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PARADIGM SHIFT: EFFICIENT AND COST EFFECTIVE REAL-TIME NUTRITIONAL ASSESSMENT TECHNIQUE

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ABSTRACT

For several decades, nutritional anthropometry has been used in the assessment of nutritional status and growth monitoring for individuals and at population level. Techniques, equipment and standardization procedures endorsed by The United Nations Children's Fund (UNICEF) and The World Health Organization (WHO) for measurements of body size are extensively used, have evolved and advanced in precision. However, new challenges are emerging with each new equipment and technique for data collection, including; difficulty in calibrating and durability of equipment, frequent observational errors, delays in generating nutritional data, relatively high cost of data collection in the field, and scarcity of nutritional experts to manage assessments and analyse data. Moreover, some health facilities collect selective nutritional data (weight and age) required for drug prescriptions only and often lack a repository for the raw data, making it difficult to assess nutritional trends for individual patients and compare nutritional status of populations over time. In the last one decade, there has been a shift towards the use of high technology in data collection for social studies, which is faster, more accurate and reliable when compared to conventional methods. Advancement in technology has seen the development of high precision digital clinical scales for measuring weight and height/length for individuals and populations with readily installed software for calculating nutritional indices and interfaces, such as, Bluetooth, USB or Wi-Fi, for transmitting data. In the proposed real-time nutritional assessment system, we combine GPS-Coordinates, anthropometric data from high precision digital clinical scales; fingerprint coded data, with indicators derived from food security, water, sanitation, maternal and child health data in the smartphone platform. Through the cellular network, the combined data is transmitted to a specialised designed web-based visualisation interface where it is analysed and presented on a dashboard in a form of interactive dynamic graphs and charts. After deriving the nutritional indices, the system superimposes colour coded anthropometric results for study subjects to display their immediate nutritional status. Subsequently, these assessment results are simultaneously transmitted through live-web to the desktops of assessment supervisors, programmers, and developing partners who actively interact as results trickle in and can make intervention decisions in real time. This efficient and cost-effective nutrition assessment system is proposed because it generates nutritional data that provides the most current nutritional status of an individual and target population; monitors trends of nutritional status; identifies priority individuals and areas for immediate nutritional interventions; and evaluates the effectiveness of nutrition and health intervention programmes.

Key words: Nutrition assessments, Anthropometric, Mobile data collection, Real-time, Data Visualization

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INTRODUCTION

Five decades ago, Jelliffe defined nutritional anthropometry as the measurement of variation of the physical dimensions and the gross composition of the human body at different ages and degree of nutrition [1]. Since then nutritional anthropometry has widely been used in the assessment of nutritional status and growth monitoring for individuals and at population level. Anthropometric information collected at growth monitoring points is an essential nutritional management tool to promote health related activities and foster health education counselling.

Most common measurements of body size include length, height, weight, triceps and subscapular skinfolds, head and arm circumferences. Over the years, the assessment techniques for these measurements have evolved with each method advancing in precision. Today, the conventional method for measuring weight is using hanging scales precisely the Salter scale® (UNICEF, catalogue 0145555, Copenhagen, Denmark) for children less than 59 months. The measurements are made to the nearest 100g; standing height (children ≥24 months or ≥ 85cm) within 0.1cm and recumbent length (children ≤24 months or ≤ 85cm) within 0.1cm using measuring height and length wooden boards (UNICEF, catalogue 0114500) respectively. In addition, mid-upper arm circumference, a marker of wasting, is measured using a calibrated tape (UNICEF, catalogue 145600) within 0.1cm. The Standardized Monitoring and Assessment of Relief and Transition (SMART) guidelines provide an integrated approach in assessing nutritional status and mortality rate in a humanitarian crisis [2]. The guidelines provide step-by-step instructions on how to conduct a field nutritional survey including collection of anthropometric data and data analysis using either WHO Anthro software vs.3.2.2 (www.who.int/childgrowth/software/) or ENA for SMART software (www.nutrisurvey.de/ena/ena.html). Subsequent interventions are implemented based on the assessment findings and recommendations.

Collection of anthropometric data in growth monitoring programs use weighing scales and height boards that are either the same or different from UNICEF's collection of scales, to monitor the growth of the individuals, and evaluate the performance of nutrition interventions. Whereas the anthropometric data and any other relevant nutrition information generated are extremely useful to decision makers, a few concerns have been raised on the anthropometric equipment and systems used for nutritional data collection. These include:

Reliability of anthropometric equipment in collecting nutritional data

The anthropometric equipment and methodologies for collecting nutrition data have advanced, but new challenges are emerging with each new equipment and methodology. For example, the traditional beam balances used for population measurement in health institutions are not portable, and as such, cannot be used to conduct household nutritional surveys. Subsequently, these have been substituted by the electronic digital scales that are easy to operate and are portable. Nonetheless, the electronic scales are usually difficult to calibrate and their durability is questionable. Bathroom scales, commonly used in private clinics and hospitals that serve small populations, are easy to use and less expensive than the electronic scales, but not suited

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for large populations because they have low precision, require frequent calibration and easily break down. The hanging scales, such as the Salter scale® are designed to take weight measurements for children under five years in nutrition surveys and in health facilities. The hanging scales are portable and easy to calibrate using standard weights. However, they require hanging pants whose use are often cumbersome especially when young children do not feel comfortable to wear them or when the children are agitated and shake when hanging on the scales which can result in observational errors.

The height/length boards are easy to use, do not require calibration and can be produced locally but their precision is conditional and highly dependent on the measurer [3,4]. In normal circumstances, the measurer is required to keenly and accurately observe the age of child, posture of child while standing or lying down or hanging on the scale, and maintain a good reading position before taking the reading [4]. An inexperienced or inappropriately trained measurer of height or length is prone to making observation errors [5]. Further, there is a huge precision variation in the types of anthropometric equipment. For example, in a growth monitoring and promotion program, whenever community health workers use different weighing scales, either hanging scales or beam balances, to compare weights of children in the same community over time, the information obtained may lead to wrong conclusions.

The World Health Organization (WHO) has developed anthropometry standardization methods as part of quality assurance measures [6]. Standardization methods are essential for monitoring measurement techniques, identify possible sources of errors or bias; and retrain teams or individuals as necessary. Whereas the WHO standardization sessions have been shown to yield positive results [6], a trending limitation of standardization is the recurrent anthropometric equipment errors, partly due to low innate precision and poor handling of the equipment by measurers, inexperienced survey supervisors and poorly trained data collectors [5].

Undue delays in generating nutritional data

The generic SMART method provides timely and reliable data in a standardized way for prioritizing humanitarian assistance for policy and program decisions [2]. Ideally, an estimated 8-10 weeks is required to conduct and compile results of a conventional nutrition survey. This duration is explained by: the first two weeks spent on agreeing with the community leaders on the best days to conduct the surveys; identifying survey geographical areas (clusters), recruiting and training staff; testing and standardization of survey tools. The following 2-3 weeks spent on travelling to selected clusters; identifying target individuals; undertaking anthropometric measurements and conducting interviews. The remaining 4-5 weeks are used in data entry; data cleaning and analysis; report writing and sharing of survey results. Additional time is often required to obtain feedback from stakeholders and finalising the report. Given this scenario, it is possible that by the time the report is disseminated to the implementing and funding agencies, most children's nutritional status may have deteriorated and a substantial increase in the cost of intervention is likely to occur.

A depository for raw anthropometric data is lacking in many rural health facilities. This absence can be attributed to either lack of computers or compatible software and

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computer illiteracy, yet such data is very crucial for determining aggregate nutritional trends for community members whenever needed to initiate a nutrition intervention as quickly as possible. In some health facilities, only age and weight measurements of patients are taken for determining the quantity of drug prescription. If there were a system to provide the health practitioners with nutritional status of each patient, the nutritional data would play a major role in augmenting diagnosis and thus improve the nutritional status of the patient at the same time.

As discussed above, overall time taken between nutritional assessment and the implementation of an intervention may take nearly 1-4 months or more, further delays may be accrued when an implementing agency sets out to identify malnourished individuals through the conventional recruitment procedures for interventions. During a nutritional assessment, personal and household characteristics data is collected. Similar data is collected during enrolment into an intervention. Thus, a smooth link between the nutrition survey database and data collected during recruitment, that could be used for timely decision-making, is lacking.

Scarcity of experts to undertake nutritional assessment

Survey supervisors are the most skilled and knowledgeable members of the assessment team. Their selection criteria require that they attain tertiary level of education with at least 3-5 years' experience in managing nutritional assessment, data analysis and report writing, but persons with these qualifications are not easy to find and often are expensive, so less skilled staff are sometimes employed, compromising the quality of the assessment. Additionally, data generated by the Anthro software requires the use of other analytical software such as Microsoft Excel or the Statistical Program for Social Studies, to observe trends and correlation of data to understand the magnitude and causal factors of malnutrition. This in-depth analysis requires the services of a statistician experienced in analysing nutrition data, especially if the survey supervisor is unable to analyse data. Engaging the services of a separate data analyst has cost implications and may delay release of nutritional assessment results. Often, in a survey area, the local community members are best suited to collect data because; they are familiar with the surroundings, able to identify households with the target individual and are fluent in speaking the local language. These data collectors must have relatively high levels of education, must be proficient in reading, in writing the local language and in interpreting nutritional data. However, few community members attain these criteria so alternative members from other communities are often recruited, which may compromise the quality of data collected.

Relative high cost for conducting nutritional surveys

The cost of conducting a conventional nutritional assessment in the field is relatively high. This amount excludes costs of anthropometric equipment, (hanging scales plus weighing pants, height and length boards, MUAC tapes), that are often obtained from UNICEF or the Ministry of Health (the case in Kenya) at no cost. Recently, SMART surveys were conducted in several drought stricken counties in Kenya to understand the magnitude and severity of drought. The estimated cost of the SMART surveys ranged between 15,000 to 20,000 USD per survey (*Nutrition Specialist, UNICEF-Kenya).* Main factors affecting cost of surveys include distance and remoteness; and the number

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of enumerators that comprise of approximately 6 field teams each with 3-4 members, data entry clerks, logisticians, administrative staff and an overall coordinator (Survey supervisor). Additional costs include transport, training, stationary, printing of questionnaires, computers and statistical software. These costs may increase because of delays likely to occur during data collection. Unexpected occurrences such as funerals, poor road conditions, broken bridges and migration of community members, often lead to the survey team failing to attain the required sample size per day which may substantially increase survey expenses. Hence, in a multi-stage data collection system, budget and timeframe constraints necessitate creative ways for data collection to achieve the desired results. Such delays in the data collection process occasioned by field conditions could be offset by a much faster and cost effective data collection system. Further, although the dissemination of the final report to stakeholders and particularly development partners may be swift, funding for the proposed intervention program is often not adequate because in a span of 4-6 weeks post survey, the reported nutritional status is likely to have deteriorated and more resources required, to address the nutritional needs.

Success in using high technology systems to conduct nutrition assessment offers promising prospects for addressing the challenges posed by conventional anthropometric methods. In the last one decade, there has been a shift towards the use of high technology in data collection for social studies, which is more accurate and reliable when compared to the conventional methods. For example, a food intake assessment was conducted to determine the reliability and validity of the use of camera-enabled cell phones with a data transfer capability (through cellular network) of the remote food photography method. The results of the camera enabled cell phones were more reliable when compared to the conventional self-reporting method [7]. More recently, a study conducted to determine adherence of daily home fortification of micronutrient powders in young children (12-36 months) showed that measurement of adherence using an electronic device was accurate and more reliable when compared to sachet counts and self-reporting methods that are easy to use and relatively inexpensive [8].

Use of smart phone platforms for nutritional data collection is recommended in the SMART guidelines for nutritional data collection and is currently in use by the United Nations High Commissioner for Refugees (UNHCR), and a community nutrition intervention program in Uganda (USAID, community connector project). The mobile data platform is reliable and swiftly transmits data to programmers by use of cellular network, to monitor intervention progress and fast track interventions. However, the anthropometric measurement is manually conducted, and thus, the system has not been able to fully eliminate errors related to observation, reading and recording of anthropometric measurements, necessitating frequent and intense training of measurers and data verifications at different levels increasing the cost of data collection and delays [9].

Model for the real-time nutritional assessment system

Based on the above concerns, and the promising opportunity presented by technological advances, this proposal to use a real-time nutritional assessment system

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that engages digital data gathering applications in conjunction with relevant nutritional statistical packages to increase efficiency, monitor trends, and reduce time and costs of conducting nutritional assessments may be the most appropriate.

Advancement in technology has seen the development of high precision digital clinical scales for children below five years. The digital scales with a built-in memory, combine weight, height and length measurements with age and gender specific WHO growth charts to generate nutritional status of a child. These digital scales assemble quickly and are easily detachable, less bulky than conventional scales, and are portable. Taking anthropometric measurement with the digital scales is easy. The measurer is only required to ensure that the child is well positioned on the scale before his/her nutritional status is electronically generated (details and specification of the digital scales are presented elsewhere). In addition, the digital scales are fitted with either a USB interface, Bluetooth software or Wi-Fi outputs essential for direct transfer of the individual anthropometric data, to a data gathering application such as the already existing WHO smart phone data platform. Additional information such as baseline characteristics for individuals, household characteristics, and any other relevant information as stipulated in the SMART guidelines is directly added to the mobile data platform by a trained assessment staff. The system ensures that both data collected and recorded has minimal errors because any supportive data that requires manual inputting into the mobile data platform is validated before it is transmitted to the users or decision makers. In addition, the system can identify the location of the individual, household or health facility in real-time using the GPS coordinates installed in the smart phone. When cell phone network services are limited in the field, the measurer can continue with data collection and transmit the data when the network is active.

Thus, the mobile data collection tool coupled with either WHO Anthro software or ENA for SMART software is linked to a specifically designed web-based visualization interface for nutritional data analysis. The visualization interface is designed to share interactive, dynamic graphs and charts to present the assessment results. As new data comes in, these can be manipulated and filtered as needed and updated automatically, enabling the survey supervisors or programmers to immediately spot trends and make necessary adjustments before the assessment team leave the field. After deriving the nutritional indices, the system superimposes colour coded anthropometric results for study subjects to display their immediate nutritional status. For example, a child whose nutritional status is normal will be coded as green, moderately malnourished as yellow and severely malnourished as red on the GPS coordinates found on the survey area map. This is crucial to enable the programmers locate the malnourished individuals and start planning for intervention accordingly. In addition, we will collect biometric data, , using a fingerprint sensor enabled smartphone device. This will serve to assist in tracking individuals previously assessed in a nutritional assessment for admission into an intervention; and to assist nutrition service providers identify and match individual children as they grow older with any subsequent collected data, hence creating a follow up tracking system. In 2011, use of fingerprint technology to access school lunch was reported [10]. The scanner and software used was designed in such a way that it did not record the information on the students' fingerprints but rather created vital identification points based on the fingerprint that was further explained by the

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proprietary software each time the student placed his/her finger on the scanner [10]. Use of biometric data for nutritional assessments such as a child's finger print has not been used elsewhere, hence its use is cautiously proposed following the recommendations of the joint research technical report that concluded that a child's finger print requires the most stringent safeguards to guarantee the highest level of care for preserving their rights [11]

This data collection system is not just suited to field surveys but can also efficiently work in a heath facility where anthropometric data collected by a measurer such as a nurse can be transmitted to the health practitioner in real time to determine appropriate diagnosis and prescriptions.

Initially, the amount of data trickling into the web-based visualization interface may be too small to draw any meaningful conclusions. As more observations are made, any interesting or unexpected result may trigger the need for qualitative data collection either through focus group discussions or key informants, providing an opportunity for results to be triangulated without having to wait for detailed quantitative data analysis to be completed. This also reduces chances of collecting unwanted qualitative data thus minimising erroneous conclusions and recommendations.

If customised statistical analysis is required especially to explain causes of malnutrition, raw data can easily be downloaded from the cloud space and transferred to the desired statistical software, hence the assessment supervisor or statistician who is not necessarily in the study area may access the raw data and perform the analysis and immediately update the assessment results. Since this is a multi-client application system a more secure and reliable central server or database to store information is used and a restriction of access feature based on privilege is installed. This allows only the data users to synchronize information more easily and provide storage space, which is limited in mobile data tools.

It may be argued that the cost of our novel high technology nutritional assessment system is high, partly because the initial cost of setting up the system involves costs of digital scales, smartphones with fingerprint enabled scanners, computers, internet bundles, and nutrition assessment web-based visualisation software. However, it presents the best option for collecting nutritional assessment data because it highly minimises errors, reduces data collection time, cuts down on recurrent survey costs, and guarantees a secure raw data depository for nutrition surveys. This system directly excludes several main assessment phases, namely the measurers manual engagement in taking the height/length and weight measurements, data reading, data recording, and data inputting into desired statistical software, basic data analysis and immediate reporting of basic results. Identification of colour coded malnourished individuals and their location is real-time and finger-print data enables an efficient link between individual and household characteristic data needed by programmers for follow-up and admission into subsequent interventions.

Additionally, the anthropometric equipment is light and portable, and a smartphone replaces the huge stack of hard copy questionnaires, all these reduce the bulk of

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luggage carried by the survey team and hence one person can comfortably conduct the interview and administer the anthropometric measurements; only two survey members may be needed per team (a data collector and a community guide). A motorbike or bicycle may be the most preferred mode of transport. For these reasons, the costs and time spent on conducting the nutritional assessment in the field is highly reduced (Figure 1).

The whole field survey team including field supervisors are thoroughly trained before data collection and a piloting phase of the survey is conducted on the use of digital scales as per the digital scale manufactures manual and on the use of smartphone data platform. The data users are also trained on web-based visualization interface. Our system closely follows the instructions in the SMART guidelines especially on approaching the survey community, determining geographical survey areas (clusters), interviewing techniques, and data presentation and reporting.

Overall, this efficient and cost effective nutrition assessment system is proposed because it generates nutritional data that provides the most current nutritional status of an individual and target population; monitors trends for nutritional status for both individuals and population; identifies priority individuals and areas for immediate nutritional interventions; and evaluates the effectiveness of nutrition and health intervention programmes.

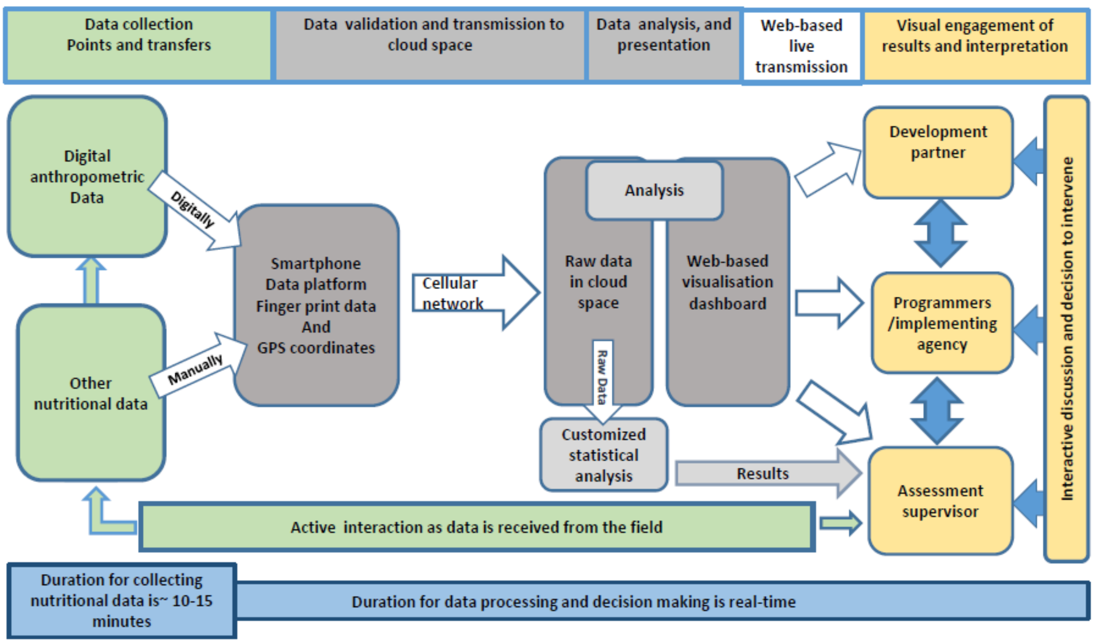

Figure 1: Nutritional assessment data processing system

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