Boosting Diabetes and Pre-Diabetes Screening in Rural Ghana via Mobile Phones Apps

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ABSTRACT

Background: Diabetes is a growing worldwide disease with serious consequences to health and high financial burden. Ghana is one of the developing African countries where the prevalence of diabetes is increasing. Moreover, many cases remained undiagnosed, when along with per-diabetic cases they can be easily detected. Pre-diabetes condition occurs when blood sugar levels are higher than normal but are not high enough to be classified as diabetes, and it is still reversible.

Methods: This study proposes a novel method to increase diabetes and pre-diabetes detection, and to find new behavioral determinants related in rural Ghana. The screening approach was based on tests performed pro-actively by community nurses using glucometers and mobile phone apps. As a pilot for future policies, those glycemic tests were carried out on 101 subjects from rural communities in Ghana deemed at risk and unaware of their diabetic/pre-diabetic status. A comparison of dietary and lifestyle habits of the screened people was conducted in regards to a cohort of 103 diabetic patients from the same rural communities.

Results: The pilot screening detected 2 diabetic subjects (2% of the cohort) showing WHO diabetic glycemic values, and 20 pre-diabetic subjects (19.8% of the cohort) which

showed the effectiveness of the user-friendliness approach. The need of further campaigns on alcohol consumption and physical activities has emerged even for the rural areas.

Conclusions: Policies based on prevention screening as reported in the manuscript have the potential to reduce diabetes incidence and its related health-care costs in the country.

Trial registration: Noguchi Memorial Institute for Medical Research-IRB Study Number: 076/13-14 registered on 20.02.2017

Keywords: diabetes, mHealth, community nurses, community health workers, pre-diabetes, Ghana, rural health

1. BACKGROUND

Diabetes is one of the fastest growing non-communicable killer diseases in the world, claiming one life every eight seconds and a limb lost at every thirty seconds [1] . Diabetes of all types can lead to complication in many parts of the body and can increase the overall risk of dying prematurely [2]. Pre-diabetes condition occurs when blood sugar levels are higher than normal but are not high enough to be classified as diabetes, often exhibits no symptoms, and it is reversible [3].

The International Diabetes Federation (IDF) estimates that 450 million people are living with diabetes, with 5.1 million dying from it annually worldwide [4]. According to the latest 2016 data from the World Health Organization (WHO), it is estimated that 422 million adults are living with diabetes meillitus. Nearly 80% of people with diabetes live in low and middle-income countries such as Asia and Eastern Pacific region. In 2011 China had the largest number of adults with diabetes (i.e. 90 million people), followed by India (61.3 million people) and Bangladesh (8.4 million people) [5]. The prevalence of diabetes in

adults worldwide is expected to rise to 5.4% by the year 2025 and the number of adults with diabetes in the world would rise to 300 million in the year 2025 [6]. Diabetes can cause serious health complications such as heart disease, blindness, kidney failure, lower extremity amputations, hypoglycemic and hyperglycemia attacks [7]. Complications of Diabetes account for increased morbidity, disability, and mortality and represent a threat for the economies of all countries, especially the developing ones [8]. With the dominance of the urban immigration in developing countries, urban population is predicted to double between 2000 and 2030, with an estimated 82 million adults aged 64 and above will have diabetes [9] . Type 2 diabetes accounts for about 90% of diabetes in Sub-Saharan Africa and population prevalence proportions ranged from 1% in rural Uganda to 12% in urban Kenya. Gestational diabetes prevalence varied from 0% in Tanzania to 9% in Ethiopia [10].

Ghana is challenged with the increasing prevalence of diabetes which is similar to that of other African countries, with an increasing prevalence of 1.9 in adults and 266,200 diagnosed cases within the country [11]. The prevalence of diabetes in some parts of Ghana has been identified as higher than the world average of 2.8% [12]. Moreover, the 2015 report of the IDF indicated many other cases probably remain undiagnosed, posing an increased danger of complications for people living with diabetes unaware of the consequences. Previous studies in the country showed that low level of physical activity and obesity were associated with increased odds of diabetes among women while old age and level of education were associated with increased the odds of diabetes among men [4] . It has also been observed that within the country drinking sugary drinks is linked to type 2 diabetes [13] . Community-based health planning and services (CHPS) is a national health policy in Ghana adopted in 1999 to reduce barriers to geographical access to health care [14]. According to the CHPS policy, relocating nurses directly to communities could outperform an entire sub-district health centers. The cost-effectiveness of CHPS for

malaria, diarrhea, and pneumonia has been recently reported [15] . However, specific implementation for non-communicable diseases as diabetes have not yet been investigated within the CHPS policy.

Vulnerable populations as those in low- and middle-income countries are generally more affected by diabetes related complications [16]. As in different fields of healthcare, mobile health (mHealth) has the potential of reducing disparity and be effective for vulnerable populations with diabetes [17]. This can occur either by sending reminders or by increasing access to patient management [18]. Despite the plethora of studies on mHealth and diabetes management [18,19, 20], no study has been carried out among rural Africa with the aim of improving detection of diabetes and pre-diabetes by using mobile technologies and community nurses.

This study proposes a novel screening approach based on community nurses using glucometers and mobile phones, performing tests on undiagnosed and diagnosed subjects proactively within the community without waiting for the people to go to the clinic. The main objective is to have a novel method to increase diabetes and pre-diabetes detection, and to find new behavioral determinants related to those conditions. For this purpose, a pilot project was carried out in some rural communities of the Central Region of Ghana. Similar to a project carried out in the same area about improving prenatal care [21], the project entrusted community nurses instead of the overall rural population to assure reliable glucose levels data collection.

2. METHODS

2.1. Data source

The research was conducted in the central region of Ghana, specifically within the Biriwa and Anomabo communities. These two communities are in the Mfantsiman Municipal District and based on the 2010 census, the two towns have a population of about 7,500 and 14,389 respectively. Those communities have been chosen since they have been involved in other past researches of the authors [21], and therefore interaction with the community chiefs and community people was already established. Nevertheless, they can be considered as average representative of rural communities in Ghana not too isolated but at the same time not so close to large urban centers.

Community nurses from rural clinics were instructed to visit proactively rural communities performing glucose screening at fasting when possible, or alternatively at random regime, to subjects known to have diabetes and to subjects deemed at risk or willing to be tested. A total number of 204 people were tested in a window period of 6 months (from June to December 2017). This sample size was reached as it was planned that each community nurse can screen about 15 people per month. The rationale behind this estimate was related to logistics. Namely, the screening is performed by the nurses in addition to their normal activities without representing an overtime or compromising the other activities they are already carrying out.

The nurses were equipped with glucometers and low cost Android smart phones. Data were stored through mobile phone app into a server to improve management and to facilitate eventual longitudinal screening. The developed app was based on the CommcareHQ framework (https://www.commcarehq.org), and comprised a series of guided questions that the nurses were filling jointly to a glucose test. Some screen-shots of

those questions are depicted in Figure 1. If network was not available at the moment of data collection, information could be sent later when the network was available.

Figure 2 shows a typical two steps of the screening, first a nurse is performing a glucose test (on the left), and then the data are recorded through the app (on the right).

Collected data from respondents were from the rural communities, both male and female, including pregnant women with the intent of capturing eventual gestational diabetes case [22]. The sampling of candidates at risk was based on physical factors and at the nurses discretion. During regular visits to the rural communities the nurses assessed whether the person to be tested was a potential diabetic candidate and therefore deemed to be tested, paying particular attention to pregnant women. Doing so we have introduced a piloted biases (as overweight people, pregnant women and other cases were deemed at risk by the nurses). Therefore the resulting statistics can be an overestimate if seen as a random sampling of the overall population. Nevertheless, our focus is not to estimate of total incidence of undetected diabetes or pre-diabetes, but to propose an approach that can detect as much as possible cases which otherwise will go unnoticed.

However, to avoid too strong bias also people deemed healthy willing to be tested were included. Data were collected on known diabetic patients as well, to evaluate the difference in lifestyle among the various groups. The inclusion criteria for the people with diabetes was that they were already assessed in the past, while for the unaware group was that they have never been reported as diabetic of any type. No age limits were set, as age is not a primary effect but an indirect effect related to fat deposition and physical inactivity [23]. Given a mobile phone app, the community nurses could also keep track of longitudinal changes or whether a subject has been already tested, in a similar manner of a project conducted in the same area about boosting prenatal care [21]. Subjects who came into contact with community nurses were asked the last time they took their meal,

based on this blood glucose measurement was tested as either fasting blood sugar test or random blood sugar test. Furthermore the following information were recorded from the subject a) Anthropometric indices (weight, height, body mass index (BMI)) b) Demographic Information (sex,age) c) Blood glucose Measurement (fasting or random sugar test) d) Information on risk factors (pregnancy, family history of diabetes, subject history of hypertension, kidney disorder, alcoholism, less exercise and unhealthy eating habits). OneTouch Ultra (Milpitas, CA, USA) and Accu-Check (Hoffmann–La Roche SA, Basel, Switzerland) strips and glucometers were used to measure the blood glucose level. According to the WHO [24], a fasting blood glucose level greater 110 mg/dL but less than 126 mg/dL was considered pre-diabetic. A fasting blood sugar level 126 mg/dL or above was considered diabetic. On the other hand, a random blood sugar level greater 140 mg/dL but less 200 mg/dL was considered pre-diabetic. Above 200mg/dL was considered diabetic.

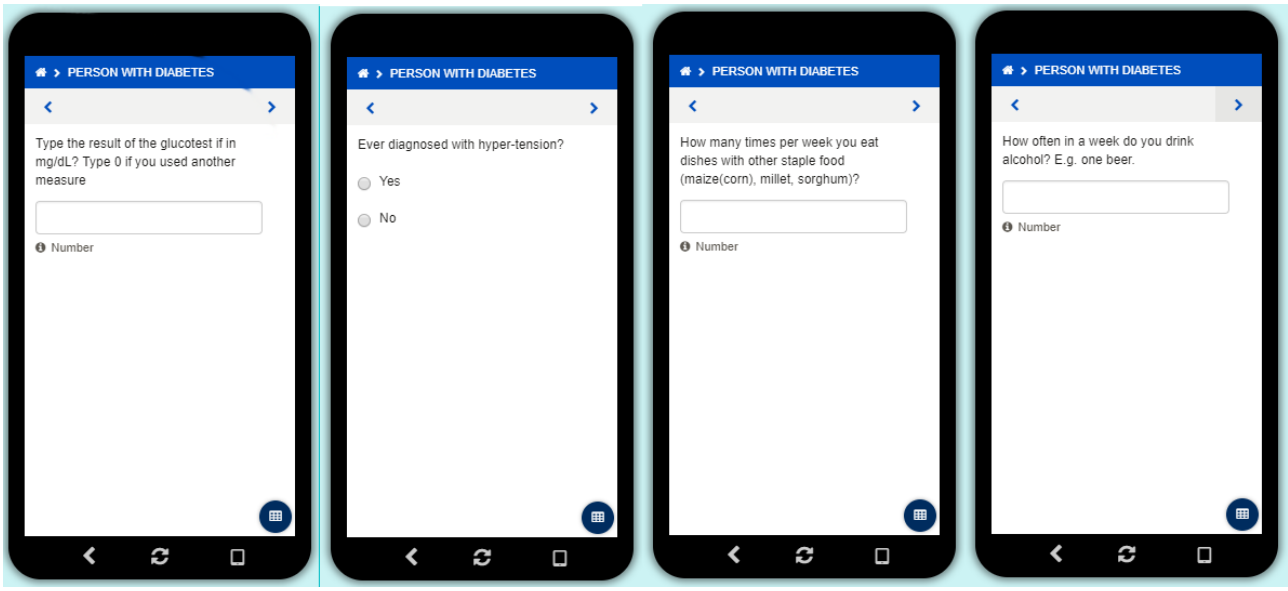

Figure 1. Screen-shots showing some of the guided questions the community nurse was filling while performing the glucose tests.

Figure 2 A typical two steps screening, first a nurse is performing a glucose test (on the left), and then the data are recorded through the app (on the right).

2.2. Analytical approach

The main question of the study is whether it is possible to easily detect diabetic and pre-diabetic subjects through community nurses already involved and active within the CHPS policy. Additionally, dietary habits and demographic information were collected by the community nurses along with glucose level to explore novel determinants related to the disease.

The data entered through the mobile phone app were downloaded and analyzed by R computing software. Sanity check on the data was performed and forms deemed clearly erroneous were removed. Statistically significant relationships among the collected information were sought comparing the population at risk and the population with assessed diabetes, and a p-value less or equal to 0.05 was considered to indicate a significant value.

The study also took advantage of the screening process to collect further insights through qualitative methods. Hence, the quantitative information was complemented with qualitative data obtained through the interviews performed to the community nurses to identify further relevant elements. After revision of notes, the transcripts were typed and coded by using the software NVivo 10 (QSR International, Melbourne, Australia). The interviews were thus analyzed by using qualitative conventional content analysis. The starting open questions were “what are your general comments about the projects?”, “Which shortcomings did you notice?”, “What are your suggestions?”.

3. RESULTS

The diabetes screening saw over 204 inhabitants in Anomabo and Biriwa over a period of 6 months. Those were 103 previously confirmed diabetic people (CDP) and 101 people with unknown status of diabetes (USP). Originally 211 forms were found in the system. However 7 of them were deemed erroneous during the sanity check and therefore were removed before the analysis. For each person data were collected only once. The CDP cohort comprised 66 female and 37 male subjects, while the USP cohort comprised 95 female and 6 male subjects. Details of some characteristics revealed for the two groups are reported in Table 1.

Table 1: Features difference across the cohort reported as average and standard deviation, (co-) occurrence of hypertension or close relative with diabetes is reported as cardinality and percentage within the cohort.

Cohort/Features	Age (year)	BMI	Occurrence of hypertension	Close relatives with diabetes
CDP	62.9 ±11.2	24.2±5.1	N=63 (61.2%)	N=72 (69.1%)
USP	30 ±9.7	26.7±4.6	N = 2 (1.9%)	N = 33 (32.7%)

Two-sample *t*-test performed comparing the BMIs was statistically significant although they were both normoweight. Some subjects of the CDP cohort also presented the co-occurrence of ulcer (n=4), asthma (n=1), arthritis and rheumatism (n=3), kidney disease (n=1). At the moment of the glucose level test, the tested people in the USP cohort presented co-occurrence of asthma (n=4), arthritis and rheumatism (n=1), and typhoid (n=1). The subject presenting typhoid fever showed a random glucose blood level of 132 mg/dL which could not be considered neither diabetic nor pre-diabetic. Therefore typhoid fever was not considered a confounding factor and the subject was included in the statistics.

3.1 Cases detection

During the proactive screening performed by the community nurses, 2 subjects (1 female, not pregnant, with hypertension, 35.4 BMI; 1 male 25.7 BMI) were detected with hyperglycemia at fasting which can consider them diabetic according to the current WHO threshold. These subjects were not aware of their condition despite close relatives with diagnosed diabetes (son in one case and siblings in the other). They did not show further symptoms, and they were not habitual consumer of alcohol or red meat. However, they were used to consume constantly dishes with maize corn, cassava and rice.

The detected pre-diabetic cases according to the WHO threshold were 20, 4 tested at fasting and 16 at random (19 female; 1 male). No hypertension or other symptoms recognized, 5 of them with relatives with diabetes (mother or father), half of the detected subject reported to consume almost daily red meat, and all of them claimed to avoid alcohol consumption. However, they were also use to consume constantly dishes with maize corn, cassava and rice with an average of 8.5, 8.5 and 3.5 times per week respectively. Within the 6 months of observation no further symptoms raised for this subjects and they have been informed of being pre-diabetics.

All subjects of both groups claimed they were used to do physical activities due to their daily job. No statistical difference across the two cohort was detected per weekly consumption of red meat, maize corn, cassava or rice. The average consumption of alcohol across the two populations was also not significantly different but in the CDP cohort 14 subjects declared to consume at least 1 alcoholic beverage per week (plus 10 claimed to be former alcohol drinkers before their diagnosis and then changed this behavior) while in the USP cohort were only 6. Further, in the CDP cohort 3 subjects claimed to have reduced the consumption of cassava based product and 2 of red meat. 88 subjects reported to have drastically reduced the consumption of sugar or salt or both but not to have altered their diet. No case of gestational diabetes was detected. Table 2 reports the average and standard deviation of the blood glucose level for both cohort distinguishing whether fasting or random.

Table 2. Report the average glucose level with standard deviation for the two groups and the types of screening and the related p-value.

Cohort/Glucose level	CDP	USP	p-value

Fasting	160.6 ± 71.6	103.1 ± 181	<0.001
Random	173.9 ± 65.4	123.3 ± 20.6	0.002

3.2. Qualitative comments from the nurses

The two nurses who performed the screening in the rural areas were asked to give their qualitative opinion at the end of the 6 months pilot. Here are reported extracts of those interviews.

- OKA , Enrolled Nurse, Anomabo Health Centre, Anomabo:

"*There should be continuous education of the masses on Diabetes to create awareness, regular screening if possible for free of charge as some health facilities take money before checking for once blood glucose. There should also be financial support from government, Non Governmental Organizations to aid routine check up of known Diabetes patients, this will encourage them to always take their medication as regular checking of blood glucose level for free help them to know the progress with their condition.*"

- OD, Clinical Nurse, Boabab Health Clinic,Biriwa:

"Female clients above the age forty were pleased to participate in the screening exercise." "Furthermore, some clients were not able to provide information about their diet and family history."

4. DISCUSSION

Mobile phone apps and pro-active screening can help community nurses to spot new cases of diabetes and pre-diabetes. In particular, the proposed approach was based on

pro-actively performing blood screening during rural visits of the community nurses, who were collecting information via mobile phone app. This can also help tracking and monitoring as the nurses can check in future visits the status of the pre-diabetic people.

The method proved that some people in vulnerable populations as those in rural Ghana, are not aware of becoming diabetic or being in diabetic condition. In the Results section we reported 2 cases of diabetic people in the USP cohort (the 2% of it) and 20 being pre-diabetic (19.8% of the cohort), which are high numbers. However, we have to keep in mind that the cohort construction was not purely random, and piloted biases were introduced as the subject to be tested were chosen according to nurse discretion. Therefore, these percentages should not be taken as a representative sample of the national population. The proposed approach aims instead at detecting as much cases as possible of diabetes and pre-diabetes which otherwise will be unnoticed, and for this purpose it proved to be successful, inexpensive and easy to be integrated in the standard duties community nurses are already doing.

Initially the nurses were equipped with ihealth glucometer dongles for the smartphone (ihealth, Mountain View, CA, USA). The anecdotal comments which we can report is that despite the initial interest those tools were not practical to collect data for screening in community, though they might be suitable for a single individual. The reason can be related to the familiarity of the nurses to known tools as Accu-Check and OneTouch, or the cumbersome use practice of switching continuously between the mobile app of the glucometer dongle and the app to record the data if both have to be used on one phone. During the qualitative interviews, one nurse pointed out that despite the marginal costs of glucose tests both patients and government are not promoting it, while it could be cost-effective for Ghanaian institutions to detect pre-diabetic cases instead of dealing with a growing diabetic population, as it has been already shown for similar vulnerable

populations [25]. Despite the progresses made in Ghana to achieve universal health access and coverage, financial barriers to diabetes service utilization still exist. As subjects refrained themselves from inexpensive glucose tests being out-of-pocket, since they are not included in the reimbursements of standard insurances, similarly as reported in Nigeria and Tanzania [26]. The other nurse mentioned that subjects were often not aware of the impact of their dietary habits at the point that they have difficulties in reporting it.

At population level the CDP and USP cohort were normoweight according to their BMI, though there were subjects which were obese and with hypertension in both groups. It is worthwhile to mention that the CDP subjects might have some dietary changes already after being informed of being diabetic which could have affected their weight. However, from the interview it seems that the major changes were the reduction of consumption of salt and sugar, few of them increasing the consumption of vegetables and fruit, and some reducing the consumption of alcohol beverages. No statistically significant difference in alcohol consumption between the two groups was detected. Most likely there could have been as the CDP cohort did change its dietary habits (10 people reported to have cut out alcohol consumption after their diagnosis), and since the nurses were instructed to focus for both groups on women which might consume less alcoholic beverages than men. Nevertheless, the general impression of the nurses was that the alcoholic consumption has its impact. With the increase of quality of life in the country, western habits such as alcohol consumption might be also increasing and therefore augmenting the risk of diabetes. It has been noticed that people informed of their condition tend to change their dietary habits but given the intricate social changes related to alcohol beverage in the country, social marketing campaign [27] should be addressed, or at least further investigation on the alcohol consumption in the country is needed.

Almost all subjects of both groups reported to perform regular physical activities related to their job. However, this information seems vague and it is not clear whether this physical activity is aerobic or resistance or whether it is sufficient to keep a healthy glucose level. Most likely further activities should be proposed. Jogging and other sport activities are inexpensive and easy to promote. Therefore, promoting this type of sport activities can address this issue.

Given the current low income of the investigated population, proposing regular sport activities beyond the work-related physical activities seems cumbersome.

The country is experiencing an exponential increase of mobile network, social media and smartphones in the recent years [28]. Beyond the screening of the population carried out by nurses. Smartphones can have an impact on glycemic control, as smartphone dongle can be inexpensive and attractive to young users. Strategies such as gamification, and social media should be explored to increase awareness on glycemic level as shown in other contexts [29].

5. CONCLUSION

Proactive glycemic screening on vulnerable population – such as those living in rural areas – can be effective in detecting new cases of diabetes and pre-diabetes. Our approach using community nurses screening subjects deemed at risk and collecting data on mobile phone showed to be effective, and suitable for longitudinal studies. Campaign increasing awareness on alcohol consumption, physical activity, nutrition and healthy habits should be emphasized in any prevention strategy as the population seems still unaware of the consequences.

Despite studies with larger population are required to confirm the results, the diabetes and pre-diabetes screening described in this manuscript can be easily included into the national CHPS policy with several potential benefits.

6. LIST OF ABBREVIATIONS

IDF International Diabetes Federation

WHO World Health Organization

CHPS Community-based health planning and services

BMI body mass index

CDP confirmed diabetic people

USP unknown status of diabetes people

7. DECLARATIONS

Compliance with ethical standards

The study was recorded by the Noguchi Memorial Institute of the University of Ghana.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Availability of data and materials:

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Conflict of interest: The authors declare no conflict of interest.

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Authors' contributions

BEN and RSA have contributed equally to the data collection and data analysis. BEN has performed a screening and quality assessment of the data. BEN and RSA have drafted the manuscript. AC has been responsible of the study design, he contributed to the interpretation of data, and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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