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# BMJ Open

## Association between cardio-metabolic risk factors and body mass index, waist circumferences and body fat in a Zanzibari cross-sectional study

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Manuscripts

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3 **1 Association between cardio-metabolic risk factors and body mass index, waist**  
4 **2 circumferences and body fat in a Zanzibari cross-sectional study**  
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## 26 Abstract

27 **Objectives:** To determine the prevalence of obesity indices (body mass index (BMI), waist  
28 circumference (WC), body fat percent (BF%)) and cardio-metabolic risk factors. To  
29 investigate the association between obesity indices and cardio-metabolic risk factors in a  
30 Zanzibari population.

31 **Designs:** Cross-sectional study.

32 **Settings:** Participants randomly selected from 80 Shehias (wards) in Unguja, Zanzibar in  
33 2013.

34 **Participants:** A total of 470 participants between 5-95 years were examined. Data on socio-  
35 economic status, area of residence, anthropometry and venous blood were collected.  
36 Associations between obesity indices and cardio-metabolic risk factors were investigated  
37 using multilevel logistic regression analyses.

38 **Results:** The proportion of overweight/obese individuals was 26.4%, high WC (24.9%) and  
39 high BF% (31.1%). Cardio-metabolic risk factors with highest prevalence of abnormal values  
40 included hypertension (24.5%), low HDL-C (29.4%), high HDL-C (21.3%) and high HbA1c  
41 (19.1%). Obesity and hypertension increased with age, most prevalent in participants above  
42 45 years of age. Low-HDL-C was most prevalent among participants  $\geq 18$  to  $< 45$  years old,  
43 while high LDL-C was more prevalent above 45 years. BMI, WC and BF% were associated  
44 with hypertension (OR=2.41 (1.33, 4.47); OR=3.68 (1.81, 7.52); OR=2.51 (1.40, 4.51),  
45 respectively). High WC or high BF% was associated with higher chances of high levels of  
46 LDL-C (OR=2.52 (1.24, 5.13), OR=1.91 (1.02, 3.58), respectively). Additionally, BMI and  
47 WC were associated with levels of HbA1c (OR=2.08 (1.15, 3.79), OR=3.01 (1.51, 6.03),  
48 respectively). Considering obesity indices within one regression model, only high WC was  
49 associated with higher chances for hypertension (OR=2.62 (1.14, 6.06)) and for high levels of  
50 HbA1c (OR=2.62 (1.12, 6.15)). **Conclusion:** High BMI, WC and BF% were strongly

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3 51 associated with hypertension, individuals with high WC were twice more likely to have  
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5 52 hypertension. Overweight/obesity and cardio-metabolic risk factors were highly prevalent in  
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7 53 the present study population which calls for early and effective screening strategies for this  
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9 54 population.

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13 56 **Key words:** hypertension, diabetes, children, adolescents, adults, sub-Saharan Africa  
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## 18 19 20 58 **Strengths and limitations of this study**

- 21  
22  
23 59 • This is the first study to report the associations between obesity indices with cardio-  
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25 60 metabolic risk factors in Zanzibar.
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27 61 • The household-based approach, which involved visiting the families in the home setting,  
28  
29 62 resulted in a high individual response rate, thus minimise risk of selection bias
- 30  
31 63 • The cross-sectional design hindered us from concluding the impact of changes in obesity  
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33 64 indices on risk factors
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35 65 • Bioelectrical Impedance Analysis (BIA) was used to estimate body fat percentage which  
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37 66 might have underestimated adiposity in children.

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## 68 Introduction

69 Worldwide, cardiovascular diseases (CVDs) are the leading cause of death in individuals  
70 above 45 years of age <sup>1</sup> at least three quarters of the world's deaths from CVDs occur in low-  
71 and-middle-income countries (LMIC) <sup>2</sup> and CVDs are emerging as notable public health  
72 problem in sub-Saharan Africa <sup>3</sup>. These countries are undergoing epidemiological transition  
73 from communicable to non-communicable diseases (NCDs), which has been closely linked to  
74 increased urbanization and rural-urban migration which leads to unhealthy behaviours  
75 including poor dietary habits and sedentary lifestyles <sup>3 4</sup>. Most LMIC are dealing with a  
76 double burden of coexistence of underweight children and overweight/obese adults <sup>5</sup>, thus  
77 making it particularly difficult for policy makers to address the diverse population needs.  
78 Obesity is one of the global public health problems that is associated with CVDs <sup>6</sup>. Data from  
79 mainland Tanzania showed increasing prevalence of overweight and obesity in urban, peri-  
80 urban and rural areas <sup>7</sup>. According to the International Diabetes Federation (IDF) about 12  
81 million people are estimated to have type 2 diabetes mellitus in Africa <sup>8</sup>, where the  
82 prevalence ranged from 1% in rural Uganda to 12 % in urban Kenya <sup>9 10</sup>. Overweight and  
83 obesity have been identified to be modifiable risk factors for cardio-metabolic and other  
84 chronic diseases <sup>11</sup> including hypertension <sup>12</sup>, diabetes <sup>13</sup> and dyslipidemia <sup>14</sup>. Previous  
85 research <sup>15 16</sup> reported that both total body fat and adipose tissue distribution were associated  
86 with cardio-metabolic risk. Previous studies from sub-Saharan African countries described  
87 high prevalences of obesity and cardio-metabolic risk factors in adults in rural and urban  
88 areas <sup>11</sup>. Also associations between cardio-metabolic risk factors and socio-economic status  
89 (SES), urbanisation and lifestyle patterns in adults were found to be low <sup>3</sup>. However, there is  
90 still a dearth of population-based studies in sub-Saharan Africa investigating these  
91 associations with multiple cardio-metabolic risk factors and different obesity indices  
92 including body fat percent, e.g. in both Tanzania mainland and Zanzibar Island.

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3 93 Thus, based on cross-sectional data of 470 individuals between 5-95 years recruited in 2013  
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5 94 in Unguja Island, Zanzibar, this study first describes the prevalence of overweight/obesity  
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7 95 and cardio-metabolic risk factors in three age groups ( $\geq 5$  to  $< 18$  years,  $\geq 18$  to  $< 45$  years and  
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9 96 above 45 years), and secondly investigates the association of BMI, WC and BF% with  
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11 97 cardio-metabolic risk factors (hypertension, total cholesterol, triglycerides, high-density-  
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13 98 lipoprotein, low-density-lipoprotein, Glycated HbA1c, fasting plasma glucose and HOMA-  
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15 99 IR) considering either three obesity indices independently as well as BMI, WC, and BF%  
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17 100 combined reflecting different aspects of body composition.  
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## 102 **Subjects and Methods**

### 103 Study population and design

104 We conducted a cross-sectional survey from September to December 2013 in a representative  
105 population sample in Unguja Island, Zanzibar. A total of 239 households were randomly  
106 selected and all household members were invited for the examination. 1,443 family members  
107 were willing to participate and completed anthropometric and blood pressure measurements,  
108 interviewer-administered questionnaires, collection of morning spot urine and venous blood;  
109 detailed subgroup examinations were described below. The complete description of the study  
110 design and methods has been described in detail elsewhere <sup>17</sup>. The study was performed  
111 according to the Helsinki Declaration and the study protocol was evaluated and approved by  
112 the Ethics Committees of the University of Bremen and of the Zanzibar Ministry of Health  
113 and the Zanzibar Medical Research and Ethics Committee. All participants gave a written  
114 consent and parents/guardians gave a written consent on behalf of their children.

### 116 Patient and Public Involvement

117 Patients were not involved in this study.

### 119 Questionnaires and anthropometric measurements

120 Questionnaires were developed in English, translated into Swahili, and then back-translated  
121 to control for translation errors. Parents reported age and sex of their children and of  
122 themselves. Age was grouped into three categories  $\geq 5$  to  $<18$  years,  $\geq 18$  to  $<45$  years and 45  
123 years and above. In addition, their highest educational level according to the International  
124 Standard Classification of Education (ISCED) <sup>18</sup> was used as a proxy indicator for socio-



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3 125 economic status (SES) of the family and categorized into low education (no education and  
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5 126 primary school) and high education (secondary school and above). For assessing area of  
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7 127 residence of the participants, information on region, district and Shehia (the smallest  
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9 128 administrative unit in Zanzibar) were recorded and two categories for area of residence were  
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11 129 developed (urban and rural). For quality data collection, this study used proven examination  
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13 130 methods and laboratory standards<sup>19 20</sup>. All anthropometric measurements and physical  
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15 131 examinations were adopted from the IDEFICS Study and conducted following standardized  
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17 132 procedures<sup>21 22</sup>. Measurement of body weight was carried out to the nearest 0.1kg and body  
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19 133 fat percent was determined using bioelectrical impedance analysis (BIA) method using an  
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21 134 electronic scale (TANITA BC-420 SMA, Germany). Height was measured using (SECA 213  
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23 135 stadiometer. UK) and waist circumference (WC) was measured using an inelastic measuring  
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25 136 tape (SECA 201) midway between the lowest rib and the iliac crest, all measurements were  
26  
27 137 taken over light clothing and on standing position and were recorded to the nearest 0.1cm.  
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29 138 The complete description of the anthropometric measurements of the study have been  
30  
31 139 described elsewhere<sup>17</sup>.

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36 140 For children and adolescents, Body Mass Index (BMI) was calculated as  $\text{kg/m}^2$  and then  
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38 141 transformed to age-and sex-specific z-score and percentiles as well as categories for  
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40 142 overweight (BMI between  $>75^{\text{th}}$  and  $<95^{\text{th}}$  percentile) and obesity (BMI  $>95^{\text{th}}$  percentile)  
41  
42 143 according to the WHO centile curves<sup>23 24</sup>. For adults, overweight/obesity was defined as BMI  
43  
44 144  $\geq 25 \text{kg/m}^2$  as recommended by WHO<sup>25</sup>. Considering waist circumference (WC), high  
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46 145 abdominal obesity was defined as (WC  $\geq 90^{\text{th}}$  percentile) for children below 10 years<sup>26</sup>, WC  
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48 146  $\geq 90^{\text{th}}$  percentile for adolescents below 16 years and WC  $>94$  cm for men and  $> 80$  cm for  
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50 147 women for participants above 16 years as recommended by IDF<sup>27</sup>. Body fat percentage  
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52 148 (BF%) was categorized as high according to the  $\geq 85^{\text{th}}$  percentile with regard to boys and  
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54 149 girls below 18 years as recommended by McCarthy et al.<sup>28</sup>. For adults above 18 years, high  
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3 150 BF% was categorised as  $\geq 20$  for men and  $\geq 32$  for women <sup>29</sup>. The cut-offs and references are  
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5 151 listed in Table 1 below.  
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11 153 Cardio-metabolic risk factors  
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13 154 Fasting blood samples were collected from all eligible participants over 5 years of age by  
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15 155 venepuncture <sup>30</sup>, detailed procedures about the collection, processing and storage of blood  
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17 156 samples are described elsewhere <sup>17</sup>. Anthropometric measurements and collection of venous  
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19 157 blood was carried out in fasting status and processed according to international standards <sup>20</sup>.  
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21 158 Not being in fasting status was recorded using anthropometry documentation sheet.  
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23 159 Metabolic parameters were categorized for investigating the prevalence of cardio-metabolic  
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25 160 disorders in the study population. Due to the wide range of age groups in this study  
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27 161 population, different cardio-metabolic risk definitions and cut-offs were used (Table 1).  
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29 162 Cardio-metabolic risk for children between 5-10 years was defined according to age-sex-  
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31 163 specific cut-offs including hypertension (Systolic Blood Pressure (SBP) and Diastolic Blood  
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33 164 Pressure (DBP)), blood lipids (high Total Cholesterol (TC), high Triglycerides (TG), Low-  
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35 165 Density-Lipoprotein Cholesterol (LDL-C) and High-Density-Lipoprotein Cholesterol (HDL-  
36  
37 166 C)) and blood glucose/insulin (Homeostasis Model Assessment of Insulin Resistance  
38  
39 167 (HOMA-IR) and elevated Fasting Plasma Glucose (FPG) were defined according to the  
40  
41 168 IDEFICS Study <sup>26 31</sup> and Glycated hemoglobin (HbA1c) was defined according to Rodoo et  
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43 169 al. <sup>32</sup> for children under 17 years. For children, adolescence and adults from 10 years and  
44  
45 170 above, hypertension was defined according to age-sex-specific cut-offs as recommended <sup>33</sup>  
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47 171 we used this cut-off for children between 10 and 18 years only and for adult above 18 years  
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49 172 hypertension was defined as recommended <sup>34</sup>. Blood lipids (TC and LDL-C) were defined  
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51 173 according to National Cholesterol Education Program (NCEP) <sup>35</sup> and TG, HDL-C and FPG  
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174 were defined according to International Diabetes Federation (IDF) <sup>27</sup> . HbA1c for adults  
 175 above 17 years was defined according to Stern et al. <sup>36</sup> and insulin resistance was estimated as  
 176 HOMA-IR according to reference value of HOMA-IR as recommended by Shashaj et al. <sup>37</sup>.  
 177 In the present study, 75<sup>th</sup> percentile cut-off was used for children and adolescents from 10 till  
 178 17 years and for participants above 17 years, HOMA-IR was defined according to von Eyben  
 179 et al <sup>38</sup>. HOMA-IR was calculated from glucose (mmol/l) and insulin ( $\mu$ U/ml)  
 180 concentrations using the formula:  $HOMA-IR = (\text{fasting insulin} \times \text{fasting glucose} / 22.5)^{39}$ .

181 Table 1. Cardio-metabolic risk definitions and references

Age group	Obesity Indices and Blood Pressure	Blood lipids	Blood Glucose/Insulin
Children: $\leq 10$ y	BMI $\geq 75^{\text{th}}$ percentile <sup>1</sup>	TC $\geq 90^{\text{th}}$ percentile <sup>2</sup>	HbA1c $\geq 97.5^{\text{th}}$ percentile <sup>10</sup>
	WC $\geq 90^{\text{th}}$ percentile <sup>2</sup>	TG $\geq 90^{\text{th}}$ percentile <sup>2</sup>	HOMA-IR $\geq 95^{\text{th}}$ percentile <sup>2</sup>
	BF % $\geq 85^{\text{th}}$ percentile <sup>3</sup>	HDL-C $\leq 10^{\text{th}}$ percentile <sup>2</sup>	FPG $\geq 95^{\text{th}}$ percentile <sup>2</sup>
	SBP $\geq 90^{\text{th}}$ centile or DBP $\geq 90^{\text{th}}$ centile <sup>2</sup>	LDL $\geq 90^{\text{th}}$ percentile <sup>2</sup>	
Adolescents: >10 to <16 y	BMI $\geq 75^{\text{th}}$ percentile <sup>1</sup>	TC $\geq 5.2$ mmol/L <sup>6</sup>	HbA1c $\geq 97.5^{\text{th}}$ percentile <sup>10</sup>
	WC $\geq 90^{\text{th}}$ percentile <sup>4</sup>	TG $\geq 1.7$ mmol/L <sup>4</sup>	HOMA-IR $\geq 75^{\text{th}}$ percentile <sup>9</sup>
	BF % $\geq 85^{\text{th}}$ percentile <sup>3</sup>	HDL-C $< 1.03$ <sup>4</sup>	FPG $\geq 5.6$ mmol/L <sup>4</sup>
	SBP $\geq 140$ mmHg or DBP $\geq 90$ mmHg <sup>11</sup>	LDL $\geq 3.4$ mmol/L <sup>6</sup>	
Adults: $\geq 16$ y	BMI $\geq 25$ kg/m <sup>1</sup>	TC $\geq 5.2$ mmol/l <sup>6</sup>	HbA1c $\geq 6.1\%$ <sup>5</sup>
	WC $\geq 94$ cm male, $\geq 80$ cm female <sup>4</sup>	TG $\geq 1.7$ mmol/L, <sup>4</sup>	HOMA-IR $> 4.65$ or HOMA-IR $> 3.60$ and BMI $> 27.5$ kg/m <sup>2</sup> <sup>7</sup>
	BF % $\geq 20$ male and $\geq 32$ female <sup>8</sup>	HDL-C $< 1.03$ male, $< 1.29$ female <sup>4</sup>	FPG $\geq 5.6$ mmol/L <sup>4</sup>
	SBP $\geq 140$ mmHg or DBP $\geq 90$ mmHg <sup>12</sup>	LDL $\geq 3.4$ mmol/L <sup>6</sup>	

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183 1 WHO

184 2 IDEFICS Study

185 3 McCarthy, H.D., et al. (2006)

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3 186 4 IDF  
4 187 5 Stern, S.E., et al (2003) for adults above 17 years  
5 188 6 NCEP  
6 189 7 von Eyben, F.E., et al (2005)  
7 190 8 Gallagher, D., et al (200)  
8 191 9 Shashaj et al. (2015)for children and adolescence under 17 years  
9 192 10 Rodoo P et al. (2013)  
10 193 11, 12 National Institute of Health 3<sup>rd</sup> and 7<sup>th</sup> report respectively  
11 194

### 13 195 Inclusion criteria for study sample

15 196 Out of 1,443 individuals who participated in this study, 1,314 fulfilled the inclusion criteria  
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17 197 (age, sex, weight, height) for the overall study analysis. Of the 1,314 participants, 1,234  
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19 198 provided complete waist circumference and body fat percent measurements. Among those,  
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21 199 557 provided complete blood samples for the cardio-metabolic risk analysis and out of those  
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23 200 only 505 were on fasting status. Top 1% was excluded for cardio-metabolic risk and obesity  
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25 201 indices variables with high extreme values, thus remaining with a complete sample size of  
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27 202 470 participants included in the analysis.  
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### 32 204 Statistical analysis

34 205 Descriptive analyses were conducted to calculate mean standard deviation (SD) and range  
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36 206 (minimum, maximum) for continuous variables as well as distribution of the categorical data  
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38 207 in N and percentages (%). Mixed logistic regression models were used to analyse the  
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40 208 association between obesity indices and cardio-metabolic risk factors. In addition, potential  
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42 209 clustering within households was considered in terms of a random intercept. Following the  
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44 210 hierarchy of the municipal structure in Zanzibar, we conducted sensitivity analysis modeling  
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46 211 either shehias or households within shehias as a random intercept in the models. Since results  
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48 212 of the models showed only marginal differences, we only considered household as a random  
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50 213 intercept in our analyses. First, logistic regression models were calculated separately for each  
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52 214 obesity indicator (BMI, WC and BF%) as exposure variables against each of the risk factors  
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3 215 (hypertension, TC, TG, HDL-C, LDL-C, HbA1C, FPG and HOMA-IR) as dependent  
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5 216 variables. Since BMI, WC and BF% are interrelated, their predictive power on cardio-  
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7 217 metabolic risk factors was investigated in a regression model considering all obesity indices  
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9 218 against each of the risk factors. All models were adjusted for potential confounders such as  
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11 219 gender, age, education level (ISCED) and area of residence, while with regard to  
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13 220 hypertension, utilization of medication was also included in the analysis. Statistical analyses  
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15 221 were performed using SAS 9.3 (SAS Institute. Cary. NC. U SA) and particularly mixed  
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17 222 logistic regression models were conducted based on the GLIMMIX procedure.  
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## 224 Results

### 225 Characteristics of study population

226 General characteristics of the study sample (N=470) are described in Table 2. Mean age was  
 227 29 ( $\pm 18$ ) years with the highest proportion of participants from the age group ( $\geq 18$  to  $< 45$   
 228 years). The overall mean BMI was 22 ( $\pm 5.2$ )kg/m<sup>2</sup>, WC was 75 ( $\pm 16$ ) cm and BF% was 22  
 229 ( $\pm 11$ ) %, the mean BMI 26 ( $\pm 5.7$ )kg/m<sup>2</sup> for participants above 45 years was slightly higher  
 230 than normal indicating overweight. Mean diastolic blood pressure was on normal range for all  
 231 the age groups, a higher mean value of systolic blood pressure 150 ( $\pm 28$ )mmHg was  
 232 observed among participants above 45 years. The mean values of most of the variables  
 233 showed an increase with age group except for HDL-C and diabetes markers (HbA1c, serum  
 234 insulin, plasma glucose and HOMA-IR) which showed no specific trend.

235 Table 2: characteristics of study population (n=470) in terms of means and standard deviation  
 236 (SD) and range.

	$\geq 5$ to $< 18$ years (n=165)		$\geq 18$ to $< 45$ years (n=195)		45+years (n=110)		Total (n=470)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Age (years)	12 (3.4)	4.9 -18	28 (8.1)	18-44	57 (9.8)	45-95	29 (18)	4.9-95
BMI (kg/m)	17 (3.4)	11-34	23 (4.5)	16-37	26 (5.7)	15-49	22 (5.7)	11-49
WC (cm)	61 (11)	12-103	79 (12)	37-111	88 (0.2)	35-126	75 (16)	12-126
BF (%)	15 (7.0)	1.6-45	23 ( 11)	3.0-53	28 (10)	6.2-53	22 (11)	1.6-53
DBP (mmHg)	67 (9.8)	44-97	76 (10)	53-126	88 (15)	62-140	75 (14)	44-140
SBP (mmHg)	110 (13)	69-152	123 (16)	72-197	150 (28)	100-229	125 (24)	69-229
TC (mmol/l)	3.7 (0.7)	1.8-5.9	3.9 (0.8)	2.1-6.0	4.2 (0.8)	0.2-5.9	3.9 (0.8)	0.2-6.0
TG (mmol/l)	0.8 (0.3)	0.3-2.5	0.9 (0.4)	0.0-2.6	1.0 (0.4)	0.4-2.7	0.9 (0.4)	0.0-2.7
HDL-C (mmol/l)	1.4 (0.5)	0.7-3.3	1.5 (0.5)	0.6-3.7	1.4 (0.4)	0.6-3.6	1.4 (0.5)	0.6-3.7
LDL-C (mmol/l)	2.3 (0.9)	0.0-5.0	2.5 (0.9)	0.7-5.1	3.0 (1.0)	0.6-5.1	2.5 (1.0)	0.0-5.1
HbA1c (%)	5.7 (0.5)	4.2-8.5	5.6 (0.6)	3.9-9.4	6.0 (0.8)	4.4-10	5.8 (0.6)	3.9-10
Serum Insulin (mmol/l)	4.3 (3.1)	0.4-18	4.8 (2.8)	0.8-17	3.6 (2.3)	0.4-17	4.4 (2.8)	0.4-18
FPG (mmol/l)	4.9 (0.8)	2.0-7.7	4.8 (0.9)	0.5-9.4	5.1 (1.3)	0.2-13	4.9 (1.0)	0.2-13
HOMA-IR	1.0 (0.7)	0.1-4.6	1.1 (0.7)	0.0-4.3	0.9 (0.6)	0.0-4.0	1.0 (0.7)	0.0-4.6

237

238 Distribution of obesity and cardio-metabolic risk in the study population by age groups

239 Table 3 shows the distribution of obesity markers and cardio-metabolic risks by age-group.  
 240 Of the 470 participants, more than half were women 52.6% (n=247). The overall proportion  
 241 of overweight/obesity with regard to BMI, WC and BF % was 26.4%, 24.9% and 31.1%  
 242 respectively and increased with age, where the highest proportions were observed in  
 243 participants above 45 years. We observed different trends in the prevalence of metabolic  
 244 parameters and hypertension across age groups: the prevalence of hypertension, total  
 245 cholesterol, LDL-C and HbA1c increased with age except for triglycerides and HOMA-IR  
 246 which decreased with age. The most prevalent factors were reduced HDL-C (29.4%),  
 247 hypertension (24.5%), raised LDL-C (21.3%) and HbA1c levels (19.1%). Hypertension,  
 248 LDL-C and HbA1c were more prevalent in participants above 45 years, and low HDL-C was  
 249 most prevalent among  $\geq 18$  to  $< 45$  year olds.

250

251 Table 3: Distribution of obesity and cardio-metabolic risk in the study population by age  
 252 group, n=470.

	$\geq 5$ to $< 18$ years		$\geq 18$ to $< 45$ years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
All	165	(100)	195	(100)	110	(100)	470	(100)
Gender								
Male	85	(51.5)	86	(44.1)	52	(47.3)	223	(47.4)
Female	80	(48.5)	109	(55.9)	58	(52.7)	247	(52.6)
<b>Obesity Indices</b>								
BMI								
Underweight	83	(50.3)	29	(14.9)	9	(8.18)	121	(25.7)
Normal weight	73	(44.2)	106	(54.4)	46	(41.8)	225	(47.9)
Overweight/obese	9	(5.45)	60	(30.8)	55	(50.0)	124	(26.4)
Waist circumference								
Normal	165	(100)	141	(72.2)	47	(42.7)	353	(75.1)

	≥5 to <18 years		≥18 to <45 years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
High <sup>a</sup>	0	(0)	54	(27.7)	63	(57.3)	117	(24.9)
<b>Body fat %</b>								
Normal	157	(95.2)	121	(62.1)	46	(41.8)	324	(69.0)
High <sup>b</sup>	8	(4.86)	74	(37.9)	64	(58.2)	146	(31.1)
<b>Hypertension</b>								
Normal	123	(74.5)	76	(39.0)	10	(9.09)	209	(44.5)
Pre-hypertension	25	(15.8)	89	(45.6)	31	(28.2)	146	(31.1)
Hypertension	16	(9.70)	30	(15.4)	69	(62.7)	115	(24.5)
<b>Dyslipidaemia<sup>c</sup></b>								
<b>Total cholesterol</b>								
Normal	161	(97.6)	183	(93.8)	102	(92.7)	446	(94.9)
High	4	(2.42)	12	(6.15)	8	(7.27)	24	(5.11)
<b>Triglycerides</b>								
Normal	157	(95.2)	186	(95.4)	105	(95.5)	448	(95.3)
High	8	(4.85)	9	(4.62)	5	(4.55)	22	(4.68)
<b>HDL-cholesterol</b>								
Normal	126	(76.4)	128	(65.6)	78	(70.9)	332	(70.5)
Low	39	(23.6)	67	(34.4)	32	(29.1)	138	(29.4)
<b>LDL-cholesterol</b>								
Normal	141	(85.5)	163	(83.6)	66	(60.0)	370	(78.7)
High	24	(14.5)	32	(16.4)	44	(40.0)	100	(21.3)
<b>Diabetes Markers<sup>d</sup></b>								
<b>HbA1C</b>								
Normal	142	(86.1)	166	(85.1)	72	(65.5)	380	(80.9)
High	23	(13.9)	29	(14.9)	38	(34.5)	90	(19.1)
<b>Plasma glucose</b>								
Normal	136	(82.4)	167	(85.6)	88	(80.0)	391	(83.2)
High	29	(17.6)	28	(14.4)	22	(20.0)	79	(16.8)
<b>HOMA-IR</b>								
Normal	162	(98.2)	193	(99.0)	109	(99.1)	464	(98.7)
High	3	(1.82)	2	(1.03)	1	(0.91)	6	(1.28)

253

254 <sup>a</sup> High WC was defined as WC ≥90<sup>th</sup> percentile for children under 10y<sup>26</sup>. Adolescents  
 255 between 10-16 years and adults above 16 years WC > 94 cm for men and > 80 cm for women  
 256 according to IDF cut-off<sup>27</sup>

257 <sup>b</sup> High BF% for adults (overweight/obese) ≥ 20 for men and ≥32 for women according to  
 258 (NIH/WHO) BMI guidelines<sup>29</sup> and ≥85<sup>th</sup> percentile for children<sup>28</sup>

259 <sup>c</sup> High dyslipidemia for adults; was defined as total serum cholesterol (≥6.2mmol/l) and  
 260 LDL-cholesterol (≥3.4mmol/l)<sup>35</sup> low HDL-C:<1.03 mmol/l in men or <1.29 mmol/l in



261 women high and hypertriglyceridemia ( $\geq 1.7$  mmol/l)<sup>27</sup> and for children according to  
 262 IDEFICS study<sup>26</sup>  
 263 <sup>d</sup> High diabetes risk markers; high HbA1C ( $>6.1\%$ )<sup>38</sup>, high fasting plasma glucose ( $\geq 5.6$   
 264 mmol/l)<sup>27</sup> and HOMA-insulin resistance was defined as HOMA-IR  $>4.65$ . or HOMA-IR  
 265  $>3.60$  and BMI  $>27.5$  kg/m<sup>2</sup><sup>36</sup> and for children high HbA1c ( $\geq 97.5^{\text{th}}$  percentile), high fasting  
 266 plasma glucose  $\geq 95^{\text{th}}$  percentile and HOMA-IR  $\geq 95^{\text{th}}$  percentile.  
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#### 270 Association between obesity indices and cardio-metabolic risk factors

271 Results of the mixed logistic regression models are presented in Table 4. Obesity indices  
 272 (BMI, WC and BF %) were found to be associated with one or more risk factors. Participants  
 273 having high BMI (OR=2.41 (1.33, 4.47)), high WC (OR=3.68 (1.81, 7.52)) or high BF%  
 274 (OR=2.51 (1.40, 4.51)) were more likely to be hypertensive. Having high WC (OR=2.52  
 275 (1.24, 5.13)) or high BF% (OR=1.91 (1.02, 3.58)) were associated with higher chances of  
 276 having high LDL-C. Furthermore, BMI (OR=2.08 (1.15-3.79)) and WC (OR=3.01 (1.51-  
 277 6.03)) were associated with HbA1c levels. We further observed increased OR for obesity  
 278 indices with regard to high total cholesterol, high triglycerides, low HDL-C, elevated glucose  
 279 and HOMA-IR. Due to a very small sample in HOMA-IR, the results were omitted. Looking  
 280 at goodness of fit of the the models, the AIC values showed that models including WC as an  
 281 obesity index tend to have a slightly stronger predictive power compared to models including  
 282 BMI and BF%.

283

284 Table 4: Associations between obesity indices (independent) and cardio-metabolic risk  
 285 factors (dependent), adjusted for gender, age, education level, area of residence, and  
 286 medication (for hypertension only) (n=470)

Obesity indices	High BMI			High WC			High BF%		
	Risk factors	OR	(95% CI)	AIC	OR	(95% CI)	AIC	OR	(95% CI)

Hypertension	<b>2.41</b>	<b>1.33</b>	<b>4.47</b>	<b>504.86</b>	<b>3.68</b>	<b>1.81</b>	<b>7.52</b>	<b>499.79</b>	<b>2.51</b>	<b>1.40</b>	<b>4.51</b>	<b>503.46</b>
High Total cholesterol	1.13	0.40	3.19	192.74	0.84	0.27	2.66	192.71	1.05	0.37	2.95	192.79
High Triglycerides	1.79	0.55	5.77	189.88	2.23	0.58	8.66	189.38	1.64	0.52	5.14	190.11
Low HDL cholesterol	1.21	0.62	2.37	516.08	1.15	0.55	2.42	516.25	1.06	0.54	2.05	516.37
High LDL cholesterol	1.45	0.78	2.69	457.62	<b>2.52</b>	<b>1.24</b>	<b>5.13</b>	<b>452.23</b>	<b>1.91</b>	<b>1.02</b>	<b>3.58</b>	<b>454.77</b>
High HbA1c	<b>2.08</b>	<b>1.15</b>	<b>3.79</b>	<b>442.70</b>	<b>3.01</b>	<b>1.51</b>	<b>6.03</b>	<b>438.53</b>	1.75	0.96	3.18	445.23
High Glucose	2.04	0.93	4.50	397.36	2.07	0.84	5.07	397.98	1.76	0.80	3.87	398.56

287

288 Table 5 presents results of mixed logistic regression models including all three obesity  
 289 indices to investigate the association with single cardio-metabolic risk factors. Compared to  
 290 the separate regression models, the ORs for most of the associations were attenuated.  
 291 However, having high WC again was associated with a higher chance of hypertension  
 292 (OR=2.62 (1.14, 6.06)) and having high HbA1c levels (OR=2.62 (1.12, 6.15)).

293

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295 Table 5: Associations between obesity indices (independent) and cardio-metabolic risk  
 296 factors (outcome) adjusted by gender, age, education level and area of residence (n=470)

Obesity indices	Combined Obesity Indices									AIC total
	BMI			WC			BF%			
	OR	(95% CI)		OR	(95% CI)		OR	(95% CI)		
Hypertension	1.19	0.48	2.95	<b>2.62</b>	<b>1.1</b>	<b>6.06</b>	1.48	0.63	3.51	501.3
High Total	1.31	0.25	6.79	0.71	0.1	2.92	1.01	0.19	5.32	196.5
High Triglycerides	1.34	0.25	7.16	1.90	0.3	9.52	1.02	0.19	5.52	193.2
Low HDL	1.35	0.48	3.76	1.09	0.4	2.67	0.82	0.98	2.25	519.9
High LDL	0.63	0.24	1.65	2.34	0.9	5.50	1.81	0.70	4.70	454.6
High HbA1c	1.53	0.61	3.81	<b>2.62</b>	<b>1.1</b>	<b>6.15</b>	0.82	0.32	2.10	441.6
Elevated Glucose	1.67	0.55	5.06	1.54	0.5	4.44	1.03	0.33	3.17	400.6

## 297 **Discussion**

298 This study is the first population-based survey in Unguja Island that investigated the  
299 association between multiple obesity indices (BMI, WC and BF%) with multiple cardio-  
300 metabolic risk factors in a representative Zanzibari population, aged between 5-95 years. This  
301 study population, like in many other LMICs is undergoing a coexistence of a double burden  
302 of underweight children and overweight/obese adults. Generally, about a quarter of the study  
303 population were overweight/obese, and obesity increased with age, this has also been  
304 reported in demographic health surveys from seven sub-Saharan African countries<sup>40</sup>. In the  
305 adult population, the prevalence of overweight/obesity was lower than the prevalence  
306 reported for example in Ghana<sup>11</sup> but higher than that reported in Nigeria<sup>3</sup> and Benin<sup>41</sup>. In  
307 parallel, more than 50% of the children in this study were underweight, which is higher than  
308 the reported prevalence in other sub-Saharan African countries (Kenya, Nigeria, South Africa,  
309 Equatorial Guinea and Cameroon)<sup>42</sup>.

310 Dyslipidemia is a risk for variety of cardiovascular diseases and is becoming more prevalent  
311 in sub-Saharan Africa, particularly in terms of low HDL-C<sup>43 44</sup>. Despite the relatively normal  
312 levels of total cholesterol and triglycerides, low HDL-C affected about 29% of the overall  
313 population, an indication that low HDL-C affects a large proportion of adults above 18  
314 years, this is in line with a recent study in sub-Saharan Africa and Middle East with 30% of  
315 the participant having low HDL-C<sup>45</sup>; other studies in sub-Saharan Africa reported even a  
316 higher prevalence of 43.1% in Nigeria<sup>3</sup> and 80% in Botswana<sup>46</sup>, mostly affecting individuals  
317 between 35-54 years.

318 In the present study, high proportion of participants with high HbA1c (14.1%) and elevated  
319 fasting glucose (18%) are children below 18 years; since diabetes in children in LMICs has  
320 not been given much attention, there is a high chance of having more children with sub-

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3 321 clinical complications due to delayed or missed diagnosis and lack of frequent monitoring.  
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5 322 The high proportions in this study could be due to the fact that majority of the diabetic  
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7 323 participants are not aware of their status and are not monitored or treated. However, when  
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9 324 using WHO diabetes diagnostic criteria <sup>47</sup>, i.e. HbA1c cut-off  $\geq 6.5\%$  and FPG  $\geq 7.0$ mmol/l,  
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11 325 the prevalence of diabetes in participants above 18 years reduced to 8.14% and 3.05%,  
12  
13 326 respectively (data not shown). The most intriguing result is the risk for diabetes and/or  
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15 327 diabetic in children below 18 years when screened by elevated fasting glucose levels  
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17 328  $\geq 5.6$ mmol/l, as recommended by IDF <sup>27</sup>. In this study, the prevalence is higher than that of  
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19 329 adults above 18 years but less than adults above 45 years. This could be due to both a)  
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21 330 misreporting (children did not report having eaten prior to the blood drawing) and b) a true  
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23 331 high risk within this age group. However, when using WHO <sup>47</sup> diabetes diagnostic criteria  
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25 332 (FPG  $\geq 7$ mmol/l) for the same age group, the prevalence reduced to 0.61% (data not shown).  
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27 333 This indicates, that majority of the children are at risk for diabetes and that the cut-off for  
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29 334 HbA1c  $\geq 6.1\%$  as well as elevated FPG  $\geq 5.6$  mmol/l seem to be better screening tools in  
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31 335 identifying those at risk earlier.  
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36 336 Our study showed that there is an association between BMI, WC and BF% with major cardio-  
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38 337 metabolic risk factors in the study population. These findings are in agreement with other  
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40 338 studies who also reported the association between hypertension/pre-hypertension, BMI and  
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42 339 WC <sup>48</sup> as well as BF% <sup>11</sup>. This study also observed a strong association between WC and  
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44 340 LDL-C levels, similar association has also been reported in a comparative cross-sectional  
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46 341 study in Ghana by Obirikorang <sup>11</sup>. In the separate models, strong associations were observed  
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48 342 between BMI and WC with HbA1c levels, which could be explained by the interrelation of  
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50 343 the two indices, since abdominal fat accumulation is increased in proportion to BMI <sup>49</sup> and  
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52 344 BMI is one of the main risk factors for diabetes and pre-diabetes <sup>50 51</sup>. However, considering  
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3 345 the association of all three obesity indices, only the strong associations of WC with HbA1c  
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5 346 levels and hypertension remained.  
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8 347 This study has some limitations that should be considered. First, we were only able to  
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10 348 investigate the association between obesity indices and risk factors using cross-sectional data,  
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12 349 thus the impact of changes in obesity indices on risk factors could not be considered. Second,  
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14 350 we used Bioelectrical Impedance Analysis (BIA) to estimate body fat percentage as many  
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16 351 epidemiological studies and clinical trials. Still, BIA measurements compared to skinfold  
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18 352 measurements may underestimate adiposity in children <sup>52</sup> Third, even though participants  
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20 353 who reported food or beverage intake prior to blood drawing were excluded during the data  
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22 354 cleaning process, we can not entirely exclude misreporting of “fasting status”.  
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26 355 The main strengths of the present study are; the random selection of the study participants,  
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28 356 and the standardised assessment of anthropometrical and laboratory measurements.  
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30 357 Moreover, we consequently applied age- and sex-specific cut-offs that take into account the  
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32 358 physiological development characteristic of the young age group rather than applying the  
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34 359 fixed cut-offs used in the adult population. There is little information on the association of  
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36 360 multiple obesity indices with multiple cardio-metabolic risk factors in this population, hence  
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38 361 this study to our knowledge is the first to report such associations in the Island of Unguja in  
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40 362 Zanzibar.  
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## 365 **Conclusion**

366 This study adds up to the literature that obesity is associated with higher risks for having  
367 hypertension, dyslipidemia and type 2 diabetes mellitus, but for the first time in a Zanzibari  
368 population. For similar epidemiological studies including children, adolescents, adults and  
369 elderly, we suggest to set diabetes and/or pre-diabetes cut-offs of HbA1c at  $\geq 6.1\%$  and/or  
370 elevated fasting glucose at  $\geq 5.6\text{mmol/l}$ . The study also suggests, when feasible, using BF%  
371 and WC besides BMI in screening and health monitoring for dyslipidemia and hypertension.  
372 We further conclude, there is a need for effective interventions to create awareness and a  
373 need for primary prevention strategies for cardio-metabolic risks and its complications in  
374 Unguja Island using local multidisciplinary approaches in the local language, Swahili.  
375 Additionally, health surveillance initiatives, targeting in particular the age group  $\geq 18$  to  $< 45$   
376 years will help to monitor prevention activities in future.

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3 378 **List of Abbreviations**  
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BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
HbA1c	Glycated Haemoglobin
HDL-C	High Density-Lipoprotein Cholesterol
HOMA-IR	homeostasis model assessment of insulin resistance
IDEFICS	Identification and prevention of Dietary-and lifestyle-induced health EFects In Children and infantS
IDF	International Diabetes Federation
ISCED	International Standard Classification of Education
LDL-C	Low Density-Lipoprotein Cholesterol
LMICs	Low-middle-Income Countries
NCDs	Non-Communicable Diseases
WC	Waist Circumference
WHO	World Health Organization

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## 381 **Declarations**

### 382 **Ethics Approval and Consent to participate**

383 Ethical approval was obtained from the Ethics Committees of the University of Bremen in  
384 Germany with a reference number 06-3 and of the Zanzibar Ministry of Health and the  
385 Zanzibar Medical Research and Ethics Committee in Zanzibar, Tanzania with a reference  
386 number ZAMREC/0001/AUGUST/013. Written informed consents were taken from all  
387 participants and parents/guardians gave a written informed consent for their children. The  
388 consent forms were approved by the Institutional Ethics Committee.

### 390 **Competing interests**

391 The authors declare that they have no competing interests.

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### 396 **Author Contributions**

397 The authors' responsibilities were as follows: AH and SK were responsible for study design.  
398 AH and MAN conducted data collection and developed study hypothesis. MAN and CB  
399 conducted statistical analyses and KB assisted in the statistical data cleaning. MAN wrote  
400 the manuscript and had primary responsibility for final content. MN,CB,SK,MS,KB and AH  
401 critically revised the manuscript and gave final consent.

### 403 **Availability of data and materials**



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2  
3 404 The datasets generated and/or analysed during the current study are not publicly available  
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5 405 since a follow-up study is planned.  
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9 407 **Consent for publication**

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11 408 All participants agreed and signed that; the data collected during the survey can be stored and  
12  
13 409 used for future analysis.  
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18 411 **Acknowledgement**

19  
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# BMJ Open

## Association between cardio-metabolic risk factors and body mass index, waist circumferences and body fat in a Zanzibari cross-sectional study

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3 **1 Association between cardio-metabolic risk factors and body mass index, waist**  
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5 **2 circumferences and body fat in a Zanzibari cross-sectional study**  
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## 26 Abstract

27 **Objectives:** To determine the prevalence of obesity indices (body mass index (BMI), waist  
28 circumference (WC), body fat percent (BF%)) and cardio-metabolic risk factors. To  
29 investigate the association between obesity indices and cardio-metabolic risk factors in a  
30 Zanzibari population.

31 **Designs:** Cross-sectional study.

32 **Settings:** Participants randomly selected from 80 Shehias (wards) in Unguja, Zanzibar in  
33 2013.

34 **Participants:** A total of 470 participants between 5-95 years were examined. Data on socio-  
35 economic status, area of residence, anthropometry and venous blood were collected.  
36 Associations between obesity indices and cardio-metabolic risk factors were investigated  
37 using multilevel logistic regression analyses in two steps: first, each obesity indicator was  
38 tested independently; second, all indicators combined in one model were tested for their  
39 association with cardio-metabolic risk factors.

40 **Results:** The proportion of overweight/obese individuals was 26.4%, high WC (24.9%) and  
41 high BF% (31.1%). Cardio-metabolic risk factors with highest prevalence of abnormal values  
42 included hypertension (24.5%), low HDL-C (29.4%), high LDL-C (21.3%) and high HbA1c  
43 (19.1%). Obesity and hypertension increased with age, and were most prevalent in  
44 participants aged 45 years and above. Low HDL-C was most prevalent among participants  
45  $\geq 18$  to  $< 45$  years old, while high LDL-C was more prevalent in those above 45 years. High  
46 WC and high BF% were associated with high levels of LDL-C (OR=2.52 (1.24, 5.13),  
47 OR=1.91 (1.02, 3.58), respectively). Additionally, BMI and WC were associated with high  
48 levels of HbA1c (OR=2.08 (1.15, 3.79), OR=3.01 (1.51, 6.03), respectively). In the combined  
49 regression model WC was associated with higher chances for hypertension (OR=2.62 (1.14,  
50 6.06)) and for high levels of HbA1c (OR=2.62 (1.12, 6.15)). **Conclusion:** High BMI, WC

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3 51 and BF% were strongly associated with hypertension, with individuals with high WC being  
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5 52 twice more likely to have hypertension; this calls for early and effective screening strategies  
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8 53 for this study population.  
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12 55 **Key words:** hypertension, diabetes, children, adolescents, adults, sub-Saharan Africa  
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## 18 19 57 **Strengths and limitations of this study**

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22 58 • This is the first study to report the associations between obesity indices and cardio-  
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24 59 metabolic risk factors in Zanzibar.  
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27 60 • The household-based approach, which involved visiting the families in the home setting,  
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29 61 resulted in a high individual response rate, thus minimising risk of selection bias.  
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32 62 • The cross-sectional design prevents us from drawing conclusions regarding the impact of  
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34 63 changes in obesity indices on risk factors.  
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37 64 • Bioelectrical Impedance Analysis (BIA) was used to estimate body fat percentage, which  
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39 65 might have underestimated adiposity in children.  
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## 67 Introduction

68 Worldwide, cardiovascular diseases (CVDs) are not only the leading cause of death<sup>1</sup>, they are  
69 also emerging as a notable public health problem in sub-Saharan African countries <sup>2</sup>. These  
70 countries are undergoing epidemiological transitions from communicable to non-  
71 communicable diseases (NCDs) that have been closely linked to increased urbanization and  
72 rural-urban migration, which has led to unhealthy behaviours, including poor dietary habits  
73 and sedentary lifestyles <sup>2 3</sup>. According to the International Diabetes Federation (IDF), about  
74 12 million people in Africa are estimated to have type 2 diabetes mellitus <sup>4</sup>, with the  
75 prevalence ranging from 1% in rural Uganda to 12 % in urban Kenya <sup>5 6</sup>. Overweight and  
76 obesity have been found to be modifiable risk factors for cardio-metabolic and other chronic  
77 diseases <sup>7</sup> including hypertension <sup>8</sup>, diabetes <sup>9</sup> and dyslipidemia <sup>10</sup>. The third report of the  
78 National Cholesterol Education Program-Adult treatment Panel (NCEP-ATP III) also  
79 identified central obesity, dyslipidemia (hypertriglyceridemia and low levels of high-density  
80 lipoprotein cholesterol [HDL-C]), impaired glucose tolerance, and elevated blood pressure as  
81 cardio-metabolic risk factors<sup>11</sup>.

82 Multiple obesity indices such as BMI, Waist Circumference (WC), Body fat percent (BF%)  
83 and Waist to Hip Ratio (WtHR) have been widely used to screen individuals for cardio-  
84 metabolic risk in clinical and research settings<sup>12-14</sup> due to their low-cost and ease of  
85 administration. The performance of anthropometric indices may however vary according to  
86 different factors, including ethnicity, age, geographical area and population<sup>13 15</sup>. BMI, which  
87 is based on weight and height, is the most widely used marker to assess body mass. In  
88 children and adolescents, the z-scores are used to classify obesity status <sup>16</sup>, which is linked to  
89 metabolic risk, e.g. in South African youth<sup>17</sup>. However, BMI does not distinguish well  
90 between lean mass and fat mass<sup>18</sup>. In contrast, WC is a measure of total body and abdominal  
91 fat accumulation and is better correlated with visceral adipose tissues than BMI. The

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3 92 correlation on the other hand varies significantly across ethnicities<sup>19 20</sup>. Another approach for  
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5 93 measuring body fat is through bioelectrical impedance analysis, which has also been done in  
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8 94 several epidemiological studies<sup>21</sup>. The use of different anthropometric measurements might  
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10 95 also provide complementary information which can be used to aid screening for cardio-  
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12 96 metabolic risk in different population settings<sup>22 23</sup>.  
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14 97 Few studies have investigated the performance of different obesity indices in association with  
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16 98 cardio-metabolic risk factors in sub Saharan African populations<sup>2 7 18</sup>. Data from mainland  
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18 99 Tanzania have shown an increasing prevalence of overweight and obesity in urban, peri-  
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20 100 urban and rural areas<sup>24</sup>. However, there is still a dearth of population-based studies  
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22 101 investigating the associations of cardio-metabolic risk factors with obesity indices in  
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24 102 Tanzania mainland and Zanzibar. To help fill this gap, this study uses cross-sectional data of  
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26 103 470 individuals between 5-95 years who were examined in 2013 in Unguja Island, Zanzibar,  
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28 104 to describe the prevalence of overweight/obesity and cardio-metabolic risk factors in three  
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30 105 age groups ( $\geq 5$  to  $< 18$  years,  $\geq 18$  to  $< 45$  years and above 45 years). The aim of the study was  
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32 106 to identify vulnerable groups in the Zanzibari population with respect to cardio-metabolic  
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34 107 risk. Consequently, we investigated the association of BMI, WC and BF% with cardio-  
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36 108 metabolic risk factors (hypertension, total cholesterol, triglycerides, high-density-lipoprotein,  
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38 109 low-density-lipoprotein, glycated HbA1c, fasting plasma glucose and HOMA-IR). We  
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40 110 considered the three obesity indices independently as well as combined, thereby reflecting  
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42 111 different aspects of body composition.  
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## 113 **Subjects and Methods**

### 114 Study population and design

115 We conducted a cross-sectional survey from September to December 2013 in a representative  
116 population sample in Unguja Island, Zanzibar. A total of 239 households were randomly  
117 selected and all household members were invited for the examination. As we also aimed to  
118 identify vulnerable groups within the families, we included young children and the elderly,  
119 who both normally depend on the family food environment. A two-staged sampling approach  
120 was used: (1) from a list of all 213 Shehias (wards), 80 Shehias were randomly selected; (2)  
121 households were randomly selected based on the Shehia's registration records. Participation  
122 agreement was requested from all members of a household. A total of 1,443 family members  
123 agreed to participate and completed anthropometric and blood pressure measurements, as  
124 well as interviewer-administered questionnaires. Venous blood was also collected. The  
125 subgroup examinations are described in detail below. The complete description of the study  
126 design and methods has been described in detail elsewhere <sup>25</sup>. The study was performed  
127 according to the Helsinki Declaration and the study protocol was evaluated and approved by  
128 the Ethics Committees of the University of Bremen and of the Zanzibar Ministry of Health  
129 and the Zanzibar Medical Research and Ethics Committee. All participants gave written  
130 informed consent and parents/guardians consented on behalf of minors in writing.

### 131 Patient and Public Involvement

132 During the development of the survey tools, measurements and the study protocol, a meeting  
133 was held with the local partners, government officials and researchers in Zanzibar to discuss  
134 the needs and gaps of the nutrition and health survey planned in Zanzibar. The documents  
135 and instruments were then modified according to the needs of the Zanzibari population as  
136 recommended in the meeting.

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3 137 A year after the survey, preliminary results on the major health outcomes and related risk  
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5 138 factors were presented and discussed during a two days feedback workshop with the  
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8 139 administrative leaders (e.g. Shehas, district commissioners), stakeholders (from health  
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10 140 services, government officials, food safety) and our local partners in Zanzibar (academics and  
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12 141 research). Each Sheha was handed a poster of the preliminary results, which was then  
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14 142 displayed at their local offices for all Shehia members to see. District commissioners received  
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17 143 a summary report on all Shehias of their districts. The preliminary results were further  
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19 144 publicised on TV and print media. The same group of workshop participants was invited to a  
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21 145 further workshop in 2018, whose aim was to identify target populations and channels for  
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23 146 future nutrition education to address the aetiology and prevention of NCDs in the Zanzibari  
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26 147 population, taking into consideration the survey results presented also in this study.  
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29 148 This observational epidemiological study examined participants in their home environment  
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31 149 and did not enrol clinical patients.  
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### 34 35 Questionnaires and anthropometric measurements 36

37 151 Questionnaires were developed in English, translated into Swahili, and then back-translated  
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39 152 to control for translation errors. Information was collected during an interviewer administered  
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41 153 personal interview conducted by trained survey staff. Parents reported their age and sex, as  
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43 154 well as of their children. Age was grouped into three categories  $\geq 5$  to  $< 18$  years,  $\geq 18$  to  $< 45$   
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45 155 years, and 45 years and above. In addition, parental highest educational level according to the  
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47 156 International Standard Classification of Education (ISCED) <sup>26</sup> was used as a proxy indicator  
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49 157 for socio-economic status (SES) of the family. It was categorized into low education (no  
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51 158 education and primary school) and high education (secondary school and above). To  
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53 159 determine participants' area of residence, information on region, district and Shehia (the  
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55 160 smallest administrative unit in Zanzibar) was recorded and two categories for area of  
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57 161 residence were developed (urban and rural). Utilization of medication was also documented  
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3 162 in the questionnaire. Regarding medication for obesity-related conditions, participants  
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5 163 reported use of hypertension medication but not of diabetes or dyslipoproteinemia medication.  
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8 164 Hence, the variable was later categorized as “hypertension medication” and “other  
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10 165 medication” (e.g. anti-Malaria therapy or antipyretic products). To ensure a high quality of  
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12 166 data collection, this study used proven examination methods and laboratory standards <sup>27 28</sup>.

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14 167 All anthropometric measurements and physical examinations were adopted from the  
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16 168 IDEFICS Study and conducted following standardized procedures <sup>29 30</sup>. Measurement of body  
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18 169 weight was carried out to the nearest 0.1kg and body fat percent was determined using the  
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20 170 bioelectrical impedance analysis (BIA) method using an electronic scale (TANITA BC-420  
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22 171 SMA, Germany). Height was measured using a SECA 213 stadiometer, UK, and waist  
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24 172 circumference (WC) was measured midway between the lowest rib and the iliac crest, using  
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26 173 an inelastic measuring tape (SECA 201). For all measurements, participants wore light  
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28 174 clothing and were standing. The measures were recorded to the nearest 0.1cm. The complete  
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30 175 description of the anthropometric measurements of the study is described elsewhere <sup>25</sup>.

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33 176 For children and adolescents, Body Mass Index (BMI) was calculated as kg/m<sup>2</sup> and then  
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35 177 transformed to age-and sex-specific z-score and percentiles. Thereafter, categories for  
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37 178 overweight (BMI between >75<sup>th</sup> and <95<sup>th</sup> percentile) and obesity (BMI >95<sup>th</sup> percentile)  
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39 179 were built according to the WHO centile curves <sup>31 32</sup>. For adults, overweight/obesity was  
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41 180 defined as BMI  $\geq 25$ kg/m<sup>2</sup> as recommended by WHO <sup>33</sup>. For statistical analysis, the BMI  
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43 181 categories were merged into two 1) under-weight/ normal weight ( $\leq 75^{\text{th}}$  percentile for  
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45 182 children and adolescents and  $< 25$ kg/m<sup>2</sup> for adults) and 2) overweight/obesity ( $>75^{\text{th}}$   
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47 183 percentile and  $\geq 25$ kg/m<sup>2</sup> ). Regarding waist circumference (WC), high abdominal obesity  
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49 184 was defined as WC  $\geq 90^{\text{th}}$  percentile for children below 10 years <sup>34</sup>; WC  $\geq 90^{\text{th}}$  percentile for  
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51 185 adolescents aged 10 - <16 years; and WC  $>94$  cm for men and  $> 80$  cm for women for  
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53 186 participants 16 years and older, as recommended by the IDF <sup>35</sup>. As recommended by  
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3 187 McCarthy et al.<sup>36</sup>, for boys and girls below 18 years, high body fat percentage (BF%) was set  
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5 188 at  $\geq 85$ th percentile. For adults above 18 years, high BF% was defined as  $\geq 20$  % for men and  
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8 189  $\geq 32$  % for women<sup>37</sup>. The cut-offs and references are listed in Table 1.  
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### 10 11 190 Cardio-metabolic risk factors

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13 191 All blood samples were drawn after overnight fasting and were collected from all eligible  
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15 192 participants over 5 years of age by venepuncture<sup>38</sup>. To reduce pain, children below 10 years  
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17 193 of age were given a local anaesthetic plaster before blood drawing, which motivated the  
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19 194 children to participate. Before blood drawing, the procedure was once again explained to all  
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21 195 participants in easy language and they were informed that they still could refuse to  
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23 196 participate. For children weighing 10kg, the blood collection was restricted to 1%,  
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25 197 corresponding to approximately 8 mL. For healthy, non-pregnant adults weighing at least 50  
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27 198 kg, a maximum of 20.5 mL venous blood was drawn. All blood samples collected at the field  
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29 199 were kept at 4°C and the processing was performed immediately at the laboratory in  
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31 200 Zanzibar, according to international standards<sup>28</sup>. EDTA Blood was centrifuged for 10 minutes  
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33 201 at 2500g and then separated into 3 aliquots; plasma, red blood cells (RBC) and white blood  
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35 202 cells (WBC), which were then stored at -80 °C. Detailed procedures about the collection,  
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37 203 processing and storage of blood samples are described elsewhere<sup>25</sup>.  
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42  
43 204 Metabolic parameters were categorized for investigating the prevalence of cardio-metabolic  
44  
45 205 disorders in the study population. Due to the wide range of age groups in this study  
46  
47 206 population, different cardio-metabolic risk definitions and cut-offs were used (Table 1).  
48  
49 207 Cardio-metabolic risk for children between 5-10 years was defined according to age-sex-  
50  
51 208 specific cut-offs. The parameters, including hypertension (Systolic Blood Pressure (SBP) and  
52  
53 209 Diastolic Blood Pressure (DBP)), blood lipids (high Total Cholesterol (TC), high  
54  
55 210 Triglycerides (TG), Low-Density-Lipoprotein Cholesterol (LDL-C) and High-Density-  
56  
57 211 Lipoprotein Cholesterol (HDL-C)), blood glucose/insulin (Homeostasis Model Assessment of  
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212 Insulin Resistance (HOMA-IR) and elevated Fasting Plasma Glucose (FPG), were defined  
 213 according to the IDEFICS Study<sup>34 39</sup>. Glycated haemoglobin (HbA1c) was defined according  
 214 to Rodoo et al.<sup>40</sup> for children under 17 years. For children and adolescents between 10 years  
 215 and 16 years, hypertension was defined according to age-sex-specific cut-offs as  
 216 recommended<sup>41</sup>; for adolescents and adults above 16 years hypertension was defined as  
 217 recommended<sup>42</sup>. Blood lipids (TC and LDL-C) were defined according to the National  
 218 Cholesterol Education Program (NCEP)<sup>11</sup> and TG, HDL-C and FPG according to the  
 219 International Diabetes Federation (IDF)<sup>35</sup>. HbA1c for participants above 17 years was  
 220 defined according to Stern et al.<sup>43</sup> and insulin resistance was estimated as HOMA-IR  
 221 according to the reference value of HOMA-IR as recommended by Shashaj et al.<sup>44</sup>. In the  
 222 present study, the 75<sup>th</sup> percentile cut-off was used for children and adolescents from 10 to 17  
 223 years. For participants above 17 years, HOMA-IR was defined according to von Eyben et al  
 224<sup>45</sup>. HOMA-IR was calculated from glucose (mmol/l) and insulin ( $\mu$ U/ml) concentrations  
 225 using the formula:  $HOMA-IR = (\text{fasting insulin} \times \text{fasting glucose} / 22.5)^{46}$ .

227 Table 1. Cardio-metabolic risk definitions and references

Age group	Obesity Indices and Blood Pressure	Blood lipids	Blood Glucose/Insulin
Children: $\leq 10$ y	BMI $\geq 75^{\text{th}}$ percentile <sup>1</sup>	TC $\geq 90^{\text{th}}$ percentile <sup>2</sup>	HbA1c $\geq 97.5^{\text{th}}$ percentile <sup>10</sup>
	WC $\geq 90^{\text{th}}$ percentile <sup>2</sup>	TG $\geq 90^{\text{th}}$ percentile <sup>2</sup>	HOMA-IR $\geq 95^{\text{th}}$ percentile <sup>2</sup>
	BF % $\geq 85^{\text{th}}$ percentile <sup>3</sup>	HDL-C $\leq 10^{\text{th}}$ percentile <sup>2</sup>	FPG $\geq 95^{\text{th}}$ percentile <sup>2</sup>
	SBP $\geq 90^{\text{th}}$ centile or DBP $\geq 90^{\text{th}}$ centile <sup>2</sup>	LDL $\geq 90^{\text{th}}$ percentile <sup>2</sup>	
Adolescents: >10 to <16 y	BMI $\geq 75^{\text{th}}$ percentile <sup>1</sup>	TC $\geq 5.2$ mmol/L <sup>6</sup>	HbA1c $\geq 97.5^{\text{th}}$ percentile <sup>10</sup>
	WC $\geq 90^{\text{th}}$ percentile <sup>4</sup>	TG $\geq 1.7$ mmol/L <sup>4</sup>	HOMA-IR $\geq 75^{\text{th}}$ percentile <sup>9</sup>
	BF % $\geq 85^{\text{th}}$ percentile <sup>3</sup>	HDL-C $< 1.03$ <sup>4</sup>	FPG $\geq 5.6$ mmol/L <sup>4</sup>
	SBP $\geq 140$ mmHg or	LDL $\geq 3.4$ mmol/L <sup>6</sup>	

	DBP $\geq$ 90mmHg <sup>11</sup>		
Adults:	BMI $\geq$ 25 kg/m <sup>1</sup>	TC $\geq$ 5.2 mmol/l <sup>6</sup>	HbA1c $\geq$ 6.1% <sup>5</sup>
$\geq$ 16y	WC $\geq$ 94 cm male, $\geq$ 80cm female <sup>4</sup>	TG $\geq$ 1.7mmol/L, <sup>4</sup>	HOMA-IR >4.65 or HOMA-IR >3.60 and BMI >27.5 kg/m <sup>2</sup> <sup>7</sup>
	BF % $\geq$ 20 % male and $\geq$ 32 % female <sup>8</sup>	HDL-C < 1.03 male,< 1.29 female <sup>4</sup>	FPG $\geq$ 5.6mmol/L <sup>4</sup>
	SBP $\geq$ 140mmHg or DBP $\geq$ 90mmHg <sup>12</sup>	LDL $\geq$ 3.4mmol/L <sup>6</sup>	

228

229 1 WHO

230 2 IDEFICS Study

231 3 McCarthy, H.D., et al. (2006)

232 4 IDF

233 5 Stern, S.E., et al (2003) for adults above 17 years

234 6 NCEP

235 7 von Eyben, F.E., et al (2005)

236 8 Gallagher, D., et al (200)

237 9 Shashaj et al. (2015) for children and adolescents under 17 years

238 10 Rodoo P et al. (2013)

239 11, 12 National Institute of Health 3<sup>rd</sup> and 7<sup>th</sup> report respectively

240

241 Inclusion criteria for study sample

242 Of 1,443 individuals who participated in this study, 1,314 fulfilled the inclusion criteria (age, sex, weight, height) for the overall study analysis. Of the 1,314, 1,234 provided complete waist circumference and body fat percent measurements. Among these, 557 provided complete blood samples for the cardio-metabolic risk analysis and only 505 were on fasting status. To reduce bias when estimating mean and SD in the regression analysis, we excluded the top 1% of individuals with extremely high values for cardio-metabolic risk and obesity indices, leaving us with a complete sample of 470 participants for the analysis.

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250 Statistical analysis

251 Descriptive analysis was conducted to calculate the mean standard deviation (SD) and range (minimum, maximum) for continuous variables, as well as the distribution of the categorical

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3 253 data in N and percentages (%). As part of the regression analysis, we tested the necessary  
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5 254 assumptions in terms of symmetry and normality using residual-plots and Q-Q-Plots. Mixed  
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8 255 logistic regression models were used to analyse the association between obesity indices and  
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10 256 cardio-metabolic risk factors. In addition, potential clustering within households was  
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12 257 considered in terms of a random intercept. Following the hierarchy of the municipal structure  
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15 258 in Zanzibar, we conducted sensitivity analysis modelling either Shehias or households within  
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17 259 Shehias as a random intercept in the models. Since the results of the models only showed  
18  
19 260 marginal differences, we only considered the household as a random intercept in our  
20  
21 261 analyses. First, mixed logistic regression models were conducted to estimate the association  
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23 262 between each of the three obesity indicators (BMI, WC and BF%) as exposure variables and  
24  
25 263 each of the eight risk factors (hypertension, TC, TG, HDL-C, LDL-C, HbA1c, FPG and  
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27 264 HOMA-IR) as dependent variables, in terms of odds ratios (OR) and 95% confidence limits  
28  
29 265 (CI). Since BMI, WC and BF% are interrelated, their predictive power on cardio-metabolic  
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31 266 risk factors was investigated by conducting mixed logistic regression models. This was done  
32  
33 267 by estimating the association (ORs and 95% CIs) between all three obesity indices as  
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35 268 dependent variables in one model and each of the eight risk factors as outcome variables. All  
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37 269 models were adjusted for potential confounders and covariates such as gender, age, education  
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39 270 level (ISCED), area of residence and utilization of hypertension medication. Statistical  
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41 271 analysis was performed using SAS 9.3 (SAS Institute. Cary. NC. U SA); mixed logistic  
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43 272 regression models were conducted based on the GLIMMIX procedure; statistical significance  
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45 273 was set at  $\alpha = 0.05$ .  
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## 274 Results

### 275 Distribution of obesity and cardio-metabolic risk and characteristics of the study population 276 by age groups (n=470)

277 The mean age was 29 ( $\pm 18$ ) years, with the highest proportion being in the age group ( $\geq 18$  to  
278  $< 45$  years) (Table 2). The overall mean values for BMI, WC and BF% were as follows: BMI  
279 22 ( $\pm 5.2$ ) kg/m<sup>2</sup>, WC 75 ( $\pm 16$ ) cm and BF% 22 ( $\pm 11$ ) %. The mean BMI of 26 ( $\pm 5.7$ )  
280 kg/m<sup>2</sup> for participants above 45 years was slightly higher than normal, indicating overweight.  
281 Mean diastolic blood pressure was in the normal range for all the age groups, but a higher  
282 mean value of systolic blood pressure, 150 ( $\pm 280$ ) mmHg, was observed among participants  
283 above 45 years. The mean values of most of the variables showed an increase with age group,  
284 except for HDL-C and diabetes markers (HbA1c, serum insulin, plasma glucose and HOMA-  
285 IR), which showed no specific trend.

286 Of the 470 participants, more than half were women 52.6% (n=247), 51.9% (244) had a  
287 higher education level and 73.4% (345) resided in urban area. Regarding education level, the  
288 majority of those with a higher education level were aged  $\geq 18$ - $< 45$  years (150/244 = 61%)  
289 (Table 3).

290  
291 Table 2: Distribution of obesity and cardio-metabolic risk in the study population (n=470) by  
292 age group (means and standard deviation (SD))

	$\geq 5$ to $< 18$ years (n=165)		$\geq 18$ to $< 45$ years (n=195)		45+years (n=110)		Total (n=470)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Age (years)	12 (3.4)	4.9 -18	28 (8.1)	18-44	57 (9.8)	45-95	29 (18)	4.9-95
BMI (kg/m)	17 (3.4)	11-34	23 (4.5)	16-37	26 (5.7)	15-49	22 (5.7)	11-49
WC (cm)	61 (11)	12-103	79 (12)	37-111	88 (0.2)	35-126	75 (16)	12-126
BF (%)	15 (7.0)	1.6-45	23 ( 11)	3.0-53	28 (10)	6.2-53	22 (11)	1.6-53

DBP (mmHg)	67 (9.8)	44-97	76 (10)	53-126	88 (15)	62-140	75 (14)	44-140
SBP (mmHg)	110 (13)	69-152	123 (16)	72-197	150 (28)	100-229	125 (24)	69-229
TC (mmol/l)	3.7 (0.7)	1.8-5.9	3.9 (0.8)	2.1-6.0	4.2 (0.8)	0.2-5.9	3.9 (0.8)	0.2-6.0
TG (mmol/l)	0.8 (0.3)	0.3-2.5	0.9 (0.4)	0.0-2.6	1.0 (0.4)	0.4-2.7	0.9 (0.4)	0.0-2.7
HDL-C (mmol/l)	1.4 (0.5)	0.7-3.3	1.5 (0.5)	0.6-3.7	1.4 (0.4)	0.6-3.6	1.4 (0.5)	0.6-3.7
LDL-C (mmol/l)	2.3 (0.9)	0.0-5.0	2.5 (0.9)	0.7-5.1	3.0 (1.0)	0.6-5.1	2.5 (1.0)	0.0-5.1
HbA1c (%)	5.7 (0.5)	4.2-8.5	5.6 (0.6)	3.9-9.4	6.0 (0.8)	4.4-10	5.8 (0.6)	3.9-10
Serum Insulin (mmol/l)	4.3 (3.1)	0.4-18	4.8 (2.8)	0.8-17	3.6 (2.3)	0.4-17	4.4 (2.8)	0.4-18
FPG (mmol/l)	4.9 (0.8)	2.0-7.7	4.8 (0.9)	0.5-9.4	5.1 (1.3)	0.2-13	4.9 (1.0)	0.2-13
HOMA-IR	1.0 (0.7)	0.1-4.6	1.1 (0.7)	0.0-4.3	0.9 (0.6)	0.0-4.0	1.0 (0.7)	0.0-4.6

293

294 The overall proportion of overweight/obesity with regard to BMI, WC and BF % was 26.4%,  
 295 24.9% and 31.1% respectively, and increased with age (Table 2). The highest proportion was  
 296 observed among participants above 45 years. We observed different trends in the prevalence  
 297 of metabolic parameters and hypertension across age groups. The prevalence of hypertension,  
 298 high total cholesterol, LDL-C and HbA1c increased with age, while that for triglycerides and  
 299 HOMA-IR decreased with age. The most prevalent factors were reduced HDL-C (29.4%),  
 300 hypertension (24.5%) as well as raised LDL-C (21.3%) and HbA1c levels (19.1%). Although  
 301 hypertension was more prevalent among participants above 45 years, only 9.4% (10) of the  
 302 participants in this age group were on hypertension medication. Further, high LDL-C and  
 303 HbA1c were more prevalent among participants above 45 years, and low HDL-C was most  
 304 prevalent among  $\geq 18$  to  $< 45$  year olds.

305

306 Table 3: Characteristics of the study population (n=470) by age group (n/%)

	$\geq 5$ to $< 18$ years		$\geq 18$ to $< 45$ years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
All	165	(100)	195	(100)	110	(100)	470	(100)
Gender								
Male	85	(51.5)	86	(44.1)	52	(47.3)	223	(47.4)

	≥5 to <18 years		≥18 to <45 years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
Female	80	(48.5)	109	(55.9)	58	(52.7)	247	(52.6)
Education level								
Low	122	(73.9)	45	(23.1)	59	(53.6)	226	(48.1)
High	43	(26.1)	150	(76.9)	51	(46.4)	244	(51.9)
Area of residence								
Rural	43	(26.1)	49	(25.1)	33	(30.0)	125	(26.6)
Urban	122	(73.9)	146	(74.9)	77	(70.0)	345	(73.4)
<b>Obesity Indices</b>								
BMI								
Underweight	83	(50.3)	29	(14.9)	9	(8.18)	121	(25.7)
Normal weight	73	(44.2)	106	(54.4)	46	(41.8)	225	(47.9)
Overweight/obese	9	(5.45)	60	(30.8)	55	(50.0)	124	(26.4)
Waist circumference								
Normal	165	(100)	141	(72.2)	47	(42.7)	353	(75.1)
High <sup>a</sup>	0	(0)	54	(27.7)	63	(57.3)	117	(24.9)
Body fat %								
Normal	157	(95.2)	121	(62.1)	46	(41.8)	324	(69.0)
High <sup>b</sup>	8	(4.86)	74	(37.9)	64	(58.2)	146	(31.1)
<b>Hypertension</b>								
Normal	123	(74.5)	76	(39.0)	10	(9.09)	209	(44.5)
Pre-hypertension	25	(15.8)	89	(45.6)	31	(28.2)	146	(31.1)
Hypertension	16	(9.70)	30	(15.4)	69	(62.7)	115	(24.5)
Hypertension medication <sup>c</sup>								
Yes	1	(0.61)	12	(6.38)	10	(9.43)	23	(5.02)
No	163	(99.4)	176	(93.6)	96	(90.6)	435	(95.0)
<b>Dyslipidaemia <sup>d</sup></b>								
Total cholesterol								
Normal	161	(97.6)	183	(93.8)	102	(92.7)	446	(94.9)
High	4	(2.42)	12	(6.15)	8	(7.27)	24	(5.11)
Triglycerides								
Normal	157	(95.2)	186	(95.4)	105	(95.5)	448	(95.3)
High	8	(4.85)	9	(4.62)	5	(4.55)	22	(4.68)
HDL-cholesterol								
Normal	126	(76.4)	128	(65.6)	78	(70.9)	332	(70.5)
Low	39	(23.6)	67	(34.4)	32	(29.1)	138	(29.4)
LDL-cholesterol								
Normal	141	(85.5)	163	(83.6)	66	(60.0)	370	(78.7)
High	24	(14.5)	32	(16.4)	44	(40.0)	100	(21.3)

	≥5 to <18 years		≥18 to <45 years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
<b>Diabetes Markers <sup>c</sup></b>								
HbA1c								
Normal	142	(86.1)	166	(85.1)	72	(65.5)	380	(80.9)
High	23	(13.9)	29	(14.9)	38	(34.5)	90	(19.1)
Plasma glucose								
Normal	136	(82.4)	167	(85.6)	88	(80.0)	391	(83.2)
High	29	(17.6)	28	(14.4)	22	(20.0)	79	(16.8)
HOMA-IR								
Normal	162	(98.2)	193	(99.0)	109	(99.1)	464	(98.7)
High	3	(1.82)	2	(1.03)	1	(0.91)	6	(1.28)

<sup>a</sup> High WC was defined as WC ≥90<sup>th</sup> percentile for children under 10y <sup>34</sup>. Adolescents between 10-16 years and adults above 16 years WC > 94 cm for men and > 80 cm for women according to IDF cut-off <sup>35</sup>

<sup>b</sup> High BF% for adults (overweight/obese) ≥ 20 for men and ≥32 for women according to (NIH/WHO) BMI guidelines <sup>37</sup> and ≥85<sup>th</sup> percentile for children <sup>36</sup>

<sup>c</sup> Missing information from 12 participants (n=458)

<sup>d</sup> High dyslipidemia for adults; was defined as total serum cholesterol (≥6.2mmol/l) and LDL-cholesterol (≥3.4mmol/l) <sup>11</sup> low HDL-C: <1.03 mmol/l in men or <1.29 mmol/l in women high and hypertriglyceridemia (≥1.7 mmol/l) <sup>35</sup> and for children according to IDEFICS study <sup>34</sup>

<sup>e</sup> High diabetes risk markers; high HbA1c (>6.1%) <sup>45</sup>, high fasting plasma glucose (≥5.6 mmol/l) <sup>35</sup> and HOMA-insulin resistance was defined as HOMA-IR >4.65. or HOMA-IR >3.60 and BMI >27.5 kg/m<sup>2</sup> <sup>43</sup> and for children high HbA1c (≥97.5<sup>th</sup> percentile), high fasting plasma glucose ≥95<sup>th</sup> percentile and HOMA-IR ≥95<sup>th</sup> percentile.

### Association between obesity indices and cardio-metabolic risk factors

Obesity indices (BMI, WC and BF %) were observed to be associated with one or more risk factors. Participants with high BMI (OR=2.41 (1.33, 4.47)), high WC (OR=3.68 (1.81, 7.52)) or high BF% (OR=2.51 (1.40, 4.51)) were more likely to be hypertensive (Table 4). Having high WC (OR=2.52 (1.24, 5.13)) or high BF% (OR=1.91 (1.02, 3.58)) was associated with higher chances of having high LDL-C. Furthermore, BMI (OR=2.08 (1.15-3.79)) and WC (OR=3.01 (1.51-6.03)) were associated with HbA1c levels. We further observed increased OR for obesity indices with regard to high total cholesterol, high triglycerides, low HDL-C, elevated glucose and HOMA-IR. As the proportion of individuals with high HOMA-IR was

332 very small in our sample (1,28%/n=6), the results was not considered in the final regression  
 333 analysis. Regarding goodness of fit of the models, values of the Akaike Information Criterion  
 334 (AIC), which estimates the quality of each model relative to that of each of the other models,  
 335 showed that models including WC as an obesity index tended to have a slightly stronger  
 336 predictive power compared to those including BMI and BF%.

337

338 Table 4: Associations between obesity indices (independent) and cardio-metabolic risk  
 339 factors (dependent), adjusted for gender, age, education level, area of residence, and  
 340 hypertension medication (n=470)

Obesity indices	High BMI			High WC			High BF%					
	OR	(95% CI)	AIC	OR	(95% CI)	AIC	OR	(95% CI)	AIC			
Hypertension	<b>2.41</b>	<b>1.33</b>	<b>4.47</b>	<b>504.86</b>	<b>3.68</b>	<b>1.81</b>	<b>7.52</b>	<b>499.79</b>	<b>2.51</b>	<b>1.40</b>	<b>4.51</b>	<b>503.46</b>
High Total cholesterol	1.13	0.40	3.19	192.74	0.84	0.27	2.66	192.71	1.05	0.37	2.95	192.79
High Triglycerides	1.79	0.55	5.77	189.88	2.23	0.58	8.66	189.38	1.64	0.52	5.14	190.11
Low HDL cholesterol	1.21	0.62	2.37	516.08	1.15	0.55	2.42	516.25	1.06	0.54	2.05	516.37
High LDL cholesterol	1.45	0.78	2.69	457.62	<b>2.52</b>	<b>1.24</b>	<b>5.13</b>	<b>452.23</b>	<b>1.91</b>	<b>1.02</b>	<b>3.58</b>	<b>454.77</b>
High HbA1c	<b>2.08</b>	<b>1.15</b>	<b>3.79</b>	<b>442.70</b>	<b>3.01</b>	<b>1.51</b>	<b>6.03</b>	<b>438.53</b>	1.75	0.96	3.18	445.23
High Glucose	2.04	0.93	4.50	397.36	2.07	0.84	5.07	397.98	1.76	0.80	3.87	398.56

341

342 Table 5 presents results of mixed logistic regression models including all three obesity  
 343 indices to investigate the association with single cardio-metabolic risk factors. Compared to  
 344 the separate regression models, the ORs for most of the associations were attenuated.  
 345 However, having high WC was again associated with a higher chance of having hypertension  
 346 (OR=2.62 (1.14, 6.06)) and having high HbA1c levels (OR=2.62 (1.12, 6.15)). Again, as the  
 347 proportion of individuals with high HOMA-IR (1,28%/n=6), the results are not shown was  
 348 very small, it was not considered in the final regression analysis. in our sample.

349

350 Table 5: Associations between obesity indices (independent) and cardio-metabolic risk  
 351 factors (outcome) adjusted by gender, age, education level and area of residence (n=470)

Obesity indices	Combined Obesity Indices									AIC total
	BMI			WC			BF%			
Risk Factors	OR	(95% CI)		OR	(95% CI)		OR	(95% CI)		
Hypertension	1.19	0.48	2.95	<b>2.62</b>	<b>1.1</b>	<b>6.06</b>	1.48	0.63	3.51	501.3
High Total	1.31	0.25	6.79	0.71	0.1	2.92	1.01	0.19	5.32	196.5
High Triglycerides	1.34	0.25	7.16	1.90	0.3	9.52	1.02	0.19	5.52	193.2
Low HDL	1.35	0.48	3.76	1.09	0.4	2.67	0.82	0.98	2.25	519.9
High LDL	0.63	0.24	1.65	2.34	0.9	5.50	1.81	0.70	4.70	454.6
High HbA1c	1.53	0.61	3.81	<b>2.62</b>	<b>1.1</b>	<b>6.15</b>	0.82	0.32	2.10	441.6
Elevated Glucose	1.67	0.55	5.06	1.54	0.5	4.44	1.03	0.33	3.17	400.6

## 353 Discussion

354 This study is the first population-based survey in Unguja Island that investigated the  
355 association between multiple obesity indices (BMI, WC and BF%) and multiple cardio-  
356 metabolic risk factors in a representative Zanzibari population, aged 5-95 years. This study  
357 population, as in many other LMICs, is undergoing a coexistence of the double burden of  
358 underweight children and overweight/obese adults. Generally, about a quarter of the study  
359 population was overweight/obese, and obesity increased with age. This observation has also  
360 been reported in demographic health surveys from seven sub-Saharan African countries <sup>47</sup>. In  
361 the adult population, the prevalence of overweight/obesity was lower than that in Ghana <sup>7</sup>, but  
362 higher than in Nigeria <sup>2</sup> and Benin <sup>48</sup>. On the other hand, more than 50% of the children in  
363 this study were underweight, a proportion higher than that in other sub-Saharan African  
364 countries (Kenya, Nigeria, South Africa, Equatorial Guinea and Cameroon) <sup>49</sup>.

365 Dyslipidemia is a risk factor for a variety of cardiovascular diseases and is becoming more  
366 prevalent in sub-Saharan Africa, particularly the form of low HDL-C <sup>50 51</sup>. Despite the  
367 relatively normal levels of total cholesterol and triglycerides, low HDL-C affected about 29%  
368 of the overall population, an indication that low HDL-C affects a large proportion of adults  
369 above 18 years. As HDL-C plays a key role in reverse cholesterol transport, has anti-  
370 thrombotic, anti-inflammatory and anti-oxidant properties, as well as the ability to improve  
371 diabetic control and promote angiogenesis, it is referred to as cardioprotective<sup>52</sup>. The low  
372 HDL-C levels observed in our study population might therefore be indicative of a notable and  
373 evolving cardiovascular risk in the study region. Our results are in line with a recent study in  
374 sub-Saharan Africa and Middle East with 30% of the participant having low HDL-C <sup>53</sup>. Other  
375 studies in sub-Saharan Africa reported even higher prevalence of low HDL-C, 43.1% in  
376 Nigeria <sup>2</sup> and 80% in Botswana <sup>54</sup>, mostly affecting individuals between 35-54 years.



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3 377 In the present study, a high proportion of participants with high HbA1c (14%) and elevated  
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5 378 fasting glucose (18%) are children below 18 years. Since diabetes in children in LMICs has  
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8 379 not received much attention, it is likely that there is a high number of children with sub-  
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10 380 clinical complications due to delayed or missed diagnosis as well as a lack of regular  
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12 381 monitoring. The high proportions observed in this study are a possible indication that a large  
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14 382 proportion of diabetic participants are not aware of their status and are hence not monitored  
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17 383 or treated. The fact that diabetes medication was not reported in this sample supports this  
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19 384 assumption. However, when using WHO diabetes diagnostic criteria <sup>55</sup>, i.e. HbA1c cut-off  
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21 385  $\geq 6.5\%$  and FPG  $\geq 7.0\text{mmol/l}$ , the prevalence of diabetes in participants above 18 years  
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23 386 decreased to 8.14% and 3.05%, respectively (data not shown). The most intriguing result  
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25 387 however is the high proportion of children between 5 and <18 years being at high risk for  
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28 388 diabetes with elevated FPG levels when using cut-off of  $\geq 5.6\text{mmol/l}$ , as recommended by  
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30 389 IDF <sup>35</sup>. Our results showed that the prevalence of FPG and HOMA-IR in children and  
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33 390 adolescents below 18 years was in general higher than that of adults above 18 years, but less  
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35 391 than that of adults above 45 years. Results from previous cross-sectional studies have shown  
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37 392 that physiological transient insulin resistance develops in children during puberty<sup>56</sup> and  
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40 393 decreases again by the end of puberty, regardless of obesity. The decrease in insulin  
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42 394 sensitivity in the pubertal period is said to lead to an increase in glucose-stimulated insulin  
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44 395 secretion<sup>57</sup>. The high prevalence of FPG and HOMA-IR observed in children and adolescents  
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47 396 in our study could hence be due to physiological changes in children and adolescents during  
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49 397 pre-pubertal period and puberty. They could however also be due to misreporting (children  
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51 398 did not report having eaten prior to the blood drawing), or to a true high risk within this age  
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54 399 group. Taking this into account, we adjusted for age in the regression models in order to  
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56 400 control for possible confounding effects of physiological changes through maturation and  
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58 401 aging. Interestingly, the prevalence of high FPG decreased from approximately 18% to  
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3 402 0.61% when we used the WHO <sup>55</sup> diabetes diagnostic criteria (FPG  $\geq$ 7mmol/l) for the same  
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5 403 age group (data not shown). This, in our opinion, indicates that the majority of the children  
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7 404 are at risk for diabetes, and that the cut-off for HbA1c  $\geq$ 6.1% as well as elevated FPG $\geq$ 5.6  
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9 405 mmol/l seem to be better screening tools for identifying those at risk, earlier.

10 406 Our study showed a strong association between BMI, WC and BF% and hypertension in the  
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12 407 study population. These findings are in agreement with other studies that also reported an  
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14 408 association between hypertension/pre-hypertension, BMI and WC <sup>58</sup> as well as BF% <sup>7</sup>.  
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16 409 Moreover, the association between hypertension and high WC was twice as strong as that  
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18 410 with high BMI and high %BF. This result suggests that central obesity may be a better  
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20 411 predictor for the risk of hypertension and other cardiovascular diseases in our study  
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22 412 population. Thus, optimal body weight control and reduced central obesity risk may have  
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24 413 beneficial effects on hypertension control in this population. This study also observed a  
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26 414 strong association between WC and LDL-C levels. Obirikorang also reported similar  
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28 415 associations in a comparative cross-sectional study conducted in Ghana <sup>7</sup>.

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30 416 In the separate models, strong associations were observed between BMI, WC and HbA1c  
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32 417 levels, which can be explained by the interrelation of the two indices, since abdominal fat  
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34 418 accumulation increases in proportion to BMI <sup>59</sup> and BMI is one of the main risk factors for  
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36 419 diabetes and pre-diabetes <sup>60</sup>. However, when all three obesity indices were considered  
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38 420 combined, it is only the association between WC and HbA1c levels and hypertension that  
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40 421 remained strong. Excessive visceral fat in abdominal obesity is the main source of free fatty  
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42 422 acids and inflammatory cytokines, which, according to the literature, might lead to insulin  
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44 423 resistance and type 2 diabetes mellitus<sup>61</sup>. This probably explains why WC was strongly  
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46 424 associated with diabetes and hypertension in our study population. Therefore, measuring WC  
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48 425 using optimal WC cut-off values as was done in this study would be a feasible, less time  
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3 426 consuming and cost-effective screening tool to identify at-risk individuals in the Zanzibari  
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5 427 population.  
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8 428 This study has some limitations that should be considered. First, we were only able to  
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10 429 investigate the association between obesity indices and risk factors using cross-sectional data,  
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12 430 thus the impact of changes in obesity indices on risk factors could not be considered. Second,  
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14 431 as is done in many epidemiological studies and clinical trials, we used Bioelectrical  
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16 432 Impedance Analysis (BIA) to estimate body fat percentage. However, compared to skinfold  
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18 433 measurements, BIA measurements may underestimate adiposity in children <sup>62</sup>. Third, even  
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20 434 though participants who reported food or beverage intake prior to blood drawing were  
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22 435 excluded during the data cleaning process, we cannot entirely rule out misreporting of the  
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24 436 “fasting status”. According to our power calculation, our sample size of 1,314 individuals  
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26 437 would have been enough to reach a statistical power. However, our study sample decreased to  
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28 438 470 due to the individual opt-out option for particular examinations as well as the exclusion  
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30 439 of outliers and the requirement of completeness of variables of interest. We nevertheless  
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32 440 believe that our findings provide important information for public health stakeholders, policy  
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34 441 makers and researchers, despite the fact that some of the detected associations did not reach  
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36 442 the significance threshold due to the small sample size.  
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44 443 The results of this research, the first study providing information on the prevalence and risk  
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46 444 of NCDs with particular focus on identifying vulnerable age groups in Zanzibar, can be used  
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48 445 for the development of interventions or policies by researchers, stakeholders and government  
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50 446 officials. The random selection of the study participants and the standardised assessment of  
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52 447 anthropometrical and laboratory measurements are main strengths of the present study.  
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54 448 Moreover, we consequently applied age- and sex-specific cut-offs that take into account the  
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56 449 physiological development characteristic of the young age group, rather than applying the  
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58 450 fixed cut-offs used in the adult population. There is little information on the association of  
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3 451 multiple obesity indices with multiple cardio-metabolic risk factors in this population; hence,  
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5 452 our study provides an important contribution towards filling this gap.  
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## 9 453 Conclusion

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11 454 This study adds to the literature on the association of obesity with higher risks for  
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13 455 hypertension, dyslipidemia and type 2 diabetes mellitus, but for the first time in a Zanzibari  
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15 456 population. Based on our findings, we recommend that similar epidemiological studies  
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17 457 including children, adolescents, adults and elderly set diabetes and/or pre-diabetes cut-offs of  
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19 458 HbA1c at  $\geq 6.1\%$  and/or elevated fasting glucose at  $\geq 5.6\text{mmol/l}$ . Where feasible, BF% and  
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21 459 WC should be used in addition to BMI for screening and monitoring for dyslipidemia and  
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23 460 hypertension. We further conclude that there is a need for effective interventions to create  
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25 461 awareness as well as for primary prevention strategies for cardio-metabolic risks and its  
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27 462 complications in Unguja Island, using local multidisciplinary approaches in the local  
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29 463 language, Swahili. Additionally, there is a need for health surveillance initiatives that  
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31 464 particularly target the age group  $\geq 18$  to  $< 45$  years. These can also be used to help monitor  
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33 465 prevention activities.  
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4 467 **List of Abbreviations**

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BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
HbA1c	Glycated Haemoglobin
HDL-C	High Density-Lipoprotein Cholesterol
HOMA-IR	homeostasis model assessment of insulin resistance
IDEFICS	Identification and prevention of Dietary-and lifestyle-induced health EFects In Children and infantS
IDF	International Diabetes Federation
ISCED	International Standard Classification of Education
LDL-C	Low Density-Lipoprotein Cholesterol
LMICs	Low-middle-Income Countries
NCDs	Non-Communicable Diseases
WC	Waist Circumference
WHO	World Health Organization

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4 470 **Declarations**

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6 471 **Funding**

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9 472 The Leibniz-Gemeinschaft grant number SAW-2012-ZMT-4 supported this work

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13 474 **Competing interests**

14  
15 475 The authors declare that they have no competing interests.

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20 477 **Author's Contribution**

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22 478 The authors' responsibilities were as follows: AH and MN were responsible for study

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24 479 design. AH , MN and SK conducted data collection and developed study hypothesis. MAN

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26 480 and CB conducted statistical analyses and KB assisted in the statistical data cleaning. MAN

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28 481 wrote the manuscript and had primary responsibility for final content. MN, CB, SK, MS ,KB

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30 482 and AH critically revised the manuscript and gave final consent.

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35 484 **STROBE checklist**

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37 485 STROBE Statement—Checklist of items that should be included in reports of *cross-sectional*  
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39 486 *studies*

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	<b>Item No</b>	<b>Recommendation</b>
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract Cross-sectional study
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found Completed in the abstract, please refer to <i>line 27-53</i>
<b>Introduction</b>		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported This has been explained in the Introduction section .
Objectives	3	State specific objectives, including any prespecified

		<p>hypotheses</p> <p>-To determine the prevalence of obesity indices (body mass index (BMI), waist circumference (WC), body fat percent (BF%)) and cardio-metabolic risk factors.</p> <p>-To investigate the association between obesity indices and cardio-metabolic risk factors in a Zanzibari population.</p>
<b>Methods</b>		
Study design	4	<p>Present key elements of study design early in the paper This has been presented in the abstract, please refer to <i>line 31-34</i>.</p> <p><b>Key elements of study design</b> : cross-sectional survey , in a representative population sample in Unguja Island, Zanzibar, households were randomly selected and all household members were invited for the examination.</p>
Setting	5	<p>Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection This has been described in the method section, please refer to <i>line 115-125</i></p>
Participants	6	<p>(a) Give the eligibility criteria, and the sources and methods of selection of participants This has been described in the method section, refer to <i>line 116-124</i></p>
Variables	7	<p>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable This has been defined in the method section, refer to <i>line 150-225</i> including <b>Table 1</b> <i>line 225-237</i> <i>Since clinical patients were not included, diagnostic criteria is not applicable</i></p>
Data sources/ measurement	8*	<p>For each variable of interest, give sources of data and details of methods of assessment (measurement). -Please refer to method section <i>line 161-225</i> Describe comparability of assessment methods if there is more than one group <i>-Not applicable</i></p>

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489 **Data sharing statement**

490 The datasets generated and/or analysed during the current study are not publicly available

491 since a follow-up study is planned.

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3 492 **Acknowledgement**  
4

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7  
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9  
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11  
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13  
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Or peer review only



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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract  Cross-sectional study (b) Provide in the abstract an informative and balanced summary of what was done and what was found  Completed in the abstract, please refer to <i>line 27-53</i>
<b>Introduction</b>		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported  This has been explained in the Introduction section .
Objectives	3	State specific objectives, including any prespecified hypotheses  -To determine the prevalence of obesity indices (body mass index (BMI), waist circumference (WC), body fat percent (BF%)) and cardio-metabolic risk factors. -To investigate the association between obesity indices and cardio-metabolic risk factors in a Zanzibari population.
<b>Methods</b>		
Study design	4	Present key elements of study design early in the paper  This has been presented in the abstract , please refer to <i>line 31-34</i> .  <b>Key elements of study design</b> : cross-sectional survey , in a representative population sample in Unguja Island, Zanzibar, households were randomly selected and all household members were invited for the examination.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection  This has been described in the method section, please refer to <i>line 115-125</i>
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants  This has been described in the method section, refer to <i>line 116-124</i>
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable  This has been defined in the method section, refer to <i>line 150-225</i> including <b>Table 1</b> <i>line 225-237</i> <i>Since clinical patients were not included, diagnostic criteria is not applicable</i>
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). -Please refer to method section <i>line 161-225</i>  Describe comparability of assessment methods if there is more than one group

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60*-Not applicable*

Bias	9	Describe any efforts to address potential sources of bias  This was described in the inclusion criteria where outliers were deleted from the sample in order to reduce bias. Refer to <i>line 246</i>
Study size	10	Explain how the study size was arrived at  This has been described in <i>line 119-122</i>
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why  -Quantitative variables were grouped into categories according to the given cut-offs, please refer to method sections <i>anthropometric measurements and cardiometabolic risk factors</i>
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses  -all the above points have been discussed in the statistical analysis, refer to <i>line 251-272</i>
<b>Results</b>		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed  This has been described in <i>line 242-246</i> (b) Give reasons for non-participation at each stage  This has been described in <i>line 242-246</i> (c) Consider use of a flow diagram  -Not feasible because of different age groups
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders  Please refer to <i>line 277-304 and Tables 2 and 3</i> (b) Indicate number of participants with missing data for each variable of interest  -This was not described in the manuscript, the missing data for each variable of interest were deleted during data cleaning and before running the statistical analysis. Please refer to the inclusion criteria section for general overview, <i>line 242-248</i>
Outcome data	15*	Report numbers of outcome events or summary measures  -Please refer to result sections table 3
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

		adjusted for and why they were included
		(b) Report category boundaries when continuous variables were categorized
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period . <i>Not relevant</i>
		-Please refer to result section tables 4 and 5
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
		-This is was not applied to this manuscript.
<b>Discussion</b>		
Key results	18	Summarise key results with reference to study objectives
		-This has been decribed in the discussion section, please refer to <i>line 348 onwards</i>
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
		-Limitations of the study have been described in <i>line 427-441</i>
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
		-Please refer to the conclusion section from <i>line 353 onwards</i>
Generalisability	21	Discuss the generalisability (external validity) of the study results
		-Based on the findings of the study, similar epidemiological surveys could be conducted in the rest of the Island. Please refer to the conclusion section.
<b>Other information</b>		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based
		-This work was supported by the Leibniz-Gemeinschaft grant number SAW-2012-ZMT-4. <i>See line 483</i>
		-The present article is based on the “Access to Food and Nutritional Status of the Zanzibari population” study, <i>please refer to reference no.25</i>

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Association between cardio-metabolic risk factors and body mass index, waist circumferences and body fat in a Zanzibari cross-sectional study

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<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Epidemiology, Diabetes and endocrinology
Keywords:	Hypertension < CARDIOLOGY, children, DIABETES & ENDOCRINOLOGY, adolescents, adults, sub-Saharan Africa

SCHOLARONE™  
Manuscripts



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3 **1 Association between cardio-metabolic risk factors and body mass index, waist**  
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12 5 Maria Adam Nyangasa <sup>1</sup>, Christoph Buck <sup>1</sup>, Soerge Kelm <sup>2</sup>, Mohammed Ali Sheikh<sup>3</sup>, Kim  
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## 26 Abstract

27 **Objectives:** To determine the prevalence of obesity indices (body mass index (BMI), waist  
28 circumference (WC), body fat percent (BF%)) and cardio-metabolic risk factors. To  
29 investigate the association between obesity indices and cardio-metabolic risk factors in a  
30 Zanzibari population.

31 **Designs:** Cross-sectional study.

32 **Settings:** Participants randomly selected from 80 Shehias (wards) in Unguja, Zanzibar in  
33 2013.

34 **Participants:** A total of 470 participants between 5-95 years were examined. Data on socio-  
35 economic status, area of residence, anthropometry and venous blood were collected.  
36 Associations between obesity indices and cardio-metabolic risk factors were investigated  
37 using multilevel logistic regression analyses in two steps: first, each obesity indicator was  
38 tested independently; second, all indicators combined in one model were tested for their  
39 association with cardio-metabolic risk factors.

40 **Results:** The proportion of overweight/obese individuals was 26.4%, high WC (24.9%) and  
41 high BF% (31.1%). Cardio-metabolic risk factors with highest prevalence of abnormal values  
42 included hypertension (24.5%), low HDL-C (29.4%), high LDL-C (21.3%) and high HbA1c  
43 (19.1%). Obesity and hypertension increased with age, and were most prevalent in  
44 participants aged 45 years and above. Low HDL-C was most prevalent among participants  
45  $\geq 18$  to  $< 45$  years old, while high LDL-C was more prevalent in those above 45 years. High  
46 WC and high BF% were associated with high levels of LDL-C (OR=2.52 (1.24, 5.13),  
47 OR=1.91 (1.02, 3.58), respectively). Additionally, BMI and WC were associated with high  
48 levels of HbA1c (OR=2.08 (1.15, 3.79), OR=3.01 (1.51, 6.03), respectively). In the combined  
49 regression model WC was associated with higher chances for hypertension (OR=2.62 (1.14,  
50 6.06)) and for high levels of HbA1c (OR=2.62 (1.12, 6.15)). **Conclusion:** High BMI, WC

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3 51 and BF% were strongly associated with hypertension, with individuals with high WC being  
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5 52 twice more likely to have hypertension; this calls for early and effective screening strategies  
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8 53 for this study population.  
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12 55 **Key words:** hypertension, diabetes, children, adolescents, adults, sub-Saharan Africa  
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## 18 19 57 **Strengths and limitations of this study**

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22 58 • This is the first study to report the associations between obesity indices and cardio-  
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24 59 metabolic risk factors in Zanzibar.  
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27 60 • The household-based approach, which involved visiting the families in the home setting,  
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29 61 resulted in a high individual response rate, thus minimising risk of selection bias.  
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32 62 • The cross-sectional design prevents us from drawing conclusions regarding the impact of  
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34 63 changes in obesity indices on risk factors.  
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37 64 • Bioelectrical Impedance Analysis (BIA) was used to estimate body fat percentage, which  
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39 65 might have underestimated adiposity in children.  
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## 67 Introduction

68 Worldwide, cardiovascular diseases (CVDs) are not only the leading cause of death<sup>1</sup>, they are  
69 also emerging as a notable public health problem in sub-Saharan African countries <sup>2</sup>. These  
70 countries are undergoing epidemiological transitions from communicable to non-  
71 communicable diseases (NCDs) that have been closely linked to increased urbanization and  
72 rural-urban migration, which has led to unhealthy behaviours, including poor dietary habits  
73 and sedentary lifestyles <sup>2 3</sup>. According to the International Diabetes Federation (IDF), about  
74 12 million people in Africa are estimated to have type 2 diabetes mellitus <sup>4</sup>, with the  
75 prevalence ranging from 1% in rural Uganda to 12 % in urban Kenya <sup>5 6</sup>. Overweight and  
76 obesity have been found to be modifiable risk factors for cardio-metabolic and other chronic  
77 diseases <sup>7</sup> including hypertension <sup>8</sup>, diabetes <sup>9</sup> and dyslipidemia <sup>10</sup>. The third report of the  
78 National Cholesterol Education Program-Adult treatment Panel (NCEP-ATP III) also  
79 identified central obesity, dyslipidemia (hypertriglyceridemia and low levels of high-density  
80 lipoprotein cholesterol [HDL-C]), impaired glucose tolerance, and elevated blood pressure as  
81 cardio-metabolic risk factors<sup>11</sup>.

82 Multiple obesity indices such as BMI, Waist Circumference (WC), Body fat percent (BF%)  
83 and Waist to Hip Ratio (WtHR) have been widely used to screen individuals for cardio-  
84 metabolic risk in clinical and research settings<sup>12-14</sup> due to their low-cost and ease of  
85 administration. The performance of anthropometric indices may however vary according to  
86 different factors, including ethnicity, age, geographical area and population<sup>13 15</sup>. BMI, which  
87 is based on weight and height, is the most widely used marker to assess body mass. In  
88 children and adolescents, the z-scores are used to classify obesity status <sup>16</sup>, which is linked to  
89 metabolic risk, e.g. in South African youth<sup>17</sup>. However, BMI does not distinguish well  
90 between lean mass and fat mass<sup>18</sup>. In contrast, WC is a measure of total body and abdominal  
91 fat accumulation and is better correlated with visceral adipose tissues than BMI. The

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3 92 correlation on the other hand varies significantly across ethnicities<sup>19 20</sup>. Another approach for  
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5 93 measuring body fat is through bioelectrical impedance analysis, which has also been done in  
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7 94 several epidemiological studies<sup>21</sup>. The use of different anthropometric measurements might  
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9 95 also provide complementary information which can be used to aid screening for cardio-  
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11 96 metabolic risk in different population settings<sup>22 23</sup>.  
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14 97 Few studies have investigated the performance of different obesity indices in association with  
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16 98 cardio-metabolic risk factors in sub Saharan African populations<sup>2 7 18</sup>. Data from mainland  
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18 99 Tanzania have shown an increasing prevalence of overweight and obesity in urban, peri-  
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20 100 urban and rural areas<sup>24</sup>. However, there is still a dearth of population-based studies  
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22 101 investigating the associations of cardio-metabolic risk factors with obesity indices in  
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24 102 Tanzania mainland and Zanzibar. To help fill this gap, this study uses cross-sectional data of  
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26 103 470 individuals between 5-95 years who were examined in 2013 in Unguja Island, Zanzibar,  
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28 104 to describe the prevalence of overweight/obesity and cardio-metabolic risk factors in three  
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30 105 age groups ( $\geq 5$  to  $< 18$  years,  $\geq 18$  to  $< 45$  years and above 45 years). The aim of the study was  
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32 106 to identify vulnerable groups in the Zanzibari population with respect to cardio-metabolic  
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34 107 risk. Consequently, we investigated the association of BMI, WC and BF% with cardio-  
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36 108 metabolic risk factors (hypertension, total cholesterol, triglycerides, high-density-lipoprotein,  
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38 109 low-density-lipoprotein, glycated HbA1c, fasting plasma glucose and HOMA-IR). We  
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40 110 considered the three obesity indices independently as well as combined, thereby reflecting  
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42 111 different aspects of body composition.  
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## 113 **Subjects and Methods**

### 114 Study population and design

115 We conducted a cross-sectional survey from September to December 2013 in a representative  
116 population sample in Unguja Island, Zanzibar. A total of 239 households were randomly  
117 selected and all household members were invited for the examination. As we also aimed to  
118 identify vulnerable groups within the families, we included young children and the elderly,  
119 who both normally depend on the family food environment. A two-staged sampling approach  
120 was used: (1) from a list of all 213 Shehias (wards), 80 Shehias were randomly selected; (2)  
121 households were randomly selected based on the Shehia's registration records. Participation  
122 agreement was requested from all members of a household. A total of 1,443 family members  
123 agreed to participate and completed anthropometric and blood pressure measurements, as  
124 well as interviewer-administered questionnaires. Venous blood was also collected. The  
125 subgroup examinations are described in detail below. The complete description of the study  
126 design and methods has been described in detail elsewhere <sup>25</sup>. The study was performed  
127 according to the Helsinki Declaration and the study protocol was evaluated and approved by  
128 the Ethics Committees of the University of Bremen and of the Zanzibar Ministry of Health  
129 and the Zanzibar Medical Research and Ethics Committee. All participants gave written  
130 informed consent and parents/guardians consented on behalf of their children in writing.

### 131 Patient and Public Involvement

132 During the development of the survey tools, measurements and the study protocol, a meeting  
133 was held with the local partners, government officials and researchers in Zanzibar to discuss  
134 the needs and gaps of the nutrition and health survey planned in Zanzibar. The documents  
135 and instruments were then modified according to the needs of the Zanzibari population as  
136 recommended in the meeting.

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3 137 A year after the survey, preliminary results on the major health outcomes and related risk  
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5 138 factors were presented and discussed during a two days feedback workshop with the  
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7 139 administrative leaders (e.g. Shehas, district commissioners), stakeholders (from health  
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9 140 services, government officials, food safety) and our local partners in Zanzibar (academics and  
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11 141 research). Each Sheha was handed a poster of the preliminary results, which was then  
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13 142 displayed at their local offices for all Shehia members to see. District commissioners received  
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15 143 a summary report on all Shehias of their districts. The preliminary results were further  
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17 144 publicised on TV and print media. The same group of workshop participants was invited to a  
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19 145 further workshop in 2018, whose aim was to identify target populations and channels for  
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21 146 future nutrition education to address the aetiology and prevention of NCDs in the Zanzibari  
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23 147 population, taking into consideration the survey results presented also in this study.

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26 148 This observational epidemiological study examined participants in their home environment  
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28 149 and did not enrol clinical patients.

#### 29 30 31 32 33 34 150 Questionnaires and anthropometric measurements

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37 151 Questionnaires were developed in English, translated into Swahili, and then back translated to  
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39 152 control for translation errors. Trained field staff collected the survey information. Parents  
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41 153 reported their age and sex, as well as that of their children. Age was grouped into three  
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43 154 categories  $\geq 5$  to  $< 18$  years,  $\geq 18$  to  $< 45$  years, and 45 years and above. In addition, parental  
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45 155 highest educational level according to the International Standard Classification of Education  
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47 156 (ISCED) <sup>26</sup> was used as a proxy indicator for socio-economic status (SES) of the family.  
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49 157 Education was categorized into low education (no education and primary school) and high  
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51 158 education (secondary school and above). To determine participants' area of residence,  
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53 159 information on region, district and Shehia (the smallest administrative unit in Zanzibar) was  
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55 160 recorded and two categories for area of residence were developed (urban and rural).  
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57 161 Utilization of medication was also documented in the questionnaire. Regarding medication

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3 162 for obesity-related conditions, participants reported use of hypertension medication but not of  
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5 163 diabetes or dyslipoproteinemia medication. Hence, the variable was later categorized as  
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7 164 “hypertension medication” and “other medication” (e.g. anti-Malaria therapy or antipyretic  
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9 165 products). To ensure a high quality of data collection, this study used proven examination  
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11 166 methods and laboratory standards <sup>27 28</sup>. All anthropometric measurements and physical  
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13 167 examinations were adopted from the IDEFICS Study and conducted following standardized  
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15 168 procedures <sup>29 30</sup>. Measurement of body weight was carried out to the nearest 0.1kg and body  
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17 169 fat percent was determined using the bioelectrical impedance analysis (BIA) method using an  
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19 170 electronic scale (TANITA BC-420 SMA, Germany). Height was measured using a SECA  
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21 171 213 stadiometer, UK, and waist circumference (WC) was measured midway between the  
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23 172 lowest rib and the iliac crest, using an inelastic measuring tape (SECA 201). For all  
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25 173 measurements, participants wore light clothing. The measures were recorded to the nearest  
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27 174 0.1cm. The complete description of the anthropometric measurements of the study is  
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29 175 described elsewhere <sup>25</sup>.

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36 176 For children and adolescents, Body Mass Index (BMI) was calculated as kg/m<sup>2</sup> and then  
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38 177 transformed to age-and sex-specific z-score and percentiles. Thereafter, categories for  
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40 178 overweight (BMI between >75<sup>th</sup> and <95<sup>th</sup> percentile) and obesity (BMI >95<sup>th</sup> percentile)  
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42 179 were built according to the WHO centile curves <sup>31 32</sup>. For adults, overweight/obesity was  
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44 180 defined as BMI  $\geq 25$ kg/m<sup>2</sup> as recommended by WHO <sup>33</sup>. For statistical analysis, the BMI  
45  
46 181 categories were merged into two 1) under-weight/ normal weight ( $\leq 75^{\text{th}}$  percentile for  
47  
48 182 children and adolescents and  $< 25$ kg/m<sup>2</sup> for adults) and 2) overweight/obesity ( $>75^{\text{th}}$   
49  
50 183 percentile and  $\geq 25$ kg/m<sup>2</sup> ). Regarding waist circumference (WC), high abdominal obesity  
51  
52 184 was defined as WC  $\geq 90^{\text{th}}$  percentile for children below 10 years <sup>34</sup>; WC  $\geq 90^{\text{th}}$  percentile for  
53  
54 185 adolescents aged 10 - <16 years; and WC  $>94$  cm for men and  $> 80$  cm for women for  
55  
56 186 participants 16 years and older, as recommended by the IDF <sup>35</sup>. As recommended by



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2  
3 187 McCarthy et al.<sup>36</sup>, for boys and girls below 18 years, high body fat percentage (BF%) was set  
4  
5 188 at  $\geq 85$ th percentile. For adults above 18 years, high BF% was defined as  $\geq 20$  % for men and  
6  
7  
8 189  $\geq 32$  % for women<sup>37</sup>. The cut-offs and references are listed in Table 1.  
9

### 10 11 190 Cardio-metabolic risk factors

12  
13 191 All blood samples were drawn after overnight fasting and were collected from all eligible  
14  
15 192 participants over 5 years of age by venepuncture<sup>38</sup>. To reduce pain, children below 10 years  
16  
17 193 of age were given a local anaesthetic plaster before blood drawing, which motivated the  
18  
19 194 children to participate. Before blood drawing, the procedure was once again explained to all  
20  
21 195 participants in easy language and they were informed that they still could refuse to  
22  
23 196 participate. For children weighing 10kg, the blood collection was restricted to 1%,  
24  
25 197 corresponding to approximately 8 mL. For healthy, non-pregnant adults weighing at least 50  
26  
27 198 kg, a maximum of 20.5 mL venous blood was drawn. Collection, processing and storage of  
28  
29 199 blood samples are described elsewhere<sup>25</sup>.  
30  
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33  
34 200 Metabolic parameters were categorized for investigating the prevalence of cardio-metabolic  
35  
36 201 disorders in the study population. Due to the wide range of age groups in this study  
37  
38 202 population, different cardio-metabolic risk definitions and cut-offs were used (Table 1).  
39  
40 203 Cardio-metabolic risk for children between 5-10 years was defined according to age-sex-  
41  
42 204 specific cut-offs. The parameters, including hypertension (Systolic Blood Pressure (SBP) and  
43  
44 205 Diastolic Blood Pressure (DBP)), blood lipids (high Total Cholesterol (TC), high  
45  
46 206 Triglycerides (TG), Low-Density-Lipoprotein Cholesterol (LDL-C) and High-Density-  
47  
48 207 Lipoprotein Cholesterol (HDL-C)), blood glucose/insulin (Homeostasis Model Assessment of  
49  
50 208 Insulin Resistance (HOMA-IR) and elevated Fasting Plasma Glucose (FPG), were defined  
51  
52 209 according to the IDEFICS Study<sup>34 39</sup>. Glycated haemoglobin (HbA1c) was defined according  
53  
54 210 to Rodoo et al.<sup>40</sup> for children under 17 years. For children and adolescents between 10 years  
55  
56 211 and 16 years, hypertension was defined according to age-sex-specific cut-offs as  
57  
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59  
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212 recommended <sup>41</sup>; for adolescents and adults above 16 years hypertension was defined as  
 213 recommended <sup>42</sup>. Blood lipids (TC and LDL-C) were defined according to the National  
 214 Cholesterol Education Program (NCEP) <sup>11</sup> and TG, HDL-C and FPG according to the  
 215 International Diabetes Federation (IDF) <sup>35</sup>. HbA1c for participants above 17 years was  
 216 defined according to Stern et al. <sup>43</sup> and insulin resistance was estimated as HOMA-IR  
 217 according to the reference value of HOMA-IR as recommended by Shashaj et al. <sup>44</sup>. In the  
 218 present study, the 75<sup>th</sup> percentile cut-off was used for children and adolescents from 10 to 17  
 219 years. For participants above 17 years, HOMA-IR was defined according to von Eyben et al  
 220 <sup>45</sup>. HOMA-IR was calculated from glucose (mmol/l) and insulin ( $\mu$ U/ml) concentrations  
 221 using the formula:  $HOMA-IR = (\text{fasting insulin} \times \text{fasting glucose} / 22.5)^{46}$ .

223 Table 1. Cardio-metabolic risk definitions and references

Age group	Obesity Indices and Blood Pressure	Blood lipids	Blood Glucose/Insulin
Children: $\leq 10$ y	BMI $\geq 75^{\text{th}}$ percentile <sup>1</sup>	TC $\geq 90^{\text{th}}$ percentile <sup>2</sup>	HbA1c $\geq 97.5^{\text{th}}$ percentile <sup>10</sup>
	WC $\geq 90^{\text{th}}$ percentile <sup>2</sup>	TG $\geq 90^{\text{th}}$ percentile <sup>2</sup>	HOMA-IR $\geq 95^{\text{th}}$ percentile <sup>2</sup>
	BF % $\geq 85^{\text{th}}$ percentile <sup>3</sup>	HDL-C $\leq 10^{\text{th}}$ percentile <sup>2</sup>	FPG $\geq 95^{\text{th}}$ percentile <sup>2</sup>
	SBP $\geq 90^{\text{th}}$ centile or DBP $\geq 90^{\text{th}}$ centile <sup>2</sup>	LDL $\geq 90^{\text{th}}$ percentile <sup>2</sup>	
Adolescents: >10 to <16 y	BMI $\geq 75^{\text{th}}$ percentile <sup>1</sup>	TC $\geq 5.2$ mmol/L <sup>6</sup>	HbA1c $\geq 97.5^{\text{th}}$ percentile <sup>10</sup>
	WC $\geq 90^{\text{th}}$ percentile <sup>4</sup>	TG $\geq 1.7$ mmol/L <sup>4</sup>	HOMA-IR $\geq 75^{\text{th}}$ percentile <sup>9</sup>
	BF % $\geq 85^{\text{th}}$ percentile <sup>3</sup>	HDL-C $< 1.03$ <sup>4</sup>	FPG $\geq 5.6$ mmol/L <sup>4</sup>
	SBP $\geq 140$ mmHg or DBP $\geq 90$ mmHg <sup>11</sup>	LDL $\geq 3.4$ mmol/L <sup>6</sup>	
Adults: $\geq 16$ y	BMI $\geq 25$ kg/m <sup>1</sup>	TC $\geq 5.2$ mmol/l <sup>6</sup>	HbA1c $\geq 6.1\%$ <sup>5</sup>
	WC $\geq 94$ cm male, $\geq 80$ cm female <sup>4</sup>	TG $\geq 1.7$ mmol/L, <sup>4</sup>	HOMA-IR $> 4.65$ or HOMA-IR $> 3.60$ and BMI $> 27.5$ kg/m <sup>2</sup> <sup>7</sup>
	BF % $\geq 20$ % male and	HDL-C $< 1.03$ male, $< 1.29$	FPG $\geq 5.6$ mmol/L <sup>4</sup>

	$\geq 32$ % female <sup>8</sup>	female <sup>4</sup>	
	SBP $\geq 140$ mmHg or DBP $\geq 90$ mmHg <sup>12</sup>	LDL $\geq 3.4$ mmol/L <sup>6</sup>	

224

225 1 WHO

226 2 IDEFICS Study

227 3 McCarthy, H.D., et al. (2006)

228 4 IDF

229 5 Stern, S.E., et al (2003) for adults above 17 years

230 6 NCEP

231 7 von Eyben, F.E., et al (2005)

232 8 Gallagher, D., et al (200)

233 9 Shashaj et al. (2015) for children and adolescents under 17 years

234 10 Rodoo P et al. (2013)

235 11, 12 National Institute of Health 3<sup>rd</sup> and 7<sup>th</sup> report respectively

236

237 Inclusion criteria for study sample

238 Of 1,443 individuals who participated in this study, 1,314 fulfilled the inclusion criteria (age, sex, weight, height) for the overall study analysis. Of the 1,314 participants, 1,234 provided complete waist circumference and body fat percent measurements. Among these, 557 provided complete blood samples for the cardio-metabolic risk analysis and only 505 were on fasting status. To reduce bias while estimating mean and SD in the regression analysis, we excluded the top 1% of individuals with extremely high values for cardio-metabolic risk and obesity indices, leaving us with a complete sample of 470 participants for the analysis.

245 Statistical analysis

246 Descriptive analysis was conducted to calculate the mean standard deviation (SD) and range (minimum, maximum) for continuous variables, as well as the distribution of the categorical data in N and percentages (%). As part of the regression analysis, we tested the necessary assumptions in terms of symmetry and normality using residual-plots and Q-Q-Plots. Mixed logistic regression models were used to analyse the association between obesity indices and cardio-metabolic risk factors. In addition, potential clustering within households was considered in terms of a random intercept. Following the hierarchy of the municipal structure

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3 253 in Zanzibar, we conducted sensitivity analysis modelling either Shehias or households within  
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5 254 Shehias as a random intercept in the models. Since the results of the models only showed  
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8 255 marginal differences, we only considered the household as a random intercept in our  
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10 256 analyses. First, mixed logistic regression models were conducted to estimate the association  
11  
12 257 between each of the three obesity indicators (BMI, WC and BF%) as exposure variables and  
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14 258 each of the eight risk factors (hypertension, TC, TG, HDL-C, LDL-C, HbA1c, FPG and  
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16 259 HOMA-IR) as dependent variables, in terms of odds ratios (OR) and 95% confidence limits  
17  
18 260 (CI). Since BMI, WC and BF% are interrelated, the strongest relationship with cardio-  
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20 261 metabolic risk factors was investigated by conducting mixed logistic regression models. This  
21  
22 262 was done by estimating the association (ORs and 95% CIs) between all three obesity indices  
23  
24 263 as dependent variables in one model and each of the eight risk factors as outcome variables.  
25  
26 264 All models were adjusted for potential confounders and covariates such as gender, age,  
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28 265 education level (ISCED), area of residence and utilization of hypertension medication.  
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30 266 Statistical analysis was performed using SAS 9.3 (SAS Institute. Cary. NC. U SA); mixed  
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32 267 logistic regression models were conducted based on the GLIMMIX procedure; statistical  
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34 268 significance was set at  $\alpha = 0.05$ .  
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## Results

### Distribution of obesity and cardio-metabolic risk and characteristics of the study population by age groups (n=470)

The mean age was 29 ( $\pm 18$ ) years, with the highest proportion being in the age group ( $\geq 18$  to  $< 45$  years) (Table 2). The overall mean values for BMI, WC and BF% were as follows: BMI 22 ( $\pm 5.2$ ) kg/m<sup>2</sup>, WC 75 ( $\pm 16$ ) cm and BF% 22 ( $\pm 11$ ) %. The mean BMI of 26 ( $\pm 5.7$ ) kg/m<sup>2</sup> for participants above 45 years was slightly higher than normal, indicating overweight. Mean diastolic blood pressure was in the normal range for all the age groups, but a higher mean value of systolic blood pressure, 150 ( $\pm 280$ ) mmHg, was observed among participants above 45 years. The mean values of most of the variables showed an increase with age group, except for HDL-C and diabetes markers (HbA1c, serum insulin, plasma glucose and HOMA-IR), which showed no specific trend.

Of the 470 participants, more than half were women 52.6% (n=247), 51.9% (244) had higher education level and 73.4% (345) resided in urban area. Regarding education level, the majority of those with higher education level were aged  $\geq 18$ - $< 45$  years (150/244 = 61%) (Table 3).

Table 2: Distribution of obesity and cardio-metabolic risk in the study population (n=470) by age group (means and standard deviation (SD))

	$\geq 5$ to $< 18$ years (n=165)		$\geq 18$ to $< 45$ years (n=195)		45+years (n=110)		Total (n=470)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Age (years)	12 (3.4)	4.9 -18	28 (8.1)	18-44	57 (9.8)	45-95	29 (18)	4.9-95
BMI (kg/m)	17 (3.4)	11-34	23 (4.5)	16-37	26 (5.7)	15-49	22 (5.7)	11-49
WC (cm)	61 (11)	12-103	79 (12)	37-111	88 (0.2)	35-126	75 (16)	12-126
BF (%)	15 (7.0)	1.6-45	23 ( 11)	3.0-53	28 (10)	6.2-53	22 (11)	1.6-53

DBP (mmHg)	67 (9.8)	44-97	76 (10)	53-126	88 (15)	62-140	75 (14)	44-140
SBP (mmHg)	110 (13)	69-152	123 (16)	72-197	150 (28)	100-229	125 (24)	69-229
TC (mmol/l)	3.7 (0.7)	1.8-5.9	3.9 (0.8)	2.1-6.0	4.2 (0.8)	0.2-5.9	3.9 (0.8)	0.2-6.0
TG (mmol/l)	0.8 (0.3)	0.3-2.5	0.9 (0.4)	0.0-2.6	1.0 (0.4)	0.4-2.7	0.9 (0.4)	0.0-2.7
HDL-C (mmol/l)	1.4 (0.5)	0.7-3.3	1.5 (0.5)	0.6-3.7	1.4 (0.4)	0.6-3.6	1.4 (0.5)	0.6-3.7
LDL-C (mmol/l)	2.3 (0.9)	0.0-5.0	2.5 (0.9)	0.7-5.1	3.0 (1.0)	0.6-5.1	2.5 (1.0)	0.0-5.1
HbA1c (%)	5.7 (0.5)	4.2-8.5	5.6 (0.6)	3.9-9.4	6.0 (0.8)	4.4-10	5.8 (0.6)	3.9-10
Serum Insulin (mmol/l)	4.3 (3.1)	0.4-18	4.8 (2.8)	0.8-17	3.6 (2.3)	0.4-17	4.4 (2.8)	0.4-18
FPG (mmol/l)	4.9 (0.8)	2.0-7.7	4.8 (0.9)	0.5-9.4	5.1 (1.3)	0.2-13	4.9 (1.0)	0.2-13
HOMA-IR	1.0 (0.7)	0.1-4.6	1.1 (0.7)	0.0-4.3	0.9 (0.6)	0.0-4.0	1.0 (0.7)	0.0-4.6

288

289 The overall proportion of overweight/obesity with regard to BMI, WC and BF % was 26.4%,  
 290 24.9% and 31.1% respectively, and increased with age (Table 2). The highest proportion was  
 291 observed among participants above 45 years. We observed different trends in the prevalence  
 292 of metabolic parameters and hypertension across age groups. The prevalence of hypertension,  
 293 high total cholesterol, LDL-C and HbA1c increased with age, while that for triglycerides and  
 294 HOMA-IR decreased with age. The most prevalent factors were reduced HDL-C (29.4%),  
 295 hypertension (24.5%) as well as raised LDL-C (21.3%) and HbA1c levels (19.1%). Although  
 296 hypertension was more prevalent among participants above 45 years, only about 9.4% (10) of  
 297 the participants in this age group were on hypertension medication. Further, high LDL-C and  
 298 HbA1c were more prevalent among participants above 45 years, and low HDL-C was most  
 299 prevalent among  $\geq 18$  to  $< 45$  year olds.

300

301 Table 3: Characteristics of the study population (n=470) by age group (n/%)

	$\geq 5$ to $< 18$ years		$\geq 18$ to $< 45$ years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
All	165	(100)	195	(100)	110	(100)	470	(100)
Gender								
Male	85	(51.5)	86	(44.1)	52	(47.3)	223	(47.4)

	≥5 to <18 years		≥18 to <45 years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
Female	80	(48.5)	109	(55.9)	58	(52.7)	247	(52.6)
Education level								
Low	122	(73.9)	45	(23.1)	59	(53.6)	226	(48.1)
High	43	(26.1)	150	(76.9)	51	(46.4)	244	(51.9)
Area of residence								
Rural	43	(26.1)	49	(25.1)	33	(30.0)	125	(26.6)
Urban	122	(73.9)	146	(74.9)	77	(70.0)	345	(73.4)
<b>Obesity Indices</b>								
BMI								
Underweight	83	(50.3)	29	(14.9)	9	(8.18)	121	(25.7)
Normal weight	73	(44.2)	106	(54.4)	46	(41.8)	225	(47.9)
Overweight/obese	9	(5.45)	60	(30.8)	55	(50.0)	124	(26.4)
Waist circumference								
Normal	165	(100)	141	(72.2)	47	(42.7)	353	(75.1)
High <sup>a</sup>	0	(0)	54	(27.7)	63	(57.3)	117	(24.9)
Body fat %								
Normal	157	(95.2)	121	(62.1)	46	(41.8)	324	(69.0)
High <sup>b</sup>	8	(4.86)	74	(37.9)	64	(58.2)	146	(31.1)
<b>Hypertension</b>								
Normal	123	(74.5)	76	(39.0)	10	(9.09)	209	(44.5)
Pre-hypertension	25	(15.8)	89	(45.6)	31	(28.2)	146	(31.1)
Hypertension	16	(9.70)	30	(15.4)	69	(62.7)	115	(24.5)
Hypertension medication <sup>c</sup>								
Yes	1	(0.61)	12	(6.38)	10	(9.43)	23	(5.02)
No	163	(99.4)	176	(93.6)	96	(90.6)	435	(95.0)
<b>Dyslipidaemia <sup>d</sup></b>								
Total cholesterol								
Normal	161	(97.6)	183	(93.8)	102	(92.7)	446	(94.9)
High	4	(2.42)	12	(6.15)	8	(7.27)	24	(5.11)
Triglycerides								
Normal	157	(95.2)	186	(95.4)	105	(95.5)	448	(95.3)
High	8	(4.85)	9	(4.62)	5	(4.55)	22	(4.68)
HDL-cholesterol								
Normal	126	(76.4)	128	(65.6)	78	(70.9)	332	(70.5)
Low	39	(23.6)	67	(34.4)	32	(29.1)	138	(29.4)
LDL-cholesterol								
Normal	141	(85.5)	163	(83.6)	66	(60.0)	370	(78.7)
High	24	(14.5)	32	(16.4)	44	(40.0)	100	(21.3)

	≥5 to <18 years		≥18 to <45 years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
<b>Diabetes Markers <sup>c</sup></b>								
HbA1c								
Normal	142	(86.1)	166	(85.1)	72	(65.5)	380	(80.9)
High	23	(13.9)	29	(14.9)	38	(34.5)	90	(19.1)
Plasma glucose								
Normal	136	(82.4)	167	(85.6)	88	(80.0)	391	(83.2)
High	29	(17.6)	28	(14.4)	22	(20.0)	79	(16.8)
HOMA-IR								
Normal	162	(98.2)	193	(99.0)	109	(99.1)	464	(98.7)
High	3	(1.82)	2	(1.03)	1	(0.91)	6	(1.28)

<sup>a</sup> High WC was defined as WC ≥90<sup>th</sup> percentile for children under 10y <sup>34</sup>. Adolescents between 10-16 years and adults above 16 years WC > 94 cm for men and > 80 cm for women according to IDF cut-off <sup>35</sup>

<sup>b</sup> High BF% for adults (overweight/obese) ≥ 20 for men and ≥32 for women according to (NIH/WHO) BMI guidelines <sup>37</sup> and ≥85<sup>th</sup> percentile for children <sup>36</sup>

<sup>c</sup> Missing information from 12 participants (n=458)

<sup>d</sup> High dyslipidemia for adults; was defined as total serum cholesterol (≥6.2mmol/l) and LDL-cholesterol (≥3.4mmol/l) <sup>11</sup> low HDL-C: <1.03 mmol/l in men or <1.29 mmol/l in women high and hypertriglyceridemia (≥1.7 mmol/l) <sup>35</sup> and for children according to IDEFICS study <sup>34</sup>

<sup>e</sup> High diabetes risk markers; high HbA1c (>6.1%) <sup>45</sup>, high fasting plasma glucose (≥5.6 mmol/l) <sup>35</sup> and HOMA-insulin resistance was defined as HOMA-IR >4.65. or HOMA-IR >3.60 and BMI >27.5 kg/m<sup>2</sup> <sup>43</sup> and for children high HbA1c (≥97.5<sup>th</sup> percentile), high fasting plasma glucose ≥95<sup>th</sup> percentile and HOMA-IR ≥95<sup>th</sup> percentile.

### Association between obesity indices and cardio-metabolic risk factors

Obesity indices (BMI, WC and BF %) were observed to be associated with one or more risk factors. Participants with high BMI (OR=2.41 (1.33, 4.47)), high WC (OR=3.68 (1.81, 7.52)) or high BF% (OR=2.51 (1.40, 4.51)) were more likely to be hypertensive (Table 4). Having high WC (OR=2.52 (1.24, 5.13)) or high BF% (OR=1.91 (1.02, 3.58)) was associated with higher chances of having high LDL-C. Furthermore, BMI (OR=2.08 (1.15-3.79)) and WC (OR=3.01 (1.51-6.03)) were associated with HbA1c levels. We further observed increased OR for obesity indices with regard to high total cholesterol, high triglycerides, low HDL-C, elevated glucose and HOMA-IR. As the proportion of individuals with high HOMA-IR was



327 very small in our sample (1,28%/n=6), the results was not considered in the final regression  
 328 analysis. Regarding goodness of fit of the models, values of the Akaike Information Criterion  
 329 (AIC), which estimates the quality of each model relative to that of each of the other models,  
 330 showed that models including WC as an obesity index tended to have a slightly stronger  
 331 relationship compared to those including BMI and BF%.

332

333 Table 4: Associations between obesity indices (independent) and cardio-metabolic risk  
 334 factors (dependent), adjusted for gender, age, education level, area of residence, and  
 335 hypertension medication (n=470)

Obesity indices	High BMI			High WC			High BF%					
	OR	(95% CI)	AIC	OR	(95% CI)	AIC	OR	(95% CI)	AIC			
Hypertension	<b>2.41</b>	<b>1.33</b>	<b>4.47</b>	<b>504.86</b>	<b>3.68</b>	<b>1.81</b>	<b>7.52</b>	<b>499.79</b>	<b>2.51</b>	<b>1.40</b>	<b>4.51</b>	<b>503.46</b>
High Total cholesterol	1.13	0.40	3.19	192.74	0.84	0.27	2.66	192.71	1.05	0.37	2.95	192.79
High Triglycerides	1.79	0.55	5.77	189.88	2.23	0.58	8.66	189.38	1.64	0.52	5.14	190.11
Low HDL cholesterol	1.21	0.62	2.37	516.08	1.15	0.55	2.42	516.25	1.06	0.54	2.05	516.37
High LDL cholesterol	1.45	0.78	2.69	457.62	<b>2.52</b>	<b>1.24</b>	<b>5.13</b>	<b>452.23</b>	<b>1.91</b>	<b>1.02</b>	<b>3.58</b>	<b>454.77</b>
High HbA1c	<b>2.08</b>	<b>1.15</b>	<b>3.79</b>	<b>442.70</b>	<b>3.01</b>	<b>1.51</b>	<b>6.03</b>	<b>438.53</b>	1.75	0.96	3.18	445.23
High Glucose	2.04	0.93	4.50	397.36	2.07	0.84	5.07	397.98	1.76	0.80	3.87	398.56

336

337 Table 5 presents results of mixed logistic regression models including all three obesity  
 338 indices to investigate the association with single cardio-metabolic risk factors. Compared to  
 339 the separate regression models, the ORs for most of the associations were attenuated.  
 340 However, having high WC was again associated with a higher chance of having hypertension  
 341 (OR=2.62 (1.14, 6.06)) and having high HbA1c levels (OR=2.62 (1.12, 6.15)). Again, as the  
 342 proportion of individuals with high HOMA-IR levels was very small in our sample  
 343 (1,28%/n=6), HOMA-IR was not considered in the final regression analysis.

344 Table 5: Associations between obesity indices (independent) and cardio-metabolic risk  
 345 factors (outcome) adjusted by gender, age, education level and area of residence (n=470)

Obesity indices	Combined Obesity Indices									AIC total
	BMI			WC			BF%			
Risk Factors	OR	(95% CI)		OR	(95% CI)		OR	(95% CI)		
Hypertension	1.19	0.48	2.95	<b>2.62</b>	<b>1.1</b>	<b>6.06</b>	1.48	0.63	3.51	501.3
High Total	1.31	0.25	6.79	0.71	0.1	2.92	1.01	0.19	5.32	196.5
High Triglycerides	1.34	0.25	7.16	1.90	0.3	9.52	1.02	0.19	5.52	193.2
Low HDL	1.35	0.48	3.76	1.09	0.4	2.67	0.82	0.98	2.25	519.9
High LDL	0.63	0.24	1.65	2.34	0.9	5.50	1.81	0.70	4.70	454.6
High HbA1c	1.53	0.61	3.81	<b>2.62</b>	<b>1.1</b>	<b>6.15</b>	0.82	0.32	2.10	441.6
Elevated Glucose	1.67	0.55	5.06	1.54	0.5	4.44	1.03	0.33	3.17	400.6

## 347 Discussion

348 This study is the first population-based survey in Unguja Island that investigated the  
349 association between multiple obesity indices (BMI, WC and BF%) and multiple cardio-  
350 metabolic risk factors in a representative Zanzibari population, aged 5-95 years. This study  
351 population, as in many other LMICs, is undergoing a coexistence of the double burden of  
352 underweight children and overweight/obese adults. Generally, about a quarter of the study  
353 population were overweight/obese, and obesity increased with age. This observation has also  
354 been reported in demographic health surveys from seven sub-Saharan African countries <sup>47</sup>. In  
355 the adult population, the prevalence of overweight/obesity was lower than that in Ghana <sup>7</sup>, but  
356 higher than in Nigeria <sup>2</sup> and Benin <sup>48</sup>. On the other hand, more than 50% of the children in  
357 this study were underweight, a proportion higher than that in other sub-Saharan African  
358 countries (Kenya, Nigeria, South Africa, Equatorial Guinea and Cameroon) <sup>49</sup>.

359 Dyslipidemia is a risk factor for a variety of cardiovascular diseases and is becoming more  
360 prevalent in sub-Saharan Africa, particularly the form of low HDL-C <sup>50 51</sup>. Despite the  
361 relatively normal levels of total cholesterol and triglycerides, low HDL-C affected about 29%  
362 of the overall population, an indication that low HDL-C affects a large proportion of adults  
363 above 18 years.. The low HDL-C levels observed in our study population might therefore be  
364 indicative of a notable and evolving cardiovascular risk in the study region. Our results are in  
365 line with a recent study in sub-Saharan Africa and Middle East with 30% of the participant  
366 having low HDL-C <sup>52</sup>. Other studies in sub-Saharan Africa reported even higher prevalence  
367 of low HDL-C, 43.1% in Nigeria <sup>2</sup> and 80% in Botswana <sup>53</sup>, mostly affecting individuals  
368 between 35-54 years.

369 In the present study, a high proportion of participants with high HbA1c (14%) and elevated  
370 fasting glucose (18%) are children below 18 years. Since diabetes in children in LMICs has

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3 371 not received much attention, it is likely that there is a high number of children with sub-  
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5 372 clinical complications due to delayed or missed diagnosis as well as a lack of regular  
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7 373 monitoring. The high proportions observed in this study are a possible indication that a large  
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10 374 proportion of diabetic participants are not aware of their status and are hence not monitored  
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12 375 or treated. The fact that diabetes medication was not reported in this sample supports this  
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14 376 assumption. However, when using WHO diabetes diagnostic criteria <sup>54</sup>, i.e. HbA1c cut-off  
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16 377  $\geq 6.5\%$  and FPG  $\geq 7.0\text{mmol/l}$ , the prevalence of diabetes in participants above 18 years  
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18 378 decreased to 8.14% and 3.05%, respectively (data not shown). The most intriguing result  
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20 379 however is the high proportion of children between 5 and <18 years being at high risk for  
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22 380 diabetes with elevated FPG levels when using cut-off of  $\geq 5.6\text{mmol/l}$ . Our results showed that  
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24 381 the prevalence of FPG and HOMA-IR in children and adolescents below 18 years was in  
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26 382 general higher than that of adults above 18 years, but less than that of adults above 45 years.  
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28 383 Results from previous cross-sectional studies have shown that physiological transient insulin  
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30 384 resistance develops in children during puberty<sup>55</sup> and decreases again by the end of puberty,  
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32 385 regardless of obesity. The decrease in insulin sensitivity in the pubertal period is said to lead  
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34 386 to an increase in glucose-stimulated insulin secretion<sup>56</sup>. The high prevalence of FPG and  
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36 387 HOMA-IR observed in children and adolescents in our study could hence be due to  
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38 388 physiological changes in children and adolescents during pre-pubertal period and puberty.  
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40 389 They could however also be due to misreporting (children did not report having eaten prior to  
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42 390 the blood drawing), or to a true high risk within this age group. Considering this, we adjusted  
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44 391 for age in the regression models in order to control for possible confounding effects of  
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46 392 physiological changes through maturation and aging. Interestingly, the prevalence of high  
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48 393 FPG decreased from approximately 18% to 0.61% when we used the WHO <sup>54</sup> diabetes  
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50 394 diagnostic criteria (FPG  $\geq 7\text{mmol/l}$ ) for the same age group (data not shown). This, in our  
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52 395 opinion, indicates that the majority of the children are at risk for diabetes, and that the cut-off  
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3 396 for HbA1c  $\geq 6.1\%$  as well as elevated FPG  $\geq 5.6$  mmol/l seem to be better screening tools for  
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5 397 identifying those at risk, earlier.

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8 398 Our study showed a strong association between BMI, WC and BF% and hypertension in the  
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10 399 study population. These findings are in agreement with other studies that also reported an  
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12 400 association between hypertension/pre-hypertension, BMI and WC <sup>57</sup> as well as BF% <sup>7</sup>.  
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14 401 Moreover, the association between hypertension and high WC was twice as strong as that  
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16 402 with high BMI and high %BF. This result suggests that central obesity may be a better  
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18 403 indicator for the risk of hypertension and other cardiovascular diseases in our study  
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20 404 population. Thus, optimal body weight control and reduced central obesity risk may have  
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22 405 beneficial effects on hypertension control in this population. This study also observed a  
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24 406 strong association between WC and LDL-C levels. Obirikorang also reported similar  
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26 407 associations in a comparative cross-sectional study conducted in Ghana <sup>7</sup>.

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31 408 In the separate models, strong associations were observed between BMI, WC and HbA1c  
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33 409 levels, which can be explained by the interrelation of the two indices, since abdominal fat  
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35 410 accumulation increases in proportion to BMI <sup>58</sup> and BMI is one of the main risk factors for  
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37 411 diabetes and pre-diabetes <sup>59</sup>. However, when all three obesity indices were combined, it is  
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39 412 only the association between WC and HbA1c levels and hypertension that remained strong.  
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41 413 Excessive visceral fat in abdominal obesity is the main source of free fatty acids and  
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43 414 inflammatory cytokines, which, according to the literature, might lead to insulin resistance  
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45 415 and type 2 diabetes mellitus<sup>60</sup>. This probably explains why WC was strongly associated with  
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47 416 diabetes and hypertension in our study population. Therefore, measuring WC using optimal  
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49 417 WC cut-off values as was done in this study would be a feasible, less time consuming and  
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51 418 cost-effective screening tool to identify at-risk individuals in the Zanzibari population.

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58 419 This study has some limitations that should be considered. First, this study investigated the  
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60 420 association between obesity indices and cardio-metabolic risk factors using cross-sectional

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3 421 data; thus we were not able to examine the impact of changes in obesity indices on risk  
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5 422 factors. Second, as is done in many epidemiological studies and clinical trials, we used  
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7 423 Bioelectrical Impedance Analysis (BIA) to estimate body fat percentage. However, compared  
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9 424 to skinfold measurements, BIA measurements may underestimate adiposity in children <sup>61</sup>.  
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11 425 Third, even though we excluded participants who reported food or beverage intake prior to  
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13 426 blood drawing during the data cleaning process, we cannot entirely rule out misreporting of  
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15 427 the “fasting status”. According to our power calculation, our sample size of 1,314 individuals  
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17 428 would have been enough to reach a statistical power. However, our study sample decreased to  
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19 429 470 due to the individual opt-out option for particular examinations as well as the exclusion  
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21 430 of outliers and the requirement of completeness of variables of interest. We nevertheless  
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23 431 believe that our findings provide important information for public health stakeholders, policy  
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25 432 makers and researchers, despite the fact that some of the detected associations did not reach  
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27 433 the significance threshold due to the small sample size.  
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34 434 The results of this research can be used for the development of interventions or policies by  
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36 435 researchers, stakeholders and government officials. The random selection of the study  
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38 436 participants and the standardised assessment of anthropometrical and laboratory  
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40 437 measurements are main strengths of the present study. Moreover, we consequently applied  
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42 438 age- and sex-specific cut-offs that take into account the physiological development  
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44 439 characteristic of the young age group, rather than applying the fixed cut-offs used in the adult  
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46 440 population. There is little information on the association of multiple obesity indices with  
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48 441 multiple cardio-metabolic risk factors in this population; hence, our study provides an  
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50 442 important contribution towards filling this gap.  
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## 444 Conclusion

445 This study adds to the literature on the association of obesity with higher risks for  
446 hypertension, dyslipidemia and type 2 diabetes mellitus, but for the first time in a Zanzibari  
447 population. Based on our findings, we recommend that similar epidemiological studies  
448 including children, adolescents, adults and elderly set diabetes and/or pre-diabetes cut-offs of  
449 HbA1c at  $\geq 6.1\%$  and/or elevated fasting glucose at  $\geq 5.6\text{mmol/l}$ . Where feasible, BF% and  
450 WC should be used in addition to BMI for screening and monitoring for dyslipidemia and  
451 hypertension. We further conclude that there is a need for effective interventions to create  
452 awareness as well as for primary prevention strategies for cardio-metabolic risks and its  
453 complications in Unguja Island, using local multidisciplinary approaches in the local  
454 language, Swahili. Additionally, there is a need for health surveillance initiatives that  
455 particularly target the age group  $\geq 18$  to  $< 45$  years. These can also be used to help monitor  
456 prevention activities.

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### 461 **Competing interests**

462 The authors declare that they have no competing interests.

### 464 **Author's Contribution**

465 The authors' responsibilities were as follows: AH and MN were responsible for study  
466 design. AH, MN and SK conducted data collection and developed study hypothesis. MAN  
467 and CB conducted statistical analyses and KB assisted in the statistical data cleaning. MAN  
468 wrote the manuscript and had primary responsibility for final content. MN, CB, SK, MS, KB  
469 and AH critically revised the manuscript and gave final consent.

### 471 **Data sharing statement**

472 The datasets generated and/or analysed during the current study are not publicly available  
473 since a follow-up study is planned.

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60STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract  Cross-sectional study (b) Provide in the abstract an informative and balanced summary of what was done and what was found  Completed in the abstract, please refer to <i>line 27-53</i>
<b>Introduction</b>		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported  This has been explained in the Introduction section .
Objectives	3	State specific objectives, including any prespecified hypotheses  -To determine the prevalence of obesity indices (body mass index (BMI), waist circumference (WC), body fat percent (BF%)) and cardio-metabolic risk factors. -To investigate the association between obesity indices and cardio-metabolic risk factors in a Zanzibari population.
<b>Methods</b>		
Study design	4	Present key elements of study design early in the paper  This has been presented in the abstract , please refer to <i>line 31-34</i> .  <b>Key elements of study design</b> : cross-sectional survey , in a representative population sample in Unguja Island, Zanzibar, households were randomly selected and all household members were invited for the examination.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection  This has been described in the method section, please refer to <i>line 115-125</i>
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants  This has been described in the method section, refer to <i>line 116-124</i>
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable  This has been defined in the method section, refer to <i>line 150-225</i> including <b>Table 1</b> <i>line 225-237</i> <i>Since clinical patients were not included, diagnostic criteria is not applicable</i>
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). -Please refer to method section <i>line 161-225</i>  Describe comparability of assessment methods if there is more than one group

-Not applicable

Bias	9	Describe any efforts to address potential sources of bias
		This was described in the inclusion criteria where outliers were deleted from the sample in order to reduce bias. Refer to <i>line 246</i>
Study size	10	Explain how the study size was arrived at
		This has been described in <i>line 119-122</i>
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
		-Quantitative variables were grouped into categories according to the given cut-offs, please refer to method sections <i>anthropometric measurements and cardiometabolic risk factors</i>
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
		(b) Describe any methods used to examine subgroups and interactions
		(c) Explain how missing data were addressed
		(d) If applicable, describe analytical methods taking account of sampling strategy
		(e) Describe any sensitivity analyses
		-all the above points have been discussed in the statistical analysis, refer to <i>line 251-272</i>
<b>Results</b>		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		This has been described in <i>line 242-246</i>
		(b) Give reasons for non-participation at each stage
		This has been described in <i>line 242-246</i>
		(c) Consider use of a flow diagram
		-Not feasible because of different age groups
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		Please refer to <i>line 277-304</i> and <i>Tables 2 and 3</i>
		(b) Indicate number of participants with missing data for each variable of interest
		-This was not described in the manuscript, the missing data for each variable of interest were deleted during data cleaning and before running the statistical analysis. Please refer to the inclusion criteria section for general overview, <i>line 242-248</i>
Outcome data	15*	Report numbers of outcome events or summary measures
		-Please refer to result sections table 3
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

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adjusted for and why they were included

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(b) Report category boundaries when continuous variables were categorized

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(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period . *Not relevant*

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-Please refer to result section tables 4 and 5

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Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
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-This is was not applied to this manuscript.

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### Discussion

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Key results	18	Summarise key results with reference to study objectives
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-This has been decribed in the discussion section, please refer to *line 348 onwards*

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Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
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-Limitations of the study have been described in *line 427-441*

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Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
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-Please refer to the conclusion section from *line 353 onwards*

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Generalisability	21	Discuss the generalisability (external validity) of the study results
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-Based on the findings of the study, similar epidemiological surveys could be conducted in the rest of the Island. Please refer to the conclusion section.

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### Other information

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Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based
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-This work was supported by the Leibniz-Gemeinschaft grant number SAW-2012-ZMT-4. *See line 483*

-The present article is based on the “Access to Food and Nutritional Status of the Zanzibari population” study, *please refer to reference no.25*

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\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Association between cardio-metabolic risk factors and body mass index, waist circumferences and body fat in a Zanzibari cross-sectional study

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-025397.R3
Article Type:	Research
Date Submitted by the Author:	16-Apr-2019
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<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Epidemiology, Diabetes and endocrinology
Keywords:	Hypertension < CARDIOLOGY, children, DIABETES & ENDOCRINOLOGY, adolescents, adults, sub-Saharan Africa

SCHOLARONE™  
Manuscripts



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3 **1 Association between cardio-metabolic risk factors and body mass index, waist**  
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5 **2 circumferences and body fat in a Zanzibari cross-sectional study**  
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12 5 Maria Adam Nyangasa <sup>1</sup>, Christoph Buck <sup>1</sup>, Soerge Kelm <sup>2</sup>, Mohammed Ali Sheikh<sup>3</sup>, Kim  
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14 6 Brackmann <sup>1</sup>, Antje Hebestreit <sup>1\*</sup>  
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## 26 Abstract

27 **Objectives:** To determine the prevalence of obesity indices (body mass index (BMI), waist  
28 circumference (WC), body fat percent (BF%)) and cardio-metabolic risk factors. To  
29 investigate the association between obesity indices and cardio-metabolic risk factors in a  
30 Zanzibari population.

31 **Designs:** Cross-sectional study.

32 **Settings:** Participants randomly selected from 80 Shehias (wards) in Unguja, Zanzibar in  
33 2013.

34 **Participants:** A total of 470 participants between 5-95 years were examined. Data on socio-  
35 economic status, area of residence, anthropometry and venous blood were collected.  
36 Associations between obesity indices and cardio-metabolic risk factors were investigated  
37 using multilevel logistic regression analyses in two steps: first, each obesity indicator was  
38 tested independently; second, all indicators combined in one model were tested for their  
39 association with cardio-metabolic risk factors.

40 **Results:** The proportion of overweight/obese individuals was 26.4%, high WC (24.9%) and  
41 high BF% (31.1%). Cardio-metabolic risk factors with highest prevalence of abnormal values  
42 included hypertension (24.5%), low HDL-C (29.4%), high LDL-C (21.3%) and high HbA1c  
43 (19.1%). Obesity and hypertension increased with age, and were most prevalent in  
44 participants aged 45 years and above. Low HDL-C was most prevalent among participants  
45  $\geq 18$  to  $< 45$  years old, while high LDL-C was more prevalent in those above 45 years. High  
46 WC and high BF% were associated with high levels of LDL-C (OR=2.52 (1.24, 5.13),  
47 OR=1.91 (1.02, 3.58), respectively). Additionally, BMI and WC were associated with high  
48 levels of HbA1c (OR=2.08 (1.15, 3.79), OR=3.01 (1.51, 6.03), respectively). In the combined  
49 regression model WC was associated with higher chances for hypertension (OR=2.62 (1.14,  
50 6.06)) and for high levels of HbA1c (OR=2.62 (1.12, 6.15)). **Conclusion:** High BMI, WC

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3 51 and BF% were strongly associated with hypertension, with individuals with high WC being  
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5 52 twice more likely to have hypertension; this calls for early and effective screening strategies  
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8 53 for this study population.  
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12 55 **Key words:** hypertension, diabetes, children, adolescents, adults, sub-Saharan Africa  
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## 19 57 **Strengths and limitations of this study**

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22 58 • This is the first study to report the associations between obesity indices and cardio-  
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24 59 metabolic risk factors in Zanzibar.  
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27 60 • The household-based approach, which involved visiting the families in the home setting,  
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29 61 resulted in a high individual response rate, thus minimising risk of selection bias.  
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32 62 • The cross-sectional design prevents us from drawing conclusions regarding the impact of  
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34 63 changes in obesity indices on risk factors.  
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37 64 • Bioelectrical Impedance Analysis (BIA) was used to estimate body fat percentage, which  
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39 65 might have underestimated adiposity in children.  
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## 67 Introduction

68 Worldwide, cardiovascular diseases (CVDs) are not only the leading cause of death<sup>1</sup>, they are  
69 also emerging as a notable public health problem in sub-Saharan African countries <sup>2</sup>. These  
70 countries are undergoing epidemiological transitions from communicable to non-  
71 communicable diseases (NCDs) that have been closely linked to increased urbanization and  
72 rural-urban migration, which has led to unhealthy behaviours, including poor dietary habits  
73 and sedentary lifestyles <sup>2 3</sup>. According to the International Diabetes Federation (IDF), about  
74 12 million people in Africa are estimated to have type 2 diabetes mellitus <sup>4</sup>, with the  
75 prevalence ranging from 1% in rural Uganda to 12 % in urban Kenya <sup>5 6</sup>. Overweight and  
76 obesity have been found to be modifiable risk factors for cardio-metabolic and other chronic  
77 diseases <sup>7</sup> including hypertension <sup>8</sup>, diabetes <sup>9</sup> and dyslipidemia <sup>10</sup>. The third report of the  
78 National Cholesterol Education Program-Adult treatment Panel (NCEP-ATP III) also  
79 identified central obesity, dyslipidemia (hypertriglyceridemia and low levels of high-density  
80 lipoprotein cholesterol [HDL-C]), impaired glucose tolerance, and elevated blood pressure as  
81 cardio-metabolic risk factors<sup>11</sup>.

82 Multiple obesity indices such as BMI, Waist Circumference (WC), Body fat percent (BF%)  
83 and Waist to Hip Ratio (WtHR) have been widely used to screen individuals for cardio-  
84 metabolic risk in clinical and research settings<sup>12-14</sup> due to their low-cost and ease of  
85 administration. The performance of anthropometric indices may however vary according to  
86 different factors, including ethnicity, age, geographical area and population<sup>13 15</sup>. BMI, which  
87 is based on weight and height, is the most widely used marker to assess body mass. In  
88 children and adolescents, the z-scores are used to classify obesity status <sup>16</sup>, which is linked to  
89 metabolic risk, e.g. in South African youth<sup>17</sup>. However, BMI does not distinguish well  
90 between lean mass and fat mass<sup>18</sup>. In contrast, WC is a measure of total body and abdominal  
91 fat accumulation and is better correlated with visceral adipose tissues than BMI. The

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3 92 correlation on the other hand varies significantly across ethnicities<sup>19 20</sup>. Another approach for  
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5 93 measuring body fat is through bioelectrical impedance analysis, which has also been done in  
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8 94 several epidemiological studies<sup>21</sup>. The use of different anthropometric measurements might  
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10 95 also provide complementary information which can be used to aid screening for cardio-  
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12 96 metabolic risk in different population settings<sup>22 23</sup>.  
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14 97 Few studies have investigated the performance of different obesity indices in association with  
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16 98 cardio-metabolic risk factors in sub Saharan African populations<sup>2 7 18</sup>. Data from mainland  
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18 99 Tanzania have shown an increasing prevalence of overweight and obesity in urban, peri-  
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20 100 urban and rural areas<sup>24</sup>. However, there is still a dearth of population-based studies  
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22 101 investigating the associations of cardio-metabolic risk factors with obesity indices in  
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24 102 Tanzania mainland and Zanzibar. To help fill this gap, this study uses cross-sectional data of  
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26 103 470 individuals between 5-95 years who were examined in 2013 in Unguja Island, Zanzibar,  
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28 104 to describe the prevalence of overweight/obesity and cardio-metabolic risk factors in three  
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30 105 age groups ( $\geq 5$  to  $< 18$  years,  $\geq 18$  to  $< 45$  years and above 45 years). The aim of the study was  
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32 106 to identify vulnerable groups in the Zanzibari population with respect to cardio-metabolic  
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34 107 risk. Consequently, we investigated the association of BMI, WC and BF% with cardio-  
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36 108 metabolic risk factors (hypertension, total cholesterol, triglycerides, high-density-lipoprotein,  
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38 109 low-density-lipoprotein, glycated HbA1c, fasting plasma glucose and HOMA-IR). We  
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40 110 considered the three obesity indices independently as well as combined, thereby reflecting  
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42 111 different aspects of body composition.  
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## 113 **Subjects and Methods**

### 114 Study population and design

115 We conducted a cross-sectional survey from September to December 2013 in a representative  
116 population sample in Unguja Island, Zanzibar. A total of 239 households were randomly  
117 selected and all household members were invited for the examination. As we also aimed to  
118 identify vulnerable groups within the families, we included young children and the elderly,  
119 who both normally depend on the family food environment. A two-staged sampling approach  
120 was used: (1) from a list of all 213 Shehias (wards), 80 Shehias were randomly selected; (2)  
121 households were randomly selected based on the Shehia's registration records. Participation  
122 agreement was requested from all members of a household. A total of 1,443 family members  
123 agreed to participate and completed anthropometric and blood pressure measurements, as  
124 well as interviewer-administered questionnaires. Venous blood was also collected. The  
125 subgroup examinations are described in detail below. The complete description of the study  
126 design and methods has been described in detail elsewhere <sup>25</sup>. The study was performed  
127 according to the Helsinki Declaration and the study protocol was evaluated and approved by  
128 the Ethics Committees of the University of Bremen and of the Zanzibar Ministry of Health  
129 and the Zanzibar Medical Research and Ethics Committee. All participants gave written  
130 informed consent and parents/guardians consented on behalf of their children in writing.

### 131 Patient and Public Involvement

132 During the development of the survey tools, measurements and the study protocol, a meeting  
133 was held with the local partners, government officials and researchers in Zanzibar to discuss  
134 the needs and gaps of the nutrition and health survey planned in Zanzibar. The documents  
135 and instruments were then modified according to the needs of the Zanzibari population as  
136 recommended in the meeting.

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3 137 A year after the survey, preliminary results on the major health outcomes and related risk  
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5 138 factors were presented and discussed during a two days feedback workshop with the  
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7 139 administrative leaders (e.g. Shehas, district commissioners), stakeholders (from health  
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9 140 services, government officials, food safety) and our local partners in Zanzibar (academics and  
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11 141 research). Each Sheha was handed a poster of the preliminary results, which was then  
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13 142 displayed at their local offices for all Shehia members to see. District commissioners received  
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15 143 a summary report on all Shehias of their districts. The preliminary results were further  
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17 144 publicised on TV and print media. The same group of workshop participants was invited to a  
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19 145 further workshop in 2018, whose aim was to identify target populations and channels for  
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21 146 future nutrition education to address the aetiology and prevention of NCDs in the Zanzibari  
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23 147 population, taking into consideration the survey results presented also in this study.

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26 148 This observational epidemiological study examined participants in their home environment  
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28 149 and did not enrol clinical patients.

#### 29 30 31 32 33 34 150 Questionnaires and anthropometric measurements

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37 151 Questionnaires were developed in English, translated into Swahili, and then back translated to  
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39 152 control for translation errors. Trained field staff collected the survey information. Parents  
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41 153 reported their age and sex, as well as that of their children. Age was grouped into three  
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43 154 categories  $\geq 5$  to  $< 18$  years,  $\geq 18$  to  $< 45$  years, and 45 years and above. In addition, parental  
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45 155 highest educational level according to the International Standard Classification of Education  
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47 156 (ISCED) <sup>26</sup> was used as a proxy indicator for socio-economic status (SES) of the family.  
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49 157 Education was categorized into low education (no education and primary school) and high  
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51 158 education (secondary school and above). To determine participants' area of residence,  
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53 159 information on region, district and Shehia (the smallest administrative unit in Zanzibar) was  
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55 160 recorded and two categories for area of residence were developed (urban and rural).  
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57 161 Utilization of medication was also documented in the questionnaire. Regarding medication

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3 162 for obesity-related conditions, participants reported use of hypertension medication but not of  
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5 163 diabetes or dyslipoproteinemia medication. Hence, the variable was later categorized as  
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7 164 “hypertension medication” and “other medication” (e.g. anti-Malaria therapy or antipyretic  
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9 165 products). To ensure a high quality of data collection, this study used proven examination  
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11 166 methods and laboratory standards <sup>27 28</sup>. All anthropometric measurements and physical  
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13 167 examinations were adopted from the IDEFICS Study and conducted following standardized  
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15 168 procedures <sup>29 30</sup>. Measurement of body weight was carried out to the nearest 0.1kg and body  
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17 169 fat percent was determined using the bioelectrical impedance analysis (BIA) method using an  
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19 170 electronic scale (TANITA BC-420 SMA, Germany). Height was measured using a SECA  
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21 171 213 stadiometer, UK, and waist circumference (WC) was measured midway between the  
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23 172 lowest rib and the iliac crest, using an inelastic measuring tape (SECA 201). For all  
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25 173 measurements, participants wore light clothing. The measures were recorded to the nearest  
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27 174 0.1cm. The complete description of the anthropometric measurements of the study is  
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29 175 described elsewhere <sup>25</sup>.

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36 176 For children and adolescents, Body Mass Index (BMI) was calculated as kg/m<sup>2</sup> and then  
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38 177 transformed to age-and sex-specific z-score and percentiles. Thereafter, categories for  
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40 178 overweight (BMI between >75<sup>th</sup> and <95<sup>th</sup> percentile) and obesity (BMI >95<sup>th</sup> percentile)  
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42 179 were built according to the WHO centile curves <sup>31 32</sup>. For adults, overweight/obesity was  
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44 180 defined as BMI  $\geq 25$ kg/m<sup>2</sup> as recommended by WHO <sup>33</sup>. For statistical analysis, the BMI  
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46 181 categories were merged into two 1) under-weight/ normal weight ( $\leq 75^{\text{th}}$  percentile for  
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48 182 children and adolescents and  $< 25$ kg/m<sup>2</sup> for adults) and 2) overweight/obesity ( $>75^{\text{th}}$   
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50 183 percentile and  $\geq 25$ kg/m<sup>2</sup> ). Regarding waist circumference (WC), high abdominal obesity  
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52 184 was defined as WC  $\geq 90^{\text{th}}$  percentile for children below 10 years <sup>34</sup>; WC  $\geq 90^{\text{th}}$  percentile for  
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54 185 adolescents aged 10 - <16 years; and WC  $>94$  cm for men and  $> 80$  cm for women for  
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56 186 participants 16 years and older, as recommended by the IDF <sup>35</sup>. As recommended by



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3 187 McCarthy et al. <sup>36</sup>, for boys and girls below 18 years, high body fat percentage (BF%) was set  
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5 188 at  $\geq 85$ th percentile. For adults above 18 years, high BF% was defined as  $\geq 20$  % for men and  
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7 189  $\geq 32$  % for women <sup>37</sup>. The cut-offs and references are listed in Table 1.  
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### 10 11 190 Cardio-metabolic risk factors 12

13 191 All blood samples were drawn after overnight fasting and were collected from all eligible  
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15 192 participants over 5 years of age by venepuncture <sup>38</sup>. To reduce pain, children below 10 years  
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17 193 of age were given a local anaesthetic plaster before blood drawing, which motivated the  
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19 194 children to participate. Before blood drawing, the procedure was once again explained to all  
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21 195 participants in easy language and they were informed that they still could refuse to  
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23 196 participate. For children weighing 10kg, the blood collection was restricted to 1%,  
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25 197 corresponding to approximately 8 mL. For healthy, non-pregnant adults weighing at least 50  
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27 198 kg, a maximum of 20.5 mL venous blood was drawn. Collection, processing and storage of  
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29 199 blood samples are described elsewhere <sup>25</sup>.  
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34 200 Metabolic parameters were categorized for investigating the prevalence of cardio-metabolic  
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36 201 disorders in the study population. Due to the wide range of age groups in this study  
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38 202 population, different cardio-metabolic risk definitions and cut-offs were used (Table 1).  
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40 203 Cardio-metabolic risk for children between 5-10 years was defined according to age-sex-  
41  
42 204 specific cut-offs. The parameters, including hypertension (Systolic Blood Pressure (SBP) and  
43  
44 205 Diastolic Blood Pressure (DBP)), blood lipids (high Total Cholesterol (TC), high  
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46 206 Triglycerides (TG), Low-Density-Lipoprotein Cholesterol (LDL-C) and High-Density-  
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48 207 Lipoprotein Cholesterol (HDL-C)), blood glucose/insulin (Homeostasis Model Assessment of  
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50 208 Insulin Resistance (HOMA-IR) and elevated Fasting Plasma Glucose (FPG), were defined  
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52 209 according to the IDEFICS Study <sup>34 39</sup>. Glycated haemoglobin (HbA1c) was defined according  
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54 210 to Rodoo et al. <sup>40</sup> for children under 17 years. For children and adolescents between 10 years  
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56 211 and 16 years, hypertension was defined according to age-sex-specific cut-offs as  
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212 recommended <sup>41</sup>; for adolescents and adults above 16 years hypertension was defined as  
 213 recommended <sup>42</sup>. Blood lipids (TC and LDL-C) were defined according to the National  
 214 Cholesterol Education Program (NCEP) <sup>11</sup> and TG, HDL-C and FPG according to the  
 215 International Diabetes Federation (IDF) <sup>35</sup>. HbA1c for participants above 17 years was  
 216 defined according to Stern et al. <sup>43</sup> and insulin resistance was estimated as HOMA-IR  
 217 according to the reference value of HOMA-IR as recommended by Shashaj et al. <sup>44</sup>. In the  
 218 present study, the 75<sup>th</sup> percentile cut-off was used for children and adolescents from 10 to 17  
 219 years. For participants above 17 years, HOMA-IR was defined according to von Eyben et al  
 220 <sup>45</sup>. HOMA-IR was calculated from glucose (mmol/l)) and insulin ( $\mu$ U/ml) concentrations  
 221 using the formula:  $HOMA-IR = (\text{fasting insulin} \times \text{fasting glucose} / 22.5)^{46}$ .

223 Table 1. Cardio-metabolic risk definitions and references

Age group	Obesity Indices and Blood Pressure	Blood lipids	Blood Glucose/Insulin
Children: $\leq 10$ y	BMI $\geq 75^{\text{th}}$ percentile <sup>1</sup>	TC $\geq 90^{\text{th}}$ percentile <sup>2</sup>	HbA1c $\geq 97.5^{\text{th}}$ percentile <sup>10</sup>
	WC $\geq 90^{\text{th}}$ percentile <sup>2</sup>	TG $\geq 90^{\text{th}}$ percentile <sup>2</sup>	HOMA-IR $\geq 95^{\text{th}}$ percentile <sup>2</sup>
	BF % $\geq 85^{\text{th}}$ percentile <sup>3</sup>	HDL-C $\leq 10^{\text{th}}$ percentile <sup>2</sup>	FPG $\geq 95^{\text{th}}$ percentile <sup>2</sup>
	SBP $\geq 90^{\text{th}}$ centile or DBP $\geq 90^{\text{th}}$ centile <sup>2</sup>	LDL $\geq 90^{\text{th}}$ percentile <sup>2</sup>	
Adolescents: >10 to <16 y	BMI $\geq 75^{\text{th}}$ percentile <sup>1</sup>	TC $\geq 5.2$ mmol/L <sup>6</sup>	HbA1c $\geq 97.5^{\text{th}}$ percentile <sup>10</sup>
	WC $\geq 90^{\text{th}}$ percentile <sup>4</sup>	TG $\geq 1.7$ mmol/L <sup>4</sup>	HOMA-IR $\geq 75^{\text{th}}$ percentile <sup>9</sup>
	BF % $\geq 85^{\text{th}}$ percentile <sup>3</sup>	HDL-C $< 1.03$ <sup>4</sup>	FPG $\geq 5.6$ mmol/L <sup>4</sup>
	SBP $\geq 140$ mmHg or DBP $\geq 90$ mmHg <sup>11</sup>	LDL $\geq 3.4$ mmol/L <sup>6</sup>	
Adults: $\geq 16$ y	BMI $\geq 25$ kg/m <sup>1</sup>	TC $\geq 5.2$ mmol/l <sup>6</sup>	HbA1c $\geq 6.1\%$ <sup>5</sup>
	WC $\geq 94$ cm male, $\geq 80$ cm female <sup>4</sup>	TG $\geq 1.7$ mmol/L, <sup>4</sup>	HOMA-IR $>4.65$ or HOMA-IR $>3.60$ and BMI $>27.5$ kg/m <sup>2</sup> <sup>7</sup>
	BF % $\geq 20$ % male and	HDL-C $< 1.03$ male, $< 1.29$	FPG $\geq 5.6$ mmol/L <sup>4</sup>

	$\geq 32$ % female <sup>8</sup>	female <sup>4</sup>	
	SBP $\geq 140$ mmHg or DBP $\geq 90$ mmHg <sup>12</sup>	LDL $\geq 3.4$ mmol/L <sup>6</sup>	

- 224  
225 1 WHO  
226 2 IDEFICS Study  
227 3 McCarthy, H.D., et al. (2006)  
228 4 IDF  
229 5 Stern, S.E., et al (2003) for adults above 17 years  
230 6 NCEP  
231 7 von Eyben, F.E., et al (2005)  
232 8 Gallagher, D., et al (200)  
233 9 Shashaj et al. (2015) for children and adolescents under 17 years  
234 10 Rodoo P et al. (2013)  
235 11, 12 National Institute of Health 3<sup>rd</sup> and 7<sup>th</sup> report respectively  
236

### 237 Inclusion criteria for study sample

238 Of 1,443 individuals who participated in this study, 1,314 fulfilled the inclusion criteria (age,  
239 sex, weight, height) for the overall study analysis. Of the 1,314 participants, 1,234 provided  
240 complete waist circumference and body fat percent measurements. Among these, 557  
241 provided complete blood samples for the cardio-metabolic risk analysis and only 505 were on  
242 fasting status. To reduce bias while estimating mean and SD in the regression analysis, we  
243 excluded the top 1% of individuals with extremely high values for cardio-metabolic risk and  
244 obesity indices, leaving us with a complete sample of 470 participants for the analysis.

### 245 Statistical analysis

246 Descriptive analysis was conducted to calculate the mean standard deviation (SD) and range  
247 (minimum, maximum) for continuous variables, as well as the distribution of the categorical  
248 data in N and percentages (%). As part of the regression analysis, we tested the necessary  
249 assumptions in terms of symmetry and normality using residual-plots and Q-Q-Plots. Mixed  
250 logistic regression models were used to analyse the association between obesity indices and  
251 cardio-metabolic risk factors. In addition, potential clustering within households was  
252 considered in terms of a random intercept. Following the hierarchy of the municipal structure

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3 253 in Zanzibar, we conducted sensitivity analysis modelling either Shehias or households within  
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5 254 Shehias as a random intercept in the models. Since the results of the models only showed  
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8 255 marginal differences, we only considered the household as a random intercept in our  
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10 256 analyses. First, mixed logistic regression models were conducted to estimate the association  
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12 257 between each of the three obesity indicators (BMI, WC and BF%) as exposure variables and  
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14 258 each of the eight risk factors (hypertension, TC, TG, HDL-C, LDL-C, HbA1c, FPG and  
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16 259 HOMA-IR) as dependent variables, in terms of odds ratios (OR) and 95% confidence limits  
17  
18 260 (CI). Since BMI, WC and BF% are interrelated, the strongest relationship with cardio-  
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20 261 metabolic risk factors was investigated by conducting mixed logistic regression models. This  
21  
22 262 was done by estimating the association (ORs and 95% CIs) between all three obesity indices  
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24 263 as dependent variables in one model and each of the eight risk factors as outcome variables.  
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26 264 All models were adjusted for potential confounders and covariates such as gender, age,  
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28 265 education level (ISCED), area of residence and utilization of hypertension medication.  
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30 266 Statistical analysis was performed using SAS 9.3 (SAS Institute. Cary. NC. U SA); mixed  
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32 267 logistic regression models were conducted based on the GLIMMIX procedure; statistical  
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34 268 significance was set at  $\alpha = 0.05$ .  
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## 269 Results

### 270 Distribution of obesity and cardio-metabolic risk and characteristics of the study population 271 by age groups (n=470)

272 The mean age was 29 ( $\pm 18$ ) years, with the highest proportion being in the age group ( $\geq 18$  to  
273  $< 45$  years) (Table 2). The overall mean values for BMI, WC and BF% were as follows: BMI  
274 22 ( $\pm 5.2$ ) kg/m<sup>2</sup>, WC 75 ( $\pm 16$ ) cm and BF% 22 ( $\pm 11$ ) %. The mean BMI of 26 ( $\pm 5.7$ )  
275 kg/m<sup>2</sup> for participants above 45 years was slightly higher than normal, indicating overweight.  
276 Mean diastolic blood pressure was in the normal range for all the age groups, but a higher  
277 mean value of systolic blood pressure, 150 ( $\pm 280$ ) mmHg, was observed among participants  
278 above 45 years. The mean values of most of the variables showed an increase with age group,  
279 except for HDL-C and diabetes markers (HbA1c, serum insulin, plasma glucose and HOMA-  
280 IR), which showed no specific trend.

281 Of the 470 participants, more than half were women 52.6% (n=247), 51.9% (244) had higher  
282 education level and 73.4% (345) resided in urban area. Regarding education level, the  
283 majority of those with higher education level were aged  $\geq 18$ - $< 45$  years (150/244 = 61%)  
284 (Table 3).

285  
286 Table 2: Distribution of obesity and cardio-metabolic risk in the study population (n=470) by  
287 age group (means and standard deviation (SD))

	$\geq 5$ to $< 18$ years (n=165)		$\geq 18$ to $< 45$ years (n=195)		45+years (n=110)		Total (n=470)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Age (years)	12 (3.4)	4.9 -18	28 (8.1)	18-44	57 (9.8)	45-95	29 (18)	4.9-95
BMI (kg/m)	17 (3.4)	11-34	23 (4.5)	16-37	26 (5.7)	15-49	22 (5.7)	11-49
WC (cm)	61 (11)	12-103	79 (12)	37-111	88 (0.2)	35-126	75 (16)	12-126
BF (%)	15 (7.0)	1.6-45	23 ( 11)	3.0-53	28 (10)	6.2-53	22 (11)	1.6-53

DBP (mmHg)	67 (9.8)	44-97	76 (10)	53-126	88 (15)	62-140	75 (14)	44-140
SBP (mmHg)	110 (13)	69-152	123 (16)	72-197	150 (28)	100-229	125 (24)	69-229
TC (mmol/l)	3.7 (0.7)	1.8-5.9	3.9 (0.8)	2.1-6.0	4.2 (0.8)	0.2-5.9	3.9 (0.8)	0.2-6.0
TG (mmol/l)	0.8 (0.3)	0.3-2.5	0.9 (0.4)	0.0-2.6	1.0 (0.4)	0.4-2.7	0.9 (0.4)	0.0-2.7
HDL-C (mmol/l)	1.4 (0.5)	0.7-3.3	1.5 (0.5)	0.6-3.7	1.4 (0.4)	0.6-3.6	1.4 (0.5)	0.6-3.7
LDL-C (mmol/l)	2.3 (0.9)	0.0-5.0	2.5 (0.9)	0.7-5.1	3.0 (1.0)	0.6-5.1	2.5 (1.0)	0.0-5.1
HbA1c (%)	5.7 (0.5)	4.2-8.5	5.6 (0.6)	3.9-9.4	6.0 (0.8)	4.4-10	5.8 (0.6)	3.9-10
Serum Insulin (mmol/l)	4.3 (3.1)	0.4-18	4.8 (2.8)	0.8-17	3.6 (2.3)	0.4-17	4.4 (2.8)	0.4-18
FPG (mmol/l)	4.9 (0.8)	2.0-7.7	4.8 (0.9)	0.5-9.4	5.1 (1.3)	0.2-13	4.9 (1.0)	0.2-13
HOMA-IR	1.0 (0.7)	0.1-4.6	1.1 (0.7)	0.0-4.3	0.9 (0.6)	0.0-4.0	1.0 (0.7)	0.0-4.6

288

289 The overall proportion of overweight/obesity with regard to BMI, WC and BF % was 26.4%,  
 290 24.9% and 31.1% respectively, and increased with age (Table 2). The highest proportion was  
 291 observed among participants above 45 years. We observed different trends in the prevalence  
 292 of metabolic parameters and hypertension across age groups. The prevalence of hypertension,  
 293 high total cholesterol, LDL-C and HbA1c increased with age, while that for triglycerides and  
 294 HOMA-IR decreased with age. The most prevalent factors were reduced HDL-C (29.4%),  
 295 hypertension (24.5%) as well as raised LDL-C (21.3%) and HbA1c levels (19.1%). Although  
 296 hypertension was more prevalent among participants above 45 years, only about 9.4% (10) of  
 297 the participants in this age group were on hypertension medication. Further, high LDL-C and  
 298 HbA1c were more prevalent among participants above 45 years, and low HDL-C was most  
 299 prevalent among  $\geq 18$  to  $< 45$  year olds.

300

301 Table 3: Characteristics of the study population (n=470) by age group (n/%)

	$\geq 5$ to $< 18$ years		$\geq 18$ to $< 45$ years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
All	165	(100)	195	(100)	110	(100)	470	(100)
Gender								
Male	85	(51.5)	86	(44.1)	52	(47.3)	223	(47.4)

	≥5 to <18 years		≥18 to <45 years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
Female	80	(48.5)	109	(55.9)	58	(52.7)	247	(52.6)
Education level								
Low	122	(73.9)	45	(23.1)	59	(53.6)	226	(48.1)
High	43	(26.1)	150	(76.9)	51	(46.4)	244	(51.9)
Area of residence								
Rural	43	(26.1)	49	(25.1)	33	(30.0)	125	(26.6)
Urban	122	(73.9)	146	(74.9)	77	(70.0)	345	(73.4)
<b>Obesity Indices</b>								
BMI								
Underweight	83	(50.3)	29	(14.9)	9	(8.18)	121	(25.7)
Normal weight	73	(44.2)	106	(54.4)	46	(41.8)	225	(47.9)
Overweight/obese	9	(5.45)	60	(30.8)	55	(50.0)	124	(26.4)
Waist circumference								
Normal	165	(100)	141	(72.2)	47	(42.7)	353	(75.1)
High <sup>a</sup>	0	(0)	54	(27.7)	63	(57.3)	117	(24.9)
Body fat %								
Normal	157	(95.2)	121	(62.1)	46	(41.8)	324	(69.0)
High <sup>b</sup>	8	(4.86)	74	(37.9)	64	(58.2)	146	(31.1)
<b>Hypertension</b>								
Normal	123	(74.5)	76	(39.0)	10	(9.09)	209	(44.5)
Pre-hypertension	25	(15.8)	89	(45.6)	31	(28.2)	146	(31.1)
Hypertension	16	(9.70)	30	(15.4)	69	(62.7)	115	(24.5)
Hypertension medication <sup>c</sup>								
Yes	1	(0.61)	12	(6.38)	10	(9.43)	23	(5.02)
No	163	(99.4)	176	(93.6)	96	(90.6)	435	(95.0)
<b>Dyslipidaemia <sup>d</sup></b>								
Total cholesterol								
Normal	161	(97.6)	183	(93.8)	102	(92.7)	446	(94.9)
High	4	(2.42)	12	(6.15)	8	(7.27)	24	(5.11)
Triglycerides								
Normal	157	(95.2)	186	(95.4)	105	(95.5)	448	(95.3)
High	8	(4.85)	9	(4.62)	5	(4.55)	22	(4.68)
HDL-cholesterol								
Normal	126	(76.4)	128	(65.6)	78	(70.9)	332	(70.5)
Low	39	(23.6)	67	(34.4)	32	(29.1)	138	(29.4)
LDL-cholesterol								
Normal	141	(85.5)	163	(83.6)	66	(60.0)	370	(78.7)
High	24	(14.5)	32	(16.4)	44	(40.0)	100	(21.3)

	≥5 to <18 years		≥18 to <45 years		45+ years		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
<b>Diabetes Markers <sup>c</sup></b>								
HbA1c								
Normal	142	(86.1)	166	(85.1)	72	(65.5)	380	(80.9)
High	23	(13.9)	29	(14.9)	38	(34.5)	90	(19.1)
Plasma glucose								
Normal	136	(82.4)	167	(85.6)	88	(80.0)	391	(83.2)
High	29	(17.6)	28	(14.4)	22	(20.0)	79	(16.8)
HOMA-IR								
Normal	162	(98.2)	193	(99.0)	109	(99.1)	464	(98.7)
High	3	(1.82)	2	(1.03)	1	(0.91)	6	(1.28)

<sup>a</sup> High WC was defined as WC ≥90<sup>th</sup> percentile for children under 10y <sup>34</sup>. Adolescents between 10-16 years and adults above 16 years WC > 94 cm for men and > 80 cm for women according to IDF cut-off <sup>35</sup>

<sup>b</sup> High BF% for adults (overweight/obese) ≥ 20 for men and ≥32 for women according to (NIH/WHO) BMI guidelines <sup>37</sup> and ≥85<sup>th</sup> percentile for children <sup>36</sup>

<sup>c</sup> Missing information from 12 participants (n=458)

<sup>d</sup> High dyslipidemia for adults; was defined as total serum cholesterol (≥6.2mmol/l) and LDL-cholesterol (≥3.4mmol/l) <sup>11</sup> low HDL-C: <1.03 mmol/l in men or <1.29 mmol/l in women high and hypertriglyceridemia (≥1.7 mmol/l) <sup>35</sup> and for children according to IDEFICS study <sup>34</sup>

<sup>e</sup> High diabetes risk markers; high HbA1c (>6.1%) <sup>45</sup>, high fasting plasma glucose (≥5.6 mmol/l) <sup>35</sup> and HOMA-insulin resistance was defined as HOMA-IR >4.65. or HOMA-IR >3.60 and BMI >27.5 kg/m<sup>2</sup> <sup>43</sup> and for children high HbA1c (≥97.5<sup>th</sup> percentile), high fasting plasma glucose ≥95<sup>th</sup> percentile and HOMA-IR ≥95<sup>th</sup> percentile.

### Association between obesity indices and cardio-metabolic risk factors

Obesity indices (BMI, WC and BF %) were observed to be associated with one or more risk factors. Participants with high BMI (OR=2.41 (1.33, 4.47)), high WC (OR=3.68 (1.81, 7.52)) or high BF% (OR=2.51 (1.40, 4.51)) were more likely to be hypertensive (Table 4). Having high WC (OR=2.52 (1.24, 5.13)) or high BF% (OR=1.91 (1.02, 3.58)) was associated with higher chances of having high LDL-C. Furthermore, BMI (OR=2.08 (1.15-3.79)) and WC (OR=3.01 (1.51-6.03)) were associated with HbA1c levels. We further observed increased OR for obesity indices with regard to high total cholesterol, high triglycerides, low HDL-C, elevated glucose and HOMA-IR. As the proportion of individuals with high HOMA-IR was



327 very small in our sample (1,28%/n=6), the results was not considered in the final regression  
 328 analysis. Regarding goodness of fit of the models, values of the Akaike Information Criterion  
 329 (AIC), which estimates the quality of each model relative to that of each of the other models,  
 330 showed that models including WC as an obesity index tended to have a slightly stronger  
 331 relationship compared to those including BMI and BF%.

332

333 Table 4: Associations between obesity indices (independent) and cardio-metabolic risk  
 334 factors (dependent), adjusted for gender, age, education level, area of residence, and  
 335 hypertension medication (n=470)

Obesity indices	High BMI			High WC			High BF%					
	OR	(95% CI)	AIC	OR	(95% CI)	AIC	OR	(95% CI)	AIC			
Hypertension	<b>2.41</b>	<b>1.33</b>	<b>4.47</b>	<b>504.86</b>	<b>3.68</b>	<b>1.81</b>	<b>7.52</b>	<b>499.79</b>	<b>2.51</b>	<b>1.40</b>	<b>4.51</b>	<b>503.46</b>
High Total cholesterol	1.13	0.40	3.19	192.74	0.84	0.27	2.66	192.71	1.05	0.37	2.95	192.79
High Triglycerides	1.79	0.55	5.77	189.88	2.23	0.58	8.66	189.38	1.64	0.52	5.14	190.11
Low HDL cholesterol	1.21	0.62	2.37	516.08	1.15	0.55	2.42	516.25	1.06	0.54	2.05	516.37
High LDL cholesterol	1.45	0.78	2.69	457.62	<b>2.52</b>	<b>1.24</b>	<b>5.13</b>	<b>452.23</b>	<b>1.91</b>	<b>1.02</b>	<b>3.58</b>	<b>454.77</b>
High HbA1c	<b>2.08</b>	<b>1.15</b>	<b>3.79</b>	<b>442.70</b>	<b>3.01</b>	<b>1.51</b>	<b>6.03</b>	<b>438.53</b>	1.75	0.96	3.18	445.23
High Glucose	2.04	0.93	4.50	397.36	2.07	0.84	5.07	397.98	1.76	0.80	3.87	398.56

336

337 Table 5 presents results of mixed logistic regression models including all three obesity  
 338 indices to investigate the association with single cardio-metabolic risk factors. Compared to  
 339 the separate regression models, the ORs for most of the associations were attenuated.  
 340 However, having high WC was again associated with a higher chance of having hypertension  
 341 (OR=2.62 (1.14, 6.06)) and having high HbA1c levels (OR=2.62 (1.12, 6.15)). Again, as the  
 342 proportion of individuals with high HOMA-IR levels was very small in our sample  
 343 (1,28%/n=6), HOMA-IR was not considered in the final regression analysis.

344 Table 5: Associations between obesity indices (independent) and cardio-metabolic risk  
 345 factors (outcome) adjusted by gender, age, education level and area of residence (n=470)

Obesity indices	Combined Obesity Indices									AIC total
	BMI			WC			BF%			
Risk Factors	OR	(95% CI)		OR	(95% CI)		OR	(95% CI)		
Hypertension	1.19	0.48	2.95	<b>2.62</b>	<b>1.1</b>	<b>6.06</b>	1.48	0.63	3.51	501.3
High Total	1.31	0.25	6.79	0.71	0.1	2.92	1.01	0.19	5.32	196.5
High Triglycerides	1.34	0.25	7.16	1.90	0.3	9.52	1.02	0.19	5.52	193.2
Low HDL	1.35	0.48	3.76	1.09	0.4	2.67	0.82	0.98	2.25	519.9
High LDL	0.63	0.24	1.65	2.34	0.9	5.50	1.81	0.70	4.70	454.6
High HbA1c	1.53	0.61	3.81	<b>2.62</b>	<b>1.1</b>	<b>6.15</b>	0.82	0.32	2.10	441.6
Elevated Glucose	1.67	0.55	5.06	1.54	0.5	4.44	1.03	0.33	3.17	400.6

## 347 Discussion

348 This study is the first population-based survey in Unguja Island that investigated the  
349 association between multiple obesity indices (BMI, WC and BF%) and multiple cardio-  
350 metabolic risk factors in a representative Zanzibari population, aged 5-95 years. This study  
351 population, as in many other LMICs, is undergoing a coexistence of the double burden of  
352 underweight children and overweight/obese adults. Generally, about a quarter of the study  
353 population were overweight/obese, and obesity increased with age. This observation has also  
354 been reported in demographic health surveys from seven sub-Saharan African countries <sup>47</sup>. In  
355 the adult population, the prevalence of overweight/obesity was lower than that in Ghana <sup>7</sup>, but  
356 higher than in Nigeria <sup>2</sup> and Benin <sup>48</sup>. On the other hand, more than 50% of the children in  
357 this study were underweight, a proportion higher than that in other sub-Saharan African  
358 countries (Kenya, Nigeria, South Africa, Equatorial Guinea and Cameroon) <sup>49</sup>.

359 Dyslipidemia is a risk factor for a variety of cardiovascular diseases and is becoming more  
360 prevalent in sub-Saharan Africa, particularly the form of low HDL-C <sup>50 51</sup>. Despite the  
361 relatively normal levels of total cholesterol and triglycerides, low HDL-C affected about 29%  
362 of the overall population, an indication that low HDL-C affects a large proportion of adults  
363 above 18 years.. The low HDL-C levels observed in our study population might therefore be  
364 indicative of a notable and evolving cardiovascular risk in the study region. Our results are in  
365 line with a recent study in sub-Saharan Africa and Middle East with 30% of the participant  
366 having low HDL-C <sup>52</sup>. Other studies in sub-Saharan Africa reported even higher prevalence  
367 of low HDL-C, 43.1% in Nigeria <sup>2</sup> and 80% in Botswana <sup>53</sup>, mostly affecting individuals  
368 between 35-54 years.

369 In the present study, a high proportion of participants with high HbA1c (14%) and elevated  
370 fasting glucose (18%) are children below 18 years. Since diabetes in children in LMICs has

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3 371 not received much attention, it is likely that there is a high number of children with sub-  
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5 372 clinical complications due to delayed or missed diagnosis as well as a lack of regular  
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7 373 monitoring. The high proportions observed in this study are a possible indication that a large  
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9 374 proportion of diabetic participants are not aware of their status and are hence not monitored  
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11 375 or treated. The fact that diabetes medication was not reported in this sample supports this  
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13 376 assumption. However, when using WHO diabetes diagnostic criteria <sup>54</sup>, i.e. HbA1c cut-off  
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15 377  $\geq 6.5\%$  and FPG  $\geq 7.0\text{mmol/l}$ , the prevalence of diabetes in participants above 18 years  
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17 378 decreased to 8.14% and 3.05%, respectively (data not shown). The most intriguing result  
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19 379 however is the high proportion of children between 5 and <18 years being at high risk for  
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21 380 diabetes with elevated FPG levels when using cut-off of  $\geq 5.6\text{mmol/l}$ . Our results showed that  
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23 381 the prevalence of FPG and HOMA-IR in children and adolescents below 18 years was in  
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25 382 general higher than that of adults above 18 years, but less than that of adults above 45 years.  
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27 383 Results from previous cross-sectional studies have shown that physiological transient insulin  
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29 384 resistance develops in children during puberty<sup>55</sup> and decreases again by the end of puberty,  
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31 385 regardless of obesity. The decrease in insulin sensitivity in the pubertal period is said to lead  
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33 386 to an increase in glucose-stimulated insulin secretion<sup>56</sup>. The high prevalence of FPG and  
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35 387 HOMA-IR observed in children and adolescents in our study could hence be due to  
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37 388 physiological changes in children and adolescents during pre-pubertal period and puberty.  
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39 389 They could however also be due to misreporting (children did not report having eaten prior to  
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41 390 the blood drawing), or to a true high risk within this age group. Considering this, we adjusted  
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43 391 for age in the regression models in order to control for possible confounding effects of  
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45 392 physiological changes through maturation and aging. Interestingly, the prevalence of high  
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47 393 FPG decreased from approximately 18% to 0.61% when we used the WHO <sup>54</sup> diabetes  
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49 394 diagnostic criteria (FPG  $\geq 7\text{mmol/l}$ ) for the same age group (data not shown). This, in our  
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51 395 opinion, indicates that the majority of the children are at risk for diabetes, and that the cut-off  
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3 396 for HbA1c  $\geq 6.1\%$  as well as elevated FPG  $\geq 5.6$  mmol/l seem to be better screening tools for  
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5 397 identifying those at risk, earlier.

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8 398 Our study showed a strong association between BMI, WC and BF% and hypertension in the  
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10 399 study population. These findings are in agreement with other studies that also reported an  
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12 400 association between hypertension/pre-hypertension, BMI and WC <sup>57</sup> as well as BF% <sup>7</sup>.  
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14 401 Moreover, the association between hypertension and high WC was twice as strong as that  
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16 402 with high BMI and high %BF. This result suggests that central obesity may be a better  
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18 403 indicator for the risk of hypertension and other cardiovascular diseases in our study  
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20 404 population. Thus, optimal body weight control and reduced central obesity risk may have  
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22 405 beneficial effects on hypertension control in this population. This study also observed a  
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24 406 strong association between WC and LDL-C levels. Obirikorang also reported similar  
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26 407 associations in a comparative cross-sectional study conducted in Ghana <sup>7</sup>.

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31 408 In the separate models, strong associations were observed between BMI, WC and HbA1c  
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33 409 levels, which can be explained by the interrelation of the two indices, since abdominal fat  
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35 410 accumulation increases in proportion to BMI <sup>58</sup> and BMI is one of the main risk factors for  
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37 411 diabetes and pre-diabetes <sup>59</sup>. However, when all three obesity indices were combined, it is  
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39 412 only the association between WC and HbA1c levels and hypertension that remained strong.  
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41 413 Excessive visceral fat in abdominal obesity is the main source of free fatty acids and  
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43 414 inflammatory cytokines, which, according to the literature, might lead to insulin resistance  
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45 415 and type 2 diabetes mellitus<sup>60</sup>. This probably explains why WC was strongly associated with  
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47 416 diabetes and hypertension in our study population. Therefore, measuring WC using optimal  
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49 417 WC cut-off values as was done in this study would be a feasible, less time consuming and  
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51 418 cost-effective screening tool to identify at-risk individuals in the Zanzibari population.

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57 419 This study has some limitations that should be considered. First, this study investigated the  
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59 420 association between obesity indices and cardio-metabolic risk factors using cross-sectional

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3 421 data; thus we were not able to examine the impact of changes in obesity indices on risk  
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5 422 factors. Second, as is done in many epidemiological studies and clinical trials, we used  
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7 423 Bioelectrical Impedance Analysis (BIA) to estimate body fat percentage. However, compared  
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9 424 to skinfold measurements, BIA measurements may underestimate adiposity in children <sup>61</sup>.  
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11 425 Third, even though we excluded participants who reported food or beverage intake prior to  
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13 426 blood drawing during the data cleaning process, we cannot entirely rule out misreporting of  
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15 427 the “fasting status”. The overall aim of the study was to estimate the prevalence of  
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17 428 malnutrition in the Zanzibari population including possible correlates. Therefore, the initial  
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19 429 sample size calculation was based on the following considerations: Assuming a prevalence of  
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21 430 approximately 30% malnutrition in children <5 years of age, a sample size of 323 children <5  
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23 431 years of age was needed to estimate such a prevalence and a corresponding 95% confidence  
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25 432 interval with a precision of  $\pm 5\%$  <sup>62</sup>. To recruit this number of children, we decided to include  
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27 433 entire households. Therefore, 1,314 individuals are sufficient to estimate prevalences up to  
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29 434 30% within 5 absolute percentage points with 95% confidence (in children <5 years of age,  
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31 435 but also their fathers and mothers). The present study consists of a sub sample of the study  
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33 436 population providing all biomarkers of interest. Even though the decreased sample size may  
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35 437 limit the scope of the results obtained - and we acknowledge this as a limitation -, we are  
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37 438 convinced that the results, presented in the current paper, provide important information for  
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39 439 public health stakeholders, policy makers and researchers.

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41 440 The results of this research can be used for the development of interventions or policies by  
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43 441 researchers, stakeholders and government officials. The random selection of the study  
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45 442 participants and the standardised assessment of anthropometrical and laboratory  
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47 443 measurements are main strengths of the present study. Moreover, we consequently applied  
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49 444 age- and sex-specific cut-offs that take into account the physiological development  
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51 445 characteristic of the young age group, rather than applying the fixed cut-offs used in the adult  
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3 446 population. There is little information on the association of multiple obesity indices with  
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5 447 multiple cardio-metabolic risk factors in this population; hence, our study provides an  
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8 448 important contribution towards filling this gap.  
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## 450 Conclusion

451 This study adds to the literature on the association of obesity with higher risks for  
452 hypertension, dyslipidemia and type 2 diabetes mellitus, but for the first time in a Zanzibari  
453 population. Based on our findings, we recommend that similar epidemiological studies  
454 including children, adolescents, adults and elderly set diabetes and/or pre-diabetes cut-offs of  
455 HbA1c at  $\geq 6.1\%$  and/or elevated fasting glucose at  $\geq 5.6\text{mmol/l}$ . Where feasible, BF% and  
456 WC should be used in addition to BMI for screening and monitoring for dyslipidemia and  
457 hypertension. We further conclude that there is a need for effective interventions to create  
458 awareness as well as for primary prevention strategies for cardio-metabolic risks and its  
459 complications in Unguja Island, using local multidisciplinary approaches in the local  
460 language, Swahili. Additionally, there is a need for health surveillance initiatives that  
461 particularly target the age group  $\geq 18$  to  $< 45$  years. These can also be used to help monitor  
462 prevention activities.

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4 464 **Declarations**

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6 465 **Funding**

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13 468 **Competing interests**

14  
15 469 The authors declare that they have no competing interests.

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20 471 **Author's Contribution**

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22 472 The authors' responsibilities were as follows: AH and MAN were responsible for study  
23 473 design. AH , MAN and SK conducted data collection and developed study hypothesis. MAN  
24 474 and CB conducted statistical analyses and KB assisted in the statistical data cleaning. MAN  
25 475 wrote the manuscript and had primary responsibility for final content. MAN, CB, SK, MS  
26 476 ,KB and AH critically revised the manuscript and gave final consent.

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30 478 **Data sharing statement**

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32 479 The datasets generated and/or analysed during the current study are not publicly available  
33 480 since a follow-up study is planned.

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36  
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38  
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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract  Cross-sectional study (b) Provide in the abstract an informative and balanced summary of what was done and what was found  Completed in the abstract, please refer to <i>line 27-53</i>
<b>Introduction</b>		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported  This has been explained in the Introduction section .
Objectives	3	State specific objectives, including any prespecified hypotheses  -To determine the prevalence of obesity indices (body mass index (BMI), waist circumference (WC), body fat percent (BF%)) and cardio-metabolic risk factors. -To investigate the association between obesity indices and cardio-metabolic risk factors in a Zanzibari population.
<b>Methods</b>		
Study design	4	Present key elements of study design early in the paper  This has been presented in the abstract , please refer to <i>line 31-34</i> .  <b>Key elements of study design</b> : cross-sectional survey , in a representative population sample in Unguja Island, Zanzibar, households were randomly selected and all household members were invited for the examination.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection  This has been described in the method section, please refer to <i>line 115-125</i>
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants  This has been described in the method section, refer to <i>line 116-124</i>
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable  This has been defined in the method section, refer to <i>line 150-225</i> including <b>Table 1</b> <i>line 225-237</i> <i>Since clinical patients were not included, diagnostic criteria is not applicable</i>
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). -Please refer to method section <i>line 161-225</i>  Describe comparability of assessment methods if there is more than one group

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60*-Not applicable*

Bias	9	Describe any efforts to address potential sources of bias  This was described in the inclusion criteria where outliers were deleted from the sample in order to reduce bias. Refer to <i>line 246</i>
Study size	10	Explain how the study size was arrived at  This has been described in <i>line 119-122</i>
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why  -Quantitative variables were grouped into categories according to the given cut-offs, please refer to method sections <i>anthropometric measurements and cardiometabolic risk factors</i>
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses  -all the above points have been discussed in the statistical analysis, refer to <i>line 251-272</i>
<b>Results</b>		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed  This has been described in <i>line 242-246</i> (b) Give reasons for non-participation at each stage  This has been described in <i>line 242-246</i> (c) Consider use of a flow diagram  -Not feasible because of different age groups
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders  Please refer to <i>line 277-304</i> and <i>Tables 2 and 3</i> (b) Indicate number of participants with missing data for each variable of interest  -This was not described in the manuscript, the missing data for each variable of interest were deleted during data cleaning and before running the statistical analysis. Please refer to the inclusion criteria section for general overview, <i>line 242-248</i>
Outcome data	15*	Report numbers of outcome events or summary measures  -Please refer to result sections table 3
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

		adjusted for and why they were included
		(b) Report category boundaries when continuous variables were categorized
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period . <i>Not relevant</i>
		-Please refer to result section tables 4 and 5
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
		-This is was not applied to this manuscript.
<b>Discussion</b>		
Key results	18	Summarise key results with reference to study objectives
		-This has been decribed in the discussion section, please refer to <i>line 348 onwards</i>
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
		-Limitations of the study have been described in <i>line 427-441</i>
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
		-Please refer to the conclusion section from <i>line 353 onwards</i>
Generalisability	21	Discuss the generalisability (external validity) of the study results
		-Based on the findings of the study,similar epidemiological surveys could be conducted in the rest of the Island. Please refer to the conclusion section.
<b>Other information</b>		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based
		-This work was supported by the Leibniz-Gemeinschaft grant number SAW-2012-ZMT-4. <i>See line 483</i>
		-The present article is based on the “Access to Food and Nutritional Status of the Zanzibari population” study, <i>please refer to reference no.25</i>

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).