 3, shows increasing trends in proportions of overweight/obesity over time for both boys and girls; however, the proportions are consistently higher in girls than in boys. To determine the robustness of these findings, we examined the trends in overweight/obesity over time using the few studies that indicated having recruited a representative sample of the population. We similarly found a trend towards increasing proportions of overweight/obesity among school-aged children in this region. The findings were also similar when boys and girls were assessed separately. While not the focus of this manuscript, as shown in Figure 4, we also examined trends in overweight over time for the included studies that had also reported this proportion. We found a trend towards decreasing proportions of overweight over time in boys, a trend towards increasing proportions over time in girls, and a largely unaltered trend over time - at approximately 20% - when boys and girls were considered together.

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**Narrative synthesis**

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| First Author | Year | Study Design | Country               | Sample Size | Age Range (Years) | Body Composition Measure or Categorization System | D&B Score |
|-------------|------|--------------|-----------------------|-------------|-------------------|--------------------------------------------------|-----------|
| Prinsloo [104] | 1964 | Cross sectional | South Africa          | 261         | 5-6              | Weight, height                                  | 7         |
| Sloan [105]   | 1967 | Cross sectional | South Africa          | 393         | 15-17             | Weight, height                                  | 7         |
| Smit [106]    | 1967 | Cross sectional | South Africa          | 2250        | 6-15              | Weight, height, skin fold measures               | 7         |
| Leary [107]   | 1969 | Cross sectional | South Africa          | 301         | 7-15              | Weight, height                                  | 7         |
| Areskog [108] | 1969 | Cross sectional | Ethiopia              | 153         | 9-14              | Weight, height, skin fold measures               | 7         |
| Fisher [109]  | 1970 | Cross sectional | Zambia                | 195         | 7-16              | Weight, height                                  | 7         |
| Davies [266]  | 1971 | Cross sectional | Rhodesia (now Zimbabwe)| 252        | 7-15              | Harvard standards                               | 7         |
| Davies [111]  | 1973 | Cross sectional | Tanzania              | 141         | 7-17              | Weight, height                                  | 7         |
| Davies [110]  | 1974 | Cross sectional | Tanzania              | 1038        | 7-16              | Weight, height                                  | 7         |
| Walker [112]  | 1974 | Cross sectional | South Africa          | 400         | 16-17             | Weight, height                                  | 7         |
| Margo [268]   | 1976 | Cross sectional | South Africa          | 195         | 5-16              | None OW/OB                                      | 7         |
| Booyens [113] | 1977 | Cross sectional | South Africa          | 488         | 6-7               | Weight, height                                  | 6         |
| Richardson [267] | 1977 | Cross sectional | South Africa          | 804         | 17                | Harvard standards                               | 7         |
| Richardson [270] | 1977 | Cross sectional | South Africa          | 6598        | 7-17              | None OW/OB                                      | 6         |
| Richardson [271] | 1977 | Cross sectional | South Africa          | 4655        | 7, 12 and 17      | None OW/OB                                      | 7         |
| van Rensburg [272] | 1977 | Cross sectional | South Africa          | 488         | 6-7               | None OW/OB                                      | 6         |
| Clegg [114]   | 1978 | Cross sectional | Ethiopia              | 203         | 5-16              | Weight, height                                  | 6         |
| Coovadia [269] | 1978 | Cross sectional | South Africa          | 5743        | 5-12              | Weight, height                                  | 3         |
| Walker [273]  | 1978 | Cross sectional | South Africa          | 705         | 10-12             | None OW/OB                                      | 7         |
| Sukkar [274]a | 1979 | Cross sectional | Sudan                 | 855         | 5-13              | Tanner et al., 1966                            | 7         |
| Haller [154]  | 1980 | Cross sectional | Côte d'Ivoire         | 430         | 5-15              | None OW/OB                                      | 6         |
| Walker [115]  | 1980 | Cross sectional | South Africa          | 1240        | 16-17             | Weight, height                                  | 7         |
| Grassivaro [116]b,c | 1980 | Cross sectional | Somalia               | 1206        | 6-17              | Weight, height                                  | 9         |
| Rao [117]b,c | 1981 | Cross sectional | Zambia                | 2487        | 5-17              | Weight, height                                  | 7         |
| Carswell [275] | 1981 | Cross sectional | Tanzania              | 238         | 10-14             | Tanner et al., 1966                            | 6         |
| Singer [118]  | 1981 | Cross sectional | Namibia               | 306         | 5-17              | Weight, height                                  | 7         |
| Oyemade [276] | 1981 | Cross sectional | Nigeria               | 353         | 6-14              | None OW/OB                                      | 7         |
| Griffin [277] | 1982 | Cross sectional | Kenya                 | 109         | 7-13              | Other NCHS based system                         | 7         |
| Nnanyelugo [155] | 1982 | Cross sectional | Nigeria               | 1347        | 6-15              | Weight, height                                  | 7         |
| Kulun [119]   | 1982 | Cross sectional | Kenya                 | 656         | 10-17             | Weight, height                                  | 7         |
| Sukkar [278]  | 1982 | Cross sectional | Sudan                 | 1864        | 5-14              | Harvard standards                               | 7         |
| Power [279]b,c | 1982 | Cross sectional | South Africa          | 790         | 6-8               | Other NCHS based system                         | 9         |
| Richardson [280]b,c | 1983 | Cross sectional | South Africa          | 1337        | 8, 11, 14, and 17 | Harvard standards                               | 9         |
| Akesode [281] | 1983 | Cross sectional | Nigeria               | 394         | 6-17              | Other categorization system                     | 7         |
| Little [120]  | 1983 | Cross sectional | Kenya                 | 265         | 5-17              | Weight, height                                  | 7         |
| First Author       | Year | Study Design | Country      | Sample Size | Age Range (Years) | Body Composition Measure or Categorization System                                      | D&B Score |
|--------------------|------|--------------|--------------|-------------|------------------|----------------------------------------------------------------------------------------|-----------|
| Ng’andu [282]      | 1984 | Cross sectional | Zambia      | 374         | 7–14             | Other WHO based system                                                               | 6         |
| Rekart [121]       | 1985 | Cross sectional | Sudan        | 227         | 13–17            | Weight, height                                                                        | 6         |
| Stephenson [122]   | 1985 | Cross sectional | Kenya        | 12          | 7–15             | Weight, height, skin fold measures                                                    | 7         |
| Ndamba [123]       | 1986 | Cross sectional | Zimbabwe     | 147         | 8–15             | Weight, height                                                                        | 7         |
| Ogunranti [124]    | 1986 | Cross sectional | Nigeria      | 1165        | 5–12             | Weight                                                                                | 7         |
| Corlett [125]      | 1986 | Cross sectional | Botswana     | 721         | 6–14             | Weight, height                                                                        | 7         |
| Adams-Campbell [126]| 1987| Cross sectional | Nigeria      | 254         | 6–17             | BMI                                                                                   | 7         |
| Wagstaff [243]     | 1987 | Longitudinal  | South Africa | 864         | 5–14             | NCHS reference                                                                       | 6         |
| Villiers [244]     | 1987 | Cross sectional | South Africa | 375         | 10–17            | NCHS reference                                                                       | 7         |
| Ogunranti [127]    | 1987 | Cross sectional | Nigeria     | 600         | 5–10             | Mid upper arm circumference                                                            | 5         |
| Corlett [128]      | 1988 | Cross sectional | Botswana     | 612         | 7–12             | Weight, height                                                                        | 7         |
| Corlett [129]      | 1988 | Cross sectional | Botswana     | 483         | 7–14             | Weight, height                                                                        | 7         |
| Adeniran [130]     | 1988 | Cross sectional | Nigeria      | 18          | 13–17            | Weight, height, body fat %                                                            | 7         |
| Adeniran [131]     | 1988 | Cross sectional | Nigeria      | 23          | 13–17            | Weight, height, body fat %                                                            | 7         |
| Jacobs [283]       | 1988 | Cross sectional | South Africa | 430         | 5–10             | Other NCHS based system                                                               | 6         |
| Sigman [16]        | 1989 | Longitudinal  | Kenya        | 138         | 7 and 8          | Weight z-scores                                                                      | 7         |
| Pazuck [132][b,c]  | 1989 | Cross sectional | Mali         | 844         | 15–17            | Weight, height                                                                        | 9         |
| Ekpo [17]          | 1990 | Cross sectional | Nigeria      | 1552        | 5–16             | BMI                                                                                   | 6         |
| Walker [284][b,c]  | 1991 | Cross sectional | South Africa | 1015        | 14–17            | Other NCHS based system                                                               | 7         |
| Neumann [18]       | 1992 | Cross sectional | Kenya        | 133         | 7–9              | Weight, height                                                                        | 7         |
| Ng’andu [133]      | 1992 | Cross sectional | Zambia       | 372         | 7–16             | BMI                                                                                   | 7         |
| Benefice [19]      | 1992 | Cross sectional | Senegal      | 100         | 9–14             | BMI                                                                                   | 7         |
| Goduka [134]       | 1992 | Cross sectional | South Africa | 300         | 5–6              | Weight, height                                                                        | 7         |
| Adams-Campbell [20]| 1992 | Longitudinal  | Nigeria      | 208         | 6–17             | Skin fold measures                                                                   | 7         |
| Williams [21]      | 1992 | Cross sectional | Kenya and Nigeria | 350     | 10–15            | BMI                                                                                   | 6         |
| Ng’andu [285]      | 1992 | Cross sectional | Zambia       | 800         | 12–17            | Nominal/adjusted classification system                                                | 7         |
| Oli [135]          | 1994 | Cross sectional | Ethiopia     | 1850        | 7–14             | Weight, height                                                                        | 7         |
| McDonald [22]      | 1994 | Longitudinal  | Kenya        | 138         | 7–8              | Weight z-scores                                                                      | 8         |
| Lawless [23]       | 1994 | Longitudinal  | Kenya        | 86          | 6–11             | Weight z-scores                                                                      | 7         |
| Mabrouk [136]      | 1995 | Cross sectional | Sudan        | 400         | 7–12             | Weight, height                                                                        | 7         |
| Dufetel [137]      | 1995 | Cross sectional | Senegal      | 72          | 8–14             | Weight, height                                                                        | 7         |
| Walker [156][b,c]  | 1996 | Cross sectional | Nigeria      | 1192        | 6–12             | None OW/OB                                                                            | 8         |
| Proctor [24]       | 1996 | Cross sectional | Cameroon     | 119         | 9–14             | BMI                                                                                   | 7         |
| Benefice [25]      | 1996 | Cross sectional | Senegal      | 348         | 5–13             | Weight, height, skin fold measures                                                   | 7         |
| Pettifor [26]      | 1997 | Cross sectional | South Africa | 651         | 6–17             | BMI z-scores                                                                          | 8         |
## Table 3. Cont.

| First Author | Year | Study Design | Country | Sample Size | Age Range (Years) | Body Composition Measure or Categorization System | D&B Score |
|--------------|------|--------------|---------|-------------|-------------------|-------------------------------------------------|-----------|
| Brabin [138] | 1997 | Cross sectional | Nigeria | 914 | 14–17 | Weight, height | 7 |
| Cole [286] | 1997 | Cross sectional | Nigeria | 22 | 11–17 | Ketz 1990 system | 7 |
| Owra [287] | 1997 | Cross sectional | Nigeria | 904 | 5–15 | US reference sample | 8 |
| Longo-Mbenza [27] | 1998 | Cross sectional | Zaire (now Democratic Republic of Congo - DRC) | 4848 | 5–16 | BMI | 6 |
| Benefice [157] | 1998 | Cross sectional | Senegal | 348 | 5–13 | None OW/OB | 7 |
| Pista [158] | 1998 | Cross sectional | Mozambique | 593 | 8–15 | None OW/OB | 8 |
| Benefice [28] | 1999 | Cross sectional | Senegal | 221 | 12–13 | BMI | 8 |
| Oelfse [159] | 1999 | Cross sectional | South Africa | 131 | 5–11 | None OW/OB | 6 |
| Levitt [29] | 1999 | Prospective Cohort Study | South Africa | 818 | 5 | BMI | 7 |
| Monyeki [245] | 1999 | Cross sectional | South Africa | 1149 | 5–10 | NCHS reference | 8 |
| Nyirono [160] | 1999 | Cross sectional | Zimbabwe | 930 | 5–16 | None OW/OB | 8 |
| Akinkugbe [139] | 1999 | Cross sectional | Nigeria | 1076 | 11–15 | Weight, height | 8 |
| Sellen [30] | 1999 | Cross sectional | Tanzania & Kenya | 234 | 5–17 | BMI | 7 |
| Hamidu [140] | 2000 | Cross sectional | Nigeria | 1712 | 5–16 | Weight, height | 7 |
| Sellen [288] | 2000 | Cross sectional | Tanzania | 169 | 5–12 | Seoane & Latham 1971 | 8 |
| Dibba [141] | 2000 | Cross sectional | Gambia | 160 | 8–11 | Weight, height | 8 |
| Zweve [161] | 2001 | Cross sectional | Malawi | 493 | 6–17 | None OW/OB | 7 |
| Garnier [31] | 2001 | Cross sectional | Senegal | 80 | 13–15 | BMI | 8 |
| Benefice [32] | 2001 | Cross sectional | Senegal | 40 | 13 | BMI | 8 |
| Benefice [33] | 2001 | Cross sectional | Senegal | 40 | 13 | BMI | 8 |
| Jinabhai [246] | 2001 | Cross sectional | South Africa | 579 | 8–10 | NCHS reference | 7 |
| Beasley [162] | 2002 | Cross sectional | Chad | 1024 | 6–15 | None OW/OB | 7 |
| Pawloski [34] | 2002 | Cross sectional | Mali | 1056 | 10–17 | Weight z-scores | 7 |
| Perzanowski [142] | 2002 | Cross sectional | Kenya | 265 | 8–15 | Weight, height, body fat % | 6 |
| Underhay [187] | 2002 | Cross sectional | South Africa | 1242 | 10–15 | IOTF categories | 9 |
| Bhargava [35] | 2003 | Longitudinal | Kenya | 100 | 6–9 | BMI | 6 |
| Eckhardt [36] | 2003 | Cross sectional | South Africa | 86 | 6–16 | BMI | 7 |
| Garnier [37] | 2003 | Cross sectional | Senegal | 331 | 14–16 | Weight z-scores | 8 |
| Grillenberger [38] | 2003 | Cross sectional | Kenya | 110 | 7 | Weight z-scores | 7 |
| Maballa-Babel [289] | 2003 | Cross sectional | DRC | 1087 | 6–13 | BMI percentiles per Rolland-Cachera 1994 | 8 |
| Mukundi [163] | 2003 | Cross sectional | Kenya | 851 | 10–17 | None OW/OB | 7 |
| Pista [247] | 2003 | Cross sectional | Mozambique | 2316 | 6–17 | NCHS reference | 8 |
| Leman [39] | 2003 | Cross sectional | Nigeria | 39 | 5–8 | BMI | 7 |
| Jinabhai [184] | 2003 | Cross sectional | South Africa | 29535 | 8–11 | WHO and IOTF categories | 9 |
| First Author | Year | Study Design | Country | Sample Size | Age Range (Years) | Body Composition Measure or Categorization System | D&B Score |
|--------------|------|--------------|---------|-------------|-------------------|-----------------------------------------------|----------|
| Schutte [40]** | 2003 | Cross sectional | South Africa | 1244 | 10–15 | BMI | 9 |
| Gay [143] | 2004 | Cross sectional | Kenya | 183 | 5–16 | Weight, height | 7 |
| Micklefield [290] | 2004 | Cross sectional | South Africa | 198 | 7–11 | US reference sample | 7 |
| Larsen [41] | 2004 | Cross sectional | Kenya | 11 | 15–17 | BMI | 7 |
| Benefice [188] | 2004 | Cross sectional | Senegal | 507 | 16 | IOTF categories | 6 |
| Benefice [42] | 2004 | Cross sectional | Senegal | 40 | 13–15 | Weight z-scores | 7 |
| Monyeki [43] | 2004 | Cross sectional | South Africa | 85 | 7 | BMI | 8 |
| McVeigh [44]** | 2004 | Cross sectional | South Africa | 386 | 9 | BMI | 7 |
| Cameron [144]** | 2004 | Cross sectional | South Africa | 214 | 9 | Body fat % | 7 |
| Mukuddem-Petersen [164]** | 2004 | Cross sectional | South Africa | 1257 | 10–15 | None OW/OB | 9 |
| Pista [45] | 2005 | Cross sectional | Mozambique | 2271 | 16–17 | BMI | 8 |
| Ayemang [189]** | 2005 | Cross sectional | Ghana | 1277 | 8–16 | IOTF categories | 9 |
| Garnier [165] | 2005 | Cross sectional | Senegal | 1806 | 5–17 | CDC categories | 7 |
| Calvert [291] | 2005 | Cross sectional | South Africa | 393 | 8–12 | BMI z-score | 8 |
| Monyeki [292] | 2005 | Cross sectional | South Africa | 855 | 7–14 | US reference sample | 8 |
| Benefice [46] | 2005 | Cross sectional | Kenya | 99 | 10–13 | BMI | 8 |
| Friedman [47] | 2005 | Cross sectional | South Africa | 272 | 10–13 | BMI z-score | 8 |
| Jinabhai [190]** | 2005 | Cross sectional | South Africa | 643 | 8–11 | IOTF categories | 9 |
| Underhay [192]** | 2005 | Cross sectional | South Africa | 1242 | 10–15 | IOTF categories | 9 |
| Monyeki [191]** | 2005 | Cross sectional | South Africa | 1884 | 6–13 | IOTF categories | 8 |
| Zerfu [249] | 2006 | Cross sectional | Ethiopia | 1208 | 9–17 | NCHS reference | 6 |
| Armstrong [193]** | 2006 | Cross sectional | South Africa | 10195 | 6–13 | IOTF categories | 10 |
| Kruger [194]** | 2006 | Cross sectional | South Africa | 1257 | 10–15 | IOTF categories | 9 |
| Aandstad [48] | 2006 | Cross sectional | Tanzania | 156 | 9–10 | BMI | 7 |
| Munday [49] | 2006 | Cross sectional | Gambia | 62 | 5–10 | BMI z-scores | 7 |
| Djarova [50] | 2006 | Cross sectional | Zimbabwe | 40 | 6–14 | BMI | 6 |
| Onyewadume [51] | 2006 | Cross sectional | Botswana | 30 | 11–14 | BMI | 8 |
| Nyati [145]** | 2006 | Cross sectional | South Africa | 369 | 9 | Weight, height | 8 |
| Vidulich [52]** | 2006 | Cross sectional | South Africa | 476 | 10 | BMI | 7 |
| Micklefield [146] | 2007 | Cross sectional | South Africa | 64 | 9 | Weight, height | 7 |
| Micklefield [53] | 2007 | Cross sectional | South Africa | 400 | 9 | BMI | 8 |
| Ben-Bassey [54] | 2007 | Cross sectional | Nigeria | 1504 | 12–17 | BMI | 8 |
| Longo-Mbenza [250] | 2007 | Cross sectional | DRC | 1535 | 5–17 | NCHS reference | 6 |
| Rohner [166] | 2007 | Cross sectional | Côte d’Ivoire (Ivory Coast) | 281 | 5–15 | None OW/OB | 7 |
| First Author | Year | Study Design | Country       | Sample Size | Age Range (Years) | Body Composition Measure or Categorization System | D&B Score |
|--------------|------|--------------|---------------|-------------|-------------------|-----------------------------------------------|-----------|
| Jinabhai     | 2007 | Cross sectional | South Africa | 5322        | 13–17             | IOTF categories                               | 10        |
| Madhavan     | 2007 | Cross sectional | South Africa | 117         | 5–14              | None OW/OB                                    | 7         |
| Vidulich     | 2007 | Cross sectional | South Africa | 476         | 10                | BMI                                           | 7         |
| Monyeki      | 2007 | Longitudinal   | South Africa | 702         | 7–14              | Weight z-score                                | 8         |
| Semproli     | 2007 | Cross sectional | Kenya         | 1,383       | 5–17              | IOTF categories                               | 7         |
| Andries      | 2007 | Longitudinal   | South Africa | 702         | 7–14              | Weight z-score                                | 7         |
| Bovet        | 2007 | Cross sectional | Seychelles    | 4343        | 12–15             | IOTF categories                               | 9         |
| Goon         | 2007 | Cross sectional | Nigeria       | 2015        |                   | Body fat %                                    | 8         |
| Travill      | 2007 | Cross sectional | South Africa | 720         | 8–17              | Waterlow et al., 1977                          | 7         |
| Makgae       | 2007 | Longitudinal   | South Africa | 1902        | 6–13              | IOTF categories                               | 8         |
| Ejike         | 2008 | Cross sectional | Nigeria       | 923         | 10–17             | BMI                                           | 8         |
| Ekpo         | 2008 | Cross sectional | Nigeria       | 228         | 5–15              | None OW/OB                                    | 8         |
| Anyiam       | 2008 | Cross sectional | Nigeria       | 3802        | 5–13              | None OW/OB                                    | 10        |
| Nietaber     | 2008 | Cross sectional | South Africa | 195         | 15                | BMI                                           | 8         |
| Olivier      | 2008 | Cross sectional | Zimbabwe      | 982         | 6–17              | None OW/OB                                    | 7         |
| Monyeki      | 2008 | Longitudinal   | South Africa | 1817        | 7–13              | IOTF categories                               | 7         |
| Jeremiah     | 2008 | Cross sectional | Nigeria       | 144         | 5–8               | Other WHO based system                        | 7         |
| Funke        | 2008 | Cross sectional | Nigeria       | 315         | 10–17             | BMI                                           | 7         |
| Lennox       | 2008 | Cross sectional | South Africa | 318         | 15                | BMI                                           | 8         |
| Goon         | 2008 | Cross sectional | Nigeria       | 2015        | 9–12              | BMI                                           | 8         |
| Alaofe       | 2009 | Cross sectional | Benin         | 180         | 12–17             | NCHS reference                                | 7         |
| Priya        | 2009 | Cross sectional | Mozambique     | 256         | 6–16              | WHO categories                                | 8         |
| Micklefield  | 2009 | Cross sectional | South Africa | 400         | 9                 | BMI                                           | 8         |
| Demerath     | 2009 | Secondary analysis | South Africa | 196         | 9                 | Other NCHS based system                       | 8         |
| Cameron      | 2009 | Secondary analysis | South Africa | 227         | 8–11              | BMI                                           | 7         |
| Hawley       | 2009 | Secondary analysis | South Africa | 1164        | 9–11              | Weight z-scores                               | 6         |
| Berntsen     | 2009 | Cross sectional | Tanzania      | 190         | 9–10              | BMI                                           | 8         |
| Dapi         | 2009 | Cross sectional | Cameroon      | 581         | 12–16             | CDC categories                                | 7         |
| Ayoola       | 2009 | Cross sectional | Nigeria       | 349         | 7–16              | None OW/OB                                    | 7         |
| Senbanjo     | 2009 | Cross sectional | Nigeria       | 392         | 5–14              | BMI                                           | 8         |
| Padez        | 2009 | Cross sectional | Mozambique     | 1417        | 9–17              | WHO categories                                | 7         |
| Mulugeta     | 2009 | Cross sectional | Ethiopia      | 413         | 10–15             | BMI z-scores                                  | 7         |
| Naiho        | 2009 | Cross sectional | Nigeria       | 200         | 5–10              | BMI                                           | 6         |
| Adegoke      | 2009 | Cross-sectional | Nigeria       | 704         | 6–17              | BMI                                           | 8         |
| Amuta        | 2009 | Cross sectional | Nigeria       | 600         | 6–17              | None OW/OB                                    | 6         |
| First Author | Year | Study Design | Country | Sample Size | Age Range (Years) | Body Composition Measure or Categorization System | D&B Score |
|--------------|------|--------------|---------|-------------|------------------|-----------------------------------------------|-----------|
| Poopedi [74]b,c | 2009 | Cross sectional | South Africa | 385 | 10 | BMI | 10 |
| Kimani-Murage [252]b,c | 2010 | Cross sectional | South Africa | 1914 | 5–14 | IOTF categories | 9 |
| Bamidele [173] | 2010 | Cross sectional | Nigeria | 139 | 5–15 | Other WHO based system | 7 |
| Omigbodun [229] | 2010 | Cross sectional | Nigeria | 1503 | 10–17 | WHO categories | 7 |
| Harmse [72] | 2010 | Cross sectional | South Africa | 221 | 13–17 | BMI | 7 |
| Senbanjo [256] | 2010 | Cross sectional | Nigeria | 392 | 5–14 | CDC categories | 8 |
| Goon [73] | 2010 | Cross sectional | Nigeria | 563 | 12–17 | BMI | 7 |
| Mosha [230] | 2010 | Cross sectional | Tanzania | 428 | 6–12 | WHO categories | 5 |
| Olumumakaiye [174] | 2010 | Cross sectional | Nigeria | 315 | 10–17 | Other NCHS based system | 8 |
| Goon [186] | 2010 | Cross sectional | Nigeria | 2015 | 9–12 | CDC and IOTF categories | 8 |
| Goon [200] | 2010 | Cross sectional | Nigeria | 219 | 7–14 | IOTF categories | 7 |
| Opara [231] | 2010 | Cross sectional | Nigeria | 770 | 5–14 | WHO categories | 7 |
| Eijke [253] | 2010 | Cross sectional | Nigeria | 563 | 10–17 | NCHS reference | 7 |
| Truter [254] | 2010 | Cross sectional | South Africa | 280 | 9–13 | NCHS reference | 7 |
| Ania [75] | 2010 | Cross sectional | Nigeria | 964 | 10–17 | BMI | 8 |
| Bogale [175] | 2010 | Cross sectional | Ethiopia | 100 | 5 | None OW/OB | 7 |
| Mulugeta [176] | 2010 | Cross sectional | Ethiopia | 413 | 10–15 | None OW/OB | 8 |
| Hawkesworth [295] | 2010 | Cross sectional | Gambia | 171 | 5–10 | BMI | 8 |
| Poopedi [71] | 2011 | Cross sectional | South Africa | 385 | 10 | BMI | 7 |
| Micklefield [76] | 2011 | Cross sectional | South Africa | 471 | 13 | BMI | 7 |
| Salman [257] | 2011 | Cross sectional | Sudan | 304 | 6–12 | CDC categories | 7 |
| Nagwa [232] | 2011 | Cross sectional | Sudan | 1138 | 10–17 | WHO categories | 7 |
| Griffiths [77] | 2011 | Mixed | South Africa | 281 | 9–10 | BMI | 7 |
| Dabone [233] | 2011 | Cross sectional | Burkina Faso | 649 | 7–14 | WHO categories | 7 |
| Henry-Unaeze [78]b,c | 2011 | Cross sectional | Nigeria | 200 | 12–17 | BMI | 9 |
| Hadley [79]b,c | 2011 | Cross sectional | Ethiopia | 1943 | 13–17 | BMI | 8 |
| Odenigbo [258] | 2011 | Cross sectional | Nigeria | 119 | 6–12 | CDC categories | 7 |
| Thrandayen [80]b,c | 2009 | Retrospective longitudinal | South Africa | 672 | 10 and 15 | BMI z-scores | 8 |
| Goon [81] | 2012 | Cross sectional | South Africa | 1136 | 9–13 | BMI | 7 |
| Kruger [82]b,c | 2012 | Cross sectional | South Africa | 582 and 462 | 7–9 | Weight z-scores | 6 |
| Sempromi [83] | 2011 | Cross sectional | Kenya | 1383 | 5–17 | BMI z-scores | 7 |
| Koueta [201] | 2011 | Cross sectional | Burkina Faso | 204 | 13–16 | IOTF categories | 7 |
| Stevens [84] | 2011 | Cross sectional | Ghana | 181 | 9–16 | BMI | 7 |
| Peltzer [202]d | 2011 | Secondary analysis | Ghana & Uganda | 5613 | 13–15 | IOTF categories | 9 |
| Goon [234]b,c | 2011 | Cross sectional | Nigeria | 2015 | 9–12 | WHO categories | 9 |
| First Author | Year | Study Design | Country | Sample Size | Age Range (Years) | Body Composition Measure or Categorization System | D&B Score |
|--------------|------|--------------|---------|-------------|------------------|---------------------------------------------------|-----------|
| Nwizu [85]   | 2011 | Cross sectional | Nigeria | 728         | 10–17            | BMI                                                | 7         |
| Naude [86]   | 2011 | Cross sectional | South Africa | 162        | 12–16            | BMI z-scores                                      | 5         |
| Abolarin [87] | 2011 | Cross sectional | South Africa | 560        | 6-12             | BMI z-scores                                      | 8         |
| Abrahams [88] | 2011 | Cross sectional | South Africa | 717        | 10-12            | BMI z-scores                                      | 8         |
| M otswaupole [89] | 2011 | Cross sectional | South Africa | 919        | 9-15             | BMI z-scores                                      | 8         |
| Crotiau [90] | 2011 | Cross sectional | Kenya | 72         | 8-12             | CDC categories                                   | 7         |
| R ankin [91] | 2011 | Cross sectional | Nigeria | 1690       | 6-16             | CDC categories                                   | 7         |
| L urbi [92]  | 2011 | Cross sectional | South Africa | 81        | 13-16            | Weight                                            | 7         |
| Mokwa [93]  | 2011 | Cross sectional | Ghana | 1442       | 6-15             | CDC categories                                   | 8         |
| Motswaupole [94] | 2011 | Cross sectional | South Africa | 201       | 9-12             | BMI                                                | 6         |
| Crotiau [95] | 2011 | Secondary analysis | Kenya | 72         | 8-12             | CDC categories                                   | 7         |
| F etuga [96] | 2011 | Cross sectional | Nigeria | 1690       | 6-16             | CDC categories                                   | 8         |
| Rankin [97]  | 2011 | Cross sectional | South Africa | 919        | 9-15             | BMI z-scores                                      | 8         |
| Armstrong [98] | 2011 | Secondary analysis | South Africa | 791       | 7-11             | BMI z-scores                                      | 10        |
| B enefice [99] | 2011 | Secondary analysis | South Africa | 791       | 7-11             | BMI z-scores                                      | 10        |
| Armstrong [100] | 2011 | Cross sectional | South Africa | 944       | 4-14             | BMI z-scores                                      | 7         |
| A ngelo [101] | 2011 | Cross sectional | South Africa | 227       | 12-16            | BMI z-scores                                      | 8         |
| F etuga [102] | 2011 | Cross sectional | South Africa | 419       | 10-12            | BMI z-scores                                      | 8         |
| F etuga [103] | 2011 | Cross sectional | South Africa | 256       | 11-17            | BMI z-scores                                      | 10        |
| E ne-Obong [104] | 2011 | Cross sectional | South Africa | 891       | 7-11             | BMI z-scores                                      | 7         |
| Kramoh [105] | 2011 | Cross sectional | South Africa | 201       | 10-12            | BMI z-scores                                      | 7         |
| F etuga [106] | 2011 | Cross sectional | South Africa | 1016      | 6-10             | BMI z-scores                                      | 6         |
| M usa [107] | 2012 | Cross sectional | Nigeria | 3243       | 9-15             | BMI z-scores                                      | 7         |
| O ldewage-Theron [108] | 2012 | Cross sectional | South Africa | 97        | 6-13             | CDC categories                                   | 7         |
| First Author     | Year | Study Design | Country     | Sample Size | Age Range (Years) | Body Composition Measure or Categorization System | D&B Score |
|------------------|------|--------------|-------------|-------------|-------------------|--------------------------------------------------|-----------|
| Adesina [96]     | 2012 | Cross sectional | Nigeria     | 884         | 10–17             | BMI                                              | 8         |
| Cordeiro [178]   | 2012 | Cross sectional | Tanzania    | 670         | 10–15             | None OW/OB                                       | 9         |
| Monyeki [210]    | 2012 | Longitudinal  | South Africa | 256         | 14                | IOTF categories                                  | 8         |
| Griffiths [211]  | 2012 | Cross sectional | South Africa | 358         | 16                | IOTF categories                                  | 7         |
| Onywera [185]    | 2012 | Cross sectional | Kenya       | 169         | 9–12              | WHO categories                                   | 7         |
| Bafor [97]       | 2012 | Cross sectional | Nigeria     | 369         | 5–10              | BMI                                              | 7         |
| Reddy [212]      | 2012 | Secondary analysis | South Africa | 9522 and 9371 | 14–17 | IOTF categories | 9 |
| Opare-Addo [240]| 2012 | Cross sectional | Ghana       | 720         | 7–17              | WHO categories                                   | 8         |
| Ojiambo [98]     | 2012 | Cross sectional | Kenya       | 200         | 12–16             | BMI z-scores                                     | 7         |
| Chinenu [264]    | 2012 | Cross sectional | Nigeria     | 926         | 6–16              | CDC categories                                   | 5         |
| Craig [179]      | 2012 | Cross sectional | South Africa | 1519        | 7, 11, and 15     | None OW/OB                                       | 5         |
| Amare [180]      | 2012 | Cross sectional | South Africa | 100         | 5–15              | None OW/OB                                       | 8         |
| Moselakgomo [213]| 2012 | Cross sectional | South Africa | 1172        | 10–16             | IOTF categories                                  | 8         |
| Mcklefield [214] | 2012 | Cross sectional | South Africa | 381         | 11–15             | IOTF categories                                  | 6         |
| Monyeki [215]    | 2012 | Cross sectional | South Africa | 256         | 14                | IOTF categories                                  | 8         |
| Monyeki [298]    | 2012 | Cross sectional | South Africa | 153         | 14–15             | Not indicated                                    | 8         |
| Truter [216]     | 2012 | Cross sectional | South Africa | 280         | 9–13              | IOTF categories                                  | 7         |
| Musa [217]       | 2012 | Cross sectional | Nigeria     | 3240        | 9–16              | IOTF categories                                  | 8         |
| Bovet [218]      | 2012 | Cross sectional | Seychelles  | 8462        | 9–16              | IOTF categories                                  | 9         |
| Fetuga [299]     | 2012 | Cross sectional | Nigeria     | 1557        | 5–11              | Weight standard deviation scores                 | 8         |
| Girma [100]      | 2012 | Cross sectional | Ethiopia    | 116         | 7–9               | Weight z-scores                                  | 6         |
| Motswagole [241]| 2012 | Cross sectional | South Africa | 2111        | 6–15              | WHO categories                                   | 7         |
| Wolff [101]      | 2012 | Cross sectional | Madagascar  | 1236        | 6–15              | BMI                                              | 8         |
| Toriola [245]    | 2012 | Cross sectional | South Africa | 1172        | 10–16             | CDC categories                                   | 7         |
| Wolff [102]      | 2012 | Cross sectional | Madagascar  | 1236        | 6–15              | BMI                                              | 7         |
| Goon [153]       | 2012 | Cross sectional | Nigeria     | 2015        | 9–12              | Weight, height                                   | 10        |
| Toriola [219]    | 2012 | Longitudinal   | South Africa | 283         | 14                | IOTF categories                                  | 8         |
| Feeley [208]     | 2013 | Longitudinal   | South Africa | 1298        | 13, 15, and 17    | IOTF categories                                  | 7         |
| Wilson [220]     | 2013 | Secondary analysis | Seychelles | 380         | 11–17             | IOTF categories                                  | 8         |
| Ginsburg [221]   | 2013 | Cross sectional | South Africa | 1613        | 15                | IOTF categories                                  | 7         |
| Senbanjo [103]   | 2013 | Cross sectional | Nigeria     | 548         | 5–17              | BMI                                              | 7         |
| Malete [222]     | 2013 | Cross sectional | Botswana    | 756         | 13–16             | IOTF categories                                  | 7         |
| Neumann [181]    | 2013 | Cross sectional | Kenya       | 910         | 6–14              | None OW/OB                                       | 7         |
| Degarege [182]   | 2013 | Cross sectional | Ethiopia    | 403         | 5–15              | None OW/OB                                       | 8         |
| Puone [242]      | 2013 | Cross sectional | South Africa | 162         | 10–15             | WHO categories                                   | 7         |
Sex differences. Of the 96 studies [16–18,20,24–26,29, 36,39,40,43,45,46,48,51,53–56,59–68,70–72,74,76–80,83, 85,86,89,91,92,95,96,98,103–105,107,109–114,116–120,123,124, 126,128,129,132,133,135,136,140,143,147,149–152,163,169,170, 214,215,218,225,281,287,289,292,293,295] that reported their data by sex, 31 articles [20,25,29,40,45,59,67,68,70,71,74,76,78,79, 85,86,89,92,95,96,103,107,124,126,132,147,151,163,170,214,215] reported that girls had higher body composition measures than boys, while 5 articles [265,267,289,292,293] reported that boys had higher body composition measures than girls. The remaining studies either found no significant difference or did not report a difference between boys and girls.

Urban/rural differences. Thirty-three articles compared body composition measures in urban and rural populations. Of these, 29 studies (including 7 studies used in the quantitative synthesis) [17, 24, 27, 31, 34, 37, 54, 58, 79, 84, 87, 98, 119, 128, 129, 138, 156, 163, 206, 212, 282, 298, (185, 189, 200, 217, 233, 240, 260)] reported significantly higher body composition measures in the urban compared to the rural sample, with the remaining studies [110,111,140,280] reporting no significant difference between the two populations.

Socioeconomic status (SES) differences. Twenty-four articles reported on outcomes of interest by some measure of socioeconomic status (e.g., income quartile, public/private school attendance). Of these, 19 articles (including 8 studies used in the quantitative synthesis) [45, 54, 61, 68, 75, 77, 84, 92, 99, 101, 156, 163, 169, 218, 296, 297, (212, 228, 231, 237, 247, 250, 255, 256)] reported that higher SES was associated with higher body composition measures, whilst the remaining articles [54,75,92, 169,256] found no significant association of SES on body composition.

Age differences. Of the articles that reported on body composition measures by age, 15 studies found a largely positive relationship with age [287,170,70,147,103,95,151,20,42, 242,256,229,230,199,297], while 7 studies found a largely negative relationship with age [83,264,233,19,190,196,245]. In some cases, the relationship between age and body composition measures differed between sexes; as such, we may conclude that there was no convincing or consistent evidence of an independent age effect.

Discussion

To our knowledge, this systematic review is the first to comprehensively examine if there is evidence supporting an overweight/obesity transition in school-aged children and youth in SSA.

An overweight/obesity transition

Due to vast heterogeneity in types of measurement, classification, and analysis, both narrative and quantitative analyses (weighted proportions and bubble plots of overweight/obesity) were presented in this review. Quantitative synthesis was completed using 68 studies that categorized children and youth based on internationally accepted cut-points for weight status. The weighted averages of overweight/obesity proportions in boys and girls was 7.6% and 15.4% respectively, while obesity proportions in boys and girls was 2.0% and 3.9% respectively. Weighted averages of overweight/obesity, and obesity for the total population were 10.6% and 2.5%. Current evidence revealed a clear transition of increasing proportions of overweight/obesity in school-aged children in SSA, and a similar, but less prominent trend towards increasing proportions of obesity over time. This transition to higher proportions of overweight/obesity is similar to observed trends in developed countries; however, the weighted
Table 4. Proportions of overweight/obesity as reported by studies used in quantitative synthesis.

| First Author      | Year | Country        | Cut Off | Age Range (years) | Sample Size (n) | Proportions in Males | Proportions in Females | Proportions in Both Males and Females |
|-------------------|------|----------------|---------|-------------------|-----------------|----------------------|------------------------|---------------------------------------|
| Villiers [244]    | 1987 | South Africa   | 1       | 14–15             | 57              | 0.5                  | 0.7                    | 0.6                     |
| Wagstaff [243]    | 1987 | South Africa   | 1       | 5–14              | 937             | 21.9                 | 15.6                   | 6.3                     |
| Wagstaff [243]    | 1987 | South Africa   | 1       | 5–14              | 864             | 21.9                 | 7.1                    | 4.0                     |
| Monyeki [245]     | 1999 | South Africa   | 1       | 5–10              | 595             | 0.5                  | 0.7                    | 0.6                     |
| Prista [247]      | 2003 | Mozambique     | 1       | 6–17              | 1094            | 10.8                 | 3.2                    | 11.8                    |
| Jinabhai [184]    | 2003 | South Africa   | 2       | 8–11              | 17351           | 4.1                  | 1.5                    | 5.6                     |
| Benefice [188]    | 2004 | Senegal        | 3       | 16                | 188             | 18.4                 | 2.6                    | 20.9                    |
| Agyemang [189]    | 2005 | Ghana          | 3       | 8–16              | 616             | 6.4                  | 4.8                    | 10.2                    |
| Jinabhai [190]    | 2005 | South Africa   | 3       | 8–11              | 292             | 6.4                  | 5.1                    | 1.5                     |
| Steyn [248]       | 2005 | South Africa   | 1       | 7–8               | 544             | 6.4                  | 5.0                    | 3.3                     |
| Zerfou [249]      | 2006 | Ethiopia       | 1       | 9–17              | 918             | 23.8                 | 3.5                    | 27.3                    |
| Armstrong [193]   | 2006 | South Africa   | 3       | 6–13              | 5603            | 10.8                 | 3.2                    | 13.0                    |
| Kruger [194]      | 2006 | South Africa   | 3       | 10–15             | 608             | 4.1                  | 1.5                    | 5.6                     |
| Longo-Mbenza [250]| 2007 | DRC            | 1       | 12                | 362             | 24.0                 | 68.5                   | 35.5                    |
| Jinabhai [195]    | 2007 | South Africa   | 3       | 13–17             | 2398            | 18.4                 | 2.6                    | 20.9                    |
| Semproli [196]    | 2007 | Kenya          | 3       | 5–7               | 702             | 10.6                 | 6.3                    | 16.9                    |
| Bovet [197]       | 2007 | Seychelles     | 3       | 12–15             | 2202            | 8.1                  | 3.1                    | 11.2                    |
| Monyeki [199]     | 2008 | South Africa   | 3       | 7–13              | 938             | 13.1                 | 4.4                    | 17.5                    |
| Alaofe [251]      | 2009 | Benin          | 1       | 12–17             | 180             | 8.0                  | 1.0                    | 9.0                     |
| Prista [227]      | 2009 | Mozambique     | 2       | 6–16              | 139             | 1.3                  | 0.3                    | 1.6                     |
| Dapi [255]        | 2009 | Cameroon       | 1       | 12–16             | 248             | 3.0                  | 1.0                    | 4.0                     |
| Padez [228]       | 2009 | Mozambique     | 2       | 9–17              | 298             | 1.0                  | 0.2                    | 1.2                     |
| Goon [186]        | 2010 | Nigeria        | 1       | 9–12              | 979             | 6.5                  | 5.0                    | 11.5                    |
| Kimani-Murage [252]| 2010 | South Africa   | 3       | 5–14              | 1884            | 6.0                  | 4.0                    | 10.0                    |
| Omgbodun [229]    | 2010 | Benin          | 2       | 10–17             | 763             | 1.0                  | 0.2                    | 1.2                     |
| Senbanjo [256]    | 2010 | Nigeria        | 1       | 5–14              | 202             | 10.0                 | 3.9                    | 13.9                    |
| Mosha [230]       | 2010 | Tanzania       | 2       | 6–9               | 60              | 21.4                 | 68.8                   | 30.0                    |
| Goon [200]        | 2010 | Nigeria        | 3       | 7–14              | 107             | 2.7                  | 1.0                    | 3.7                     |
| Odenigbo [258]    | 2010 | Nigeria        | 1       | 6–12              | 119             | 29.4                 | 63.0                   | 6.7                     |
| Opara [231]       | 2010 | Nigeria        | 2       | 5–12.5            | 378             | 29.1                 | 103.0                  | 122.1                   |
| First Author | Year | Country     | Cut Off | Age Range (years) | M     | F     | Total | Proportions in Males | Proportions in Females | Proportions in Both Males and Females |
|--------------|------|-------------|---------|-------------------|-------|-------|-------|----------------------|------------------------|------------------------------------|
| Ejike [253]  | 2010 | Nigeria     | 1       | 10–17             | 337   | 226   | 563   | 5.3                  | 23.7                   | 7.2                  |
| Salman [257] | 2010 | Sudan       | 1       | 6–12              | 68    | 236   | 304   | 82.4                 | 11.8                   | 5.9                  |
| Truter [254] | 2010 | South Africa| 1       | 9–12              | 128   | 152   | 280   | 78.9                 | 15.6                   | 5.5                  |
| Nagwa [232]  | 2011 | Sudan       | 2       | 10–17             | 526   | 612   | 1138  | 17.7                 | 61.0                   | 9.9                  |
| Dabone [233]| 2011 | Burkin Faso | 2       | 7–14              | 312   | 337   | 649   | 2.7                  | 0.5                    | 9.5                  |
| Koueta [201]| 2011 | Burkin Faso | 3       | 13–16             | 204   |       |       | 11.1                 | 847                    | 42                   |
| Peltzer [202]| 2011 | Ghana & Uganda| 3      | 13–15             | 2738  | 2875  | 5613  | 2.7                  | 0.5                    | 9.5                  |
| Croteau [259]| 2011 | Kenya       | 1       | 8–12              | 29    | 43    | 72    | 11.1                 | 847                    | 42                   |
| Fetuga [226]| 2011 | Nigeria     | 2       | 6–16              | 821   | 669   | 1690  | 2.5                  | 3.3                    | 25                   |
| Larbi [290]  | 2011 | Ghana       | 1       | 6–15              | 706   | 776   | 1482  | 7.9                  | 787                    | 13.4                 |
| Kimani-Murage [204]| 2011 | South Africa| 3       | 10–14             | 944   |       |       | 7.5                  |                        |                      |
| Fetuga [235]| 2011 | Nigeria     | 2       | 6–10              | 179   | 537   | 1016  | 23.8                 | 3.8                    | 20.8                 |
| Amusa [205] | 2011 | South Africa| 3       | 7–13              | 193   | 216   | 409   | 54.3                 | 28.4                   | 25                   |
| Puckree [236]| 2011 | South Africa| 2       | 10–12             | 48    | 72    | 120   | 66.2                 | 28.8                   | 50                   |
| Goon [261]   | 2011 | Nigeria     | 1       | 12–17             | 0     | 553   | 553   | 5.4                  | 77.0                   | 11.1                 |
| Kamau [237] | 2011 | Kenya       | 2       | 10–15             | 2620  | 2705  | 5325  | 6.5                  | 2.6                    | 10.9                 |
| Kemp [207]   | 2011 | South Africa| 3       | 6–7               | 419   | 397   | 816   | 90.2                 | 3.3                    | 86.4                 |
| Oldewage-Theron [238]| 2011 | South Africa| 2       | 6–13              | 43    | 54    | 97    | 4.7                  | 0.3                    | 5.0                  |
| Armstrong [203]| 2011³ | South Africa| 3       | 8–11              | 17756 | 12609 | 30365 | 3.1                  | 1.4                    | 2.0                  |
| Armstrong [203]| 2011³ | South Africa| 3       | 8–11              | 17756 | 12609 | 30365 | 9.5                  | 2.2                    | 12.4                 |
| Okoh [262]   | 2012 | Nigeria     | 1       | 6–12              | 585   | 717   | 1302  | 11.7                 | 76.7                   | 5.9                  |
| Naidoo [263]| 2012 | South Africa| 1       | 7–10              | 70    | 100   | 170   | 54.3                 | 11.4                   | 34.3                 |
| Ene-Obong [209]| 2012 | Nigeria     | 3       | 5–9               | 706   |       |       | 19.0                 | 68.7                   | 9.5                  |
| Kramoh [239]| 2012 | Côte d’Ivoire| 2      | 12–18             | 856   | 1182  | 2038  | 68.0                 | 27.0                   | 40.0                 |
| Monyeki [210]| 2012 | South Africa| 3       | 14–16             | 100   | 156   | 256   | 44.0                 | 8.0                    | 51.9                 |
| Griffiths [211]| 2012 | South Africa| 3       | 16–18             | 190   | 168   | 358   | 63.3                 | 3.7                    | 22.2                 |
| Onyewa [185]| 2012 | Kenya       | 2       | 9–12              | 85    | 84    | 169   | 68.0                 | 16.7                   | 3.8                  |
| Opare-Addo [240]| 2012 | Ghana       | 2       | 7–17              | 0     | 720   | 720   | 6.0                  | 746                    | 10.4                 |
| Moselalakgomo [213]| 2012 | South Africa| 3       | 10–16             | 541   | 631   | 1172  | 4.6                  | 80.8                   | 5.5                  |
| Truter [216] | 2012 | South Africa| 3       | 9–13              | 128   | 152   | 280   | 15.6                 | 5.5                    | 15.1                 |

Table 4. Cont.
Table 4. Cont.

| First Author | Year | Country | Cut Off | Age Range (years) | Sample Size (n) | Proportions in Males | Proportions in Females | Proportions in Both Males and Females |
|--------------|------|---------|---------|-------------------|----------------|----------------------|----------------------|-----------------------------------|
|              |      |         |         |                   | M            | F                    | UW                  | NW                  | OW                  | OB                  |
| Musa [217]   | 2012 | Nigeria | 3       | 9–16              | 1526         | 1,714                | 3240                 | 88.5                | 9.7                 | 1.8                 |
| Motswagole [241] | 2012 | South Africa | 2       | 6–15              | 2111         | 34.2                 | 0.6                  |                     |                     |                     |
| Toriola [219] | 2012 | South Africa | 3       | 14                | 111          | 172                  | 283                  | 34.2                | 48.6                | 17.1                |
| Reddy [212]  | 2012a | South Africa | 3       | 14–17             | 4184         | 5338                 | 9522                 | 6.3                 | 1.6                 | 24.3                | 5.0                 | 16.4                | 3.5                 |
| Reddy [212]  | 2012a | South Africa | 3       | 14–17             | 4565         | 4806                 | 9371                 | 11.0                | 3.3                 | 290                 | 7.5                 | 20.2                | 5.5                 |
| Feeley [208] | 2013 | South Africa | 3       | 13–17             | 607          | 616                  | 1223                 | 8.1                 |                     | 270                 | 17.6                |
| Wilson [220] | 2013 | Seychelles | 3       | 11–17             | 278          | 302                  | 580                  | 13.4                | 15.6                | 7.7                 |
| Ginsburg [221] | 2013 | South Africa | 3       | 15                | 773          | 840                  | 1613                 | 20.3                | 71.8                | 5.4                 | 2.5                 | 9.6                 | 65.4                | 17.5                | 7.5                 | 14.2                | 68.5                | 11.7                | 5.1                 |
| Malete [222] | 2013 | Botswana   | 3       | 13–16             | 464          | 292                  | 756                  | 5.0                 | 78.4                | 11.6                | 5.1                 |
| Puoane [242] | 2013 | South Africa | 2       | 10–15             | 98           | 102                  | 200                  | 2.4                 | 61.4                | 36.2                |
| Mang’eni [223] | 2013 | Kenya     | 3       | 13–16             | 98           | 102                  | 200                  | 5.0                 |                     |                     |                     |

Sample totals (M) – weighted averages (F) – weighted averages (T) – weighted averages

Acronyms: M (male); F (female); UW (underweight); NW (normal weight); OW (overweight); OB (obese).

Weighted averages: Proportions may not add up to 100% for M, F, and T since some of the included studies did not report in each of the UW, NW, OW, and OB categories.

*Year of publication (year that corresponding data was collected included in brackets).

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Figure 2. Proportions of overweight/obesity (combined) and obesity over time in Sub Saharan Africa.
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Figure 3. Proportions of overweight/obesity (combined) in Sub Saharan Africa’s boys and girls.
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averages fall far below proportions in various high income countries. For example, in Canada, research has shown that the prevalence of overweight/obesity has more than doubled (14% to 29%) and the obesity rate has tripled (3% to 9%) over the last 25 years in children and youth 5 to 17 years of age [302,303]. In the USA, 33% of children and youth 6–19 years are considered to be overweight/obesity, and 18% are considered to obese [304].

It is important to note that across all age groups, WHO cut-points yield higher proportions of boys and girls classified as overweight/obesity than do the IOTF, or CDC cut-points [305]. While studies that used any of the three cut-points were analysed together in this review, when interpreting prevalence estimates of overweight/obesity, it is important to consider the choice of cut-point used in each study. With the largest proportion of included studies using IOTF cut-points, it could be argued that this may “dilute” the weighted average of the proportions of overweight/obesity calculated for SSA. Nonetheless, these results indicate that while there is an imminent threat of continued increases in levels of childhood overweight/obesity in SSA, implementing viable population health interventions may mitigate the associated health risks in these earlier stages.

Persistence of underweight

In discussing an overweight/obesity transition, it is important to recognize that child under-nutrition remains one of SSA’s most fundamental challenge for improved human development [306,307,308]. This is particularly concerning when considering the school-aged child population as malnutrition affects their education outcomes, and consequently opportunities for success in later years [306]. Inadequate access to food and health services as a result of poverty and broader social determinants of health are some of the underlying determinants of child under-nutrition. The underweight trend over time was largely unaltered at approximately 20% for boys and girls combined, providing the evidence of a persisting underweight problem among SSA’s children and youth, and substantiating the emergence of a public health double-edged sword. This persistence in underweight coupled with an overweight/obesity transition may place undue strain on the limited healthcare resources in SSA countries [14]. As such, frameworks for interventions to improve the nutritional status of SSA children will have to account for broader concepts such as societal organization, economic structures, and political ideologies [306]. We would however like to caution the reader that describing an underweight trend was not an objective of this systematic review; as such, pertinent articles reporting on underweight may have been omitted during the literature search thereby skewing these results.

Sex differences

Both quantitative and narrative synthesis revealed that there were increasing trends in proportions of overweight/obesity over time for both boys and girls; however, body composition measures and the proportions of overweight/obesity were proportionally higher in girls than in boys. In contrast, in North America, obesity is more common in boys than in girls, with the most significant differences observed among younger children 5–11 years [304,309]. Higher proportions of overweight/obesity in SSA girls may be related to differences in gender roles particularly those requiring higher physical exertion (e.g., boys participating in higher energy expending roles/activities); and, cultural desirability whereby being overweight (i.e., “rounder”) is an admired trait and seen as a sign of wealth and prestige, particularly in girls.

Urban/rural and SES differences

Narrative synthesis revealed higher body composition measures in the urban compared to the rural population. In addition, higher SES was associated with higher body composition measures, pointing to a positive SES relationship. Factors associated with overweight/obesity span various behavioural, social, environmental, and biological constructs making them difficult to ascertain; however, urban residence and higher SES may be positively associated with overweight/obesity in SSA owing to improved access to governance, health care, education, employment and income, in addition to increased availability of packaged foods high in saturated fats and sugars and increased sedentary behaviour, all of which are more accessible to and/or affordable for those of higher SES or individuals living in urban areas.
Strenghts, limitations, and future directions
The main strength of this review was the use of high quality standards to conceptualize and conduct the methodology and synthesis. Further, as many decisions as possible were made a priori to limit possible bias, and all levels of the review process were conducted in duplicate, ensuring a higher level of accuracy. Our assessment indicated that the quality of included studies was relatively high. The main limitation of this study lies in the vast heterogeneity in study methodology. The variety in the types of body composition measurements, analyses, definitions of SES, and reference standards limited our interpretation and presentation of the results. Quantitative synthesis was limited as those using such more widely accepted cut-points to further categorise study samples by weight status. It is also unclear if any material relevant for this review may have been published in un-indexed journals and hence not captured by the literature search.

Recognizing that future studies may increasingly employ WHO cut-points, since they represent a more robust criterion-based standard, we recommend that studies use the WHO cut-points for categorizing childhood overweight/obese in SSA, as this would allow for improved comparability and time trend analyses as attempted in this paper. A repository of studies, particularly those that are representative may be set up to this end, to allow for periodic comparative analysis for the whole of SSA. Measurements on more population representative samples are also required e.g., a multi-country survey using common measurement techniques and sampling procedures would be most desirable.

Conclusion
This systematic review provides evidence for an overweight/obesity transition in school-aged children in SSA. While the weighted averages of overweight/obesity in SSA are lower, this transition to higher proportions of overweight/obesity is similar to findings in various developed countries. The weighted average of overweight/obesity was higher in girls than in boys, and higher in those with higher SES. The review also revealed a persisting problem of underweight in the region, underpinning a double burden of risk factors. Findings of this review indicate that more nationally representative studies are needed to strengthen this field of research, and that interventions and strategies to address the growing threat of childhood overweight/obesity should focus on the higher SES and urban populations, with greater attention placed on girls.

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Supporting Information

Checklist S1 PRISMA checklist. (DOC)

Author Contributions
Conceived and designed the experiments: SKM LMW AGL MS VOO MST. Performed the experiments: SKM CEF LMW AGL MS VOO MST. Analyzed the data: SKM CEF LMW. Contributed reagents/materials/analysis tools: MS VOO MST. Wrote the paper: SKM CEF LMW AGL MS VOO MST.

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