REVIEW ARTICLE

Anthropometry Measurements to Determine Nutritional Status Among Cerebral Palsy Children: A Scoping Review

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ABSTRACT

This article aimed to review the available anthropometry measurements used in the assessment of nutritional status among Cerebral Palsy (CP) children. Searched journals were from Medline, PubMed and Ovid published from 2015 to 2018. The search identified 443 articles, and eight studies met the criteria. Anthropometric measurements included weight, height, recumbent length, knee height, tibia length, Dual-energy X-ray absorptiometry (DXA), Bioelectrical impedance (BIA), Mid arm circumference (MUAC) subscapular skinfold (SFT), Triceps skinfold (TSF) and prediction equations. Body fat composition can be obtained by DXA, BIA, skinfold measurement, and also prediction equation. The predictive equation is the most reported method to determine nutritional status among CP. This review found that TSF and SFT are more accurate to determine body fat percentage when using together with the predictive equation. Besides, predictive equations using segmental length are reliable in estimating the height and can be used to evaluate the nutritional status using the specific CP growth chart.

Keywords: Anthropometry, Body height, Cerebral Palsy, Growth charts, Nutritional status

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INTRODUCTION

Cerebral Palsy (CP) is a condition that the immature brain in children affects movement and posture disorders (1). With the incidence of 1.5 to 2.5 per 1000 lives birth, CP is the most familiar physical disability among children. CP can be classified based on motor function using Growth Motor Function System (GMFCS) (2). The GMFCS has five-level, level I (mild) – level IV (severe). The higher level of GMFCS, the severe condition of CP. Oral motor dysfunction, mental retardation, visual and hearing problems, speech, and language disorder frequently observed in children with CP (2).

CP children with motor deficiencies always associated with malnutrition. Nutritional problems such as swallowing and feeding disorders like choking, prolong feeding time and vomiting leads to malnutrition. Besides, gastrointestinal issues such as gastroesophageal reflux, constipation, and bowel obstruction often resulted in CP children having inadequate nutrition, being underweight for their age, and having poor linear growth (3). Evidence shows that the major factor contributing to faltering growth in CP children is malnutrition, which resulted from impaired feeding skills (4). The study also indicates that a higher level of gross motor dysfunction among CP children associated with stunting and malnutrition (5). Malnutrition also affects energy utilization as well as muscle and motor functions in these children. It also puts a burden on the family because malnutrition has significantly contributed to the deterioration of health (6). Early identification of signs of malnutrition and prompt intervention in CP children can help them achieve adequate nutrition, which is needed for the desired growth and development at this time and therefore for a better life (7).

Anthropometric assessment is one of the important methods used to detect malnutrition. However, this assessment was proven difficult and unreliable in this population due to associated CP conditions such as muscle atrophy, standing inability, joints contraction, and movement disorder (8). The reliability and validity of tools to assess malnutrition in CP children are crucial so that such cases do not remain unidentified. Dual X-ray absorptiometry (DXA), doubly labeled water and underwater weighing are examples of anthropometric assessments that have been used to assess body composition (9). However, these assessments are not appropriate in healthcare settings as they take more time to run and limited accessibility and availability of specialized equipment and trained staff (10).

Weight-for-height is a standard anthropometric measurement that is used to determine malnutrition. However, the measurement of weight and height is challenging in CP children due to uncontrolled movement, muscle weakness, scoliosis, and joint contractures which make height measurement procedure difficult to perform among these CP children (11). Predictive equations using segmental lengths such as knee height, tibia length, upper arm length, and ulna length, have been developed to estimate weight and height and are widely used in the western country, United States, and Europe (12). On the other hand, there is evidence that the measurement of triceps skinfold (TSF) is relatively reliable and sensitive as a predictor of malnutrition (13). Nevertheless, studies showed that mid-upper arm circumference (MUAC) is a reliable tool in anthropometric measurement to diagnose malnutrition as it produces better results than triceps skinfold measurement (14). Despite that, MUAC can estimate muscle mass in standard equations; however, its use has not been validated in CP (1). There is, therefore, a risk that it can underestimate muscle mass in children with such disabilities.

Growth charts are common methods for the monitoring of pediatric growth, development, and nutritional status (15). However, comparing children with CP with normal healthy children on standard growth charts is difficult due to differences in body composition and structure in children with CP. Development charts for children with CP stratified by the level of gross motor function would be useful for evaluating the child's nutritional status. The use of specific growth charts would be more precise to monitor the growth of cerebral palsy subjects as these growth charts take into account the difference in their severity levels and gross motor function (16). However, researchers still compare the growth of cerebral palsy children with growth charts for healthy developing children.

Assessing the nutritional status of CP children is very important, but at the same time, anthropometric assessments are difficult and unreliable in this population (8). It is very challenging to measure CP due to two factors. First, to achieve reliable and accurate measurement of growth among CP is uneasy, as most CP children have orthopedics and pathological problems such as scoliosis and joint contractures. Second, the interpretation of the growth chart using a general standard reference may not be suitable and inaccurate among CP children (1). Therefore, this article aims to review the best available anthropometric measurements in terms of ease and practicality to assess nutritional status among CP children.

MATERIALS AND METHODS

Selection Criteria

All cross-sectional studies conducted to determine nutritional status and malnutrition among CP children across countries, nationalities, and ethnicities, irrespective of gender, were the aim of this review in writing. Besides, subjects were 18 years of age or below and only CP children with GMFCS classification were included. However, studies on CP children with metabolic syndrome and chronic diseases, and studies that use only topographical distribution have been excluded. Reviews of anthropometric measurements to assess the nutritional status of CP children also selected for analysis. However, reviews that did not explicitly state their selection criteria were excluded from the list.

Search Methods for Identification of Studies

Electronic journal databases namely, Medline, PubMed, and Ovid online were chosen as they are the most comprehensive databases of peer-reviewed journals in the field of nutrition. Research articles and review papers in the English language published between 2013 and March 2018 were picked from the databases using "anthropometry," "cerebral palsy," "nutritional status," "body height" and "growth chart" as the main keywords.

Data Collection and Analysis

Two reviewers had screened the searching of titles and abstracts. The methodology has been assessed before the review was carried out. This study's important features, namely, year, study design, country, number of subjects, age, result, type of anthropometric assessment used, and nutritional status) were extracted from the selected papers and recorded in Microsoft Excel. Outcomes of the selected studies namely, anthropometric measures of body composition and indices of nutritional status among CP children, were then individually processed.

The search using the keywords mentioned earlier yielded 443 titles. After screening the abstracts, this pool narrowed down to 139 papers. Only 23 articles were eligible for full-text reading. Then longitudinal studies and studies not focusing on CP children as the study of their subjects did not give detailed information on the anthropometric measurements used were excluded, n=15 in all. As a result, only eight papers were eligible and met all the required inclusion criteria. The identification of selected papers using the PRISMA Extension for Scoping Reviews illustrated in Figure 1

RESULTS AND DISCUSSIONS

Anthropometry assessment is one of the important and well-established methods to screen malnutrition CP children. Assessing this nutritional status of CP children is highly essential. Yet at the same time, this assessment has been proven difficult in obtaining reliable measurement and cannot be evaluated within

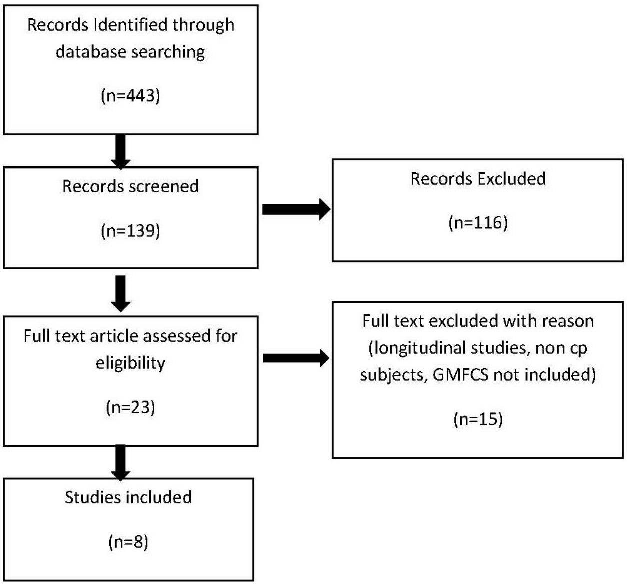

Figure 1: PRISMA Flowchart for selection of journals

the reference standard of healthy children (17). This review discusses which anthropometry measures are available and can be used routinely and easily for CP children to assess their nutritional status.

Table 1 shows a list of studies that have determined the nutritional status of CP through anthropometric measurements and a brief interpretation of their results provided therein. The assessments include weight, height, recumbent length, knee height, tibia length, MUAC, DXA, subscapular skinfold (SFT), TSF, and use of prediction equations. A total of eight cross-sectional studies among CP children aged between 2 to 18 years included.

Weight and height are fundamental to the anthropometry measurements (18). Weight measurement is relatively uncomplicated in children with CP. Their weight was obtained using a digital scale. CP children who were incapable to stand, wheelchair scales were utilized on which children could be weighed in a sitting position. In the absence of specialized equipment, the conventional reliable method can be used where the caregiver and the child weighed together on the scale. The weight measurement of the child will be obtained by deducting the weight of the caregiver.

Unlike weight, determination of height is difficult among children with CP, as this CP always presents with joint contractures, scoliosis, tone alteration and failure to stand (18). A stadiometer can obtain the measurement of height or stature of CP children in GMFCS I and II. However, in the condition that CP children were unable to stand, the segmental length is recommended for CP children (19). Tibia length, upper arm length, knee height, and lower length are the segmental length that utilized to estimate heights using predictive equations. Stevenson (19) uses knee height, tibia length, and upper arm length, while Chumlea et al. (20) use knee height, and Gauld et al. (21) use ulna and tibia length to develop predictive equations to estimate height. One study showed that knee height is more accurate than upper arm length in measuring height (22). Gauld et al. equation using tibia length underestimate height measurement in higher GMFCS level (23). This result contrast with another recent study where the tibia length prediction equation can estimate the height of CP children with GMFCS III to IV regardless of the presence of joint contracture or scoliosis (24). Also, it was reported that Stevenson Equations was less biased and more appropriate to be used for CP children aged 12 years and below (23), while the Gauld equation was more appropriate for CP children older than 7 years. On the other hand, for CP children with severe GMFCS, the Gauld equation was demonstrated as being less biased than Stevenson Equations (23). Accurate segmental measurements are important for the equation to convert segmental measurements into estimated heights.

Body composition can be obtained by dual-energy X-ray absorptiometry (DXA), bioelectrical impedance (BIA), or skinfold measurements. BIA and skinfold measurements, either triceps of the skin fold (TSF) or subscapular skinfold (SFT) used to determine the body composition of children with CP. TSF was easily measured without causing distress to the CP children but generally underestimated the fat stores because CP causes fat to be stored mostly in the central part of the abdominal cavity (8). TSF and SFT decreased among CP children who classified as level V and I (22). Both TSF and SFT had significant correlations with DXA fat mass, where r=0.884 to 0.895, respectively. The correlation of TSF and SFT with fat percentage are r=0.749 to 0.763, respectively (25). However, these SFT measurements were not reliable when used alone. A previous study found that SFT is significantly reliable and produced better results with predictive equations (25). An excellent correlation has been found between fat percentages assessed with DXA and fat percentages estimated when using Slaughter equations (r=0.819), explained rather high association of one variable to another (25). Results also showed that ambulatory CP might obtain accurate measures of body fat percentage using BIA and two skinfold measurements (10). Predictive equations which have been used to estimate body fat percentage were Slaughter Equation and Gurkha Equation. Thus the use of skinfold measurements together with predictive equations allows healthcare professionals better to assess total body fat percentage (10). With regards to DXA, body composition including fat, water, protein, and bone can be measured (24). This method has been proven to be the gold standard technique for measuring body composition and can be used for CP children with altered body posture (26). However, DXA is expensive, thus there is a demand for a cost-effective and reliable technique such as BIA. Besides low cost, BIA is also easy to transport, fast, and easy to assess fat stores in

Table I: Findings of cross-sectional studies on anthropometric measurements among CP children

Authors (Study location)	Sample size (age, CP type)	Anthropometric assessment methods	Malnutrition Status	Results
Garcia-Iniguez et al., 2017 (Mexico)	108 (2-16 years, all CP types)	Weight, height, knee height, lower leg, MUAC, Predictive Equation, Day growth chart, Brooks growth chart	31.5% below 10th centile	Nutritional status can be obtained from a specific growth chart and predictive equation using knee height and lower leg
Herrera Anaya et al., 2016 (Columbia)	177 (2-12 years, all CP types, GMFCS I-V)	Height, weight, knee height, MUAC TSF, WHO growth chart	46.3% of CP malnutrition. Malnutrition increase as the levels of GMFCS increased.	Nutritional status can be obtained from z-scores of anthropometric parameters, such as weight-for-age, BMI-for-age, tricipital and subscapular skinfolds, and height-for-age.
Finbraten et al., 2015 (Norway)	47 (8-18 years, all CP types)	Knee height, weight, DXA, TSF, and SFT, Predictive equation	severe motor impairments are more likely to have stunted growth, a higher body fat percentage, a lower lean mass, and a lower bone mass	weight-for-age and weight-for-height as proxies for body composition in children with CP may be misleading. DXA measurements used to determining body fat percentage. The Slaughter equation underestimates body fat percentage.CP specific Gurka equation is excellent to determine the fat percentage.
Kihara et al., 2015 (Japan)	50 (3-12 years, all CP types)	Height, tibia length, Predictive Equation	Tibial length increases, in children with moderate-to-severe CP	The stature of children with moderate-to-severe CP could be estimated from their tibial lengths, regardless of the presence of joint contracture or scoliosis.
Kakooza-Mwesige et al., 2015 (Uganda)	135 (2-12 years, all CP types)	Weight, height, BMI, MUAC, WHO growth chart	52% of the children were malnourished and 38% were stunting.	MUAC for age is a less sensitive anthropometric measure in CP children
Offinger et al., 2014 (Chicago, US)	120 (6-8 years, GMFCS I - III)	BIA, TSF and SFT, Predictive Equation	(49%) were categorized as having adequate body fat and 60 (47%) as having excess body fat	BIA and two skinfolds CP Gurka equation was an accurate assessment of body fat percentage Slaughter equation underestimates body fat percentage
Haapala et al., 2014 (Michigan, US)	137 (2-25 years; mean age 11 years, all CP types GMFCS I-V)	Tibial length, knee height, ulna length, Predictive Equation	Gauld equation using tibia length underestimate height measurement in higher GMFCS level	Prediction equation is strongly suggested for individuals with little impairment
Araujo et al., 2013 (Bahia, Brazil)	187 (2-6 years, all CP types GMFCS I-V)	Weight, height, Brook's growth chart, CDC growth chart	10% weight below 10th centile	Overestimated malnutrition using CDC growth curve

BIA: Bioelectrical impedance; CDC: Centre for Disease Control and Prevention; CP: Cerebral palsy; DXA: Dual-energy X-ray absorptiometry GMFCS: Growth Motor Function System; MUAC: Mid-upper arm circumference; SFT: Subscapular skinfold; TSF: Triceps skinfold; WHO: World Health Organisation

CP children. One study showed that BIA is a reliable measurement of body fat compared to skinfold (10). However, using BIA among CP children is challenging due to the impact of hardware and hydration concerns. BIA also relies on precise height measurements, which can weaken the precision of such measurements for individuals with CP (10).

MUAC is a simple and low-cost method to determine malnutrition. In the selected studies, MUAC was not used as a single anthropometric measurement to determine malnutrition. Study shows that there are significant relationships between the levels of gross motor functioning and the prevalence of malnutrition and stunting among CP(5). Another study shows that MUAC for age is a less sensitive anthropometric measure in CP children and TSF has been recommended to determine fat composition (27). From this review, TSF and SFT were frequently used as compared to DXA, BIA, and MUAC and more accurate when to use together with the prediction equation to determine body fat composition among CP children.

The use of growth charts was another common method of assessing nutritional status. A specific growth chart for CP children has been developed stratified by GMFCS level to assess nutritional status (15). Studies show that growth and weight had significantly differenced motor functions (15,18,28). Using the World Health Organisation (WHO) growth chart, more than 50% of CP children were found to be malnourished (17). It was also found that the use of the Centre for Disease Control and Prevention (CDC) growth chart overestimated malnutrition among CP (2). The usage of normal growth charts for the normal population, specifically the weight-for-height or Body Mass Index (BMI) are not directly applicable for the children with low muscle mass and bone(1). The use of BMI makes it difficult to assess nutritional status as taking accurate height measurements in CP children is difficult. (9). When standard growth charts are utilized, BMI produces poor results to predict fat stores in CP children (29). Although CDC reference charts or WHO growth charts widely used for healthy children, it has its limitation for CP children, where it has been observed that weight-for-age and stature-for-age are always under the 5th percentile (30). Studies also showed that there is a significant difference in the plotted graph between GMFCS growth chart and standard normal children growth chart (22). This review has proven that malnutrition is overestimated among CP when the CDC and WHO growth chart is used (27,28). For this reason, the newest CP specific growth chart by Brooks et al. (15) stratified using GMFCS motor is more acceptable and appropriate (28).

CONCLUSION

In conclusion, despite challenges in measuring weight and height among CP children, there are few options of anthropometry measurements that can be easily and practically used for CP children to determine nutritional status. Predictive equations are the most reported method in nutritional assessment among CP. The use of skinfold measurements, TSF, and SFT together with predictive equations is recommended as it gives the better result of total body fat percentage. Besides, to estimate height, predictive equations using segmental length are the most preferred method to be used among CP children with higher GMFCS levels. This height or stature measurement using predictive equations is very easy to perform and it is very important to have accurate height measurements before plotting on a growth chart to determine nutritional status. A specific growth chart for stratifying the GMFCS level is the most appropriate growth charts to be used in CP children.

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REFERENCES

1. Kuperminc MN, Stevenson RD. Growth and nutrition disorders in children with cerebral palsy. Dev Disabil Res Rev. 2008;14(2):137–46.
2. Araъjo LA, Silva LR. Anthropometric assessment of patients with cerebral palsy: Which curves are more appropriate? J Pediatr (Rio J) [Internet]. 2013;89(3):307–14. Available from: http://dx.doi.org/10.1016/j.jped.2012.11.008
3. Thommessen M, Heiberg A, Kase BF, Larsen S, Riis G. Feeding problems, height and weight in different groups of disabled children. Acta Paediatr Scand. 1991;80(5):527–33.
4. Skuse D. Characteristics and Management F Feeding Problems O F Young L Palsy. Dev Med Child Neurol. 1992;34(5):379–88.
5. Herrera-Anaya E, Angarita-Fonseca A, Herrera-Galindo VM, Martнnez-Marнn RDP, Rodrнguez-Bayona CN. Association between gross motor function and nutritional status in children with cerebral palsy: a cross-sectional study from Colombia. Dev Med Child Neurol. 2016;58(9):936–41.
6. Krick J, Murphy-Miller P, Zeger S, Wright E. Pattern of growth in children with cerebral palsy. Vol. 96, Journal of the American Dietetic Association. 1996. p. 680–5.
7. Rajikan R, Zakaria NM, Manaf ZA, Yusoff NAM, Shahar S, Program DS, et al. Special Issue THE EFFECT OF FEEDING PROBLEMS ON THE GROWTH OF CHILDREN AND. J Fundam Appl Sci ISSN. 2017;9(6S):787–804.
8. Gurka MJ, Kuperminc MN, Busby MG, Bennis JA, Grossberg RI, Houlihan CM, et al. Assessment and correction of skinfold thickness equations in estimating body fat in children with cerebral palsy. Dev Med Child Neurol. 2010;52(2):35–41.
9. Finbreten A-K, Martins C, Andersen GL, Skranes J, Brannsether B, Jъlнusson PB, et al. Assessment of body composition in children with cerebral palsy: a cross-sectional study in Norway. Dev Med Child Neurol [Internet]. 2015;57(9):858–64. Available from: http://doi.wiley.com/10.1111/dmcn.12752
10. Oeffinger DJ, Gurka MJ, Kuperminc M, Hassani S, Buhr N, Tylkowski C. Accuracy of skinfold and bioelectrical impedance assessments of body fat percentage in ambulatory individuals with cerebral palsy. Dev Med Child Neurol. 2014;56(5):475–81.
11. Hogan SE. Knee Height as a Predictor of Recumbent Length for Individuals with Mobility-Impaired Cerebral Palsy. J Am Coll Nutr. 1999;18(2):201–5.
12. Stevenson RD, Conaway M, Chumlea WC, Rosenbaum P, Fung EB, Henderson RC, et al. Growth and health in children with moderate-to-severe cerebral palsy. Pediatrics. 2006;118(3):1010–8.
13. Samson-Fang L, Stevenson RD. Linear growth velocity in children with cerebral palsy. Dev Med

Child Neurol. 2008;40(10):689–92.
14. Berkley J, Mwangi I, Griffiths K, Ahmed I, Mithwani S, English M, et al. Assessment of Severe Malnutrition Among Hospitalized Children in Rural Kenya. Jama. 2005;294(5):591.
15. Brooks J, Day S, Shavelle R, Strauss D. Low weight, morbidity, and mortality in children with cerebral palsy: New clinical growth charts. Pediatrics. 2011;128(2).
16. Day SM, Strauss DJ, Vachon PJ, Rosenbloom L, Shavelle RM, Wu YW. Growth patterns in a population of children and adolescents with cerebral palsy. Dev Med Child Neurol. 2007;49(3):167–71.
17. Azcue MP, Zello GA, Levy LD, Pencharz PB. Energy expenditure and body composition in children with spastic quadriplegic cerebral palsy. J Pediatr. 1996;129(6):870–6.
18. Rempel G. The Importance of Good Nutrition in Children with Cerebral Palsy. Phys Med Rehabil Clin N Am [Internet]. 2015;26(1):39–56. Available from: http://dx.doi.org/10.1016/j.pmr.2014.09.001
19. Stevenson RD. Use of Segmental Measures to Estimate Stature in Children With Cerebral Palsy Background: The assessment of stature in children with. 2015;(3). Available from: http://archpedi.jamanetwork.com/
20. Chumlea WMC, Guo SS, Steinbaugh ML. Prediction of stature from knee height for black and white adults and children with application to mobility-impaired or handicapped persons. J Am Diet Assoc. 1994;94(12):1385–91.
21. Gauld LM, Kappers J, Carlin JB, Robertson CF. Height prediction from ulna length. Dev Med Child Neurol. 2004;46(7):475–80.
22. García-Contreras AA, Vбsquez-Garibay EM, Romero-Velarde E, Ibarra-Gutiйrrez AI, Troyo-Sanromбn R, Sandoval-Montes IE. El apoyo nutricio intensivo mejora el estado nutricio y la composiciуn corporal en nicos gravemente desnutridos con parбlisis cerebral. Nutr Hosp. 2014;29(4):838–43.
23. Haapala H, Peterson MD, Daunter A, Hurvitz EA. Agreement between actual height and estimated height using segmental limb lengths for individuals with cerebral palsy. Am J Phys Med Rehabil. 2015;94(7):539–46.
24. Kihara K, Kawasaki Y, Yagi M, Takada S. Relationship between stature and tibial length for children with moderate-to-severe cerebral palsy. Brain Dev [Internet]. 2015;37(9):853–7. Available from: http://dx.doi.org/10.1016/j.braindev.2015.01.007
25. Finbreten AK, Martins C, Andersen GL, Skranes J, Brannsether B, Júlнusson PB, et al. Assessment of body composition in children with cerebral palsy: A cross-sectional study in Norway. Dev Med Child Neurol. 2015;57(9):858–64.
26. Henderson RC, Kairalla JA, Barrington JW, Abbas A, Stevenson RD. Longitudinal changes in bone density in children and adolescents with moderate to severe cerebral palsy. J Pediatr. 2005;146(6):769–75.
27. Kakooza-Mwesige A, Tumwine JK, Eliasson AC, Namusoke HK, Forssberg H. Malnutrition is common in Ugandan children with cerebral palsy, particularly those over the age of five and those who had neonatal complications. Acta Paediatr Int J Paediatr. 2015;104(12):1259–68.
28. Araújo LA, Silva LR. Jornal de. 2013;89(3):307–14.
29. Fung EB, Samson-Fang L, Stallings VA, Conaway M, Liptak G, Henderson RC, et al. Feeding dysfunction is associated with poor growth and health status in children with cerebral palsy. Vol. 102, Journal of the American Dietetic Association. 2002.
30. WHO Child Growth Standards and Identification of Severe Acute malnutrition in Infants and children, (2009). A joint statement by the World Health Organization and the United Nations Children Fund. Geneva: World Health Organization 2009. Available from: http//www.who.int/nutrition/publications/severemalnutrition/9789241598163/en Access November 2016.