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Measuring Malnutrition: The History of the MUAC Tape and the Commensurability of Human Needs

Unpacking the Humanitarian Toolbox

In February 2012, the World Food Programme organized a crisis summit in Rome to deliberate on the ongoing famine in the Sahel region. Having been criticized harshly for its late reaction to the raging famine in the Horn of Africa, the organization wanted to respond quickly to this new emergency. At the end of the summit, Kristalina Georgieva, the European Union commissioner for humanitarian aid and crisis response, summed up the meeting's aims. Holding a white bracelet with a red strip in her hand, she explained that, applied to a child's arm, it served as a kind of measuring tape for hunger. "This one centimeter," she said, "marks the difference between life and death for children. And this is what we talked about today: that we prevent one million children in the Sahel to come in the red zone."[1]

The bracelet that Georgieva showed the audience is very familiar to humanitarian practitioners and donors alike. The mid-upper-arm circumference (MUAC) tape is a strip of plastic, approximately 35 cm long, used to assess acute malnutrition in children aged one to five.[2] The tape is wrapped around the arm, halfway between the elbow and shoulder, and a color code indicates levels of nutrition: green for a normal child, yellow for malnourished, and red for severe malnutrition. Leading humanitarian organizations recommend it for screening in emergency situations.[3] MUAC has become (together with "weight for height") the main tool for nutritional assessment in emergency situations.[4] Nutritional indicators (together with mortality rates) have moreover become key figures in "global need" analyses. They have become instrumental for ranking and mapping emergencies.[5] As a result, MUAC has been widely used in Haiti, Afghanistan, South Sudan, and Syria.

Mundane humanitarian artifacts are a good entry point into the history of aid.[6] Aid workers use the MUAC tape to admit children into feeding programs, nutrition experts use it to produce nutritional surveys, and senior officers use it to raise public awareness. The tape has become a "blackbox" of humanitarian aid—a tool that plays a key role in decision-making processes while "running by itself."[7] However, the evidence produced by MUAC is less straightforward than Kristalina Georgieva's remarks might imply. This essay traces the history of the MUAC tape back to its invention and explores the reasons for its success. In particular, it underlines the tool's ability to make hunger commensurable on a global scale.

The commensurability of human need is a cornerstone of post-1945 humanitarianism. Large aid agencies feel authorized to act at the global level largely based on the

Figure 1. Commissioner for Humanitarian Affairs for the European Union Kristalina Georgiva with MUAC-strip for measuring malnutrition, September 2012. © and courtesy of Union européenne.

universality of human needs, a creed reasserted in the agencies' founding documents, principles, and guidelines, as well as in the standardization of the indicators and technical devices they use. Everyday relief work relies on instruments that fit individual pain into the language of universal needs. The trend toward "evidence-based humanitarianism" epitomizes the importance of quantified comparisons on a global scale. The success of MUAC is rightly attributed to the fact that it is a quick, simple, cheap, easily transportable and reproducible tool for identifying acute malnutrition.[8] Equally important, however, is that it can be used anywhere, on any child aged one to five, without regard for environmental, economic, or cultural background. As one proponent of mid-upper-arm circumference put it, "MUAC is universally applicable."[9]

Consequently, the history of MUAC can help us grasp the historicity of humanitarian universalism. Most of the gray literature issued by aid agencies takes the universality of human needs for granted. This does not mean that aid workers are naïve about the universal character of their organizations, nor does it mean that they are uncritical of their tools (in fact, some of the most radical criticism of MUAC comes from aid workers). But in operational settings, there simply is not time to dig deep into history. Aid workers do not have the luxury of engaging with the ontology of MUAC while trying to save children from death.

The historiography of humanitarian aid, however, should look more closely at the history of commensurability. There are substantial works on the ideological roots of humanitarianism, on the periodization of aid, and on the history of aid workers and aid beneficiaries.[10] But historians have said little about the link between relief aid and the universalization of the social in the twentieth century and into our own. On the

contrary, anthropologists of global health have problematized the "universal appeal" of humanitarianism.[11] They have showed how relief aid has shaped its objects of intervention and reframed needs in the language of biomedicine.[12] This essay, while it is informed by the anthropological literature on aid, makes a plea for historical analysis and aims to reinsert chronology into the discussion.[13] It examines how humanitarian experts, in their attempt to act "universally," have changed both the regimes of care and the definition of needs.

The history of MUAC dates back to the late 1950s. The measurement was first used in Haiti in 1958 by a tropical doctor, Derrick Jelliffe, and his team from the Caribbean Food and Nutrition Institute. In the 1950s and 1960s, tropical pediatricians experimented with different methods of nutritional assessment, with the measurement of arm circumference being just one of many other techniques of nutritional assessment.

The tipping point in the history of MUAC came in 1969. In the middle of the Nigerian Civil War (1967–70), the International Committee of the Red Cross (ICRC) conducted a large survey based on MUAC, which changed the perception of malnutrition. For the first time, a humanitarian organization adapted MUAC for its own use. The Biafran War was a pivotal moment in the emergence of a group of humanitarian experts, that is, an "epistemic" or "knowledge community."[14] MUAC provided the form of knowledge that this community needed—knowledge that not only produces data but also publicly demonstrates the gravity of the situation.[15]

Since 1969, MUAC has frequently been accused of lacking accuracy. Yet, paradoxically, the more it has been criticized for inaccuracy, the more it has come to be used. This is because supporters of MUAC, rather than defending its accuracy, have pushed for its materialization and industrialization. Even though MUAC has remained an imprecise indicator, it has been transformed into a cheap and quick tool. The MUAC tape has made malnutrition comparable, quantifiable, transportable, and—last but not least—visible.

The following pages underline three aspects of this history. First, humanitarian experts shall be seen as "off-road universalists": their main achievements are not in the realm of moral values but that of field practices. Their main contributions have less to do with rising awareness of the universal nature of needs—the famous "moral revolution" celebrated by Michael Barnett and others—than with the much more ambitious and concrete task of overcoming the local nature of needs.[16] The inventors of the MUAC tape were medical doctors specialized in areas such as pediatrics, nutrition, tropical medicine, and general medicine.[17] They inaugurated an area of knowledge that they named "field anthropometry," which targeted the populations of "less developed tropical countries."[18] Their expertise cut across various spheres of knowledge, from conventional epidemiology and geography to anthropology.[19] The inventors of nutritional anthropometry have made acute malnutrition comparable at the global level—and so successfully that we tend to forget how locally and culturally specific malnutrition was considered before.

Second, the price for this impressive achievement was high. Like any other tool, the MUAC tape carries a hidden script, including the assumption that malnutrition is more important than other diseases, that prioritizing needs is essential, and that

children around the world should be compared based on similar standards and thresholds.[20] The MUAC tape conveys the idea that children, especially those under five years of age, should be a priority for humanitarian aid. Young children are considered more important targets of aid because they are dependent on other people's actions and die more quickly of hunger (targeting severely malnourished children is one of the fastest ways to reduce mortality rates).[21] But there is also an inherent technical logic to the prioritization of children under five; the fact that children's arm circumference grows only slightly between the ages of one and five years is one of the main arguments set forth by MUAC proponents for targeting this specific population. This technical consideration has become a self-fulfilling prophecy: because this population *can* be compared using MUAC, it *should* be targeted by aid.

Third, the MUAC tape conflates very different uses of nutritional assessment. It is used as a tool of surveillance; which is to say, the nutritional status of children is used as a proxy for that of larger populations and for mapping emergencies. Children are more likely to show signs of acute malnutrition, and measuring their status makes it possible to map the magnitude and geographical distribution of malnutrition.[22] At the same time, MUAC is also used as a tool of triage or "emergency classification" by which the neediest individuals are screened to determine resource allocation and admission into feeding programs.[23]

Beginning its career as an anonymous tool of nutritional assessment, the MUAC tape has ended up being championed as a triumphant hero by the EU commissioner for humanitarian aid. As we will see, this is not a history of usurpation—there was no putsch, no plot, and no master plan. There was—and perhaps still is—an emancipatory value in the production of universalizing tools. However, if we want to keep this emancipatory potential alive, we must abandon the search for a magic bullet. Instead, we need to thoroughly rethink the way we use these tools—we must take care to separate the historical fruit from its metaphysical rind.

1. Delocalizing Hunger: The Rise of Field Anthropometry in Tropical Medicine

The first nutritional survey to use arm-circumference measurement was conducted by Derrick Jelliffe and his team in 1958 in Haiti. Jelliffe was a British pediatrician who had worked in several decolonizing countries, including Sudan, Uganda, Nigeria, and India, and who conducted nutritional surveys for the Kingston-based Caribbean Food and Nutrition Institute.[24] In the 1960s, he and a team of doctors conducted surveys in Barbados, Trinidad and Tobago, Jamaica, and Guyana, for which they used a conventional measuring tape to gauge the mid-upper arm circumference of children. This measurement was just one of various types of information that these doctors collected to assess malnutrition (protein-calorie malnutrition, or PCM, as they called it); others included other anthropometrical measurements (weight, height, calf circumference, head circumference, etc.) as well as clinical signs and the results of biochemical and biophysical tests.[25]

To understand why Jelliffe and his team spent so much time developing anthropometrical methods to assess malnutrition, it is necessary to consider the situation in which they found themselves. Contrary to popular assumption, it is not easy to know whether someone is suffering from malnutrition. The symptoms of undernutrition are

far from obvious, so that untrained eyes cannot simply "see" malnutrition by looking at a starving child; the symptoms are sometimes counterintuitive (typically, a starving child may have a "big belly" or lack appetite) and, most importantly, depend to a very high degree on contextual variables.

When Jelliffe began his work, the dominant way to determine whether a child was malnourished was through clinical judgment. The problem with this method is that local factors affect this judgment. Different societies—and, within societies, different individuals—develop different types of malnutrition-based pathologies. Even the most acute forms of malnutrition-based pathologies differ from one place to another. In the late 1960s, for reasons unknown to Jelliffe and his team, some individuals were prone to marasmus (severe undernourishment due to low weight), while others were more likely to develop kwashiorkor syndrome (a form of malnutrition involving low protein intake).[26] As Jeliffe wrote:

> The problem of devising suitable methods is complicated by the fact that in some communities kwashiorkor is the main severe syndrome and in others marasmus. Also, the clinical features vary in prevalence from one part of the world to another, depending on the interaction of numerous local variables, including genetic characteristics, associated nutrient deficiencies, types of microbiological and parasitic conditioning infections, the sequence, severity and rate of development of malnutrition and the age of onset.[27]

Not only are some societies more prone to marasmus and others to kwashiorkor, but even a single pathology can take many different forms. The "kwashiorkor of Trinidad" contrasted markedly with the "usual classical textbook tropical African case," while even in the same country—"in two parts of India," for instance—the clinical picture of kwashiorkor could vary. In the Jamaican cases seen by Jelliffe and his team, there was even an "obese variant" of kwashiorkor known as the "sugar-babies" variant. This made it difficult to compare between societies. Doctors working in one country or region, Jelliffe noticed, often confused the various clinical features of kwashiorkor because they assumed that the clinical picture they were familiar with was "necessarily identical in detail in other parts of the world."[28]

This ambiguity was even truer for less severe clinical symptoms. Virtually *all* clinical signs for identifying malnutrition (such as edema, hair depigmentation, and muscle wasting) can also be symptoms of others diseases, or even the result of nonpathological factors.[29] The list of factors that can affect these signs—and thus also judgment of nutritional status—is long:

> Other factors may include the balance of other foods in the prevailing diet, genetic influences, the age and activity of the person, and the environment in which he lives, as regards both environmental hygiene and climate, and exposure to infection and parasitism.[30]

In the 1960s, this led to frequent mistakes in the assessment of nutritional status. Many signs thought to be associated with malnutrition were, "in fact, not related to malnutrition at all."[31] An obvious example is the hair's appearance. Depigmentation of the hair was seen as a classical sign of undernutrition, while dry and dull hair

indicated a lack of protein. However, to judge hair depigmentation, it is necessary to know what constitutes normal hair color in a healthy child. In some contexts, the problem was that "it may be customary for children of one or both sexes to have their hair cut short or shaved, so that the hair color is not apparent."[32] Moreover, hair color is affected by "local factors," such as "dyeing, the effect of sunshine, salt-spray and dust, genetic factors and the habitual use of oil."[33] In addition, "scalp diseases or specific cultural practices, for instance the use of oil on the hair, as well as environmental factors such as the exposure to salt water and a very hot dry atmosphere can have an impact."[34] One can look at whether the hair is thin and sparse, but "sparseness . . . can result in adult women in parts of Africa from the tight braiding of hair into many short pigtails . . . A similar frontal baldness appears to occur in older Chinese women, possibly as a result of the traditional combed-back hair style."[35]

Similar problems occurred with the other signs of malnutrition. Skin depigmentation can be a sign of protein deficiency, but the skin's appearance may also depend on "dirt, lack of washing, a dry, hot, windy climate, and the habitual use of oil on the body"—and, of course, "genetics."[36] Eye pathologies can result from malnutrition, but they may also be due to "bright sunlight, dust, wind, smoke, and infection."[37] The appearance of the teeth works well enough in many parts of the world, but in India "the excessive chewing of betel nut preparations containing large amounts of irritant lime" could lead to false conclusions. Symptoms in the mouth, skeletal system, and cardiovascular system can also be unrelated to malnutrition. "Mental confusion" can be a sign of undernutrition, but, like any symptom requiring an extended conversation with the individual in question, it is difficult to assess in field conditions due to issues of "language, cultural interpretations and witness reliability."[38] Jelliffe and his team of tropical doctors were cursed: everything from genetics to the environment to traditional customs had the potential to falsify their results.

Clinical judgment was thought to be the most accurate way to assess malnutrition. But it was slow and required extended face-to-face interactions as well as solid knowledge of the local community. As a result, the Caribbean Food and Nutrition Institute experimented with two other methods: biochemical tests (blood and urine tests) and anthropometry. Biochemical tests were expensive and difficult to perform in the field. They required a laboratory, sterilized lancets, sterile syringes, vacuum tubes, a system of refrigeration, and so on. Flies could pollute the blood samples, as could fleas and dust. Also, physicians feared the "cross-cultural clashes" likely to occur when they took biochemical samples. Since most biochemical tests involved questions of privacy and modesty, collection techniques were not suited to crowded survey sites. Even worse, local populations might consider taking a piece of the body—especially blood—as something associated with "occult purposes" and "suspicion of witchcraft."[39]

Anthropometry is based on measuring growth failures and various bodily disproportions linked to known cases of pathology. Though approximate, anthropometrical indicators objectify malnutrition using the language of mathematical hierarchies. The most important measurements are weight, height (or length), triceps skinfold, and arm, head, and chest circumferences. These measurements can be taken by paramedical staff and require less expertise in the field than clinical judgment or chemical

tests. Moreover, anthropometrical assessments can identify undernutrition before actual clinical symptoms develop.[40] Arm circumference is particularly valued since, unlike measures such as weighing, which rely on expensive, heavy, bulky and easily damageable devices, it only requires a light and easily transportable measuring tape. In other words, the tool for measuring arm circumference is portable and thus adapted for use in the field. However, originally it was always used in combination with other indicators. A nutritional survey in Kampala, for instance, included six different anthropometrical measures along with five clinical criteria and three biochemical indicators. Arm circumference was just one of many indicators used to describe nutritional status.

2. Depoliticizing Famine: Arm Circumference Measurement in Biafra

As has already been noted, the Nigerian Civil War marked a tipping point in the use of MUAC. The massive humanitarian intervention during the Biafran conflict led to a strategic connection between humanitarian organizations (such as churches, charities, and voluntary organizations) and tropical medicine. For the first time, in Biafra, a leading organization, the International Committee of the Red Cross (ICRC), conducted a large-scale survey based on MUAC as the sole indicator of undernutrition and as a tool for determining resource allocation.

On May 30, 1967, the government of East Nigeria declared Biafra's independence. Lagos launched a brutal military reprisal and organized a blockade of the region, along with the systematic destruction of villages.[41] The main feature of the Nigerian Civil War was its high civilian mortality. Combat accounted for only a small part of the war casualties, with just 10 percent of the victims said to have died in direct combat. Most victims were civilians, most were children, and most died from malnutrition and its consequences.[42]

It took months before the international community reacted, partly because Nigeria was seen as a strong, crop-exporting agricultural nation. International institutions not only had little knowledge of the nutritional situation in Biafra but this information was a highly political matter.[43] The Biafran leadership argued that Nigeria's federal government was committing an act of genocide by attempting to starve to death the Ibo community. For its part, the federal government minimized the severity of the famine.

In the eyes of the aid agencies, even the Nigerian population itself could not be trusted. The data had to objectify the needs of the population without relying on their testimony. As one medical doctor put it, after two years of siege conditions, the population knew how to present its needs to obtain relief aid: "Every mother in Biafra knows what kwashiorkor means," he wrote, and would "make sure her child gets [supplementary skimmed dried milk] if it is available."[44]

Voluntary organizations began their work in Biafra one year into the conflict. The ICRC took the lead in the emergency relief provided by United Nations agencies and a myriad of NGOs. It struggled to collect data on the famine.[45] Resources were scarce, political pressure was high, and competition for leadership was harsh. The ICRC had very little expertise in the area of nutritional emergencies. Traditionally, it had handled tasks such as exchanging prisoners of war and managing specific medical services such

as running hospitals. In Nigeria, the ICRC had to manage staff from fourteen different nations, most of whom lacked experience in developing countries, and many of whom were only sent to the field for short periods of time.[46]

For the humanitarian agencies, the question of selection was at the heart of the problem. The ICRC was convinced that Biafra qualified as a "mass nutritional emergency," but resources were scarce.[47] One medical doctor recalled, "The roads were choked with refugees, of whom all were hungry and many had clinical signs of overt malnutrition . . . Almost everyone in the former enclave was suffering from hunger."[48]

It was not just a question of triaging the malnourished population but also of targeting acute (as opposed to chronic) malnutrition. In fact, even before the war, the Food and Agriculture Organization of the United Nations (FAO) had deemed East Nigeria's food production to be insufficient because of the region's poor agricultural situation.[49] East Nigeria was considered overpopulated and underfed.[50] An ICRC report estimated that the eastern part of Nigeria had average food availability per person of only 75 to 90 percent of the minimum basic needs.[51]

In June 1969, together with the Nigerian Red Cross, the ICRC launched an investigation of the nutritional situation in the Southeastern State.[52] The aim of the survey was to produce "objective figures" on malnutrition in order to avoid "political problems."[53] Information about the famine had become a political weapon. The Biafran leadership had even hired a public relations firm, Markpress, to publicize the effects of the famine and generate sympathy for its cause.[54] The ICRC pushed for statistical data on the famine, not just for internal use—that is, to find out "whether pockets of severe malnutrition remained in their territory"—but also for external use.[55] The political neutrality of humanitarian actors was seen as being underpinned by the objective neutrality of mathematical reason.

The Red Cross team selected sixty villages in the region between Opobo and Eket in the south and Ikot-Ekpene and Itu in the north. The villages could be reached by dirt road, foot, or dugout canoe. In each village, a team composed of an interpreter, secretary, measurer, and member the Red Cross examined approximately seventy-five children, a process that took between one and three hours. One team could survey two villages per day. The survey teams examined only children because they "generally reflect malnutrition faster than adults."[56] In other words, children were used as a "proxy" for the nutritional situation of the population as a whole. Conveniently, in Biafra, only very few households did not have children of the age being examined—that is, children between one and ten years, an age range chosen since "biological measurements" were considered to be "less precise" above the age of ten and because the children had to be old enough to be able to stand up and cooperate.[57] The measurers focused on the children's arm circumference. They preferred this technique to other anthropometrical measures because measuring tape was easy to transport (it was smaller and lighter than weighing devices) and because the decrease in muscle mass is greater than the body-weight deficit in malnourished children. Within a month, the left arms of 7,184 children had been measured.

This is a perfect example of what Bruno Latour calls an "obligatory passage point" (OPP). Just like an army might concentrate its units on a specific bridge rather than stretching them along a valley, the ICRC chose to focus its attention on the left arms

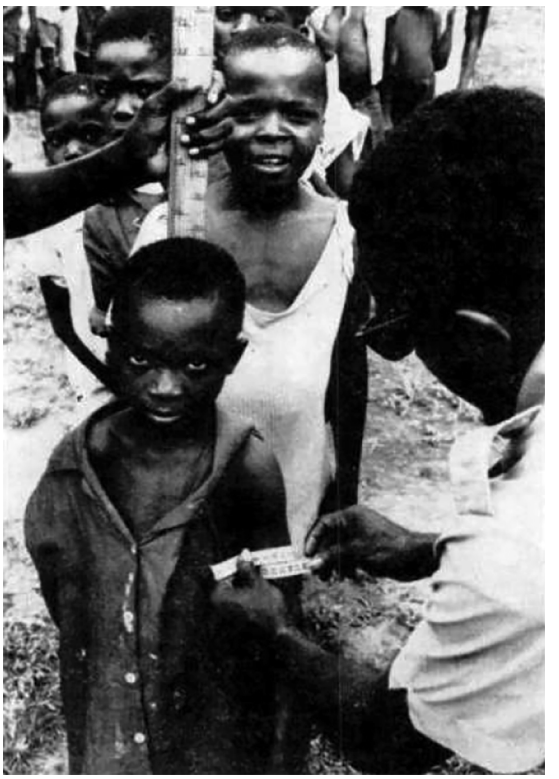

Figure 2. The Height-Arm Circumference Method Being Conducted by a Survey Team in the Southeastern State, from Larry E. Davis, "Epidemiology of Famine in the Nigerian Crisis: Rapid Evaluation of Malnutrition by Height and Arm Circumference in Large Populations," *American Journal of Clinical Nutrition* 24, no. 3 (March 1971): 360. Courtesy of the American Society for Nutrition.

of a specific sample of the population. In Biafra, the ICRC faced chaos of epic proportions. It was unaware of the food situation prior to the war, lacked basic statistical information (even the figures for Biafra's population varied between eight and twelve million), and was working in a region where the roads were blocked by the military, electricity and water supplies had broken down, hospitals were overcrowded, and most people lacked food. It chose to focus on malnutrition (singling it out from other medical issues such as disease, accidents, war casualties, etc.), on mass food distribution (rather than individual treatment), on children as a proxy for all other members of society, and on the circumference of their left arms as a proxy for undernutrition. A vast and intricate political, geographical, and cultural problem was reduced to the manageable question of the size of a toddler's arm.

However, once they had measured arm circumference, the ICRC teams faced two difficulties. To begin with, they did not know the children's ages; in the villages under study, birth dates were not systematically recorded, so a child's precise age often remained unknown. As a result, the teams decided to use height as a proxy for age. In order to deduce age from height measurements, they relied on a survey conducted by

D. C. Morley in several African villages.[58] However, the figures for height and known age recorded by Morley did not provide information for children over the age of five. For these children, the team relied on another set of height-for-age figures, established in London schools in 1954.[59] Combining the height-for-age curves of the West African children studied by Morley and the London pupils surveyed in the 1950s, the team was able to estimate the ages of the Biafran children.

The second difficulty was the lack of Nigerian data for arm circumference. In order to determine who was undernourished, the ICRC teams had to know the normal arm circumference of a healthy child. However, "no standards for this comparison existed at the time of the study."[60] For this reason, the team chose as a reference the measurements made by Napoleon Wolanski in Warsaw.[61] The ICRC combined all three sets of data—Wolanski's Polish MUAC, Morley's height-for-age figures for West African children, and the London averages from 1954—to create a composite table of normal height-to-arm-circumference ratios for Biafra.[62] Based on this, it defined a standard for malnutrition: "A child with an arm circumference below 80% of that expected for his height was found empirically to have severe malnutrition."[63]

Let us take as an example Ugwu, a boy 85 cm tall. Based on the London study, a child of this height is around two years (24 months) old, while, according to the Wolanski study, a child of this age should have an arm circumference of 16.3 cm. If Ugwu's arm circumference was less than 13 cm (80 per-cent of the Polish standard), he would be classified as severely malnourished; if it was between 13 and 13.85 cm (85 per-cent of the Polish standard), he would be classified as moderately malnourished; and for any circumference greater than that he would be considered healthy.

Based on this method, the ICRC teams found that, of the 7,184 children surveyed, 480 suffered from severe acute malnutrition. Creating nutritional maps of the region, they found that "the areas adjacent to the war front had the highest levels of malnutrition."[64] Consequently, food relief was redeployed to these areas. Medical relief teams were withdrawn from the Eket and Opobo areas and moved northward to the areas along the war front. The ICRC concentrated its efforts on the region around Akpap, and, within this area, MUAC was used again to identify the families in greatest need, with relief food being distributed to families with one or more children classified as severely malnourished.

The ICRC had displaced the problem of malnutrition. MUAC had become a way to navigate chaotic contexts. The conclusions drawn by a report on the survey touted the benefits of MUAC:

> It was reproducible and accurate; it was simple enough to be performed by unskilled Nigerians under supervision; it was economical; it yielded two levels of malnutrition, moderate and severe; it was rapidly performed; and it was based on an objective rather than a subjective standard.[65]

Measuring arm circumference provided a way of transforming a complex situation in unfamiliar terrain into "two levels of malnutrition." The tool gave a path to navigate the interests of starving children, village chiefs, the government in Lagos, the Biafran leaders, competing humanitarian organizations, and European donors.

3. Comparing Malnutrition: The Rhetorical Style of Emergency Anthropometry

Not all tropical doctors shared the enthusiasm of the proponents of MUAC. While the ICRC teams in Biafra used height-to-arm-circumference ratios as their sole tool for nutritional assessment, others continued to argue for a combination of methods. In their view, MUAC alone was not accurate enough. The way in which the measuring tape was applied left room for many mistakes. In order to measure arm circumference properly, the child's arm had to be hanging loosely, the exact midpoint between elbow and shoulder had to be found, and firm and constant pressure had to be applied with the measuring tape, which proved to be more complicated than it seemed.[66] However, the main problem was the question of standards. Could children from different continents, societies, and classes be compared with the Polish standard?

While the war in Biafra raged on, an international conference was convened to address this question.[67] The participants compared the left-arm circumferences of children from various places, including 379 children from eight Haitian villages, 136 Amerindian children in Guyana, children from Barbados and Ohio (USA), 359 children in Dodoma (Tanzania), 211 children who lived near Mount Kilimanjaro, 594 children from Northern Greece, pupils from Sweden, a range of sick children from a Ugandan clinic, some "poorly nourished" children from New Guinea, 1,351 children from villages in Sierra Leone, 795 Zambian children, 366 malnourished boys and girls from the nutrition rehabilitation center at Fond-Parisien in Haiti, 707 Nigerian children from Owu and Oba, 1,049 "Arab children" from Lebanese clinics, 640 patients of the mission feeding centers around Bukavu (Congo), and "approximately 1,000 male and 1,000 female" school children from Tunis (Tunisia).[68] The children had been selected for various reasons and in various settings; some of the MUAC measures had been taken in schools, others in religious institutions, military barracks, villages, and hospitals. Some of the children were healthy, well fed, and generally well off, while others were malnourished, and yet others were sick. They came from different environments and classes with different beliefs and cultural and nutritional customs.

Most of these studies used the Polish children measured by Wolanski as a standard of reference. However, several studies found that the children they were examining had arm-circumference measures slightly below the Warsaw standards.[69] One doctor based in Ethiopia tried his best to find the most well-fed children in the country, selecting children exclusively from "expensive private kindergartens in Addis Ababa" and only measuring the arm circumference of the most privileged and best fed among them. Yet, despite these efforts, he was forced to conclude that the Ethiopian children had an average arm circumference below Wolanski's standard.[70]

Several other doctors also found the comparison with a single European standard inadequate for their populations.[71]A Malaysian doctor preferred calculating his own local standard based on Malaysian army children.[72] For another physician working in Guyana, even establishing a local standard proved to be problematic, because he found that children "of East Indian ancestry" had markedly lower measurements than those of "predominantly African descent."[73] One doctor, after conducting a survey in West Africa, concluded that "European standards" simply were "not . . . applicable."[74]

Despite their attempts to compare children from around the world, the physicians kept an eye out for dissimilarities. Doubting the reliability of a single standard, they felt the need to disaggregate their data along what they called "racial" or "ethnic groups." One distinguished between the "Nilotic," "Nilo-Hamitic," and "Bantu" groups in Uganda, another between the "Pomaki" (*sic*) and "Moslems of Turkish origin" in Greece, while yet another differentiated between "a Negroid race," "Caucasians," "Caribs," "East Indians," and "children with mixed blood" on the Island of Dominica in the Caribbean.[75] On the whole, the participants at the conference remained skeptical about the practicability of a single universal standard. They continued to use MUAC measurements, but, like Jelliffe in the early 1960s, merely as one among many anthropometrical and other indicators.

The overall tone of the 1969 conference on arm-circumference methods contrasted sharply with Davis's enthusiastic declarations in Biafra. At least one participant, however, adopted the same rhetoric style of the ICRC doctors in Biafra. In his description of a nutritional survey in Eastern Congo, John Bennett attributed a high strategic value to MUAC.[76] As in Biafra, the crisis in Kivu was a complex situation involving political fighting, refugee flows, and chronic malnutrition. Bennett's paper exposed the four steps that would become emblematic of the rhetorical style of proponents of MUAC: First, humanitarians face a chaotic situation in which almost everyone is chronically undernourished ("[children] were all inadequately nourished, so that it was necessary to determine which were the worst"). Second, they choose a small sample of young children from the original population ("640 'under five' "). Third, all attention is concentrated on the children's left arms. Finally, based on the sample, a decision on resource allocation is made for the whole population ("This group should qualify for supplements of protein and calories issued daily in the form of skimmed milk and cereal.")[77]

The crisis in the central African region gave proponents of MUAC their line of argument for MUAC, allowing them to link a certain conception of epidemiology to the practical rationality of humanitarian intervention. By stressing the role of "field circumstances," they closely linked the production of knowledge to decision-making. It was not a question of the purity of scientific methodology; this was "front-line epidemiology," a set of "quick and dirty" methods to save lives.[78] MUAC became a way to channel humanitarian resources, to ensure that resources and needs were aligned—which, in turn, meant that needs were not to be defined independently of resources.

4. Pushing the Advantage: The Materialization of MUAC and the Silencing of Critics

During the 1970s and 1980s, MUAC measurements remained controversial. The method was exposed to harsh criticism. A number of pediatricians rejected the method either partially or completely. Critics pointed out that, within a single group of persons, different anthropometrical methods (weight, weight-for-height, arm circumference, etc.) resulted in different individuals being identified as undernourished. Studies conducted in the Caribbean, Uganda, Ethiopia, South Africa, Brazil, and West Africa showed that weight-for-height and MUAC often led to differing diagnoses.[79]

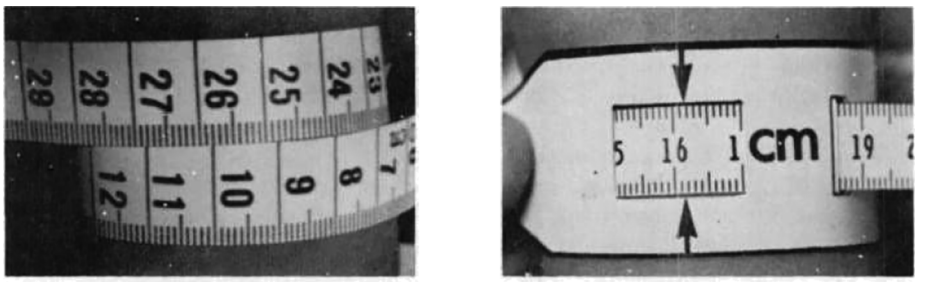

Figure 3. Insertion tape, from Alfred J. Zerfas, "The Insertion Tape: A New Circumference Tape of Use in Nutritional Assessment," *American Journal of Clinical Nutrition* 28, no. 7 (July 1975): 783. Courtesy of the American Society for Nutrition.

And these differences could be significant. In the Caribbean case, 2.5 more cases of undernutrition were diagnosed using weight than mid-arm circumference.[80] In Uganda, the mid-arm circumference assessment led to "21% false-positive diagnoses" when compared to weight assessments.[81] In other words, malnutrition-prevalence rates obtained using MUAC did not have a clear or constant relation to those diagnosed on the basis of weight. Arm circumference and weight-for-height did not identify the same population of children as malnourished.[82]

A study of children in rural India concluded that a diagnosis based on MUAC missed many malnourished children: "Some children, who were severely undernourished on the basis of weight for age, weight for height and muscle circumference were classified as normal based on arm circumference."[83] Indeed, the results of the two methods disagreed quite often; "in about 43 per cent" of cases, MUAC and weight-for-height led to different diagnoses.[84] Almost one-fifth of the children classified as "normal" based on arm circumference were underweight according to weight-for-height standards. As a result, assessments based on arm circumference resulted in the omission of cases of malnutrition.[85]

The strongest opponents of MUAC argued for other alternatives: using several indicators rather than just one, applying weight-for-height rather than MUAC, or using MUAC to create new aggregated indicators such as the ratio between arm and head circumference.[86] Some advanced a compromise: While MUAC was not accurate enough for triaging children, it was good enough for certain tasks—nutritional mapping or screening in "emergency situations such as refugee camps or severe drought."[87] For some authors, mid-arm circumference was only a useful measure "in crisis situations where malnutrition is severe and many children must be assessed rapidly."[88]

Proponents of MUAC did not attempt to prove their critics wrong.[89] They displaced the locus of confrontation to the humanitarian field. They transformed method into a simple manual tool.

A first step in this process was getting rid of the conventional measuring tape. The

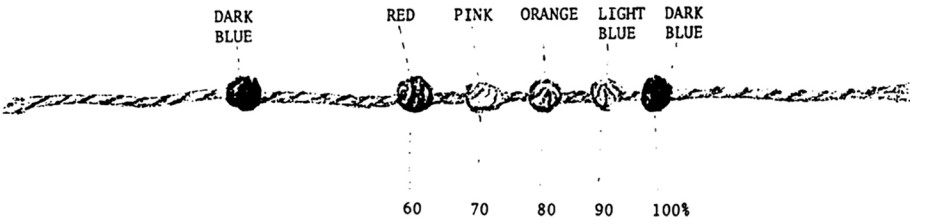

FIG. 3. Anthropometric quipu–knotted cord used for measuring mid-arm circumference in young children.

Figure 4. The "Anthropometric Quipu," from Derrick B. Jelliffe and E. F. Patrice Jelliffe, "The Quipu in Measuring Malnutrition," *American Journal of Clinical Nutrition* 28, no. 3 (March 1975): 204. Courtesy of the American Society for Nutrition.

problem with conventional commercial tapes was that they varied in diameter, thickness, graduations, and the placement of the numerals, making it difficult to standardize application of the method. Moreover, measuring a child's arm with a conventional tape was difficult because one had to align two widths of the same tape. Most observers measured "against the 10 cm mark of the tape so that your hands did not touch the arm" and then subtracted 10 cm from the actual reading.[90] Eventually, Alfred Zerfas, a nutritionist who had worked in Biafra, experimented with a range of plasticized materials and suggested using a specific paper tape with a plastic interior considered to be durable and water resistant.[91] He also designed a tape with an insertion window to allow for correct alignment of the scale and to facilitate reading.[92] He then not only promoted his technique actively within his network of tropical nutrition specialists (including the Institute of Child Health in London, the Centers for Disease Control and Prevention in Atlanta, and the University of California in Los Angeles School of Public Health) but also patented his invention in Australia and began standardized production of the tape through American firms.

A second and much more far-reaching innovation was getting rid of the numbers on the tape. Adnan Shakir of Baghdad University and David Morley from the Institute of Child Health in London divided the tape into three colored zones: red for "malnourished," yellow for "possible mild malnutrition," and green for "normal." Since numbers and arithmetic were complicated, why bother volunteers and paramedics in field situations with them? "Figures have less meaning for auxiliaries in the developing world than for health personnel in industrial societies," Shakir and Morley wrote.[93] The resulting tape was a simple object that seemed to beautifully align the universality of color categories with the putative universality of young children's needs: "Red, yellow, and green have universal significance, thanks to the ubiquitous traffic lights."[94] Shakir and Morley immediately set about standardizing their colored strip, working together with Teaching-aids at Low Cost (TALC), a nonprofit organization founded in London.[95]

Viewed in retrospect, inventing a colored tape might seem like an innocent and commonsense idea. Yet, in the context of raging controversy about the accuracy of the method, it was quite a bold strategic move. The colored tape was a Trojan horse for several plausible yet still unproven assumptions: that the same standard could be used

everywhere, that it was applicable independent of age (for children aged one to five years) and for boys and girls alike, and that it made sense to focus specifically on young children to assess entire populations.

According to Shakir and Morley, MUAC was gender and age independent. Consequently, a single colored tape could be used to assess malnutrition among children between one and five years, based on the same cut-offs (while weight varies quickly in growing children, arm circumference varies only minimally).[96] This was a very seductive idea, since age was difficult to determine in many societies. Many users, however, remained skeptical. Some physicians doubted that MUAC did not change according to age and gender. Some found that a significant number of children were misclassified using the three-colored tape, which led to false negatives in up to one-third of cases.[97] One Dutch pediatrician determined that, among the children he studied, the one-year-old girls had a mean MUAC of 16.36 cm, while the five-year-old girls had a mean of 17.91 cm—a difference of more than 1.5 cm.[98] Several other studies confirmed that MUAC was highly dependent on age and gender.[99] Yet these objections failed to reach their target; the three-colored tape was simply too easy to use to be rejected. The materialization of MUAC had rendered any criticism of it ineffective.

The only point on which the criticism of MUAC bore fruit was the question of the cut-off. When Derrick Jelliffe chose a cut-off to define malnutrition in the 1960s, it was very clear that this decision was rather "arbitrary."[100] At first, instead of establishing a single cut-off, Jelliffe preferred presenting the results according to various "levels" of malnutrition. The famous "85% of Wolanski's standard" he suggested as the cut-off to define malnutrition was based on an informed guess at best. It was changed to "80% of Wolanski's standard" as a "compromise" between various other standards.[101] Two decades after it was established, this threshold remained "essentially arbitrary."[102]

New standards have been suggested time and again. Some have argued for regional standards, others for a new universal standard.[103] However, until the mid-1990s, the standards used by Jelliffe in 1966, based on Wolanski's study of Polish children in 1964, remained the international standard.[104] Everyone knew that the Polish standard was far from perfect.[105] But MUAC defenders recommended continuing to use the same standard to assure that "the nutritional studies of the future will be comparable with those of the past."[106] This is a perfect example of what actor-network theory calls "technological path dependence": keeping a traditional tool in use to ensure system compatibility even though new information has become available that reflects reality more accurately.

Finally, in 1997, the World Health Organization (WHO) published a new standard of reference for MUAC.[107] The Polish children from the early 1960s were replaced by a sample of American children from the 1990s as a reference for the world, and though this standard has been updated since, the principle of a single universal standard is still in use.[108] Surprisingly, even though the international standard has changed very slowly, the thresholds for undernutrition have not changed very much.

Let us return to our example of two-year-old Ugwu. If the ICRC team in Biafra

in 1969 had encountered this 85 cm-tall toddler, it would have deemed him "malnourished" if his arm circumference had been less than 13.85 cm (85 percent of Wolanski) and "severely malnourished" if it had been less than 13 cm (80 percent of Wolanski). If this same child had been measured by Bennett in 1969, these thresholds would have been 13 cm and 12 cm, respectively. If he had been classified using Shakir's color strip in 1974, he would have been determined to be suffering from "possible mild malnutrition" if his MUAC had been under 13.5 cm and from "malnutrition" if it had been under 12.5 cm. In 1988, Gayle would use these same thresholds (13.5 cm and 12.5 cm), but to define "moderate malnutrition" and "severe malnutrition," respectively. If the WHO standards from 2007 had been applied to Ugwu, he would have been considered "moderately malnourished" with a MUAC under 12.5 cm and "severely malnourished" with a circumference under 11 cm. Finally, according to the WHO standards from 2009, the threshold for "moderate malnutrition" remained the same (12.5 cm), but the threshold for severe malnutrition once again changed (11.5 cm). Malnutrition, in the practices of humanitarian aid, is as much the result of a process of need assessment as the origin of aid.

Conclusion

Despite harsh critique, the industrialization of the MUAC tape has resulted in such massive diffusion of the tool that the current conception of malnutrition is closely linked to it. The colored tape has not been able to put an end to related criticism of standards and cut-offs, or to arguments about age-and-gender independence and the uniformity of muscle wasting, which continue to be debated.[109] There is general agreement that the standards are far from perfect, the thresholds arbitrary, and that the probability of mistakes is not negligible. Nevertheless, MUAC continues to be used in emergency settings every day.

Let us recall the main arguments made in this essay. First, the invention of MUAC is not the history of a "moral" achievement. It is far more than that. The universalization of the fight against hunger did not merely require "recognizing" that hunger was a global problem; it also required making hunger globally commensurable. This meant bringing universalism to the field. The medical doctors who invented MUAC paid a great deal of attention to very mundane aspects of knowledge production. They were as concerned with bringing enough fuel for their jeeps or proper waterproof equipment as they were with science. They were far from any laboratory and well aware of this fact.

Second, the invention of MUAC (and of other anthropometric tools such as weight-for-height) changed the way we address malnutrition. Determining undernutrition using clinical judgment involves an extended face-to-face interaction between a patient and a health specialist. In this interaction, the question of nutrition is not strictly separated from other needs (i.e., the health specialist may also consider other pathologies). This direct exchange requires a common language or an interpreter. It is slow and localized. In contrast, using the MUAC tape to assess undernutrition involves a brief interaction between a child and a trained individual. The knowledge—and definition—of undernutrition is inherent in the bracelet itself, thereby making it possible to save a tremendous amount of time. However, this comes at a high price.

Like any other technical device, the bracelet contains a hidden script. It is blind to some forms of undernutrition and necessarily fails to identify a certain number of malnourished children. Moreover, it implies that malnutrition can be separated from other problems, that it is more important to assess malnutrition in children than in adults, and that arm circumference is representative of overall undernutrition. It also assumes that malnutrition is age and gender independent for young children and that it is important—and possible—to compare every child with one internationally defined standard. The MUAC tape also implies that relief aid should be prioritized according to needs. This is a widespread—though not uncontested—idea (some nutritionists have for instance argued that it might be more efficient to target *all* children under two years rather than only the *malnourished* ones under the age of five).[110]

Third, there is a risk of overstretching use of the tool. The MUAC tape is currently used to survey entire populations, draw up nutritional maps, allocate resources, triage individuals in refugee camps, monitor individuals in feeding programs, etc. A year after the World Food Programme meeting in Europe, Kristalina Georgieva once again used MUAC as a didactic tool—this time to instruct her audience about the new concept of "resilience," rendered visible in her explanation by the yellow zone of the bracelet.[111] The MUAC tape, however, is probably not the magic bullet that some would like it to be.

Finally, let us not overlook that the medical doctors who invented MUAC had very good reasons to make a case for universal humanitarianism. They were born between 1920 and 1950, during the golden age of fascism, national-socialism, and colonialism. They started their tropical careers with the fear they would be confused with colonial doctors and with the ambition to heal the wounds of racialized medicine. The universalism of field anthropometrists was instrumental in breaking from colonial categories as well as from Cold War politics. After all, it is not they, but Western and African political leaders, who grossly misused figures on malnutrition; it is not they, but some of their critics, who used the terminology of "race" and "tribes."

However, it remains crucial to ask up to which point—and under what conditions—this kind of universalism continues to have emancipatory potential. The recent celebration of "data-driven" humanitarianism has unleashed competition among global databases and automatized cross-cutting of nutritional indicators.[112] Ironically, the run for humanitarian big data is occurring precisely at a time when it is being (re)discovered that biologies depend significantly on social positions and local contexts. The notions of "customary biologies" or "local biologies" "undermine the notion of biology as a universal standard against which human difference may be adequately accounted for."[113] This might be an opportune moment to historicize the tools that mediate between the discourse of universality and the plurality of individual bodies.

NOTES

I would like to thank the medical experts and aid workers who took time to give me important advice for this research, especially Rachel Alessandri, Bernward auf dem Kampe, Yvonne Grellety, Patrick Kuebart, Ines Lezama, Abel Nimpojeje, Andrew Seal, and Estelle Tabone, as well as my

colleagues from the humanities for their comments, especially Julia Eichenberg, Debora Gerstenberger, Thea Hilhorst, Jill Pöggel, and Peter Lambertz. I am also in great debt to Vincent Bonnecase and to the two reviewers of the journal for their important suggestions as well as to Sophie Schlondorff for her help in editing the text. Needless to say, all remaining mistakes are mine.

1. Quoted in Tilmann Kleinjung, "UN-Krisengipfel zur Sahel-Zone: Afrika droht die nächste Hungerkatastrophe," *Tagesschau*, February 15, 2012.

2. The MUAC tape is also referred to as MUAC band, MUAC strip, insertion tape, or strap. For an overview of MUAC uses, see Gordon C. Cook and Alimuddin I. Zumla, eds., *Manson's Tropical Diseases,* 22nd ed. (London: Elsevier, 2009), 537–38.

3. UNHCR, *Handbook for Emergencies*, 2nd ed. (Geneva: UNHCR, 2000); WHO and UNICEF and WFP and SCN, *Joint Statement: Community-Based Management of Severe Acute Malnutrition* (Geneva/New York/Rome: WHO/UNICEF/WFP/SCN, 2007); WHO and UNICEF, *WHO Child Growth Standards and the Identification of Severe Acute Malnutrition in Infants and Children: A Joint Statement by the World Health Organization and the United Nations Children's Fund* (Geneva: WHO Press, 2009); SPHERE Project, *The SPHERE Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response*, 3rd ed. (Rugby: Practical Action Publishing, 2011).

4. For the current discussion on the advantages of MUAC over weight-for-height, see Mark Myatt, Tanya Khara, and Steve Collins, "A Review of Methods to Detect Cases of Severely Malnourished Children in the Community for the Admission into Community Based Therapeutic Care Programs," *Food Nutrition Bulletin* 27, no. 3 (2006): 7–23; Mark Myatt et al., "The Effect of Body Shape on Weight-for-Height and Mid-Upper Arm Circumference Based Case Definitions of Acute Malnutrition in Ethiopian Children," *Annals of Human Biology* 36, no. 1 (2009): 5–20; WHO et al., *Joint Statement.* Main rapid needs assessment mechanisms (including the United Nations Disaster Assessment and Coordination mechanism UNDAC, the USAID Disaster Assessment and Response team, and the OCHA Rapid Assessment process) recommend the use of MUAC. Many SMART-based need surveys (Standardized Monitoring and Assessment of Relief and Transitions) include MUAC as a tool.

5. Several instruments have been developed to compare and prioritize needs and rank vulnerability, including OCHA's need overview tools, which conflate several different indicators by sectors (shelter, education, water and sanitation, protection, etc.). However, nutritional and health statistics are generally considered as the most "robust" figures in emergency context.

6. See Scott-Smith's inspiring analysis: Tom Scott-Smith, "The Fetishism of Humanitarian Objects and the Management of Malnutrition in Emergencies," *Third World Quarterly* 34, no. 5 (2013): 913.

7. Bruno Latour, *La science en action : Introduction à la sociologie des sciences* (Paris: La Découverte, 2005), 21–48.

8. This technique was said to be quick and simple only *after* it had been experimented with for more than a decade.

9. Alfred J. Zerfas, "The Insertion Tape: A New Circumference Tape of Use in Nutritional Assessment," *American Journal of Clinical Nutrition* 28, no. 7 (July 1975): 782–87.

10. On the historiography of aid, see Michael Barnett, *Empire of Humanity: A History of Humanitarianism* (Ithaca, N.Y.: Cornell University Press 2011); Eleanor Davey, John Borton, and Matthew Foley, *A History of the Humanitarian System: Western Origins and Foundations: HPG*

Working Paper (London: Overseas Development Institute, 2013); Maria Framke and Joël Glasman, "Editorial," *WerkstattGeschichte* 68 (2015): 3–12.

11. Peter Redfield, *Life in Crisis: The Ethical Journey of Doctors Without Borders* (Berkeley: University of California Press, 2013), 13.

12. Didier Fassin, "Le sens de la santé: Anthropologie des politiques de la vie," in *Anthropologie médicale : Ancrages locaux, défis globaux*, ed. Francine Saillant and Serge Genest (Québec: PUL, 2005), 383–99; Jean-Hervé Bradol and Claudine Vidal, *Innovations médicales en situations humanitaires : Le travail de Médecins sans frontières* (Paris: L'Harmattan, 2009); Didier Fassin, *La raison humanitaire: Une histoire morale du temps présent* (Paris: Gallimard, 2010); Margaret Lock and Vinh-Kim Nguyen, *An Anthropology of Biomedicine* (Hoboken: Wiley-Blackwell, 2010); Redfield, *Life in Crisis*; Scott-Smith, "The Fetishism of Humanitarian Objects and the Management of Malnutrition in Emergencies."

13. Rony Brauman and Médecins Sans Frontières, eds., *Utopies sanitaires* (Paris: Le Pommier, 2000); Michel Agier, *Gérer les indésirables: Des camps de réfugiés au gouvernement humanitaire* (Paris: Flammarion, 2008); Bradol and Vidal, *Innovations médicales en situations humanitaires*; Redfield, *Life in Crisis*; Scott-Smith, "The Fetishism of Humanitarian Objects."

14. Redfield, *Life in Crisis*, 12. Peter Haas quoted in Davey et al., *A History of the Humanitarian System*, 29.

15. Vincent Bonnecase, "Retour sur la famine au Sahel du début des années 1970: La construction d'un savoir de crise," *Politique africaine* 2, no. 130 (June 2013): 23–42.

16. Barnett, *Empire of Humanity*.

17. This essay is based on an analysis of published journal articles and unpublished reports on child nutrition in emergency situations. A rough estimate based using the *Scopus* database identified 926 articles with "MUAC" or "arm circumference" in the title (between 1969 and 2013 in a selection of 29 major academic journals). This is by far not an exhaustive count. Also, certain articles focus on topics other than nutrition or make only a passing reference to nutritional problems. However, this estimate was helpful for locating the main controversies and overall evolution of interest in this technique. Journals with more than 50 articles on the topic are the *American Journal of Clinical Nutrition*, the *European Journal of Clinical Nutrition*, *Journal of Tropical Pediatrics*, and *Clinical Nutrition*.

18. Derrick B. Jelliffe, "Field Anthropometry Independent of Precise Age," *Journal of Pediatrics* 75, no. 2 (1969): 334–35.

19. J. E. Gordon speaks of "field epidemiology": John E. Gordon, "Field Epidemiology," *American Journal of Medical Science* 246 (September 1963): 354–76.

20. This idea has been challenged by recent nutritional surveys: see Marie T. Ruel et al., "Age-Based Preventive Targeting of Food Assistance and Behaviour Change and Communication for Reduction of Childhood Undernutrition in Haiti: A Cluster Randomised Trial," *The Lancet* 371 (February 2008): 588–95.

21.Significantly, some experts arguing for the targeting of children aged one to five years for *anthropometric* reasons (assuming that the arm circumference of this age group was stable) also elicit impromptu *moral arguments* in favor of children. See Murray Last's piece, who argues that the principle of putting "children first" is unacceptable in many cultures. Murray Last, "Putting Children First," *Disasters* 18, no. 3 (September 1994): 192–202.

22. SPHERE Project, *The SPHERE Handbook*, 157.

23. F. John Bennett, "(XV) A Rapid Screening Test in Emergency Child Feeding in Kivu,

Congo," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 240. Children with measurements in the red zone are given therapeutic feeding treatments, children with measurements in the yellow zone receive supplementary food, and children with green measurements may be given a prophylactic feeding. For a recent critique of MUAC as a tool for admission into feeding program, see Emmanuel Grellety et al., "Comparison of Weight-for-Height and Mid-Upper Arm Circumference (MUAC) in a Therapeutic Feeding Programme in South Sudan: Is MUAC Alone a Sufficient Criterion for Admission of Children at High Risk of Mortality?," *Public Health Nutrition* 18, no. 14 (October 2015): 2575–81.

24. Derrick Jelliffe and his wife Patrice Jelliffe are best known for their defense of breastfeeding in the 1970s, which would greatly influence the discourse on infant feeding in the tropics. See Derrick B. Jelliffe and E. F. Patrice Jelliffe, *Human Milk in the Modern World* (Oxford: Oxford University Press, 1978).

25. Biophysical methods such as radiographic examinations and testing of physical functions (for example, deviations in visual acuity, capillary fragility, lack of muscle coordination, night-blindness, etc.) were considered not practicable in field assessments (Jelliffe, *The Assessment of the Nutritional Status of the Community*, 94–96). Derrick B. Jelliffe and E. F. Patrice Jelliffe, "Prevalence of Protein-Calorie Malnutrition in Haitian Preschool Children," *American Journal of Public Health* 50, no. 9 (September 1960): 1355–66; E. F. Patrice Jelliffe and Derrick B. Jelliffe, "(I) Background," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 179–88.

26. Jelliffe, *The Assessment of the Nutritional Status*, 179.

27. Jelliffe and Jelliffe, "(I) Background," 179

28. Jelliffe, *The Assessment of the Nutritional Status*: 181.

29. Among many signs, eleven clinical symptoms of protein-calorie malnutrition are listed by Jelliffe and Jelliffe, "(I) Background," 180. Edema (accumulation of fluid in the tissues causing swelling, usually in the feet, ankles, calves or legs), dyspigmentation of the hair, easy pluckability of the hair, thin sparse hair, straight hair, muscle wasting, depigmentation of the skin, psychomotor change, moon-face, hepatomegaly (enlarged liver), "flaky paint" dermatosis.

30. Jelliffe, *The Assessment of the Nutritional Status*, 42.

31. Ibid., 12.

32. Ibid., 18.

33. Ibid., 18.

34. Ibid., 16.

35. Ibid., 16.

36. Ibid., 33.

37. Ibid., 18.

38. Ibid., 41.

39. Ibid., 160. For an analysis of the experience of colonial medicine and the rumors on Europeans bloodsucking children in Africa, see White's monograph: Luise White, *Speaking with Vampires: Rumor and History in Colonial Africa* (Berkeley: University of California Press, 2000).

40. Nutritionists spoke of "mild moderate" undernutrition, "early" protein-calorie malnutrition, "clinically occult," "marginal malnutrition," or "pre-clinical" malnutrition.

41. John J. Stremlau, *The International Politics of the Nigerian Civil War, 1967–1970* (Princeton, N.J.: Princeton University Press, 1977); Albert Wirz, *Krieg in Afrika: Die nachkolonialen Konflikte in Nigeria, Sudan, Tschad und Kongo* (Wiesbaden: Steiner, 1982); Michael Gould, *The Struggle for Modern Nigeria* (London: I. B. Tauris, 2012).

42. Cato Aall, "Relief, Nutrition and Health Problems in the Nigerian/Biafran War," *Journal of Tropical Pediatrics* 16, no. 2 (June 1970): 75.

43. On Biafra and the birth of modern humanitarian aid, see Phillipe Ryfman, *Une histoire de l'humanitaire* (Paris: La Découverte, 2008), chap. 4; Rony Brauman, *La médecine humanitaire* (Paris: PUF, 2009), chap. 1; Kevin O'Sullivan, *Ireland, Africa and the End of Empire: Small State Identity in the Cold War, 1955–75* (Manchester: Manchester University Press, 2013), chaps. 4 and 5.

44. Bruno Gans, "A Biafran Relief Mission," *The Lancet* 293, no. 7596 (March 1969): 662.

45. The population of Biafra and number of deaths were also a matter of controversy. Casualty figures varied between one and three million.

46. Caroline Moorehead, *Dunant's Dream* (New York: Harper Collins, 1998); David P. Forsythe, *The Humanitarians: The International Committee of the Red Cross* (Cambridge: Cambridge University Press, 2005); David P. Forsythe and Barbara Ann J. Rieffer-Flanagan, eds., *The International Committee of the Red Cross* (London: Routledge, 2007).

47. Aall, "Relief, Nutrition and Health Problems in the Nigerian/Biafran War," 83.

48. Roger Hickman, "The Relief Operation in Former Biafra," *The Lancet* 296, no. 7662 (1970): 815–16.

49. Food and Agriculture Organization of the United Nations, *Agricultural Development in Nigeria, 1965–1980* (Rome: FAO, 1966), quoted in Aall, "Relief, Nutrition and Health Problems in the Nigerian/Biafran War," 72.

50. On the question of the transfer of nutritional science between metropole and colonies, see Michael Worboys, "The Discovery of Colonial Malnutrition Between the Wars," in *Imperial Medicine and Indigenous Societies: Studies in Imperialism*, ed. David Arnold (Manchester: Manchester University Press, 1988); David Arnold, "The 'Discovery' of Malnutrition and Diet in Colonial India," *Indian Economic and Social History Review* 31, no. 1 (March 1994): 1–26; Dana Simmons, "Starvation Sciences: From Colonies to Metropole," in *Food and Globalization: Consumption, Markets and Politics in the Modern World*, ed. Alexander Nützenadel and Frank Trentmann (Oxford: Berg, 2008): 173–92; James Vernon, *Hunger: A Modern History* (Cambridge, Mass.: Harvard University Press, 2007), 104–17.

51. 1,775 calories/ person, according to Aall, "Relief, Nutrition and Health Problems in the Nigerian/Biafran War," 70.

52. Larry E. Davis, "Epidemiology of Famine in the Nigerian Crisis: Rapid Evaluation of Malnutrition by Height and Arm Circumference in Large Populations," *American Journal of Clinical Nutrition* 24, no. 3 (March 1971): 358–64; Rainer Arnhold, "(XVII) The QUAC Stick: A Field Measure Used by the Quaker Service Team in Nigeria," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 243–47.

53. Davis, "Epidemiology of Famine in the Nigerian Crisis," 360.

54. Barnett, *Empire of Humanity,* 135.

55. The organization was not even able to determine exactly how many people lived in the area before the war: "about one to two million people." Davis, "Epidemiology of Famine in the Nigerian Crisis," 358.

56. Ibid., 359.

57. "Only one household in 14 failed to have children" (ibid.). Interestingly, Davis does not mention the role of "pawning" and other practices of child mobility between families in order to cope with the famine in Igbo society. Egodi Uchendu, "Recollections of Childhood Experiences

during the Nigerian Civil War," *Africa: The Journal of the International African Institute* 77, no. 3 (2007): 410. Davis, "Epidemiology of Famine in the Nigerian Crisis," 359.

58. David Morley et al., "Heights and Weights of West African Village Children from Birth to the Age of Five," *West African Medical Journal* 17, no. 1 (February 1968): 8–13.

59. *Report on the Heights and Weights of School Pupils in the County of London in 1954*, London County Council Report no. 3885, 1955. Quoted in Davis, "Epidemiology of Famine in the Nigerian Crisis," 364.

60. Davis, "Epidemiology of Famine in the Nigerian Crisis," 359.

61. Wolanski did not publish the MUAC figures for Polish children himself but rather communicated them to Derrick Jelliffe, who printed them in his report for WHO in 1966 (Jelliffe, *The Assessment of the Nutritional Status*, 228).

62. Instead of manipulating the composite table on paper, the measuring team used a "QUAC stick" (Quaker Arm Circumference measuring stick), a height measuring stick marked with arm-circumference measurements rather than height measurements. The cut-offs (85 or 80 percent) for expected circumference for a specific height were marked directly onto the stick at the corresponding height so that, in practice, the child's arm circumference was measured with a tape, with the stick placed behind the child indicating an arm circumference reading. If the child's actual height was below this mark—that is, below the level corresponding to his or her arm circumference—then his or her arm measurement was greater than 85 percent of the arm circumference of an average child of his or her height, and he or she was therefore classified as not malnourished. If he was taller than the expected level, he was classified as malnourished (Arnhold, "(XVII) The QUAC Stick," 243).

63. Ibid., 359.

64. Ibid., 360.

65. Ibid., 359.

66. Arm-circumference measurement was based on the assumption that all body musculature was uniformly affected by undernutrition, which seemed "likely" but remained "unproven." Jelliffe and Jelliffe, "(I) Background," 185.

67. Some participants to the symposium (Ian Phillips, Arnhold Rainer, Ingrid Rutishauser, Meinhard Robinow, Robert Cook) had worked with Derrick Jelliffe or with nutritionists trained by him in Uganda while he was the UNICEF Professor of Child Health at the Makerere Medical School of Kampala in the early 1960s. Others participants (like Ivan Beghin and Michael Gurney) had known Jelliffe from his work in Latin America while he was at the Caribbean Food and Nutrition Institute. Most of them later became consultants for UNICEF, the World Health Organization, or the World Food Program.

68. Jelliffe and Jelliffe, "(IX) Experience in the Caribbean"; Xenophon G. Kondakis, "(VII) Field Surveys in North Greece and Dodoma, Tanzania," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 201–4; Kondakis, "(VII) Field Surveys in North Greece and Dodoma, Tanzania"; Petter Karlberg et al., "The Development of Children in a Swedish Urban Community: A Prospective Longitudinal Study: (III) Physical Growth during the First Three Years of Life," *Acta Paediatrica Scandinavica* 57, no. 187 (December 1968): 48–66; Ingrid H. E. Rutishauser and Roger G. Whitehead, "Field Evaluation of Two Biochemical Tests Which May Reflect Nutritional Status of Three Areas of Uganda," *British Journal of Nutrition* 23, no. 1 (March 1969): 1–13; Jelliffe and Jelliffe, "(I) Background."; David M. Blankhart, "(VIII) Experience in Sierra Leone and Zambia," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 205–8; Ivan D. Beghin, "(XVIII)

Assessment of Effectiveness of a Nutrition Rehabilitation Centre at Fond-Parisien, Haiti," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 248–50; Michael J. Gurney, "(XVI) The Arm Circumference as a Public Health Index of Protein-Calorie Malnutrition of Early Childhood: Rapid Assessment in a Refugee Camp in Nigeria," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 241–42; Abdullah Kanawati, Nadra Haddad, and Donald S. McLaren, "(XIV) Preliminary Results with Mid-Arm and Muscle Mid-Arm Circumferences Used as Nutritional Screening Procedures for Pre-School Children in Lebanon," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 233–37; Bennett, "(XV) A Rapid Screening Test in Emergency Child Feeding in Kivu, Congo."; Boutourline H. Young, "(XII) Arm Measurements as Indicators of Body Composition in Tunisian Children," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 222–24.

69. Petter Karlberg et al., "The Development of Children in a Swedish Urban Community"; Kondakis, "(VII) Field Surveys in North Greece and Dodoma, Tanzania"; Jelliffe and Jelliffe, "(I) Background."

70. Eksmyr, "(IV) Upper Arm Circumference of Privileged Ethiopian Pre-School Children," 195.

71. As is often the case with new inventions, early discussions were marked by frequent use of inverted commas when referring to arm circumference as a "measure" of malnutrition, or to Wolanski as an "international standard."

72. McKay, "(X) Experience with the Mid-Arm Circumference as a Nutritional Indicator in Field Surveys in Malaysia."

73. M. T. Ashcroft, R. Bell, and C.C. Nicholson, "Anthropometric Measurements of Guyanese Schoolchildren of African and East Indian Racial Origins," *Tropical and Geographical Medicine* 20 (1968): 159–71, quoted in Jelliffe and Jelliffe, "(I) Background."

74. David M. Blankhart, "(VIII) Experience in Sierra Leone and Zambia," 206.

75. Ingrid H. E. Rutishauser, "(V) Correlations of the Circumference of the Mid-Upper Arm with Weight and Weight for Height in Three Groups in Uganda," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 196–97; Kondakis, "(VII) Field Surveys in North Greece and Dodoma, Tanzania," 202; J. R. K. Robson and M. Bazin and R. Soderstrom, "Ethnic Differences in Skin-Fold Thickness," *American Journal of Clinical Nutrition* 24, no. 7 (July 1971): 864.

76. Bennett, "(XV) A Rapid Screening Test in Emergency Child Feeding in Kivu, Congo," 238.

77. Ibid.

78. Gulamabbas Juma Ebrahim, "Frontline Epidemiology," *Journal of Tropical Pediatrics* 37, no. 4 (August 1991): 146.

79. G. Margo, "Assessing Malnutrition with the Mid Arm Circumference," *American Journal of Clinical Nutrition* 30, no. 6 (June 1977): 835–37; Bernt Lindtjorn, "Measuring Acute Malnutrition: A Need to Redefine Cutoff Points for Arm Circumference?," *The Lancet* 326, no. 8466 (November 1985): 1229–30; D. G. Rees et al., "Measures of Nutritional Status: Survey of Young Children in North-East Brazil," *The Lancet* 329, no. 8541 (May 1987): 87–89; Helene D. Gayle et al., "Arm Circumference v. Weight-for-Height in Nutritional Assessment: Are the Findings Comparable?," *Journal of Tropical Pediatrics* 34, no. 5 (October 1988): 213–17; Mercedes de Onis and Z. Mei, "The Development of MUAC-for-Age Reference Data Recommended by a WHO Expert Committee," *Bulletin of the World Health Organization* 75, no. 1 (January–February 1997): 11–18.

80. Margo, "Assessing Malnutrition with the Mid Arm Circumference," 836.

81. Margo analyzes Cook's study in Uganda. Robert Cook, "(VI) The Arm Circumference in a Field Survey in Ankole, Uganda," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 198–200; Margo, "Assessing Malnutrition with the Mid Arm Circumference," 836.

82. "AC has obvious practical advantages over w/h in field settings. Our findings, however, demonstrate that despite overlap these indicators do not identify the same population of children as being malnourished." Gayle et al., "Arm Circumference v. Weight-for-Height in Nutritional Assessment," 216.

83. Krishnaswamy Vijayaraghavan and J. Gowrinath Sastry, "The Efficacy of Arm Circumference as a Substitute for Weight in Assessment of Protein-Calorie Malnutrition," *Annals of Human Biology* 3, no. 3 (1976): 229.

84. The differences between diagnoses using MUAC versus weight-for-height remain a problem for humanitarian programs today. Some children are referred to aid programs using MUAC but are subsequently denied treatment because they do not meet the weight-for-height requirement for admission (see Myatt et al., "The Effect of Body Shape"). On the lack of correlation between weight-for-height and MUAC, see Engy Ali et al., "Is Mid-Upper Arm Circumference Alone Sufficient for Deciding Admission to a Nutritional Programme for Childhood Severe Acute Malnutrition in Bangladesh?," *Transactions of the Royal Society of Tropical Medicine and Hygiene* 107, no. 5 (May 2013): 319–23.

85. Even if there is no clear correlation between weight-for-height and MUAC, MUAC appeared to be useful for assessing mortality risks. Radheshyam Bairagi, "On Validity of Some Anthropometric Indicators as Predictors of Mortality," *American Journal of Clinical Nutrition* 34, no. 11 (November 1981): 2592–94; Krishnaswamy Vijayaraghavan, "Anthropometry for Assessment of Nutritional Status," *Indian Journal of Pediatrics* 54, no. 4 (July–August 1987): 519; Onis and Mei "The Development of MUAC-for-Age reference Data," 11.

86. A suggestion made by Kanawati, Haddad, and McLaren, which has not been followed much. Kanawati, Haddad and McLaren, "(XIV) Preliminary Results with Mid-Arm and Muscle Mid-Arm Circumferences Used as Nutritional Screening Procedures for Pre-School Children in the Lebanon," 233–37.

87. "It is thus evident that careful consideration must be given before advocating the use of arm circumference as a field tool and particularly in identifying beneficiaries in any nutrition programme. This could only be used in selecting communities for nutrition intervention on priority basis" (Vijayaraghavan and Sastry, "The Efficacy of Arm Circumference," 233). A study in India, very critical of the ICRC study in Biafra, concluded that the relationship between arm circumference and height was "very poor" (Gowrinath Sastry, "Evaluation Of QUAC-stick for Growth Assessment in Children," *Indian Journal of Medical Research* 60 [May 1972]: 747–51). See also Vijayaraghavan, "Anthropometry for Assessment of Nutritional Status," 517.

88. Margo, "Assessing Malnutrition with the Mid Arm Circumference," 837.

89. Among MUAC proponents, the staff of the Institute of Child Health in London (around J. Tanner and D. Morley), the Centers for Disease Control and Prevention in Atlanta (around D. Miller), and the UCLA School of Public Health (around D. Jelliffe) were the most influential.

90. Arnhold, "(XVII) The QUAC Stick," 246–47.

91. Alfred Zerfas worked as a physician in the United Kingdom and for Save the Children Fund. He had worked in the Biafran emergency and later joined Derrick Jelliffe at the University of California, Los Angeles. He also was a nutrition consultant for UNICEF, WFP, and FAO.

92. Zerfas, "The Insertion Tape."

93. Adnan Shakir and David Morley, "Measuring Malnutrition," *The Lancet* 303, no. 7680 (April 1974): 759.

94. Shakir and Morley, "Measuring Malnutrition," 759.

95. An alternative inspiration for the MUAC tape was the "quipu," a knotted cord used in Inca communities to record events. The "anthropometric quipu" presented by Jelliffe and Jelliffe in 1975 indicated five levels of malnutrition (red, pink, orange, light blue, dark blue) (Derrick B. Jelliffe and E. F. Patrice Jelliffe, "The Quipu in Measuring Malnutrition," *American Journal of Clinical Nutrition* 28, no. 3 [March 1975]: 203–4).

96. "Normal weight increases by about half as much again in this age range, while the arm circumference increases by only about one-eighth" (J. Michael Gurney, "(XVI) Rapid Assessment in a Refugee Camp in Nigeria," 242).

97. The color strip not only led to "false positives" (children categorized as malnourished even though they were healthy) but also to many cases of "false negatives" (children categorized as healthy even though they were found to be malnourished using other methods of assessment). The worst-case scenario—the risk of overlooking malnourished children due to "false negatives"—was very high with the color strip, up to almost one-third of cases. Vijayaraghavan, "Anthropometry for Assessment of Nutritional Status," 517; K. Ramachandran et al., "Limitation of Film Strip and Bangle Test for Identification of Malnourished Children," *American Journal of Clinical Nutrition* 31, no. 8 (August 1978): 1469–72; Ramachandran et al., "Limitation of Film Strip and Bangle Test"; Vijayaraghavan, "Anthropometry for Assessment of Nutritional Status," 517.

98. Henk W. A. Voorhoeve, "A New Reference for the Mid-Upper Arm Circumference?," *Journal of Tropical Pediatrics* 36, no. 5 (October 1990): 262.

99. A study of American and Malawian children found out that MUAC increased by "approximately 2 cm between 6 and 59 months of age" (Onis and Mei "The Development of MUAC-for-Age Reference Data," 11). A study of Vietnamese children came to the same conclusion (i.e., that MUAC was not independent of age). Le Thi Hop et al., "Mid-Upper-Arm Circumference Development and Its Validity in Assessment of Undernutrition," *Asia Pacific Journal of Clinical Nutrition* 7, no. 1 (1998): 65. In 1993, an expert committee of the World Health Organization recommended abandoning the single cut-off and presented a sex-specific MUAC-for-age indicator meant to reflect "the true pattern" of mid-upper arm growth. Onis and Mei, "The Development of MUAC-for-Age Reference Data," 11.

100. Jelliffe and Jelliffe, "(IX) Experience in the Caribbean," 209.

101. "The selection of 80% of the Wolanski standard could also be regarded as a practical compromise between the higher Caucasian (. . .) and the lower Caucasian standards" (Derrick B. Jelliffe and E. F. Patrice Jelliffe, "The Arm Circumference as a Public Health Index of Protein-Calorie Malnutrition of Early Childhood, XX: Current Conclusions," *Journal of Tropical Pediatrics* 15, no. 4 [December 1969]: 253–60). For criticism of the cut-offs, see David M. Blankhart, "(VIII) Experience in Sierra Leone and Zambia," 207; Arnhold, "(XVII) The QUAC Stick"; and Leslie H. J. Burgess and Ann P. Burgess, "A Modified Standard for Mid-Upper Arm Circumference in Young Children," *Journal of Tropical Pediatrics* 15, no. 4 (December 1969): 189–92.

102. Gayle et al., "Arm Circumference v. Weight-for-Height in Nutritional Assessment."

103. The argument was as old as the invention of MUAC as an indicator itself. "Different arm circumference standards may be needed when using this tool among different races" (Brookens, "Validation of an Age-Independent Anthropometric Tool to Assess Nutritional Status," 227). But local standards were difficult to achieve. Brookens, "Validation of an Age-Independent

Anthropometric Tool to Assess Nutritional Status," 227; Robson et al., "Ethnic Differences in Skin-Fold Thickness"; Vijayaraghavan, "Anthropometry for Assessment of Nutritional Status," 512. Wilhemus J. M. Gerver, "Measurement of the Body Proportions in Children (The Oosterwolde Study)" (Ph.D. diss., University of Groningen, 1988); Voorhoeve, "A New Reference for the Mid-Upper Arm Circumference?"

104. For the full table, see Jelliffe, *The Assessment of the Nutritional Status of the Community*.

105. If one compares Jelliffe's figures to Gerver's, the difference in measurement is more than 1 cm: Jelliffe's MUAC for five-year-old girls is 16.9 cm, whereas Gerver indicates a MUAC of 17.91 (Jelliffe, "Field Anthropometry Independent of Precise Age"; Voorhoeve, "A New Reference for the Mid-Upper Arm Circumference?," 262).

106. Voorhoeve, "A New Reference for the Mid-Upper Arm Circumference?," 256.

107. Onis and Mei "The Development of MUAC-for-Age Feference Data," 11–18. The tables were calculated based on data collected by the United States National Center for Health Statistics (NCHS).

108. However, WHO experts were well aware of the shortcomings of their data and quickly announced that the standards should be "updated or replaced in the near future." "The new reference," some predicted, "will have a short life" (Macfarlane, "More Growth-Chart Confusion").

109. The universality of standards for malnutrition remains a matter of debate. During the 2011 famine in the Horn of Africa, several humanitarian workers expressed doubts about whether the same (universal) thresholds could be used for Somali children. The Ethiopian government, acting on its own initiative, had decided to lower the cut-offs in order to lower the figures for malnourished children.

110. Ruel et al., "Age-Based Preventive Targeting of Food Assistance."

111. She stated: "Take the example of the MUAC tape (. . .) If the circumference of the arm is greater than a certain value, this means that the child is healthy. Conversely, if the circumference is lower than a certain value, the child is acutely malnourished and in a danger of dying. The 'resilience zone' is the difference between these two values. If the child finds himself in this zone, the cost for helping him is around 10 euros. If it is below that value, the cost is around 200 euros. Resilience also has a significant meaning for the European taxpayer." Speech by Kristalina Georgieva, European Union commissioner for humanitarian aid and crisis response, during a meeting of the Commission of External Relations and Foreign Affairs, February 19, 2013, accessed September 9, 2015, http://www.assemblee-nationale.fr/14/cr-cafe/12–13/c1213036.asp.

112. For an overview of the "datafication" of aid, see Patrick Meier, *Digital Humanitarians: How Big Data Is Changing the Face of Humanitarian Response* (London: Taylor & Francis, 2015).

113. Jörg Niewöhner, "Epigenetics: Embedded Bodies and the Molecularisation of Biography and Milieu," *BioSocieties* 6, no. 3 (2011): 279–98; Margaret Lock and Patricia Kaufert, "Menopause, Local Biologies, and Cultures of Aging," *American Journal of Human Biology* 13, no. 2 (February–March 2001): 494–504; Lock and Nguyen, *An Anthropology of Biomedicine*, 109.