ADDRESSING ANAEMIA IN THE WOMEN OF TANZANIA: IMPROVING SCREENING AND DIAGNOSIS

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POLYGEIA
STUDENTS SHAPING GLOBAL HEALTH POLICY

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Executive Summary

Despite the unprecedented increase in funds for procurement of health commodities over the past decade, the efficient delivery of commodities and services remains a significant challenge. Our region of interest, Sub-Saharan Africa and more specifically, East Africa, has the poorest overall health indicators in the world.

In collaboration with the Cambridge Development Initiative (CDI), we explore ways to identify and address micronutrient deficiencies in women living in this region. We specifically focus on anaemia due to its detrimental effect on both women's general and reproductive health. In fact, anaemia has consequences on child health and, from a macroeconomic perspective, productivity levels of entire nations.

In our work, we adopt a multi-pronged approach by highlighting potential technological solutions, community engagement programmes as well as policy measures that can be adopted for the effective management of this unprecedented public health crisis.

Our findings are mainly directed at the CDI but will be of interest to non-governmental organisations, local governments and international organisations who may use our results to develop robust implementation programmes.

Background

Nutrition through a gender lens: Impact of micronutrient deficiencies on women

Recently, the United Nations revealed that 815 million people worldwide suffered from undernutrition in 2016, thus affecting an additional 38 million people compared to 2015[1]. Undernutrition is the result of insufficient food intake and frequent exposure to infectious agents, causing both protein-energy undernutrition or micronutrient deficiency. The latter, also known as the 'hidden hunger'[2], is often overlooked because vitamin and mineral deficiencies usually cause less readily visible symptoms than protein-energy malnutrition. However, a third of the world's population suffers from micronutrient deficiencies[3], and many are ranked amongst the 20 leading risk factors in the global burden of disease[4]. For instance, vitamin A deficiency claims the deaths of nearly 800,000 women and children each year, just behind iron deficiency to which 814,000 deaths are attributed[5]. Although the 'hidden hunger' can affect anyone, it is most prevalent among women and children.

Three factors make women the most susceptible group to suffer from micronutrient deficiencies: poor access to food, healthcare, and education[6]. While such deficiencies are rarely the result of a single cause, a study has shown that societal norms and gender-based discrimination greatly increase the susceptibility of women to micronutrient deficiencies[3]. Women are often expected to feed their family members first before feeding themselves, and are, hence, much more likely than men to forego food consumption during periods of shortage. Furthermore, the stigmatisation of women affected by infectious diseases decreases their likelihood of seeking medical treatment[3] and, therefore, leaves them unprotected against infectious agents such as helminths. Finally, societal norms also favour the schooling of boys over girls – who are often expected to help at home – which decreases their exposure to information about diseases and medical treatments.

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[1] Food and Agriculture Organization Economic and Social Development Department. "The State of Food Insecurity in the World, 2015: Meeting the 2015 international hunger targets: taking stock of uneven progress". *Food and Agriculture Organization of the United Nations*, 2015, p. 48.
[2] Muthayya, S., Rah, J.H., Sugimoto, J.D., Roos, F.F., Kraemer, K. and Black, R.E.,2013. The global hidden hunger indices and maps: an advocacy tool for action. *PLoS One*, **8**(6), p.e67860.
[3] Darnton-Hill, I., Webb, P., Harvey, P.W., Hunt, J.M., Dalmiya, N., Chopra, M., Ball, M.J., Bloem, M.W. and De Benoist, B., 2005. Micronutrient deficiencies and gender: social and economic costs. *The American journal of clinical nutrition*, **81**(5), pp.1198S-1205S.
[4] World Health Organization, 2002. *The world health report 2002: reducing risks, promoting healthy life*. World Health Organization.
[5][5][5][5] Khan, Y. and Bhutta, Z.A., 2010. Nutritional deficiencies in the developing world: current status and opportunities for intervention. *Pediatric Clinics*, **57**(6), pp.1409-1441.
[6] Lartey, A., 2008. Maternal and child nutrition in Sub-Saharan Africa: challenges and interventions. *Proceedings of the Nutrition Society*, **67**(1), pp.105-108.

Micronutrient deficiencies are widespread in Tanzania and positively correlated with calorie deficiency[7]. Among the most common is anaemia, which can be the result of a variety of vitamin and mineral deficiencies but is most often associated with iron deficiency. According to the WHO's Global Health Observatory[8], over a third of women of reproductive age and one out of two pregnant women living in Tanzania suffer from iron deficiency anaemia. As of 2016, the latter remains a severe public health problem not only affecting women's nutritional status, but also the next generation's health and the productivity levels of entire nations. Therefore, improving maternal nutrition is at the forefront of the WHO's Global Targets 2025.

Biologically, women experience greater blood loss due to menstruation and have lower iron stores; pregnant women may have no iron stores at all[9]. Studies have shown that anaemia in pregnancy is associated with markers of infections and nutritional deficiencies, especially iron deficiency[10]. The United Nations Children's Fund (UNICEF) identified inadequate food intake, high prevalence of diseases, and increased physiologic need for nutrients as the cause[11].

Several studies have shown that micronutrient deficiencies - such as anaemia - have a direct impact on maternal and child mortality as well as children's growth and development[12]. Maternal undernutrition hinders fetal growth, thus increasing neonatal deaths[13]. Prenatal and early life nutrition also determine the nutritional status of surviving children and causes severe stunting and wasting by age two years of age when inadequate. Children who are unable to improve their diet at a young age significantly are more likely to underperform at school, have poorer adult health, and diminished work capacity[14].

In the long run, the overall fatigue and weakness caused by micronutrient deficiencies result in an inability to improve one's socioeconomic status, thus further reducing low-income households' chances of leaving poverty[13]. These households represent an enormous loss of

[7] Ecker, O., Weinberger, K. and Qaim, M., 2010. Patterns and determinants of dietary micronutrient deficiencies in rural areas of East Africa. *African Journal of Agricultural and Resource Economics*, **4**(2), pp.175-194.
[8] WHO. 2016. *Global Health Observatory (GHO)*. [Online]. Available from: http://apps.who.int/
[9] Seshadri, S., 2001. Prevalence of micronutrient deficiency particularly of iron, zinc and folic acid in pregnant women in South East Asia. *British Journal of Nutrition*, **85**(S2), pp.S87-S92.
[10] Hinderaker, S.G., Olsen, B.E., Bergsj, P., Lie, R.T., Gasheka, P. and Kvle, G., 2001. Anemia in pregnancy in the highlands of Tanzania. *Acta obstetricia et gynecologica Scandinavica*, **80**(1), pp.18-26.
[11] Tatala, S., Svanberg, U. and Mduma, B., 1998. Low dietary iron availability is a major cause of anemia: a nutrition survey in the Lindi District of Tanzania. *The American journal of clinical nutrition*, **68**(1), pp.171-178.
[12] Grantham-McGregor, S., Cheung, Y.B., Cueto, S., Glewwe, P., Richter, L., Strupp, B.and International Child Development Steering Group, 2007. Developmental potential in the first 5 years for children in developing countries. *The Lancet*, **369**(9555), pp.60-70.
[13] Black, R.E., Allen, L.H., Bhutta, Z.A., Caulfield, L.E., De Onis, M., Ezzati, M., Mathers, C., Rivera, J. and Maternal and Child Undernutrition Study Group, 2008. Maternal and child undernutrition: global and regional exposures and health consequences. *The Lancet*, **371**(9608), pp.243-260.
[14] Bailey, R.L., West Jr, K.P. and Black, R.E., 2015. The epidemiology of global micronutrient deficiencies. *Annals of Nutrition and Metabolism*, **66**(Suppl. 2), pp.22-33.

human capital and economic productivity in low- and middle-income countries. In Africa and Asia, 11% of GDP is lost to malnutrition each year compared to 0.9% of GDP worldwide[14]. The striking effects of malnutrition on national productivity have made it a key concern for governments as well as international organisations. Reducing maternal undernutrition has a direct impact on neonatal deaths and children's development, which then leads to healthier and more productive populations. Hence, mothers' nutritional status must remain a priority in the public health agenda of low- and middle-income countries (LMICs).

Overview of Nutrition Policies and Programmes in Tanzania

Current Policies

The Government of Tanzania recognises the importance of nutrition in improving the overall health of its population, which would result in a stronger economy. Table 1 presents a summary of current policies in operation in the region.

Table 1. Summary of current nutrition-related policies in Tanzania

Policy Name	Key Points	Critical Analysis
National Five Year Development Plan 2016-2021[15]	• Focuses on food self-sufficiency and decrease of micronutrient deficiencies • Recognises community behaviour, supplementation and systemic interventions	• Lacks feasibility study of various suggested interventions • Specific budget commitments towards actions not mentioned
United Nations Development Assistance Plan 2016-21[16]	• Emphasises need for larger coverage of nutritional interventions and budgetary allocations • Advocates adopting a multisectoral approach involving national, regional and district levels • Mentions training and nutrition monitoring	• Key outcomes are tailored towards maternal and newborn nutrition • Adolescent girls and older women not addressed in plan
National Multisectoral Nutrition Action Plan 2016-2021[17]	• Look at food and vitamin supplementation to combat micronutrient deficiencies • Recognises need for better integration of health systems at various levels to better combat nutrition-related problems	• Strategies include a community-centered approach • Puts forward a concrete budget (US$268 million) and clear outcomes across various areas

[15] Ministry of Finance and Planning. 2016. *National Five Year Development Plan 2016-2021*. Tanzania: The United Republic of Tanzania. [Online]. Available from: http://www.mof.go.tz/

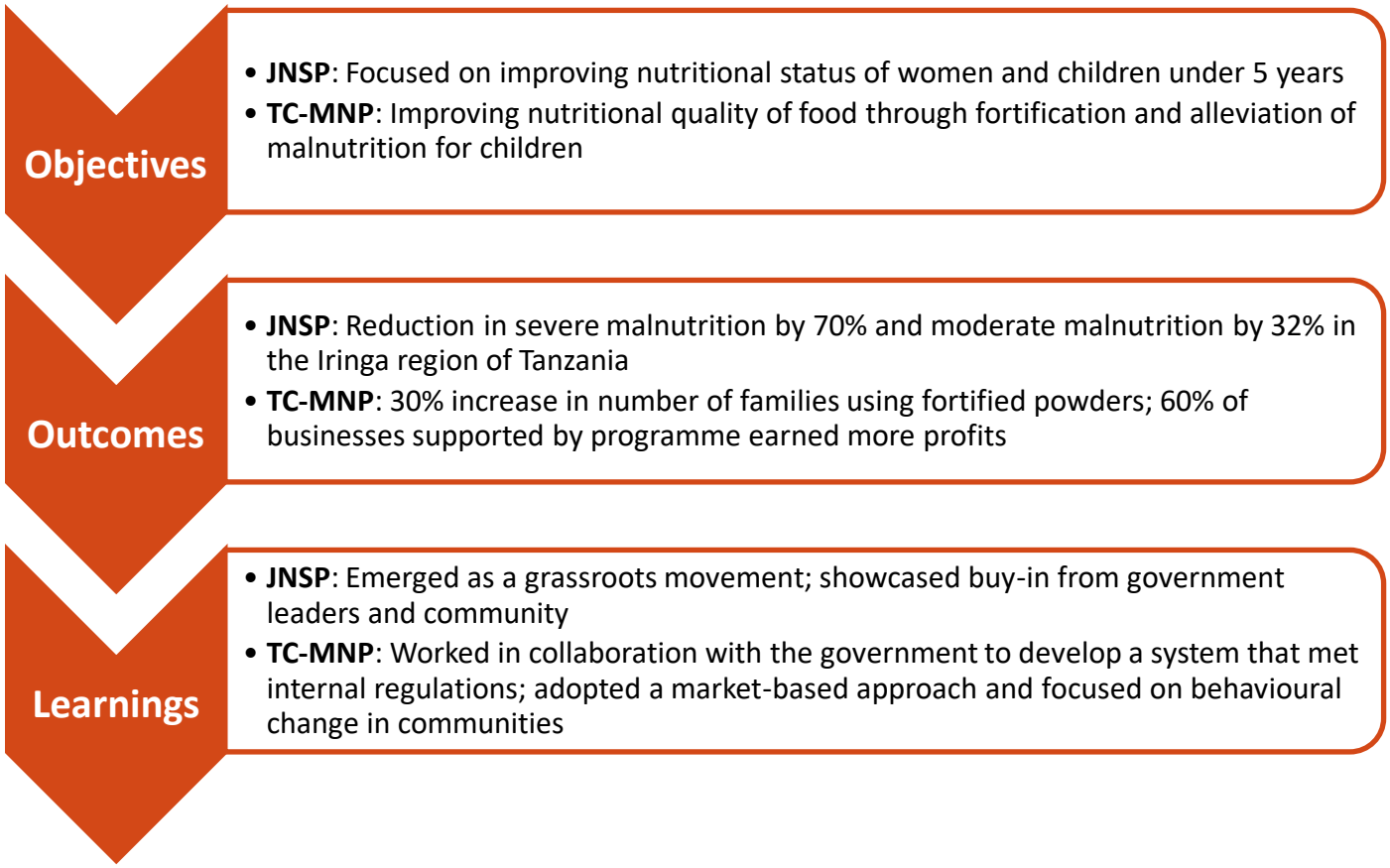
[16] United Nations Tanzania. 2016. *United Nations Development Assistance Plan 2016-2021.* Tanzania: Office of the United Nations Resident Coordinator in Tanzania. [Online]. Available from: https://www.ilo.org/

[17] Prime Minister's Office. 2016. *National Multisectoral Nutrition Action Plan 2016-2021*. Tanzania: United Republic of Tanzania. [Online]. Available from: https://www.unicef.org/

Past Programmes

Tanzania has been actively implementing programmes related to nutrition since the 1970s[18], although the desired outcomes have not yet been achieved. We will examine two key programmes (refer to Fig.1.) to evaluate outcomes and learnings for future policies.

Figure 1. Key outcomes and learnings from the Tanzania Iringa Joint Nutrition Support Programme (JNSP)[19,20,21,22] and Tuboreshe Chakula Micronutrient Powder (TC-MNP) Project by USAID[23,24]

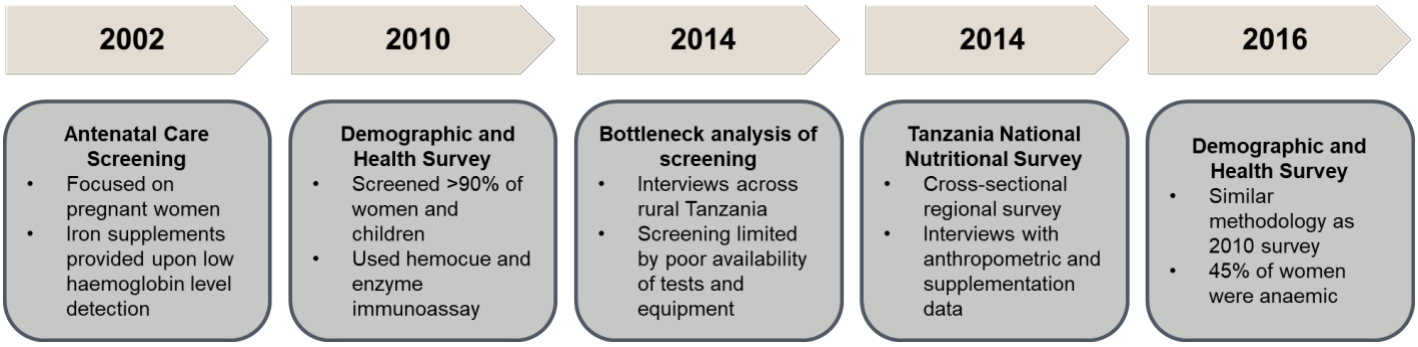


[18] WHO. 2018. *Nutrition Landscape Information System (NLiS) Country Profile: United Republic of Tanzania.* [Online]. Available from: http://apps.who.int/
[19] WHO. 2013. *Essential Nutrition Actions: Improving maternal, newborn, infant and young child health and nutrition.* [Online]. Available from: https://www.who.int/
[20] Moneti, F. and Yee, V., 1989. Mobilization for nutrition: results from Iringa. *Mothers and children*, **8**(2), pp.1-3.
[21] Kennedy, E.T., 1991. *Successful nutrition programs in Africa: what makes them work?* (Vol. 706). World Bank Publications.
[22] Institute of Development Studies. 2015. *Food, Markets and Nutrition: Maximising the Impacts of Private Sector Engagement in Tanzania*. [Online]. Available from: http://www.ign.org/
[23] Home Fortification Technical Advisory Group. 2018. *Tanzania – Tuborese Chakula MNP Project*. [Online]. Available from: http://www.hftag.org
[24] Abt Associates. 2015. *Tuboreshe Chakula: Final Report.* USAID.

Screening Programmes and Surveys

Multiple micronutrient screening programmes and surveys have been conducted in Tanzania, including antenatal care screening, nutritional and health surveys. We have also included an independent research study that conducted a bottleneck analysis for screening in rural Tanzania, particularly due to its relevance in terms of implementation issues. Fig.2 presents a timeline with key details of each iteration.

Figure 2. Summary of screening programmes and surveys in Tanzania[25,26,27,28,29]



With the exception of the Demographic and Health Surveys which were conducted within 5-6 years of each other, all the programmes and surveys above have been conducted as **'one-off'** studies. This demonstrates a key issue of tracking of nutritional status of Tanzania's population, given that multiple studies have different methodologies. This may result in either duplication or insufficient implementation of intervention measures. The Tanzanian government is using the **National Multisectoral Nutritional Action Plan 2016-17** to mitigate this to some extent.

Healthcare Provisions in Tanzania

Overview

Tanzania operates a **decentralised** public healthcare system, with a dispensary at each village and specialised consultant hospitals in cities. Furthermore, there are private hospitals across the country. A hierarchy of the healthcare system is shown in Fig. 3.

[25] Kearns, A., Hurst, T., Caglia, J. and Langer A. 2014. *Focused Antenatal Care in Tanzania: Delivering individualised, targeted and high quality care.* [Online]. Available from: https://cdn2.sph.harvard.edu/

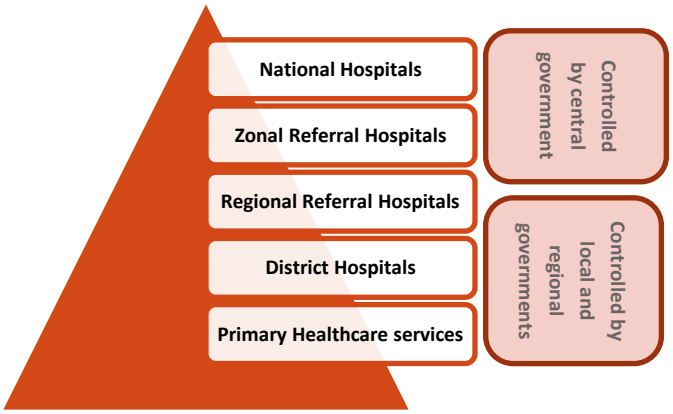
[26] National Bureau of Statistics and ICF Macro. 2011. *Tanzania Demographic and Health Survey 2010.* [Online]. Available from: https://www.dhsprogram.com/

[27] Baker, U., Okuga, M., Waiswa, P., Manzi, F., Peterson, S. and Hanson, C., 2015. Bottlenecks in the implementation of essential screening tests in antenatal care: Syphilis, HIV, and anemia testing in rural Tanzania and Uganda. *International Journal of Gynecology & Obstetrics*, **130**(S1).

[28] Tanzania Food and Nutrition Centre. 2014. *Tanzania National Nutritional Survey 2014*. [Online]. Available from: https://www.unicef.org/

[29] Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) [Tanzania Mainland], Ministry of Health (MoH) [Zanzibar], National Bureau of Statistics (NBS), Office of the Chief Government Statistician (OCGS), and ICF. 2016. *Tanzania Demographic and Health Survey and Malaria Indicator Survey (TDHS-MIS) 2015-16.* [Online]. Available from: https://dhsprogram.com/

Figure 3. Hierarchy of public healthcare system in Tanzania with entities controlling its operation[30]



Financing

The spending on healthcare by the government is currently at **6.13%** of GDP, which amounts to **$31 per capita** (2015)[31]. There are several health financing schemes[32,33,34] which allow citizens to access public health systems, namely the National Health Insurance Fund (NHIF), Social Health Insurance Benefit (SHIB), Community Health Fund (CHF) and Tiba Kwa Kadi (TIKA). Most notably, the CHF and TIKA, for which participation is voluntary, are specifically tailored for and targeted to rural citizens. Private insurance schemes also exist in Tanzania.

Issues

The two main issues Tanzania's healthcare system has been grappling with are a **shortage of trained workers** and **chronic underfunding**[35]. These further lead to many consequences, including lack of access to equipment and gaps in service delivery. The issues are particularly exacerbated in rural areas.

Strategic Plans for Development

The government is focusing on two main policies to strengthen the healthcare system, namely the **Health Sector Strategic Plan (HSSP) III** and **the Big Results Now (BRN) Initiative**.[36] The former looks at increasing budgetary allocation and the latter addresses workforce issues.

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[30] Ministry of Health, Community Development, Gender, Elderly, and Children. 2014. *List of Health Facilities with Geographical Location – Datasets*. [Online]. Available from: http://opendata.go.tz/
[31] WHO. 2018. *Global Health Expenditure Database.* [Online]. Available from: http://apps.who.int/
[32] National Social Security Fund. 2018. *National Social Security Fund: United Republic of Tanzania*. [Online]. Available from: https://www.nssf.or.tz/
[33] *The Community Health Fund Act 2001.* Tanzania: The United Republic of Tanzania.
[34] *The National Health Insurance Fund Act 1999.* Tanzania: The United Republic of Tanzania.
[35] Kwesigabo, G., et al. 2012. Tanzania's health system and workforce crisis. *Journal of Public Health Policy*, **33**(1), pp.S35-S44.
[36] West-Slevin.K. et. al. 2015. *Snapshot: Tanzania's Health System*. [Online]. Available from: https://www.healthpolicyproject.com/

Project Scope and Methodology

Our initial project remit was to conduct a **systematic literature review** of currently available assays which can detect anaemia. The search terms used for this exercise are detailed in table 2 below; the search terms were limited to **iron-deficiency anaemia** given that this was the most prevalent form in the region and therefore, the addressing of which would have the most impact. An additional manual search was also performed to include relevant articles not captured by the search criteria specified.

Table 2. Search methodology adopted for systematic literature review

Parameter	Details
Search Terms	Quantification OR Quantify OR Measure
	Micronutrient OR Nutrient
	Iron OR Ferritin
	Assay OR Device OR Test
	Anaemia OR Anemia
Databases	PubMed
	Web of Science

Upon consulting literature on what would be the ideal solution in terms of device design for Tanzania, it was observed that a holistic approach would be required mainly concerning community engagement. Therefore, our recommendations cover this aspect as well. Lastly, the national context of micronutrient deficiency could not be ignored and therefore, we touch upon these briefly in the report although it is deemed to be beyond the scope of the original project.

Literature review of currently available diagnostic and screening assays

The micronutrient of particular interest in this report is iron due to its deficiency causing iron-deficiency anaemia. Primary health care professionals generally use a complete blood count (CBC) as a first-pass diagnostic test, where levels of haemoglobin, haematocrit, RBCs, WBCs and platelets are recorded. Additional tests such as reticulocyte count, iron binding, ferritin and serum folate measurements may be recommended to confirm the type of anaemia.[37] Due to the nature of these tests, collected blood samples are sent to a laboratory, and therefore, results are received in the order of days to weeks. In areas such as Tanzania, the lack of resources and trained clinical personnel act as additional obstacles for early screening and diagnosis. However, various point-of-care and mobile-based devices are being recently proposed by researchers and companies.

Enzyme Linked Immunosorbent Assay (ELISA) Tests

ELISA tests are used to measure the levels of ferritin in bodily fluids which may include blood, urine, cell culture or tissue extracts. The assay works on the principle of antibody-tagging and a corresponding signal upon binding of analyte. Most tests work on the principle of a sandwich based ELISA as shown in Fig. 4. The platform required is that of a microplate and therefore simple to use, although a trained professional is needed to interpret results. Protocols are usually multi-step and require an hour or two to complete. There are several commercially available iterations of this assay; some manufacturers include abcam[38], Merck[39], ThermoFisher[40] and Eagle Biosciences[41].

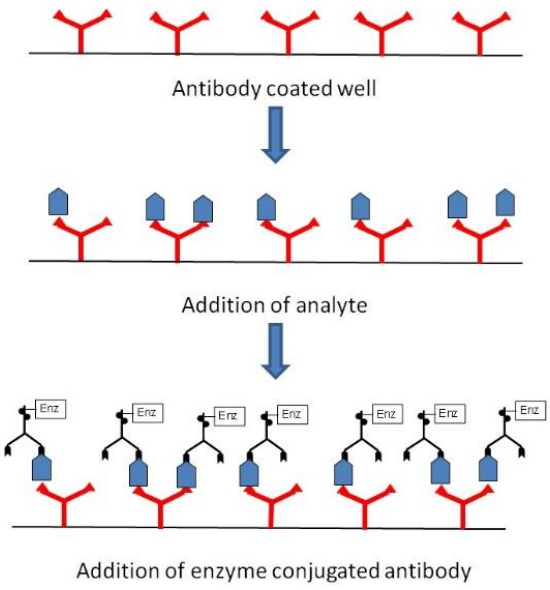


Figure 4 Principle of Sandwich-based ELISA (*Adapted from Assay Guidance Manual*)

[37] National Heart, Lung, and Blood Institute. No Date. *Iron Deficiency Anaemia.* [Online]. Available from: https://www.nhlbi.nih.gov/
[38] Abcam. 2018. *Human Ferritin ELISA Kit*. [Online]. Available from: https://www.abcam.com/
[39] Merck. 2018. *Human Ferritin ELISA Kit*. [Online]. Available from: https://www.sigmaaldrich.com/
[40] ThermoFisher. 2018. *Human Ferritin ELISA Kit.* [Online]. Available from: https://www.thermofisher.com/
[41] Eagle Biosciences. 2018. *Ferritin ELISA.* [Online]. Available from: https://eaglebio.com/

Laboratory based Tests

The 'gold standard' in terms of laboratory tests for detection of anaemia is the red blood cell count which can be performed both with manual and automated methods. The manual method involves dispersing the body fluids, usually blood, on to a haemocytometer[42] (Fig.5) and averaging the number of cells in the counting chambers. This method, while low-tech, is susceptible to human error.

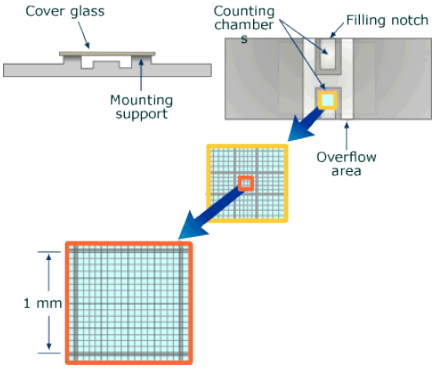


Figure 5 Principle of Haemocytometer (*Adapted from Simulab)*

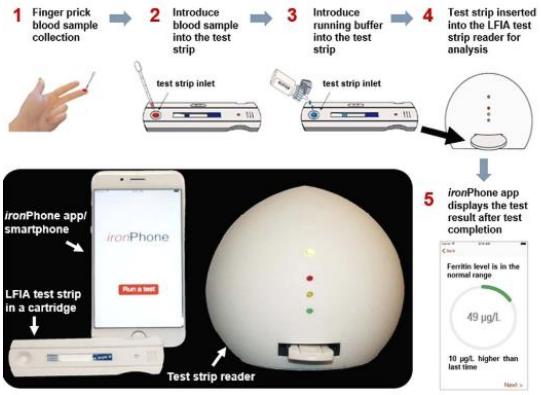
Automated methods include impedance counters[43] and flow cytometers[44]. The former uses changes in electrical resistance to approximately determine the volume of cells while the latter uses light scattering angles to determine the type and volume of cells. These techniques offer tunability in sensitivity as well as greater accuracy, however required specialised instrumentation and trained personnel.

Other types of laboratory tests include reticulocyte count[45] and peripheral smears[46], which could be performed either manually using a microscope or through techniques such as flow cytometry.

Figure 5 Working Principle of ironPhone (*Adapted from Srinivasan et. al.)*

Point-of-care Kits

As an alternative to tests that require sophisticated laboratory equipment, researchers and companies have developed devices that can provide rapid results in a low-cost manner. One such device is the ironPhone designed by Srinivasan et al.[47] which uses a test strip containing an immunoassay and a drop of blood to detect iron levels. The device is further inserted into a portable strip reader and connected to a mobile app to enable easy usage and readout.



[42] Absher, M., 1973. Hemocytometer counting. In *Tissue Culture* (pp. 395-397).
[43] Davis, B.H. and Barnes, P.W. 2012. Automated Cell Analysis: Principles. In: Kottke-Marchant, K. and Davis, B.H. ed. *Laboratory Hematology Practice.* Sussex: Blackwell Publishing, pp. 26-32.
[44] Shapiro HM. 2003. *Practical Flow Cytometry*. 4th edn. Hoboken, NJ: John Wiley & Sons.
[45] Nobes, P.R. and Carter, A.B., 1990. Reticulocyte counting using flow cytometry. *Journal of Clinical Pathology*, **43**(8), pp.675-678.
[46] Bain, B.J., 2005. Diagnosis from the blood smear. *New England Journal of Medicine*, **353**(5), pp.498-507.
[47] Srinivasan, B., O'Dell, D., Finkelstein, J.L., Lee, S., Erickson, D. and Mehta, S., 2018. ironPhone: mobile device-coupled point-of-care diagnostics for assessment of iron status by quantification of serum ferritin. *Biosensors and Bioelectronics*, **99**, pp.115-121.

Another similar testing kit is Hemocue[48], which has already been used in Tanzania for previous screening programmes. It operates on the principle of disintegrating red blood cells using pre-deposited enzymes in microcuvettes, and subsequent reactions which result in the creation of an azidemethemoglobin complex[49]. An optical detection mechanism is used by placing the cuvette in the analyser. Additionally, up to 500 readings can be stored on a single device.

Both techniques mentioned above offer significant advantages in comparison to previously mentioned methods, however also suffer from drawbacks. The ironPhone, relies on a smartphone to view results, which may not be ideal for low-resource settings. The Hemocue analyser, which overcomes this by providing both readout and storage on the same device has conflicting reports on accuracy[50,51,52,53]. Moreover, both the devices do not fully exploit the multiplexing capability of point-of-care kits by limiting detection to only ferritin/haemoglobin.

Multiplexed Assays

This class of assays generally tests for two or more conditions and may be useful in settings where multiple nutritional deficiencies are encountered. Both tests[54,55] developed in literature, offered the capacity to monitor both iron and vitamin A deficiency while combining one or more techniques mentioned in the previous sections. Erhardt et al. adapted a sandwich ELISA system to measure levels of several indicators, most importantly ferritin and soluble transferrin receptor for iron deficiency and retinol binding protein for vitamin A. The more notable aspect was that the device also monitored C-reactive protein, which is usually an inflammatory marker; this was done so as to obtain a more holistic approach for diagnosis rather than singling out individual factors. The device developed by Lu et al. also proposed an ELISA technique for diagnosis; however, this was more focused towards a point-of-care approach.

[48] Hemocue. 2017. *HemoCue® Hb 201+ System*. [Online]. Available: https://www.hemocue.com
[49] Massachusetts General Hospital - Pathology Service. 2016. *HemoCue Hb201 Hemoglobin procedure.* [Online]. Available from: https://www.massgeneral.org/pathology/assets/pdf/HemocueHgbprocedureltr19555.pdf
[50] Sharma, A., Artiss, J.D., Strandbergh, D.R. and Zak, B., 1985. The turbid specimen as an analytical medium: hemoglobin determination as a model. *Clinica chimica acta*, **147**(1), pp.7-14.
[51] Creer, M.H. and Ladenson, J., 1983. Analytical errors due to lipemia. *Laboratory Medicine*, **14**(6), pp.351-355.
[52] Bhaskaram, P., Balakrishna, N., Radhakrishna, K.V. and Krishnaswamy, K., 2003. Validation of hemoglobin estimation using Hemocue. *The Indian Journal of Pediatrics*, **70**(1), pp.25-28.
[53] Nkrumah, B., Nguah, S.B., Sarpong, N., Dekker, D., Idriss, A., May, J. and Adu-Sarkodie, Y., 2011. Hemoglobin estimation by the HemoCue® portable hemoglobin photometer in a resource poor setting. *BMC clinical pathology*, **11**(1), p.5.
[54] Erhardt, J.G., Estes, J.E., Pfeiffer, C.M., Biesalski, H.K. and Craft, N.E., 2004. Combined measurement of ferritin, soluble transferrin receptor, retinol binding protein, and C-reactive protein by an inexpensive, sensitive, and simple sandwich enzyme-linked immunosorbent assay technique. *The Journal of nutrition*, **134**(11), pp.3127-3132.
[55] Lu, Z., O'Dell, D., Srinivasan, B., Rey, E., Wang, R., Vemulapati, S., Mehta, S. and Erickson, D., 2017. Rapid diagnostic testing platform for iron and vitamin A deficiency. *Proceedings of the National Academy of Sciences*, **114**(51), pp.13513-13518.

In our opinion, multiplexed assays with contextualisation offer a cost-effective alternative to diagnose multiple prevalent conditions, while not compromising on accuracy and ease of use.

Non-invasive Assays

These assays look for physical symptoms of anaemia and would be more suitable as screening methods rather than diagnosis. One such assay which has previously been piloted in low-cost settings is ToucHb[56]. It operates on the principle of capturing the pallor in a person's conjunctiva and using optical correlation techniques to estimate haemoglobin levels. While it is non-invasive, portable and easy to use, it does not guarantee a high level of accuracy due to the difference in the manifestation of anaemia across populations.

Figure 6 Image of ToucHb (*Adapted from Biosense)*

Having considered the various types of assays and the geopolitical situation in Tanzania, we have drafted a few recommendations for CDI in the forthcoming section. We have also touched upon a few high-level recommendations which we feel would be useful for NGOs like CDI to lobby the Tanzanian government about in the future.

[56] ToucHb. Date Unknown. [Online]. Available from: http://www.biosense.in/touchb.php

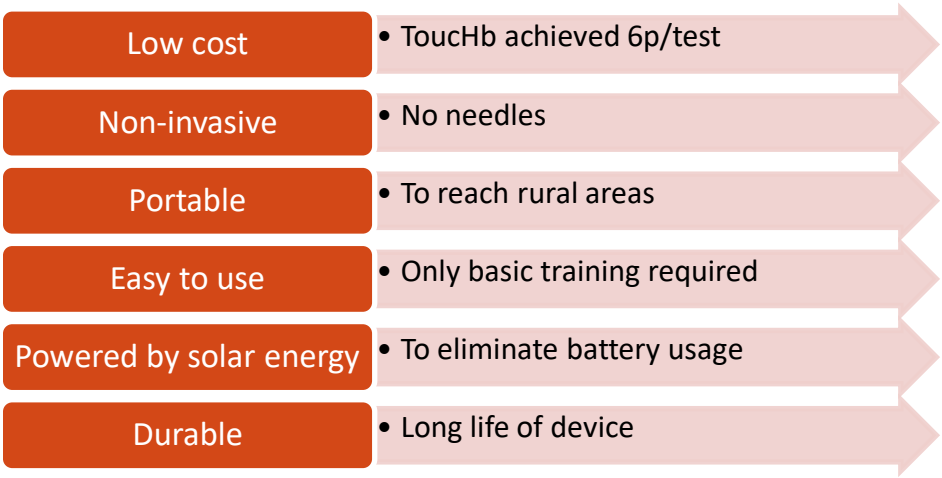
Device Recommendations

In this section, we focus on the characteristics of the device(s) required to combat anaemia in Tanzania. Firstly, we recommend a two pronged approach towards screening and diagnosis due to the following reasons:

- **Efficient use of resources:** Drawing a blood sample from every person in the target demographic is inefficient both in terms of cost and human resources. Moreover, there would be gaps in monitoring if this exercise is conducted every couple of years, as was the case in previous governmental screening programmes. Breaking down detection into screening and diagnosis can, therefore, reach larger populations, particularly those in rural areas.
- **Better screening compliance:** Approaching screening in a non-invasive manner could lead to greater uptake of programmes as there is no pain involved in the procedure. This might help reach underrepresented groups such as adolescent girls.

Recommendation 1: Non-invasive Screening Device

We propose that this 'low-tech' screening device be used as a filtering mechanism for anaemia detection. We envisage the device to possess the following characteristics as detailed below.

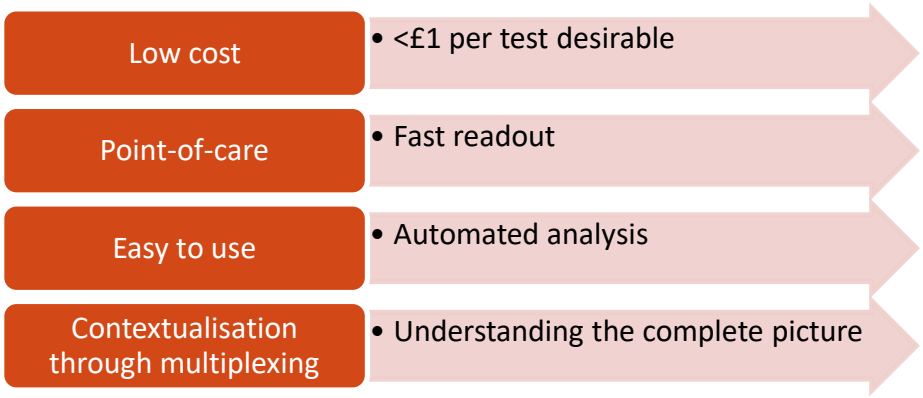


The device is to be deployed in the **primary health centres** of Tanzania with the proposal that those responsible for screening would be health workers employed in this level of the healthcare system. Additionally, **NGO volunteers** can also be involved in screening as this exercise would not amount to a medical diagnosis, but only to a further referral to a healthcare professional.

Risks and mitigation: As mentioned previously, we have identified that the major risk of adopting such an approach would be a **decreased accuracy** in the device itself. Therefore, during the device development stage, it would be imperative to identify any corroborating physical symptoms to screen for; this would reduce the number of false positives.

Recommendation 2: Multiplexed Diagnostic Device

Post-screening, we envision that some patients would be referred to a healthcare professional located either in the **district or regional referral hospital** for confirmation of anaemia. This is the setting in which we propose our multiplexed diagnostic device to be used; the characteristics desirable for such a device are based on our previous literature review and detailed below.



We particularly recommend on focusing on the '**point-of-care**' and '**contexualisation through multiplexing**' aspects of the devices previously reviewed. The former, due to the potential for rapid results to be obtained, which then creates the possibility of treatment in the same session itself. This would potentially lead to better health outcomes as the patient would not need to make repeated visits to the hospital, during which there is a chance of 'no show' and subsequent non-treatment. The latter is an important point to consider as there are cases where ferritin levels might show as abnormal due to inflammation in the body. Detecting C-reactive protein simultaneously would give the clinician a better understanding of the root cause and therefore better inform diagnosis.

Risks and mitigation: While this device would require initial purchasing investment on behalf of the government, it would result in lower costs in the long term as only those referred from the screening stage would need to be diagnosed. Device developers should also look into reducing the cost of consumables.

Community Engagement Recommendations

The proposed devices in the previous section could contribute to screening and diagnosing anaemia more effectively; however, the role of community engagement in ensuring long-term success and sustainability of combating micronutrient deficiencies cannot be ignored. Therefore, we recommend CDI to adopt the following community engagement measures in tandem with device development.

Recommendation 1: Conduct Awareness Workshops on Nutrition and Hygiene

Beliefs and practices in communities have an important role to play in the eradication of micronutrient deficiencies. Keeping in mind the close relationship between undernutrition, poverty, and disease is essential to any action against the 'hidden hunger'. For instance, studies have shown that providing micronutrient supplements without providing a deworming treatment does not improve nutritional status.

Grassroots approaches, which include any teaching passed on to influential or at risk members of a community, are the most efficient way to introduce new hygiene and sanitation habits and, hence, avoid a loss of essential nutrients to helminth infections. Furthermore, since cultural practices are an essential determinant of women's nutritional status, grassroots approaches are the most appropriate way to tackle the issue of access to food in some households.

We propose the implementation of health-awareness workshops in the following manner:

- One workshop should aim to teach women how to **avoid helminth infections**[57] through the use of simple sanitation habits, such as using latrines, handwashing, and foot-wear. Women should also be taught how to recognise the symptoms of a helminthic infection and how to seek treatment for the latter.
- A second workshop should aim to **influence nutritional behaviours** in women who are likely to forego consumption when food is scarce. Teaching women which foods to prioritise during a crisis is key in fighting micronutrient deficiencies.

[57] We focus on helminth infections in this report mainly due to the prevalence in Tanzania and also because helminth infections can cause a number of complications, including anaemia, due to their parasitic nature.

Changing behaviours at the population level requires a thorough understanding of the collective beliefs and social norms embedded in a people's culture. Hence, we also recommend an **extensive analysis of the target population's beliefs and practices**. Such studies have been undertaken by groups, such as the Africa's Voices Foundation[58], to study local beliefs and practices related to diarrhoea and cholera as well as immunisation.

Recommendation 2: Designation of Community Champions

Community engagement is critical in achieving compliance concerning supplement consumption as well as ongoing maintenance of good health. Therefore, we recommend a mechanism to ensure that members inside the community reinforce the knowledge imparted by NGOs and local governments. These members, known as '**community champions**' act to **build trust** in nutrition programmes and also serve as a **point of contact** for women, especially when healthcare workers are not available. We propose that these champions could be **midwives** who are already well integrated into women's lives and well-placed in terms of gaining the community's trust.

Recommendation 3: Expansion of Nutritional Supplementation to Adolescent Girls

Policies for nutrient supplementation implementation offers possibilities in prevention, management and control of nutrient deficiencies. In India, a national iron supplementation project for adolescent girls has successfully controlled anaemia in the decade since it has been introduced[59] and at an effective low cost, less than $1 per adolescent girl per annum.

We recommend a similar project could also be implemented in Tanzania; currently, iron-folic acid supplementation is only provided for pregnant women in the country. Expanding supplement distribution to adolescent girls have several important benefits. One benefit being that pregnant adolescents are particularly vulnerable to anaemia due to **dual iron requirements**, both for their growth and growth of the fetus, providing supplementation would be an appropriate preventative measure for future young mothers. Another benefit is that the supplementation could coincide with the **education of nutrition** and its values while adolescent

[58] Africa's Voices. 2019. [Online]. Available from: https://www.africasvoices.org/
[59] Aguayo, V.M., Paintal, K. and Singh, G., 2013. The Adolescent Girls' Anaemia Control Programme: a decade of programming experience to break the inter-generational cycle of malnutrition in India. *Public health nutrition*, **16**(9), pp.1667-1676.

girls are still at school, which could also be a way of using schoolchildren to transfer nutritional knowledge to their family and the local community.

However, factors need to be considered in order for this policy to go ahead includes that providing supplementation via schools may not reach all adolescent girls and furthermore, how would the supplementation program be maintained when they leave school. Other factors to consider include how to ensure long term compliance of taking supplements. Moreover, of course, as ever, though the cost is low per person, who would be responsible for the initial financing of this project and to ensure long-term sustainable financing.

Taking these factors into consideration, we propose that the CDI should be more involved in the **distribution of nutritional supplements to and education of adolescent girls** while the governments and aid programmes focus on financing matters.

High-level Policy Recommendations

In this section, we mainly highlight systemic challenges observed during our research of the Tanzanian healthcare system and recommended policy strategies to address them. It is to be noted that these recommendations lie beyond the initial scope of the project; however we feel that CDI could contribute to their implementation through lobbying the government in partnership with other NGOs in Tanzania.

Recommendation 1: Address Shortage of Health Workers through Training and Regulation

According to a previous study[60], only 14% of the recommended number of nurses and 20% of the clinical staff were employed at facilities in Tanzania. 44% were unavailable during the day of the survey, due to various reasons such as attendance to seminar sessions, long-training, official travel and the rest on leave. It has been reported that Reproductive and Child Health (RCH) clinic nurses are present for seven hours a day, but they only work productively 57% of the time. Although the study was conducted seven years ago, it implies the need for more regulation towards the gaps in service towards healthcare workers.

We recommend that the Ministry of Health should establish specific rules for **regulating the gaps in service** towards healthcare workers for the different types of healthcare facilities. Furthermore, studies show that clinician engagement and clinical leadership is critical to achieving and sustaining improvements to healthcare quality and safety. Thus, it is important to create a healthy work environment that would increase the workers' efficiency through their own motivation in addition to stricter regulations.

We also recommend training of **mobile health workers** who can reach people in rural areas who would have to travel long distances to reach health centres. The role of these health workers would be to increase the reach of screening programmes as well as provide general health guidance to the local population.

[60] Manzi, F., Schellenberg, J.A., Hutton, G., Wyss, K., Mbuya, C., Shirima, K., Mshinda,H., Tanner, M. and Schellenberg, D., 2012. Human resources for health care delivery in Tanzania: a multifaceted problem. *Human resources for health*,**10**(1), p.3.

Recommendation 2: Improve Uptake of Guidelines in Health Systems through Standardisation and Consultation

Failure to effectively disseminate knowledge, skills and the translation of evidence informed policy was a fundamental problem in the East African health care context[61]. Therefore, we recommend the setup of a **National Clinical Information and Learning Network** to ensure effective and widespread uptake of policy. This network would comprise of engaged and motivated stakeholders at each level of the healthcare system who would take ownership of the development of a body of standardised healthcare guidelines and subsequent implementation.

The model can build on that proposed by Irimu et al.[61], which involves using historically successful links between stakeholders in order to foster trust, supporting local ownership and leadership while addressing each stakeholder's interest. It emphasises the need for continuous communication between parties and the reliance on face to face meetings as an essential component of this.

Recommendation 3: Increase Body of Current Knowledge through Research Investment

During our research, the lack of extensive data and outdated studies in the context of micronutrient deficiencies in Tanzania specifically, and East Africa as a region, were observed. Therefore, we recommend that **more research needs to be conducted**, either as a follow-up of previous studies or as a means to find out if there is an emergence of new diseases. It would be ideal for the government to provide funds for local researchers to investigate in this area, however **international collaborations should be leveraged** to ensure the best results. An example of a potential source of funding in the UK is the Global Challenges Research Fund[62].

[61] Irimu, G., Wamae, A., Wasunna, A., Were, F., Ntoburi, S., Opiyo, N., Ayieko, P., Peshu, N. and English, M., 2008. Developing and introducing evidence based clinical practice guidelines for serious illness in Kenya. *Archives of disease in childhood*, **93**(9), pp.799-804.

[62] UKRI. 2018. *Global Challenges Research Fund*. [Online]. Available from: https://www.ukri.org/research/global-challenges-research-fund/

Conclusion

In this report, we have attempted to address the issue of anaemia in the women of Tanzania in a holistic manner by considering both technological solutions and community-based interventions.

Concerning the screening and diagnosis aspect, we recommend a two-step approach to facilitate regular monitoring in combination with maximum reach of these campaigns. We note that there is a sufficient body of literature on which the CDI can build on while developing the devices required.

However, to ensure a reduction in levels of anaemia in the long term, screening campaigns need to be supported by community engagement measurements. Adopting a grassroots approach by ensuring awareness of good nutritional practices while giving the community ownership of the issue form the crux of our recommendations in this area.

Lastly, we recognise the wider national context in which the issue of micronutrient deficiencies exists and highlight some areas where high-level governmental intervention is needed. In order to action these areas, we recommend that the CDI lobbies the government in collaboration with other NGOs.