Targeted Screening Reveals High Numbers of Prediabetes and Diabetes Mellitus in Moshi, Tanzania

Christine Ludwig[1], Melanie Streicher[2], Sandra D Habicht[3], Mark E Swai[4] and Michael B Krawinkel[3]*

[1]Department of Nutrition and Food Sciences, Nutritional Epidemiology, University of Bonn, Germany
[2]Institute for Biomedicine of Aging, Friedrich Alexander University Erlangen-Nurnberg, Germany
[3]Institute of Nutritional Sciences, Justus Liebig University Giessen, Germany
[4]Kilimanjaro Christian Medical Centre, Moshi, United Republic of Tanzania

Abstract

Objective: Chronic non-communicable diseases, such as type 2 diabetes mellitus, have become global major health problems. In the United Republic of Tanzania, previous studies showed diabetes prevalences ranging from 0.6% to 5.8% and of pre-diabetes, from 9.1% to 10.6%. The pre-diabetes screening procedure described here was a targeted screening to recruit eligible subjects for a subsequent dietary intervention in Moshi, Tanzania.

Methods: The pre-diabetes screening procedure described here was used to identify subjects for a dietary intervention in Moshi, Tanzania. Main enrollment criteria for participants were fasting plasma glucose levels of 5.6-6.9 mmol/L (100-125 mg/dL) on two days or on one day plus HbA1c in the range of 5.7-7.5% (39-58% mmol/mol), body mass index of 27-35 kg/m², and age between 30-65 years.

Results: Through pre-screening of a total of 1,256 people were examined for BMI and age; 382 people were further screened for markers of pre-diabetes. Following ADA and WHO-criteria, 51% (73%) had normal, 35% (13%) pre-diabetic, and 15% (15%) diabetic fasting plasma glucose levels. Among the individuals with hyperglycemia indicating diabetes mellitus, 60% were unaware of their condition. Applying ADA criteria for HbA1c to all people, 42% had normal, 42% had pre-diabetic, and 16% had diabetic HbA1c levels. Identified risk factors for increased fasting plasma glucose were age, waist circumference, body mass index, and a family history of diabetes mellitus.

Conclusion: Although the screening sample was not representative for the study area's population and not diagnostic, the high rates of pre-diabetic and diabetic fasting plasma glucose levels are of public health concern. The low concordance between the data for FPG and HbA1c requires further investigation, as well as the discrepancy between ADA and WHO definitions of impaired fasting glucose.

Abbreviations: BP: Blood Pressure; FPG: Fasting Plasma Glucose ;IFG: Impaired Fasting Glucose; IGT: Impaired Glucose Tolerance; OGTT: Oral Glucose Tolerance Test; RBG: Random Blood Glucose; SUR: Seemingly Unrelated Regression

Introduction

Chronic non-communicable diseases, such as type 2 diabetes mellitus, have become major health problems in high-income countries for decades but are also spreading fast in low- and middle-income countries [1]. Type 2 diabetes mellitus is a disease partially linked to overweight and obesity as well as to low physical activity [1-3]. In the age group of 20-79 years, the current estimate of global prevalence of diabetes is 8.8%, with an expected increase to 10.4% by 2040. In Sub-Saharan Africa, the current estimate of the regional prevalence is 3.2% with an expected increase to 4.2% by 2040. It is assumed that almost 67% of diabetes patients are still undiagnosed in this region [4]. In Sub-Saharan Africa as well as worldwide, 90% of all cases are type 2 diabetes mellitus [5]. The International Diabetes Federation estimated Tanzania's national diabetes prevalence to be 2.3% in 2011 [6], 7.8% in 2013 [7], and 3.5% in 2015 [4]. Other studies showed diabetes rates ranging from 0.6% to 5.8% [8,9]. Prevalence of pre-diabetes, defined as impaired glucose tolerance (IGT), were 10.6% in 2011 [6] and 9.08% in 2013 [7]. Used cut-offs for IGTs are 7.8 to 11.0 mmol/L (140 to 199 mg/dL) for 2-hour glucose levels measured during an oral glucose tolerance test (OGTT) with a 75 g glucose load [10,11]. Pre-diabetes

can also be defined as impaired fasting plasma glucose (IFG) defined by the World Health Organization (WHO) [10] and the American Diabetes Association (ADA) [11] using cut-offs of 6.0 to 6.9 mmol/L (110 to 125 mg/dL) and 5.6 to 6.9 mmol/L (100 to 125 mg/dL), respectively. The use of HbA1c to classify pre-diabetes is not universally recommended. The ADA recommends HbA1c- cut-offs of 5.7% 86 to 6.4% (39 to 46 mmol/mol) for the pre-diabetic stage [11]. Pre-diabetes can be detected during screening at clinical visits or public screening activities in communities. Different screening methods may be applied individually or in combination, depending on the purpose and scope of the screening. Such methods include questionnaires, measurement of fasting plasma glucose FPG, random blood glucose (RBG), HbA1c, or conduction of an OGTT. Screening can be performed in stages, starting, for example, with using a questionnaire to assess risk factors, followed by an assessment of the glycemic status of those with elevated risk factor scores. The ADA recommends a screening every three years for

asymptomatic adults older than 45 years of age, and for younger adults with a BMI ≥25 kg/m² who have at least one additional risk factor such as low physical activity or a first-degree family member with diabetes [12]. However, some argue that screening for diabetes mellitus and pre-diabetes is not justifiable [13], as it does not meet all criteria for disease screening [14,15]. The pre-diabetes screening procedure described here was a targeted screening to identify eligible subjects for a subsequent dietary intervention in Moshi, Tanzania. This paper addresses the screening for prediabetes only. It further aims at providing insights into the challenges of diabetes-related health problems in East Africa.

Methods

The aim of the screening was to identify otherwise healthy pre-diabetics between 30 and 65 years of age by the following the criteria: Fasting plasma glucose of 5.6-6.9 mmol/L (100-125 mg/dL) on two days or on one day plus HbA1c in the range of 5.7-7.5% (39-58% mmol/mol). To increase the chance of identifying individuals with pre diabetic glucose levels and without co-morbidities, a body mass index (BMI) between 27-35 kg/m² was chosen as an inclusion criterion for the current screening. Blood pressure (BP) between 90/60-160/110 mmHg was chosen to exclude individuals with low blood pressure. The upper cut-off values were chosen, as a previous assessment in the area detected generally high blood pressure values in the respective age group. The remaining inclusion criteria were waist circumference (WC) >80 cm for women and >90 cm for men, absence of any diagnosed disease and of any regular medication, no heavy alcohol consumption, no pregnancy, and no breastfeeding. The study-related HbA1c upper limit exceeded ADA recommended cut-offs for pre-diabetes. During the screening, HbA1c levels were indicating notably higher glycemia than the corresponding FPG levels. The use of higher cut-offs in the HbA1c criterion was approved by the institutional review boards of the National Institute for Medical Research (NIMR) and Kilimanjaro Christian Medical College. During 2013/2014, HbA1c cartridges were recalibrated by HemoCue® which resulted in lower readings compared to old cartridges. However, a conversion factor was not provided, and was instead calculated by comparing old and new cartridges analyzed by the HemoCue® 501 analyzer (HemoCue® GmbH, Germany and another HbA1c point-of-care analyzer (DCA Vantage Analyzer, Siemens, Germany). Corrected HbA1c levels are presented in the current analysis. During the screening process, eligibility criteria were based on uncorrected HbA1c values.

Study Area

The recruitment procedure including pre-screening and screening for pre-diabetic participants was conducted in Moshi Urban District, one of the six districts of the Kilimanjaro Region in northern Tanzania. In 2012, the Kilimanjaro Region had a population of 1,640,087 [16]. Moshi Municipality, the capital of Moshi Urban District, is divided into 21 wards [17] of which seven (Longuo, Rau, Karanga, Mawenzi, Majengo, Mji Mpya, Njoro, Pasua) were chosen as pre-screening areas due to their proximity to the screening facility in Longuo or due to their use in previous studies. Screening took place at the Kilimanjaro Clinical Research Institute (KCRI), which is closely associated with the Kilimanjaro Christian Medical Centre (KCMC) [18].

Recruitment Procedure

Pre-screening took place between April and October 2013 at 16 different settings in Moshi and addressed the following groups and institutions: people reached through radio announcements, doctors and nurses at KCMC, three Lutheran and four Roman Catholic churches, one convent, two banks, teachers at two primary schools, staff and lecturers at one university, one mosque, one police academy, one revenue authority, and KCRI. In addition, individuals from the wards Njoro and Pasua were invited who had been identified as pre-diabetics in a previous study. During pre-screening, information was provided about the procedures, rationale and aims. Data on sex, age, BMI, and BP as well as contact information were collected from interested volunteers. In the early stages of the study, body weight was measured with an analogue scale and height with an elastic measurement tape fixed to a straight wall. In the later stages, body weight was measured with a digital scale (Seca 877 Germany) and portable stadiometer (Seca 217, Germany). BMI was calculated as bodyweight in kg divided by the square of body height in m. While seated, each participant's BP was measured on the left arm using a Visomat Double Comfort blood pressure cuff (range: systolic 50-250 mmHg, diastolic 40-150 mmHg, Uebe Medical GmbH, Germany). All measurements were performed once. BMI and BP values were categorized according to WHO guidelines [19,20] and American Heart Association [21] guidelines, respectively. All identified participants with relevant BMI, BP and age were invited to the screening. To facilitate logistics and evaluation processes, people pre-screened at KCRI were invited to participate in all pre-screening and screening measurements at the same day.

The screening and all other data collection took place at the KCRI between July and October 2013. Appointments were scheduled between 7:30 and 10:30 a.m. Participants were instructed to fast overnight before the examination. A questionnaire-based interview was performed to assess socioeconomic and health related data. Data on body weight and height, waist and hip circumferences, BP, FPG, and HbA1c were collected according to the following procedures. Body weight was measured using a digital scale (Seca 877, Germany). Body height was measured using a portable stadiometer (Seca 217, Germany) according to FANTA protocol [22], with participants dressed in light clothing and without shoes. Measurements were performed only once. Waist circumference and hip circumference (data not shown) were measured twice using a retractable measurement band according to STEPS Surveillance [23]. If the difference between the two measurements was greater than 1 cm, a third measurement was performed. The mean of the measurements was then recorded. After sitting for 5 min, blood pressure was measured once on the left arm using a Visomat Double Comfort blood pressure cuff.

Capillary blood samples were obtained from a dry fingertip after disinfection using one disposable lancet for each person. FPG was measured using Accu-Chek Aviva® blood glucose meters (Roche Diagnostics, Switzerland). Glycosylated hemoglobin was measured using a HemoCue® 501 analyzer (HemoCue® GmbH, Germany). Both appliances are point-of-care devices and results were available after a few seconds for FPG and after five minutes for HbA1c. Participants with high glucose levels were advised to go to their nearest clinic for further medical consultation.

All participants were reimbursed for their traveling expenses and given a record chart of their data, reference ranges, and a small snack. If requested, participants were given counseling for nutrition and physical activity as part of a healthy lifestyle.

Ethics

The study protocol was approved by the Medical Research Coordinating Committee of the National Institute of Medical Research, Tanzania, the Tanzanian Food and Drug Authority, and the institutional review boards of the Kilimanjaro Christian Medical

College, and the Faculty of Medicine at Justus-Liebig-University, Giessen, Germany and the Regional Medical Office in Moshi. All pre-screened and screened participants gave verbal consent to participate in the recruitment procedure and were informed about their right to withdraw at any time without any negative consequences for them.

Statistical Analysis

Data entry and analysis were performed using Microsoft Excel, 2013 SPSS version 22, and Stata version 14. Variables are expressed as frequencies or as median and interquartile range. Only WC was consistent with a normal distribution and described by a mean and standard deviation. A Mann-Whitney U-test was used to identify differences in continuous variables between male and female participants. A Chi squared test was used to identify differences between categories in categorical variables.

Among the pre-screening sample, Spearman's ρ was calculated to assess correlations. Concordance between FPG and HbA1c data indicating hyperglycemia was calculated using Krippendorff's α [24]. Hyperglycemia was defined as FPG ≥5.6 mmol/L (≥ 100 mg/dL) or HbA1c ≥5.7% (≥39 mmol/216 mol). Among the screening sample, a non-linear model with seemingly unrelated regression (SUR) [25] was computed to analyze effects of age on FPG, HbA1c, and BP, as well as to analyze effects of WC and BMI on the dependent variables. Age was controlled for gender; WC and BMI were controlled for age and gender. If necessary, the quadric variation of the centered independent variable was used. FPG, HbA1c, and BP were log transformed (LN) prior to analyses. For these particular models, participants who take medication regularly or were pregnant were excluded. Statistical significance of different associations was assumed at a level of $p < 0.05$ as the individuals identified were regarded as sample of the screened subpopulation.

Results

A total of 1,256 people were pre-screened. Most people attended pre-screening after church services. The highest rates of eligible BMI and age were found among office workers and teachers, Table 1. Median BMI (Q25;Q75) was 27.5 kg/m² (24.1; 31.3), median age was 47.0 years (37.0; 55.0), median systolic BP was 125.0 mmHg (114.0; 142.0), and median diastolic BP was 83.0 mmHg (76.0; 91.0). About 30% of participants had arterial hypertension, Figure 1. People with high BP values were directed to go to their nearest health facility for further medical consultation. As shown in Table 2, median BMI increased across age groups until the age of 60 years. The majority of the pre-screened participants were overweight or obese, Figure 2, likely because the research team stated that it was seeking participants with an increased body weight. Systolic BP increased across age groups, reaching the highest median in the oldest age group. Diastolic BP increased up to the age group of 50-59 years. Age was correlated with systolic BP (r = 0.371) and diastolic BP (r = 240 0.207). BMI was correlated with systolic BP (r = 0.144) and diastolic BP (r = 0.244). Systolic BP was highly correlated with diastolic BP (r = 0.724). All correlations were significant at the level of $p < 0.001$. Systolic and diastolic BP was significantly higher in obese participants than in normal-weight participants (U=52793, z=4.833, p<0.001, r=0.178; U=45781, z=7.296, p<0.001, r=0.270, respectively). There was no difference between obese and overweight and between overweight and normal weight participants. Through pre-screening a total of 382 people were found eligible according to their age and BMI and therefore qualified for further screening. Based on ADA (WHO) FPG-criteria, 51% (73%) had normal, 35% (13%) had pre-diabetic, 249 and 15% (15%) had diabetic FPG levels. Among the latter group, 60%

were unaware of their high glucose levels. Among diagnosed diabetics (n=26), 50% were on prescribed medication. However, their median FPG and HbA1c values were higher compared to cases in which diabetes status was unknown Table 3. According to ADA criteria for HbA1c, 42% had normal, 42% had pre-diabetic, and 16% had diabetic HbA1c levels. In the following, only the corrected HbA1c will bepresented. Concordance of dysglycemia between FPG and HbA1c measures was 68%, with a Krippendorff's α of 0.351 indicating low reliability. Rates of hyperglycemia were higher according to HbA1c- than FPG-data. Regarding concordance of HbA1c and FPG in identifying the glycemic status, 62% were in the same criteria (31% both normal, 20% both pre-diabetic, and 11% both diabetic). Nineteen percent showed pre-diabetic HbA1c, but normal FPG, and 12% pre-diabetic FPG, but normal HbA1c. In 7% other discordant combinations were found. The highest rate of concordance was observed in the diabetic category. Fourty-one percent of all screened participants had hypertension, defined by a systolic or diastolic BP meeting at least the state-I criteria, i.e. at least systolic BP mm Hg 140-159 or diastolic BP 90-99 mm Hg. Of these, 33% had previously been diagnosed with hypertension, and one third of them were taking medication. The remaining 67% were unaware of their arterial hypertension.

There was an increase in median BP and FPG values across age groups until 50-55 and 55-59 years, respectively, Table 4. Regarding undiagnosed diabetes, no clear trend was seen. Waist circumference, BP, and prevalence of hypertension increased from normoglycemic over pre-diabetic to diabetic groups, Table 5. In the diabetes group, the highest percentage of family members with diabetes was found. Table 6 shows the results of the non-linear model with seemingly unrelated regression (SUR). In this model, the effect of age on systolic BP was stronger than on FPG and HbA1c. BMI and waist circumference had a higher effect on FPG and HbA1c than on BP. Waist circumference showed a linear association with the dependent variables, whereas BMI showed a non-linear association. However, overall R² values were relatively low, with R² ranging between 0.184 and 0.248. Correlations of dependent variables are shown in Table 7. As expected, systolic B P was highly correlated with diastolic BP (0.804), and FPG with HbA1c (0.847). Systolic BP showed a medium, and diastolic BP a low, correlation with FPG and HbA1c,.

After screening for the defined inclusion and exclusion criteria for the dietary intervention study, 74 people could be identified. Two common exclusion factors for people who met the pre-diabetes criterion were having high BP and taking regular medication. Overall,

Pre-screening site	Pre-screened n	People meeting BMI & age criteria		Attended screening	
		n	(%)	n	(%)
Bank	35	21	60.0	1	4.7
Churches	595	227	38.2	131	57.7
Convent	13	6	46.2	4	66.7
Mosque	40	12	30.0	7	58.3
Primary schools	62	31	50.0	22	71.0
Police academy	90	42	46.7	17	40.5
Revenue authority	38	29	76.3	19	65.5
University	15	10	66.7	10	100
Total outside	**888**	**378**	**42.5**	**211**	**55.8**
Total inside KCRI	368	171	46.6	171	100
Overall total	**1,256**	**549**	**43.7**	**382**	**69.6**

Table 1: Pre-screening sites and subsequent screening attendance rates.
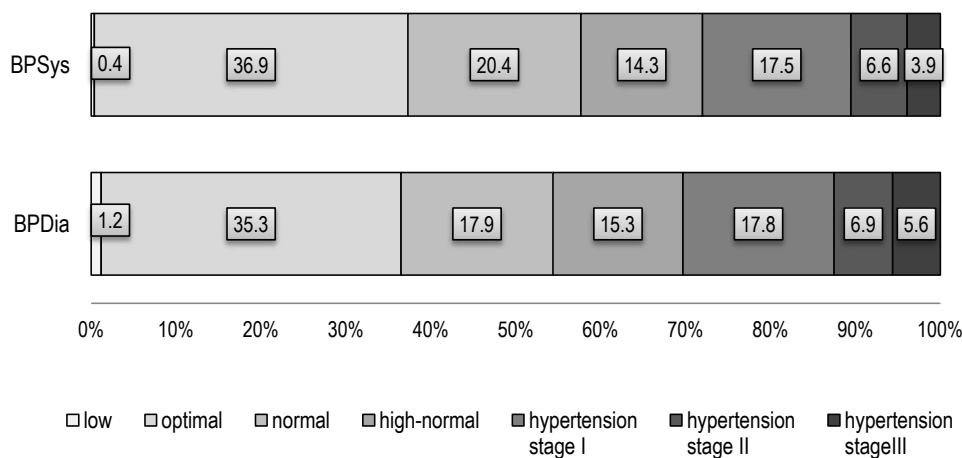
Figure 1: Classification of systolic (n = 1218) and diastolic (n = 1217) blood pressure (pre-screening).

Variable / Age	15 -19 n=9	20-29 n=96	30-39 n=237	40-49 n=316	50-59 n=322	60-69 n=124	70-79n=26	≥0 n=10
Body mass index [kg/m²]	20.8 21.2; 27.7	24.9 20.9; 27.7	27.8 20.9; 27.7	29.3 25.7; 32.5	28.6 25.7; 31.8	27.3 22.8; 30.5	24.9 21.6; 28.9	23.8 21.2; 31.0
Systolic blood pressure [mmHg]	106.0 96.5; 121.0	116.0 107.5; 125.8	120.2 109.0; 129.0	124.0 114.0; 137.0	134.0 120.0; 149.0	137.0 120.0; 152.0	143.5 123.3; 163.0	154.0 141.0; 162.5
Diastolic blood pressure [mmHg]	70.0 64.0; 74.5	77.5 71.0; 82.8	81.0 74.0; 89.9	87.0 78.0; 92.0	84.0 79.9; 95.0	84.0 76.0; 93.0	84.0 78.0; 94.0	70.0 68.0; 95.5

Table 2: Body mass index and blood pressure according to age group of the pre-screening sample n=1,140 (median & IQR).
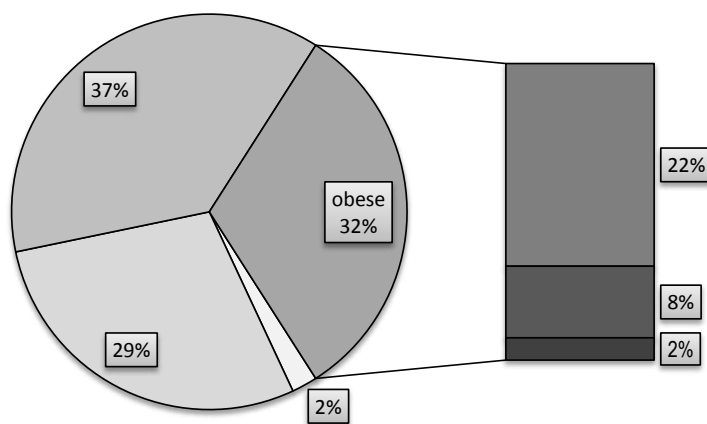

Figure 2: Classification of body mass index in the pre-screening sample, n=1,252.

the recruitment rate was 5% starting from the pre-screening phase and 16% starting from the screening phase (based on BMI and age).

Discussion

Screening for pre-diabetic volunteers was divided into two stages, a pre-screening phase and a screening phase, and was communicated via different channels. Due to word-of-mouth communication, 26% of pre-screened participants were pre-screened without prior attendance at information sessions, but were instead referred by already-pre-screened people. In the pre-screening sample, rates of overweight and obesity were 37% and 32%, respectively. However, as people with increased body weight were encouraged to participate in the recruitment procedure, relatively high rates of overweight and obesity were expected. In the most recent Tanzanian Demographic Health Survey (TDHS) of 2010, 35% and 24% of women in the Kilimanjaro Region were overweight or obese, respectively. The TDHS did not report any data for men [26]. As obesity is linked to an increased risk of chronic non-communicable diseases and negative outcomes [27], the high rates of obesity, especially of classes two and three in the current study, are a major health threat for that area. In the current study, obese participants had significantly higher BP values than normal-weight participants. Although sex was not recorded during the pre-screening, an subgroup analysis showed that women were three times more likely to be obese than male participants. This relation was also seen in a population study conducted in Mwanza District, where the obesity prevalence of women was 22% and that of men 7% in town settings [8]. In the data set of our study, a BMI in the overweight and obese ranges was more common among office workers and teachers than among people pre-screened at religious institutions. This may be linked to a more sedentary lifestyle due to jobs with low physical activity [28]. Vice

Group / Variable	All n=382	Female n=264	Male n=118
Mean Age [years]	47.5	48	45.0
Smoking [yes] [%]	2	0.4	6
Alcohol [yes] [%]	48	47	51
Education			
completed primary [%]	36	39	47
completed secondary [%]	19	18	36
college [%]	36	31	19
Reporting disease [%]	36	36	36
Regular medication [%]	22	24	19
Mean Body mass index [kg/m²]	29.9	30.7	28.3
Mean waist circumference [cm]	94.2	92.4	98.0
Diabetic family member [%]	26	29	19
Mean Fasting plasma glucose [mmol/L]	5.5	5.5	5.6
normal fasting plasma glucose [%]	51	54	44
pre-diabetic fasting plasma glucose [%]	35	32	42
diabetic FPG [%]	14	14	15
undiagnosed diabetic FPG [%]	62	66	53
Dysglycemia [%]	49	46	56
HbA1c [%, (mmol/mol)]	5.7 (39)	5.7 (39)	6.0 (42)
normal	42 (70)	45 (76)	37 (58)
pre-diabetic	42 (14)	40 (9)	46 (25)
diabetic	16 (16)	15 (15)	17 (17)
Mean Systolic blood pressure [mmHg]	128.0	127.0	129.0
Mean Diastolic blood pressure [mmHg]	86.0	86.0	87.0
Overall arterial hypertension [%]	41	41	40
Undiagnosed arterial hypertension [%]	68	65	71

Footnote: If not otherwise specified, data are expressed as median and interquartile range; waist circumference is presented as mean and SD; glycemic status based on fasting plasma glucose (FPG) is shown using ADA and WHO (shown in parantheses) criteria; dysglycemia was defined by FPG ≥ 5.6 mmol/L (ADA) or ≥ 6.1 mmol/L (WHO); HbA1c is shown using ADA criteria; hypertension was defined by having at least one value in stage I, II, or III according to American Heart Association criteria.

Table 3: Overall characteristics of screening participants (including participants with reported diseases and use of medication).

Age group / Variable	30-34 n=34	35-39 n=52	40-44 n=69	45-49 n=72	50-54 n=76	55-59 n=57	≥60 n=27
Body mass index [kg/m²]	29.2 28.3; 32.2	29.2 27.8; 32.0	30.2 28.0; 32.1	30.8 28.5; 32.8	29.7 28.2; 32.0	30.2 28.0; 31.5	30.7 28.1; 32.6
Waist circumference [cm]	91.9 (7.9)	92.3 (7.1)	93.8 (7.7)	95.4 (7.0)	95.4 (7.0)	94.2 (6.0)	94.1 (7.2)
Fasting plasma glucose [mmol/L]	5.3 4.7; 5.6	5.3 4.8; 5.6	5.4 5.0; 6.1	5.6 5.1; 6.1	5.8 5.2; 6.6	5.6 5.1; 6.8	5.7 5.3; 6.2
normal [%]	73 (91)	64 (88)	54 (75)	48 (73)	37 (61)	44 (64)	55 (68)
pre-diabetic [%]	24 (6)	30 (6)	29 (9)	35 (10)	45 (21)	40 (20)	36 (23)
diabetic [%]	3	6	16	17	18	16	9
undiagnosed diab. FPG [%]	100	33	82	58	50	67	50
Dysglycemia	27 (9)	36 (12)	45 (15)	52 (27)	63 (39)	56 (26)	47 (31)
HbA1c [% mmol/mol]	5.5 (37) 5.2 (33); 5.8 (40)	5.6 (38) 5.3 (34); 5.9 (41)	5.7 (39) 5.3 (34); 6.1 (43)	5.8 (40) 5.3 (34); 6.1 (43)	5.8 (40) 5.6 (38); 6.3 (45)	5.9 (41) 5.6 (38); 6.5 (48)	5.8 (40) 5.6 (38); 6.2 (44)
Systolic blood pressure [mmHg]	118.5 108.5; 128.3	122.5 112; 131.8	125.0 114.5; 135.5	126.0 117.0; 143.0	131.0 120.3; 146.0	139.0 126.0; 152.5	136.0 121.8; 150.5
Diastolic blood pressure [mmHg]	81.0 77.0; 87.8	86.0 80.0; 91.0	84.0 78.5; 91.0	87.0 81.0; 96.0	90.0 82.0; 96.8	86.0 79.5; 96.0	89.0 78.9; 97.0
Table 4 ctd.:							
Hypertension type I [%]	12	10	12	14	25	35	23
Hypertension type II [%]	0	2	4	9	9	9	9
Hypertension type III [%]	0	4	0	7	8	5	4
Overall hypertension [%]	12	16	16	30	42	49	36

Footnote: If not otherwise specified, data are expressed as median and interquartile range; waist circumference is presented as mean and SD; glycemic status based on fasting plasma glucose (FPG) is shown using American Diabetes Association (ADA) and World Health Organization (WHO, shown in parantheses) criteria; dysglycemia was defined by FPG ≥ 5.6 mmol/L (ADA) or ≥ 6.1 mmol/L (WHO); HbA1c is shown using ADA criteria; hypertension was defined by having at least one value in stage I, II, or III according to American Heart Association criteria.

Table 4: Anthropometric and medical data within different age groups of screened participants.

Group / Health indicator	Normal n=190	Pre-diabetic n=131	Diabetic n=52	Diagnosed diabetes n=20	Undiagnosed diabetes n=32	Treated diabetes n=13
Age [years]	45.0 38.0; 53.0	49.0 42.0; 54.0	49.0 43.3; 54.0	50.0 45.0; 54.0	47.0 43.0; 54.0	53.0 47.5; 56.0
Body mass index [kg/m²]	29.8 28.1; 32.3	30.2 28.1; 32.1	30.4 28.6; 31.9	30.3 28.4; 32.4	30.4 29.0; 31.8	30.2 28.0; 32.2
Diabetic family member [%]	22	22	54	80	38	92
Waist circumference [cm]	92.5 (6.9)	95.5 (7.1)	97.0 (6.3)	97.8 (6.7)	96.5 (6.0)	97.4 (7.9)
Fasting plasma glucose [mmol/L]	5.1 4.7; 5.3	5.9 5.7; 6.3	9.2 7.4; 13.5	12.4 8.6; 17.8	8.0 7.3; 14.1	12.2 7.5; 18.2
HbA1c [% (mmol/mol)]	5.6 (38) 5.3 (34); 5.8 (40)	5.8 (40) 5.5 (37); 6.1 (43)	7.7 (61) 6.6 (49); 9.8 (84)	9.0 (75) 7.7 (61); 10.1 (87)	6.8 (51) 6.3 (45); 8.4 (68)	8.5 (69) 6.3 (45); 10.1 (87)
Systolic blood pressure [mmHg]	123.5 114.0; 137.3	130.0 120.0; 144.0	134.0 123.0; 155.5	133.5 122.3; 152.8	135.0 123.5; 170.5	134.0 123.8; 157.5
Table 5 ctd.: Group / Health indicator	Normal n=190	Pre-diabetic n=131	Diabetic n=52	Diagnosed diabetes n=20	Undiagnosed diabetes n=32	Treated diabetes n=13
Diastolic blood pressure [mmHg]	84.0 78.0; 91.0	89.0 80.0; 96.0	90.0 84.3; 97.8	88.0 80.5; 95.3	95.5 85.1; 99.5	90.0 80.0; 98.5
Hypertension type I [%]	20	27	31	25	19	23
Hypertension type II [%]	7	12	10	10	9	15
Hypertension type III [%]	6	8	14	5	19	8
Overall hypertension [%]	33	47	55	40	47	46

Table 5: Health indicators among the different groups defined by glycemic status (according to ADA criteria)
If not otherwise specified, data are expressed as median and interquartile range; waist circumference is presented as mean and SD; hypertension was defined by having at least one value in stage I, II, or III according to American Heart Association criteria.

Variable / Predictor	Fasting plasma glucose		HbA1c		Systolic blood pressure		Diastolic blood pressure		Overall R^2
	Coefficient[c]	p	Coefficient[c]	p	Coefficient[c]	p	Coefficient[c]	p	
Age[a]	0.140	0.003	0.177	0.000	0.339	0.000	0.195	0.001	
Age_sq[a]	0.142	0.001	0.098	0.012	0.019	0.765	0.064	0.298	
R^2	0.045		0.048		0.119		0.052		0.184
Waist circumference[b]	0.219	0.000	0.221	0.000	0.114	0.047	0.123	0.029	
Waist CF_sq[b]	0.010	0.834	0.047	0.309	0.059	0.325	0.107	0.052	
R^2	0.093		0.086		0.134		0.078		0.248
Body mass index[b]	0.142	0.003	0.130	0.005	0.008	0.893	0.026	0.682	
Body mass index_sq[b]	0.162	0.000	0.091	0.051	0.014	0.798	0.061	0.281	
R^2	0.075		0.064		0.119		0.058		0.230

[a]Controlled for sex, [b]controlled for sex and age, [c]standardized, sq = quadratic

Table 6: Results of the non-linear model using seemingly unrelated regression, n=291 for predictor age and body mass index, n=290 for predictor waist circumference.

	Fasting plasma glucose	HbA1c	Systolic blood pressure
HbA_{1c}	0.847		
Systolic blood pressure	0.264	0.205	
Diastolic blood pressure	0.197	0.150	0.804

Table 7: Correlations of dependent variables (Spearman's rho) controlled for age and sex, all $p < 0.05$.

versa, another study detected a high BMI as a predictor for a sedentary lifestyle [29]. Regarding increased BMI and a trend toward non-agricultural jobs in Tanzania [30], possibilities to engage in physical activity outside work should be introduced.

In the current study, BMI increased with age until 40-49 years, similar to results reported in the TDHS [26]. This age trend was also found for systolic and diastolic BP and diastolic BP peaked at the age group of 40-49. BP was positively correlated with BMI, stronger for diastolic than systolic BP. Other studies have also demonstrated age- and BMI-related increases in systolic and diastolic BP [31] or both as

independent predictors for arterial hypertension [32]. Overall, 30% of prescreened participants were classified as hypertensive, which is similar to the WHO's age-standardized estimate of 29% [1]. The majority was unaware of their hypertensive BP values, which was also seen in other settings [8] and requires attention in public health programs for preventing cardiovascular diseases.

Although the screening sample was not representative for the population and not diagnostic, the high rates of pre-diabetic and diabetic FPG values (35% and 14%, respectively) and high HbA1c values (42% and 16%, respectively), according to ADA criteria, are of

concern.

In a multiethnic study of pre-diabetes and diabetes mellitus rates were lower compared to the current setting: pre-diabetes (IFG according to ADA criteria) and diabetes prevalences were 10% and 14% in South Africa, 18% and 14% in Southern Cone of Latin America, 17% and 10% in Peru, and 4% and 19% in South Asia, respectively [33]. In another study, rates of pre-diabetes defined as IFG were 28% in non-Hispanic black individuals, 27% in non-Hispanic white individuals, and 29% in Hispanic individuals [34].

Around 60% of the probands in Tanzania were unaware of their diabetic FPG levels, which was lower than the estimate of 67% in Sub-Saharan Africa [4]. In other studies, rates of undiagnosed diabetes ranged from 18% to 62% [8,35,36]. The overall high prevalence of diabetes among the screened sample can be explained by the observation that a high number of diabetics came to the screening with the assumption they were coming to a new diabetes clinic offering free measurements. In the subgroup of treated diabetes patients, median HbA1c was 8.5% (69 mmol/mol), higher than the recommended target level of 7% (65 mmol/mol) for glycemic control among diabetes patients [12]. In addition, HbA1c levels among people with diabetic FPG (treated and untreated; known and unknown) were high. This, together with the high levels of hypertension, indicates that interventions are urgent to prevent complications among people with diabetes mellitus in Tanzania.

According to WHO criteria, prevalence of pre-diabetes was 12%. As seen in other studies [36- 39], pre-diabetic prevalence rates varied between ADA and WHO criteria. In the current study, applying ADA criteria resulted in a 2.7 times higher prevalence rate than WHO criteria. The WHO had previously stated that lowering the threshold for IFG from 6.1 mmol/L to 5.6 mmol/L would result in a higher rate of pre-diabetes with a lack of evidence for better health outcomes [40]. Due to the tailored screening of people with higher BMI and age, as well as differences in IFG and IGT status, the pre-diabetes prevalence of 35% according to ADA-criteria was more than three times higher in this study than the reported national prevalence of 10.3% defined by IGT [7]. People with IFG may not necessarily have IGT, and vice versa [41]. In a study by Zhang et al., isolated IFG was prevalent among 27% of study participants, whereas 5.1% had isolated IGT and 10.3% had both IFG and IGT [34]. Another study by Chilelli et al., found isolated IFG in 27.1%, isolated IGT in 6.8%, and both in 4.6% [42]. Both applied ADA cut-off values for IFG, which may explain the higher rates of pre-diabetes based on FPG than based on glucose tolerance.

Probands with diabetic glucose levels showed the highest concordance between HbA1c and FPG, although the overall Krippendorff's a was low (0.351). In a cross-sectional study at a primary care setting in Spain [43], HbA1c measurements revealed a significantly lower diabetes prevalence (3.2%) compared to 2-hour OGTT (9.2%), but was similar to FPG (3.1%). In a population-based survey in a rural district of Uganda, diabetes prevalence rates were 4.8% according to FPG and 11.3% according to HbA1c. Despite the low agreement between HbA1c and FPG, they detected a high agreement among negatives (normo-glycemic FPG and normal HbA1c) [37]. Specifying universal cut-off points for HbA1c may be difficult due to ethnic differences, with higher levels observed among people of African origin [44, 45], as well as other influencing factors [46]. However, it has been argued that HbA1c is a valid predictor for diabetes, including undiagnosed cases, but should not be used to identify pre-diabetes [47].

Regarding risk factors for increased glucose or BP values, the current study showed similar results as other assessments with WC and BMI being predictors for FPG and BP. The association between WC and dependent variables was linear, whereas it was non-linear for BMI. The current study had an upper BMI limit of 35 kg/m² whereas a higher limit would be needed to assess a non-linear association between BMI and FPG and BP. In a study in Brazil, mean BMI did not differ between prediabetic or normoglycemic groups, but WC was significantly higher among pre-diabetics than among normoglycemic participants [48]. In another study, obese people were two times more affected by dysglycemia than normal-weight people [36]. The measurement of WC as a low cost and noninvasive method might serve as a good screening tool to assess risk for dysglycemia.

In the current study, there was no difference in BP or glycemic status between alcohol consumers and non-consumers. Overall, alcohol consumption in the study population was similar to national data [1]. Smoking rates were considerably lower with 6% and 0.4% among men and women, compared to national data of 28% and 4%, respectively [1]. Thus, no association with tobacco use could be found. A study by Mayega found no association of abnormal glucose regulation with sex, age group, hypertension, tobacco use, or harmful alcohol use [36].

Whether screening for diabetes will be feasible is to be discussed among health and policy institutions. It has been argued that screening for diabetes is not feasible, as it does not meet all criteria for disease screening [13] as defined by WHO [15]. One major criticism is that screening should only be done if medical treatment is available [14, 15]. Assessments indicate that there are insufficient medical supplies and treatment facilities in Tanzania [49- 51]. However, as progression of pre-diabetes to type 2 diabetes mellitus and related complications might be modified with lifestyle changes [52, 53], especially increased physical activity, a screening of pre-diabetes or diabetes may be worthwhile.

Promotion of a healthy lifestyle and related activities should be strived for generally, but could also be conducted with the help of screening, as people might be more motivated to change eating and physical activity habits after they know their own health status. In the current setting, FPG significantly dropped among some participants from the time point of the screening to the baseline measurement of the following intervention study. During the screening process, counseling on a healthy lifestyle was provided to participants if requested. The blood glucose measurement together with counseling may already have led to a change in behavior and a drop in FPG. Nevertheless, in regard to the region's high levels of elevated BP and glucose levels, health promotion strategies should be established in addition to screening activities.

Limitations

The current study did not assess glucose tolerance. Measurement of glucose tolerance is not always feasible in resource-poor or work settings, as it is cumbersome and time consuming, especially in a screening setting [37, 54]. In the current screening, which had no diagnostic character, the measurement of FPG to define glycemic status was quick and easily administered by health staff. However, Yudkin and Montori (2014) expressed concerns about the new ADA cut-offs and the subsequent increase in pre-diabetes diagnoses, as well as the overall concept of categorizing people as pre-diabetic. They argue that it diverts attention from high risk people or diabetic individuals who need medical attention [55]. Rates of pre-diabetes may be even higher when an HbA1c cut-off of 5.7 to 6.4% is applied [55]. This was

also the case in the current screening in which 42% of participants had pre-diabetic HbA1c values compared to 35% or 12% having pre diabetic IFG levels according to ADA or WHO criteria, respectively. These results were confirmed in other studies reporting higher rates of elevated FPG using HbA1c than FPG [37] or 2-hour OGTT [56]. However, some other studies showed comparable rates [43], and some missed cases or found lower rates when ADA's recommended cut-offs for HbA1c were applied [57, 58]. Because the screening was tailored to include overweight and obese people, conclusions cannot be drawn about the overall population. Most measurements were only performed once, and there was no measurement of IGT to compare with FPG levels. The measurement of FPG was choosen as an easy method of assessing glycemic status in this setting. The point-of-care device for the measurements did not require continous access to electricity or extensive training of health staff. Zhao et al. demonstrated that the measurement of glycemic status using a capillary blood sample is a feasible screening method in a low-resource setting [59]. If FPG cannot be measured, RBG may be measured instead. Studies have demonstrated that a single RBG measurement of >100 mg/dL [60] or >125 mg/dL [61] were good predictors of diabetes.

Conclusions

The current procedure used to recruit pre-diabetic participants for a dietary intervention study led to an enrollment rate of 16% among people with a BMI of 27- 35 kg/m² and an age of 30-65 years. The low concordance between FPG and HbA1c needs further investigation, as well as the discrepancy between ADA and WHO definitions of IFG. Identified risk factors for increased FPG were age, WC, BMI, and having a family member with diabetes. During the pre-screening and screening phases, high rates of obesity, undiagnosed hypertension, and undiagnosed diabetes were found which require an extension of existing health programs in scope and capacity. The visited institutions and companies were all receptive to health issues, and this attitude could be utilized for health promotion and education on prevention. This study was not designed as a population screening for diabetes, but did detect a high number of undiagnosed diabetes. Further research may focus on analyzing costs and benefits of screening for chronic non-communicable diseases in that region of Tanzania.

Acknowledgements

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