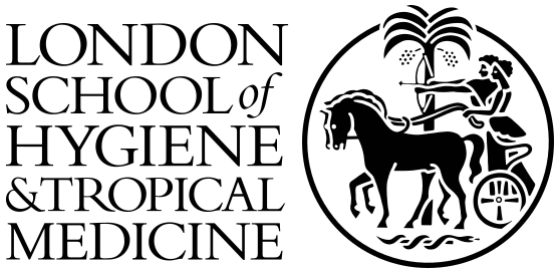

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Assessment of Neurodisability and Malnutrition in Children in Africa

Melissa Gladstone, MBChB, MRCPCH, MD,[*] Mac Mallewa, MBBS, DTM&H, MRCPCH, PhD,[†,‡] Alhaji Alusine Jalloh, MBBS,[†] Wieger Voskuijl, MD, PhD,[†] Douglas Postels, MD,[§] Nora Groce, MSc, PhD,[‖] Marko Kerac, DTM&H, MRCPCH, MPH, PhD,[‡,‖] and Elizabeth Molyneux, FRCPCH, FRCP, FCEM[†]

Neurodevelopmental delay, neurodisability, and malnutrition interact to contribute a significant burden of disease in global settings. Assessments which are well integrated with plans of management or advice are most likely to improve outcomes. Assessment tools used in clinical research and programming to evaluate outcomes include developmental and cognitive tools that vary in complexity, sensitivity, and validity as well as the target age of assessment. Few tools have been used to measure socioemotional outcomes and fewer to assess the disabled child with malnutrition. There is a paucity of tools used clinically which actually provide families and professionals with advice to improve outcomes. Brain imaging, electroencephalography, audiology, and visual assessment can also be used to assess the effect of malnutrition on brain structure and function. The interaction of neurodisability and malnutrition is powerful, and both need to be considered when assessing children. Without an integrated approach to assessment and management, we will not support children and families to reach their best potential outcomes.

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Introduction

There is good evidence for the interplay between neurodisabling conditions and malnutrition. We know that malnutrition causes neurodevelopmental delay[1] and neurodisability leads to poor growth.[2-4] A large number of tools are used in research or for programming purposes to assess neurodevelopmental outcomes in children with malnutrition; however, few tools are applied clinically. In Africa, any assessments of children with neurodisabilities and malnutrition are very limited.

Research studies have focused neurodevelopmental assessment on general development, intelligence, and school readiness,[5] with less emphasis on socioemotional regulation and wider cognition (attention and memory). There is no consensus as to which assessment tools provide the most robust evidence for assessing change. At a population level, assessment can clarify burden of disease and effectiveness of programs. Programs to improve malnutrition are most effective if they also target the neurodevelopment of children[6] and robust assessment tools are required that measure not just growth but also development.[6] Tools at this level need to be easy to provide training on, be reliable, and if possible, be linked to programs that can help families. Clinical tools are few

*Department of Women and Children's Health, Institute of Translational Medicine, University of Liverpool, Liverpool, England, UK.
†Department of Paediatrics and Child Health, College of Medicine, University of Malawi, Blantyre, Malawi.
‡Malawi-Liverpool-Wellcome Trust Clinical Research Programme, Blantyre, Malawi.
§International Neurologic and Psychiatric Epidemiology Program, Michigan State University, East Lansing, MI.
‖Leonard Cheshire Disability and Inclusive Development Centre, University College London, London, England.

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Address reprint requests to Melissa Gladstone, MBChB, MRCPCH, Department of Women and Children's Health, Institute of Translational Medicine, University of Liverpool, Alder Hey NHS Children's Foundation Trust, Eaton Road, Liverpool, England L12 2AP, UK. E-mail: m.j.gladstone@liverpool.ac.uk

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but good examples of validated tools for use in Africa include the Malawi Developmental Assessment Tool[7] and Kilifi Developmental Inventory.[8] These will be most beneficial if linked into programs for training health professionals, community provision of advice, and interventions for families for children with malnutrition or neurodisabilities or both.[6,9,10]

In this review, we discuss assessment tools as well as clinical imaging tools used to assess neurodevelopmental and neurodisabling conditions in children with malnutrition. We focus on tools validated in Africa and discuss the implications of the use of these tools.

Assessment of Neurodevelopment in Children With Malnutrition

Children's neurodevelopment may be assessed using general developmental assessment tools or more precise measures to identify specific changes in brain function as a result of malnutrition. Tools include those to assess cognition (memory, executive function, and nonverbal or verbal reasoning), specific language abilities or behavioral aspects of the child such as attention or emotional regulation. It is clearly important that the relevant domains and constructs are assessed with tools that are specific and sensitive. Tools vary depending on the nature of studies (longitudinal vs cross-sectional), age of child (infancy, preschool, school age, or adolescence), timing of insult of malnutrition (antenatal, neonatal, preschool, etc) and type of malnutrition. The effects of malnutrition on the brain may differ according to the type of malnutrition, for example, chronic malnutrition (stunting, manifested as low height for age), acute malnutrition (formerly known as protein-energy malnutrition [PEM] and manifested as either kwashiorkor or wasting, low middle-upper arm circumference [MUAC] or low weight for height), or a specific micronutrient deficiency such as iron or zinc.[11] Some deficiencies, such as chronic malnutrition, will affect global functioning of the brain and are assessed best through general developmental assessment tools. Other deficiencies such as iron deficiency may have more effect on myelination and tools to assess processing speeds may be more useful.

In assessing the neurodevelopmental status of children with malnutrition, a thorough physical examination should be made looking for evidence of chronic disease. A neurologic examination should include assessment of tone, cranial nerve problems (particularly swallowing difficulties), head circumference, and dysmorphic features to help in understanding any underlying etiology for the child's condition.

Developmental Assessment

Developmental tools are generally used for children up to the age of 5 or 6 years with more detailed cognitive assessments being used in school-aged children. Many of these require training and are expensive to buy. They include the Griffith's Scales of Mental Development[12-15] and the Bayley Scales of Infant Development.[16,17] Developmental screening tools such as the Denver II[18,19] require less training and are more user-friendly but there is debate about their sensitivity or specificity or how culturally appropriate these tools are.[20,21] Their use can lead to overreferrals of children who do not need to be treated, which is particularly difficult when resources are limited. Parental report measures such as the Ages and Stages or the Paediatric Evaluation of Development Status[22-25] are used to detect developmental delay[21,26-31] and are highly predictive of true problems. These tools require reading abilities unless a professional reads out the items to the parent. They have all been used in Africa (as referenced) to assess outcomes. Often these different developmental assessment tools are translated into local languages[32] but not adapted or validated for a particular population.[33-35] It is rare that there are standardized norms for these tools, and they are mainly used for research rather than for clinical purposes. In more recent years, some developmental tools such as the Malawi Developmental Assessment Tool and the Kilifi Developmental Inventory have been created or adapted specifically for African settings[7,8,36-38] and have gone through validation and reliability processes to show good predictive validity. The WHO Gross Motor Milestones are also used but the normal parameters for attainment on these are wide.[39] New tools are being created that may be used for surveillance with specific messages interlinked to provide parents and caregivers with advice.[9]

Cognitive and Executive Function

Specific measures to assess cognitive function, executive function, and attention are used primarily for research. Many proponents would recommend using these specific tests rather than general developmental tools as they are more sensitive to specific nutritional deficiencies.[35,40] These tests require training, time, and psychological support. Previously, IQ tests such as the Stanford-Binet[41] or the Weschler Adult intelligence scales were used.[42] Recently, tools that do not require language such as Raven's progressive matrices[43] or the Kaufman ABC[44-46] have become popular, with some tools specifically adapted for African settings such as the Kilifi ABC.[34] Other recent studies have used computer-administered tests in the form of simple touch screen games—which also have the advantage of language independence.[47,48] Developmental psychologists are recognizing how closely linked cognition is with emotional regulation, motor development, and motor activity.[5] Therefore some specific simple tests of executive function have been used, particularly with infants. These include measures of self-control or delay inhibition such as the "snack delay test."[49] Other tests of executive function in infants include "the windows test" or the A not B task.[50]

Specific Areas of Development or Language

Specific language abilities have been assessed to identify particular impairments in children that may be related to malnutrition. For example, the test of verbal analogies or the Peabody Picture Vocabulary Test. Recently, the MacArthur

Bates Communication Development Inventory has been used more widely and has been shown to provide a more sensitive description of the level of language of children between 1 and 2 years of age than many developmental tools. It has been used in different cultural settings with good validity and reliability.[50-55]

Socioemotional Functioning

It is becoming clearer how relevant and predictive socioemotional functioning is in relation to malnutrition.[56] Carers have often described the malnourished child as apathetic with little ability to interact with others. There are few assessment tools which have been used, but one research tool which has shown good validity in some settings is the Socio Emotional Development Scale.[57,58] Many researchers see maternal-child interaction as an important factor in childhood malnutrition. Maternal depression or mental health difficulties that lead to poor interaction may play a part in this.[59-64] A clinically useful assessment of the child with malnutrition should include an assessment of maternal mental health and the interaction between child and mother or caregiver. Specific tools for this exist,[63,65,66] but they vary in their use at a practical level as many take time and require equipment such as video facilities.

The Assessment of Nutritional Status and Functioning of the Child With Neurodisability

Assessing nutritional status in nondisabled children can be challenging; it is even more so in those with disabilities. As a result, nutritional status is often assessed poorly and sometimes neglected entirely. One challenge is that there are many forms of malnutrition—often coexisting in the same child—that require different types of assessment. Many of these are proxies for what really determines nutritional "health." Assessing these children in a clinical setting reveals a number of interactions which, if addressed by the family, can make big differences to the ability to feed and to nutritional intake. The most common difficulty is low nutritional intake and studies have shown that this is often the case when little time is spent with children who have difficulties feeding[67] (Fig. 1).

Firstly, understanding the specific problems for that child is important. These include understanding the underlying diagnosis. A general examination looking for signs of nutrient deficiencies should include an examination of the skin looking for depigmentation, hyperpigmentation, and desquamation, sometimes seen in kwashiorkor, as well as hyperpigmented hyperkeratosis in zinc deficiency. Other signs to look for are general pallor and koilonychia in iron deficiency. An eye examination should include looking for conjunctival pallor and dryness, wrinkling and Bitot spots (silvery plaques of desquamated epithelial cells and mucus on the bulbar aspect)—all seen in vitamin A deficiency. Examination of the locomotor system, checking for sternal deformities, rib rosaries, and bowing of the tibia will be useful—all signs of rickets (vitamin D deficiency). Children should be assessed for medical conditions (eg, cardiac or renal disease).[68] On

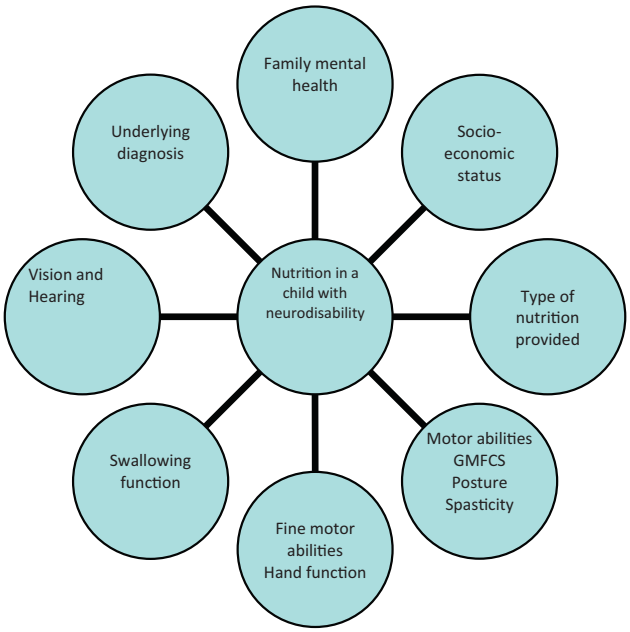

Figure 1 Interaction of multiple factors in the child with neurodisability and malnutrition.

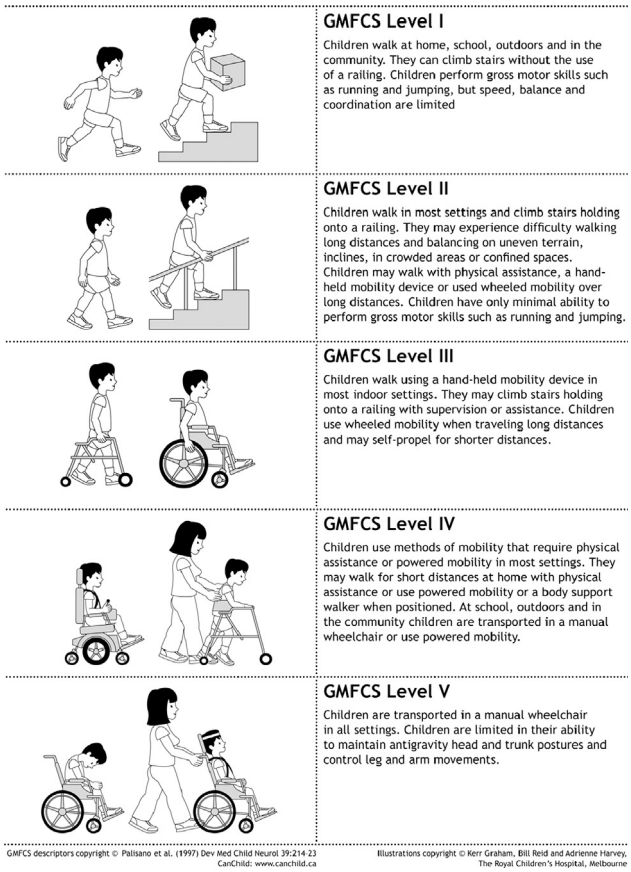

Figure 2 GMFCS E&R descriptors and illustrations for children between their 6th and 12th birthday.

neurologic assessment, the child's tone (stiff or floppy) would aid in advice about positioning (vital for good feeding).[69] The severity of a child's motor disability is known to be associated with feeding difficulties. Assessing the child's ability to sit, their use of assistive devices and their abilities and positioning for feeding in the home may provide further information for the assessor.[70] A classification system such as the Gross Motor Functioning Classification System (Fig. 2), a broad 5-category classification system of motor functional limitations and abilities, may help to put this in context[71,72] (Fig. 2).

We know that anthropometric measurement is crucial in all children but it is particularly important in children with disabilities. Their underlying difficulties can make anthropometry challenging. Measurement of height and weight are not easy in children who cannot stand or sit and who have limb or spine flexion deformities. This influences the ability to undertake height-for-age (a marker of chronic malnutrition or stunting), body mass index, and weight-for-height (a marker of wasting and a key criterion for entry to therapeutic feeding programs) evaluations. In addition, we must not use appearance alone as a way of assessing acute malnutrition as this has poor sensitivity or specificity and many children would be missed and would not get needed treatment. Arm span and tibial length, as proxy measures of height, have good validity, in particular for nonambulant children, for example, those with cerebral palsy.[73-75] Weight measurements should be encouraged but interpreted with caution. The easiest and most useful tool to assess acute malnutrition is the MUAC. MUAC avoids the need for height measurement, is cheap, quick, and easy to use, and is the assessment of choice in populations at risk of wasting.[76,77] Head circumference may imply an underlying diagnosis and likely continued progression of the neurological condition. Children with cerebral palsy or other developmental disorders have different parameters for normal growth.[78-80] Normal growth charts are often not applicable and many children do not achieve "normal" growth. Some disabilities (eg, Down syndrome and cerebral palsy) result in different growth patterns and specialized growth charts are needed to determine growth or nutrition.[81] As cerebral palsy is a heterogenous and complex group, there are different charts for each of the 5 functional levels of cerebral palsy as related to the Gross Motor Functioning Classification System. These are not always easily available so for clinicians, it is more important to just have a general awareness that these children do have different growth trajectories.

Assessment of vision and hearing helps a family understand how best they can enable some children to improve their development, play, communication, and feeding. If visual impairments are not understood, it may be difficult for children to feed. If hearing impairments are present, children can have delayed communication skills and behavioral problems that affect their ability to ask for food.

The assessment of a child with a disability should include a detailed feeding history. This includes information about how they feed, how long it takes, who feeds them, what they feed with (utensils), what kind of foods they take (soft, lumpy, and thickened only), whether they choke or cough regularly, have recurrent chest infections, and whether they drool.[4]

Understanding the social situation for a family with a child with neurodisability enables work with families to improve nutrition. Often, the families of children with disabilities do not really understand their child's diagnosis. Compounding this, families may feel isolated and stigmatized and have problems with child care.[82] Access to food is a right for children with disabilities, guaranteed under the United Nations Committee of the Rights of Disabled Persons and the United Nations Committee of the Rights of the Child. However, if parents and carers anticipate that their child will die young or will be unable to contribute to the welfare of the household as an adult, families may hesitate to provide enough food, enough nutritious food, or may withhold food altogether.[83] We need to understand issues surrounding quality of life and participation of those with disabilities within society—as promoted within the new International Classification of Functioning framework of disability.[84] It is important to consider the effect of the child's condition on the family and the community, and how this may affect the ability of the family to care for and nurture a child. Social support structures and the assessment of these for a family are vital for these children. Availability of services for children vary but in some settings there may be a social or disability welfare worker or a palliative care service which can provide advice and information for families.

Neuroimaging and Electrophysiological Assessment of Children With Malnutrition

Studies over many years have demonstrated that nutritional deficiency impairs central nervous system functioning at many levels.[85-91] Human and animal histological and imaging studies of the developing brain have shown both macrostructural and microstructural changes in the nutritionally impaired brain.[92,93] Kwashiorkor is associated with retarded brain growth,[94] reduced cerebral cellularity,[95] reduced or delayed myelination,[96] and, in the neurophysiological field, changes in electroencephalography (EEG)[97,98] and evoked potential tracings.[99]

Neuroradiology

Neuroimaging technology is now available in some low-income settings. Imaging studies have shown that cerebral atrophy and ventricular dilatation with prominent sylvian fissures and basal cisterns are common in children with kwashiorkor.[100-103] Some studies have shown that brain pathology, as demonstrated on magnetic resonance imaging, is reversible after nutritional rehabilitation.[100,101,104]

EEGs and Malnutrition

EEG, has become more useful with recent advances in EEG technology, particularly through computer analysis procedures.[105] The first studies were conducted in West Africa in the 1950s[106] where abnormal EEGs in children with PEM were shown. In these children, the dominant frequency of the EEG was much lower than in normal children. Similarly, lower frequencies over all EEG bands have been shown in up to one-

third of children with kwashiorkor. Some studies have demonstrated that with treatment these abnormalities tend to disappear but may persist for several months after nutritional rehabilitation in case of severe malnutrition and in children who had PEM before 6 months of age.[97,98] Long-term follow-up of previously marasmic children confirms that acute PEM results in marked retardation in faster EEG frequencies (α rhythm) for up to 12 years after successful nutritional treatment.[94,107] Some studies have also related poor cognitive outcomes to the EEG changes of diminished voltage and excessively slow rhythm.[108]

Auditory Evoked Potentials and Malnutrition

Auditory evoked potentials (AEP) are understood to be a sensitive measure of brain functions and have been used by many researchers both in human studies[109,110] and experimental animal studies.[111] Studies evaluating electrophysiological parameters have reported diverse nervous system consisting of auditory,[112] visual,[112,113] corticospinal,[114] and somatosensory paths,[115] as well as interhemispheric modulation.[116] Clinical studies have shown that early malnutrition (marasmus and kwashiorkor) can produce marked alterations in the electrophysiological parameters of AEP[117,118] and irreversible increased latencies of AEP waves 12 months after rehabilitation. This suggests deficiencies in the myelination process with decreased synaptic efficiency in the auditory system. Studies have shown brain recovery in laboratory animals when stimulated.[119,120] Some studies report that the effects of malnutrition on AEPs are reversed by nutritional rehabilitation if associated with daily and individual sensorimotor and environmental stimulation.[121] Sensory stimulation used in a properly directed, systematic, and individualized manner showed encouraging results in AEP recovery in these children.

Future Plans

The interaction among malnutrition, developmental delay, neurodisability, and malnutrition is strong. Nutritional assessment tools have been used in low-income settings but developmental assessment or cognitive tools have not been well used in these settings. Many tools are not designed for practical identification of developmental delay or disability with linked advice and support for families. There is an obvious need to make available simple, practical neurodevelopmental monitoring or surveillance tools that can be integrated with nutritional assessments to benefit children with neurodevelopmental delays or disabilities and nutritional disorders. All acute malnutrition units should use simple developmental monitoring tools and give advice to families. Table 1 describes some simple measures to use in a busy clinic.

Sensitive and specific tools are required to assess the effect of interventions on outcomes in malnourished children. It may be that specific cognitive and language measures that identify specific brain function problems are of more practical use than overall developmental or cognitive tools. All such tools must be valid and reliable in a variety of cultural settings.[35,36,51] Improved imaging and EEG technology has advanced the understanding of neurobiological changes in the brain as a result of malnutrition. These modalities will continue to direct

Table 1 The 5 Most Important Things to Assess in Children With Malnutrition and Those With Neurodisability

Malnutrition	Neurodevelopment or Disability
1 Middle-upper arm circumference (MUAC)*	**1 Maternal child interaction**
In children aged 6-59 mo: < 125 mm = moderate wasting < 115 mm = severe wasting	Knowing if the carer is able to interact and play with the child—encouragement of this is crucial for good feeding and development.
2 Weight for age (and weight *trend*)	**2 Developmental stages**
Weight for age may be lower than in nondisabled children, but all children should be growing. Loss of weight is a dangerous sign needing further assessment.	*Is the child sitting by 9 mo, walking by 18 mo? *Is the child understanding and able to express himself in some way? *Is the child able to use hands to play and feed? Getting an idea of the developmental level of the child can help to providing advice to carers on stimulating the child.
3 Appetite test and feeding technique	**3 Feeding and swallowing abilities**
If a malnourished child still has appetite and is able to consume a "test" feed, he or she may be eligible for home-based treatment. Those without appetite or with significant feeding problems may need admission	Some children need specific advice about what utensils and support are best used to help them to feed and swallow as well as what textures of food are helpful.
4 Oedema	**4 Muscle tone and posture (examine undressed)**
If bilateral pitting edema, then consider kwashiorkor	If a child has increased muscle tone or low muscle tone, they may need help in positioning while they feed.
5 HIV status	**5 Vision/hearing**
In HIV-prevalent areas, this is another major factor underlying malnutrition and should be tested for and excluded	Ability to hear and see has profound effects on abilities to feed and interact.

*Weight for height or length is also used to assess wasting severity but is a poorer predictor of mortality outcomes than MUAC—plus and is difficult to assess in some disabilities (eg, children who cannot stand or those with contractures).

research on anatomical areas most affected in different types of malnutrition.

The combined assessments of neurodisabilities and nutrition and growth are not always straightforward but provide the basis for appropriate advice and interventions to improve outcomes and quality of life for children and families. Comprehensive and integrated approaches between health, education, and social services will take this forward.

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