Effect of Age and Sex on The Associations Between Potentially Modifiable Risk Factors and Both Type 2 Diabetes and Impaired Fasting Glycaemia among West African Adults

Ayuba Issaka (✉ aissaka@deakin.edu.au)

School of Health and Social Development. Faculty of Health, Deakin University Geelong, Waurn Ponds Campus, Locked Bag 20000, Geelong, VIC 3220

Adrian Cameron

School of Health and Social Development. Faculty of Health, Deakin University Geelong, Waurn Ponds Campus, Locked Bag 20000, Geelong, VIC 3220

Yin Paradies

Alfred Deakin Institute for Citizenship and Globalisation Faculty of Arts and Education, Deakin University 221 Burwood Highway, Burwood, Victoria, Australia 3125

William Kofi Bosu

West Africa Health Organization 01 BP 153, Bobo-Dioulasso

Yèssito Corine Nadège Houéhanou

National School of Senior Technicians Training in Public Health and Epidemiological Surveillance University of Parakou: Postal Box 122, Parakou

Jean Baptiste Kiwallo

Directorate of Population Health Protection (DPSP) of the Burkina Faso, Ministry of Health Ouagadougou

Chea Sanford Wesseh

Ministry of Health, Republic of Liberia Congo Town, Monrovia

Dismand Stephan Houinato

Laboratory of Epidemiology of Chronic and Neurological Diseases (LEMACEN) Faculty of Health Sciences: 01 Postal Box 188 Cotonou. University of Abomey Calavi, Cotonou

Diarra Nazoum

Former Head of Noncommunicable Diseases, National Directorate of Health, Ministry of Health and Public Hygiene, Bomako

Christopher Stevenson

School of Health and Social Development. Faculty of Health, Deakin University Geelong, Waurn Ponds Campus, Locked Bag 20000, Geelong, VIC 3220

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Abstract

Introduction

Type 2 diabetes mellitus (T2DM) is becoming one of the leading causes of morbidity and mortality worldwide, including among Africans. Knowledge of the association between risk factors and both diabetes and pre-diabetes, and whether these differ by age and sex, are important for designing targeted interventions. However, little is known about these associations for African populations.

Methods

The study used data from WHO STEPS surveys, comprising 15,520 participants (6,774 men and 8,746 women) aged 25-64 years. Chi-square and T-test were used to compare differences in the prevalence of risk factors for both sexes. Multinomial logistic regression was conducted to ascertain the relative risks (RR) and 95% confidence intervals (CI) for both T2DM and IFG relating to each risk factors, including obesity (defined by BMI, waist circumference (WC), waist to hip ratio (WHR), and waist to height ratio (WHtR)), high blood pressure (HBP), fruit and vegetable consumption, physical inactivity, alcohol consumption and smoking. Models for each risk factor were fitted with interactions for age and sex.

Results

Factors associated with T2DM and IFG were age, BMI, waist circumference(WC), waist to hip ratio(WHR), waist to height ratio(WHtR), hypertension, physical inactivity, smoking, alcohol, fruit, and vegetable consumption]. Significant interaction with age was observed for the association between hypertension and T2DM($p = 0.05$); WHtR and T2DM ($p = 0.007$) and WHR with IFG ($p = 0.006$).

Conclusion

The study found that for most risk factors examined, associations with both IFG and T2DM did not vary by age and sex. Policies for the prevention may consider the impact of risk factors equally among adults of any age or sex in West Africa.

Introduction

Type 2 diabetes mellitus (T2DM) is a leading cause of morbidity and mortality globally [1, 2]. Four million people are estimated to die annually from diabetes and its complications worldwide [3], with middle- and low-income countries experiencing the highest-burden [2, 4]. In Africa, non-communicable diseases (NCDs), including T2DM, place a significant financial burden on individuals, families, and economies of countries, including direct (e.g., cost of medication, hospital bills, and admission) and indirect costs (e.g., caring for the sick and loss of productivity due to work absenteeism). Projections from 2019 to 2045 suggest a rapid global increase in the prevalence of diabetes, with sub-Saharan Africa (SSA) being the continent recording the highest growth over the period [4], with a 143% increase compared to Western Pacific (31%), South East Asia (74%), Europe (15%), South and Central America (55%) [4].

The progressive increase of the T2DM burden among the African population has been attributed to a rapid increase in urbanisation and food market globalisation that are associated with changes in lifestyle risk factors (e.g. increased obesity, smoking, alcohol consumption, physical inactivity) that are potentially modifiable [5]. However, the association between these risk factors and both T2DM and pre-diabetes can vary considerably by age and sex among different populations [6-10] with significant implications for prevention and treatment strategies [7, 9]. For example, while younger women of childbearing age are more likely to develop diabetes than younger men (due to gestational diabetes), the risk is greater for older men than women [9, 11, 12].

Sex differences in the association between NCDs risk factors and T2DM have been reported in different populations and ethnicities [7, 8, 13, 14] with some risk factors having stronger associations with T2DM in men, and others in women. A tri-ethnic prospective study showed that insulin resistance and central obesity among Indian Asians and African Caribbean populations accounted for a 2-fold greater incidence in women, but not men [15]. Various prospective studies among European populations demonstrated a positive association between BMI and T2DM only in men [6], only in women [16], and in both men and women [7, 8, 10]. Other prospective studies demonstrated risk factors such as high-density lipoprotein cholesterol and physical inactivity during leisure time to be associated with diabetes development in women only [7, 8], while elevated systolic blood pressure, regular smoking, and high daily alcohol intake predicted the development of T2DM in men only [7].

Though the association between diabetes risk factors and T2DM can be modified by age and sex in various populations [7, 11], such studies among the African populations are scarce [9, 10]. This is despite the rapidly rising T2DM rates within the continent [4]. Given that sex and age differences in the association between risk factors and T2DM may have implications for both clinical decision making and preventive health strategies, this study assesses whether sex and age modify the associations between potentially modifiable risk factors [including BMI, waist circumference (WC), waist to height ratio (WHtR), diet, smoking, alcohol, and high blood pressure (HBP)] and both T2DM and pre-diabetes among adults from five West African countries.

Methods

Study design, setting, and population

The WHO's Stepwise Approach to Surveillance (STEPS) survey method was used to collect individual population-level data between 2006 and 2013 from five different West African countries, namely, Benin, Burkina Faso, Ghana, Liberia, and Mali. The STEPS survey is a standardised instrument used to collect information on NCD risk factors in WHO member states [17]. All WHO member states eligible to participate in the survey decide what data to collect based on their needs and interests, as well as available resources and the capacity to implement the survey [17]. The STEPS survey comprises three components, which include data from eight behavioural, biological, and biochemical factors contributing to the burden of NCD, including T2DM. The information is collected

through a questionnaire (Step 1); physical examination (Step 2); and biochemical measurements (Step 3). Each country obtained ethical approval from its respective ethics committee. Informed consent was obtained from each participant. Multi-stage cluster sampling was used to randomly select participants [18].

Data Processing

The total sample included 16,845 participants before data cleaning. After excluding observations that had incomplete, inconsistent and invalid information, records on 15,520 participants were retained for analysis. To ensure data comparability between countries, only participants aged between 25 - 64 years were included. The methods for construction of the sample used in this analysis have been published previously [19]. The average survey response across included countries was 95.2%. Detailed information about the study design is available from the reports of participating countries on the WHO STEPS home page [20]. To ensure reliability and internal consistency of the data before analysis, robust validity checks were carried out. To ensure only realistic values were included, we excluded implausible values using the WHO-recommended cut-off values [18]. A measure of high blood pressure (HBP) was not available for data from Ghana, while Hip circumference was not collected in Burkina Faso meaning that the waist to hip ratio (WHR) could not be calculated for this country.

Definitions

All definitions followed the WHO standards [18]. IFG was defined as 6.1– <7.0 mmol/L (110–125 mg/dL). T2DM was defined as a fasting plasma glucose reading of ≥ 7.0 mmol/L (≥ 126 mg/dL). Hypertension was defined as diastolic blood pressure ≥ 90 mmHg and/or systolic blood pressure ≥ 140 mmHg [18]. Normal BMI was defined as 20-24.99 kg/m², overweight was defined as BMI of 25.0–29.99 kg/m² and obesity as BMI ≥ 30 kg/m². Elevated WC was defined as ≥ 80 cm for men and ≥ 94 cm for women. Elevated WHR was defined as > 0.80 for men and > 0.90 for women. Elevated WHtR was defined as WHtR > 0.5 . Fruit and vegetable consumption was defined as inadequate and adequate. Due to the low level of fruit and vegetable consumption in this sub-population, adequate fruit and vegetable consumption was defined as two serves per day. Daily smokers were defined as those who currently used tobacco daily, while current alcohol drinkers were defined as those who have drunk alcohol at least once over the last 30 days. Those who drank on every day per week were considered heavy drinkers. Physical activity (low, moderate or high) was categorised according to self-reported answers to questions from the Global Physical Activity Questionnaire (GPAQ). Among the sociodemographic variables, employment status was dichotomised as either employed and unemployed while educational status was categorised as: none; primary and secondary/tertiary.

Analysis

Stata 17.0 was utilised for all analyses. All analyses were adjusted for the clustered sampling design used, with data weighted to the age and sex profile of the African standard population [21]. Across all analyses, a p-value of $p < 0.05$ was considered statistically significant. Variables were described using simple percentages, means (reported as mean $\pm$ standard deviation), and frequencies as appropriate. Student t-tests tests were used to compare different group means of male and female participants. Chi-square was used to compare the categorical variables. Multinomial logistic regression was used in a pooled analysis, separately for males and females, to ascertain the relative risks (RR) and 95% confidence intervals (CI) of each risk factor modelled as categorical variables based on established cut-points and the same outcomes. Associations between the risk factors and both T2DM and IFG were assessed in crude analyses, and after adjusting for age, sex, education, and occupation. These confounding factors were considered as data for them were available in all five countries. We tested whether the association between risk factors and both T2DM and IFG varied between men and women and across different age groups by adding interaction terms for sex and age as continuous variables. The *testparm* command in Stata was then used to ascertain the presence of statistically significant interaction simultaneously across the categories of risk factors and both T2DM and IFG as outcomes.

Table 1: Participant Characteristics, WHO STEPS surveys in Benin (3814), Burkina Faso (4711), Ghana (2662), Liberia (2593) and Mali (1740)

Country										
Variable	Burkina Faso		Benin		Mali		Liberia		Ghana	
	Male (n= 2264)	Female (n= 2447)	Male (n= 1849)	Female (n=1965)	Male (n= 676)	Female (n=1064)	Male (n= 1096)	Female (n= 1497)	Male (n=889)	Female (n= 1100)
Age (yrs)	39.6±11.4	37.0±10.7	42.9±12.4	43.8±12.1	42.0±12.3	41.4±12.2	43.2±10.8	41.0±10.3	41.1±11.5	40.1±10.7
BMI (kg/m2)	22.2±3.2	22.4±4.7	22.7±4.0	24.6±5.7	23.6±7.4	26.6±7.7	25.2±9.6	26.2±11.1	24.9±6.3	28.8±7.5
BMI N (%)										
Normal	1890 (84.7)	1812(80.2)	1430(77.6)	1173(60.3)	483(73.9)	479(46.6)	588(56.8)	602(42.3)	476(56.5)	559(50.5)
Overweight	283(12.7)	311(13.8)	327(17.7)	481(254.7)	118(18.0)	297(28.0)	279(26.9)	400(28.1)	269(32.0)	540(49.5)
Obese	58 (2.6)	137(6.1)	86(4.7)	292(15.0)	53(8.1)	252(24.5)	169(16.3)	423(29.7)	97(11.5)	593(54.0)
WC (%)										
Normal	2115(94.5)	1422(62.9)	1642(89.0)	848(43.2)	531(79.0)	173(17.3)	899(86.9)	543(41.5)	663(75.0)	247(22.5)
Elevated	123(5.5)	840(37.1)	204 (11.1)	1113(56.8)	141(21.0)	826(82.7)	135(13.1)	767(58.6)	221(25.0)	1464(133.0)
WHR (%)										
Normal			941(51.1)	641(32.8)	419(62.5)	292(29.2)	725(70.1)	571(43.6)	510(57.8)	554(50.4)
Elevated			899(48.9)	1316(67.3)	251(37.5)	707(70.8)	309(29.9)	739(56.4)	373(42.2)	1155(105.6)
WHtR (%)										
Normal	1875(84.5)	1515(67.7)	1364(75.0)	824(42.9)	425(64.4)	204(20.8)	634(63.2)	467(36.4)	417(49.7)	286(26.2)
Elevated	343(15.5)	722(32.3)	455(25.0)	1098(57.1)	235(35.6)	776(79.2)	370(36.9)	816(63.6)	422(50.3)	1365(123.8)
Physical activity (%)										
Low	429(21.8)	695(28.5)	88(4.9)	149(7.8)	225(33.3)	458(43.1)	282(25.9)	498(33.6)	64(7.3)	389(35.3)
Medium	112(5.0)	153(6.3)	64(3.6)	122(6.4)	109(16.1)	183(17.2)	123(11.3)	169(11.4)	81(9.2)	224(20.5)
High	1648(73.2)	1595(65.3)	1653(91.6)	1650(85.9)	342(50.6)	422(39.7)	683(62.8)	817(55.1)	736(83.5)	1158(104.2)
Fruit per wk (%)										
0-13	1867(92.2)	2035(91.3)	1155(65.1)	1234(65.5)	253(64.2)	447(69.1)	833(91.0)	1141(89.6)	630(72.3)	1339(122.2)
14+	157(7.8)	195(8.7)	619(34.9)	649(34.5)	141(35.8)	200(30.9)	82(9.0)	133(10.4)	241(27.7)	396(36.2)
Vegetable per wk (%)										
0-13	1082(74.4)	1208(74.2)	1257(70.5)	1371(71.7)	134(58.8)	159(43.3)	683(82.5)	1018(85.1)	501(58.0)	1053(96.5)
14+	373(25.6)	420(25.8)	527(29.5)	542(28.3)	94(41.2)	208(56.7)	145(17.5)	178(14.9)	363(42.0)	681(62.3)
Current smokers (%)										
No	1692(74.4)	2444(99.9)	1556(84.2)	1938(98.6)	444(65.0)	1010(95.5)	910(83.5)	1451(97.3)	816(91.8)	1769(161.5)
Yes	572(25.3)	2(0.1)	291(15.8)	27(1.4)	229(34.0)	48(4.5)	182(16.7)	40(2.7)	73(8.2)	4(0.2)
Alcohol (%)										
Every day	186(8.7)	115(4.9)	306(16.6)	117(6.0)	15(2.4)	1(0.1)	74(7.3)	22(1.6)	115(13.0)	45(2.6)
5-6 time per week	52(2.4)	35(1.5)	128(7.0)	69(3.5)	9(1.5)	1(0.1)	35(3.5)	10(0.7)	39(4.4)	22(1.9)
1-4time per week	344(16.2)	311(13.1)	710(38.5)	564(28.8)	27(4.4)	3(0.3)	262(26.0)	166(11.9)	248(28.1)	349(31.7)
< 1 time per week	188(8.8)	206(8.7)	142(7.7)	270(13.8)	0	0	76(7.5)	83(6.0)	99(11.2)	242(22.1)
Never	1360(63.9)	1699(71.8)	557(30.2)	936(47.9)	567 (91.8)	1037(99.5)	562(55.7)	1113(79.8)	383(43.3)	1101(100.0)
Profession (%)										
Employed	2158(95.3)	1360(55.6)	1652(89.5)	1589(81.3)	383(57.6)	348(33.6)	819(75.1)	894(60.0)	642(72.8)	1330(121.4)
Unemployed	106(4.7)	1087(44.4)	194(10.5)	365(18.7)	282(42.4)	687(66.4)	271(24.9)	596(40.0)	240(27.2)	434(39.6)
Education (%)										
None	1649(73.1)	1979(80.9)	904(48.9)	1440(73.4)	236(36.5)	562(53.8)	241(22.2)	700(47.7)	38(4.3)	268(24.4)
Primary	413(18.3)	321(13.1)	594(32.2)	386(19.7)	46(7.1)	64(6.1)	189(17.4)	270(18.4)	66(7.5)	421(38.4)

Secondary/Tertiary	194(8.6)	147(6.0)	349(18.9)	136(6.9)	365(56.4)	419(40.1)	654(60.3)	496(33.9)	781(88.3)	1080(
Blood Pressure										
Normal	1747 (77.9)	1988(81.7)	1223 (66.4)	1300 (66.2)	549 (81.6)	759 (71.7)	727 (69.1)	1004 (69.3)	—	—
Hypertension	497 (22.3)	444(18.3)	621(33.6)	665 (33.8)	124 (18.4)	300 (28.3)	325(30.9)	444 (30.7)	—	—
* Burkina Faso excluded										
** Ghana excluded										

Table 2: Association between modifiable risk factors and both T2DM and IFG in five countries from West Africa (n=15,520)

Risk Factors	T2DM				IFG			
	Crude		Adjusted**		Crude		Adjusted**	
	RR (95% CI)	P-value	RR (95% CI)	P-value	RR (95% CI)	P-value	RR (95% CI)	P-value
Sex								
Male	Reference		Reference		Reference		Reference	
Female	1.01 (0.87, 1.19)	0.87	1.06 (0.89, 1.25)	0.51	1.01 (0.86, 1.18)	0.91	0.93 (0.79, 1.10)	0.4
Age (years)								
25-34	Reference		Reference		Reference		Reference	
35-44	1.98 (1.55, 2.51)	<0.001	2.15 (1.69, 2.75)	<0.001	1.10 (0.90, 1.34)	0.35	1.19 (0.98, 1.46)	0.09
45-54	2.56 (2.00, 3.26)	<0.001	2.96 (2.31, 3.79)	<0.001	1.19 (0.96, 1.47)	0.12	1.32 (1.06, 1.65)	0.013
55-64	4.04 (3.21, 5.07)	<0.001	4.77 (3.77, 6.04)	<0.001	1.21 (0.97, 1.51)	0.09	1.34 (1.07, 1.69)	0.011
BMI (kg/m²)								
Normal	Reference		Reference		Reference		Reference	
Overweight	1.86 (1.54, 2.25)	<0.001	1.66 (1.36, 2.03)	<0.001	1.29 (1.06, 1.58)	0.01	1.23 (1.00, 1.51)	0.05
Obese	2.54 (2.08, 3.11)	<0.001	1.96 (1.57, 2.45)	<0.001	2.29 (1.89, 2.78)	<0.001	2.10 (1.70, 2.59)	<0.001
WC								
Normal	Reference		Reference		Reference		Reference	
Elevated	2.71 (2.30, 3.20)	<0.001	2.70 (2.20, 3.32)	<0.001	1.52 (1.30, 1.78)	<0.001	1.54 (1.27, 1.88)	0.001
WHtR								
Normal	Reference		Reference		Reference			
Elevated	2.75 (2.32, 3.27)	<0.001	2.14 (1.77, 2.59)	<0.001	1.64 (1.40, 1.93)	<0.001	1.55 (1.30, 1.85)	<0.001
WHR								
Normal	Reference		Reference		Reference		Reference	
Elevated	1.81(1.50, 2.18)	<0.001	1.52 (1.24, 1.85)	<0.001	1.20 (1.00, 1.44)	0.47	1.23 (1.01, 1.49)	0.04
Physical activity								
High	Reference		Reference		Reference		Reference	
Medium	2.16 (1.69, 2.78)	<0.001	1.63 (1.26, 2.12)	<0.001	2.06 (1.62, 2.62)	<0.001	1.74 (1.36, 2.23)	<0.001
Low	2.35 (1.98, 2.80)	<0.001	2.02 (1.68, 2.42)	<0.001	2.10 (1.76, 2.50)	<0.001	1.87 (1.56, 2.24)	<0.001
Fruit per week								
14+	Reference		Reference		Reference		Reference	
0-13	1.17 (0.93, 1.46)	0.179	1.33 (1.05, 1.67)	0.02	1.21 (0.97, 1.46)	0.09	1.24 (0.99, 1.55)	0.06
Vegetables per week (%)								
14+	Reference		Reference		Reference		Reference	
0-13	0.77 (0.64, 0.94)	0.01	0.85 (0.69, 1.03)	0.1	1.07 (0.87, 1.31)	0.53	1.09 (0.88, 1.34)	0.42
Current Smoker								
No	Reference		Reference		Reference		Reference	
Yes	1.38 (1.08, 1.77)	0.01	1.71(1.31, 2.24)	<0.001	1.01 (0.83, 1.40)	0.57	1.24 (0.94, 1.64)	0.13
Alcohol								
Never	Reference		Reference		Reference		Reference	
< 1 time per week	0.45 (0.32, 0.65)	<0.001	0.40 (0.28, 0.58)	<0.001	0.61 (0.45, 0.83)	<0.001	0.56 (0.41, 0.77)	<0.001
1-4time per week	0.52 (0.41, 0.66)	<0.001	0.50 (0.39, 0.63)	<0.001	0.53 (0.42, 0.67)	<0.001	0.53 (0.42, 0.67)	<0.001
5-6 time per week	0.67 (0.40, 1.14)	0.14	0.67 (0.40, 1.15)	0.15	0.44 (0.23, 0.84)	0.012	0.46 (0.24, 0.86)	0.02
Every day	0.41 (0.27, 0.62)	<0.001	0.35 (0.22, 0.54)	<0.001	0.52 (0.36, 0.76)	<0.001	0.54 (0.37, 0.79)	0.001
Blood pressure**								

Normal	Reference		Reference		Reference		Reference	
Hypertension	2.18 (1.83, 2.60)	<0.001	1.56 (1.29, 1.90)	<0.001	1.18 (1.00, 1.41)	0.039	1.08 (0.89, 1.30)	0.42
Adjusted for sex, age, education, and profession								
* Burkina Faso excluded								
** Ghana excluded								

Table 3: Interactions with age and sex for associations between potential modifiable risk factors and both T2DM and IFG for in five countries from West Africa (n=15,520).

Risk Factors	T2DM				IFG			
	Interaction with age		Interaction with sex		Interaction with age		Interaction with sex	
	95% CI for RR	P-value	95% CI for RR	P-value	95% CI for RR	P-value	95% CI for RR	P-value
BMI								
Normal	Reference		Reference		Reference		Reference	
Overweight	1.08 (0.91, 1.28)	0.37	0.97 (0.64, 1.43)	0.89	0.99 (0.98, 1.01)	0.81	0.96 (0.64, 1.43)	0.83
Obese	1.05 (0.87, 1.26)	0.63	0.68 (0.44, 1.08)	0.1	0.88 (0.73, 1.05)	0.16	0.88 (0.56, 1.36)	0.55
WC								
Normal	Reference		Reference		Reference		Reference	
Elevated	1.01 (0.98, 1.31)	0.13	0.79 (0.54, 1.17)	0.24	0.95 (0.82, 1.09)	0.44	0.80 (0.55, 1.19)	0.26
WHR								
Normal	Reference		Reference		Reference		Reference	
Elevated	1.23 (1.06, 1.44)	0.007	1.15 (0.80, 1.67)	0.46	0.95 (0.98, 1.01)	0.5	1.00 (0.71, 1.41)	0.99
WHR								
Normal	Reference		Reference		Reference		Reference	
Elevated	1.00 (0.98, 1.02)	0.96	0.99 (0.67, 1.46)	0.94	0.79 (0.67, 0.94)	0.006	0.89 (0.61, 1.30)	0.55
Physical activity								
High	Reference		Reference		Reference		Reference	
Medium	0.98 (0.78, 1.21)	0.83	1.32 (0.78, 2.28)	0.31	0.87 (0.70, 1.08)	0.21	0.89 (0.54, 1.47)	0.66
Low	1.02 (0.87, 1.19)	0.85	1.22 (0.84, 1.77)	0.29	0.93 (0.80, 1.09)	0.38	0.85 (0.60, 1.23)	0.39
Fruit per wk								
14+	Reference		Reference		Reference		Reference	
0-13	1.01 (0.82, 1.4)	0.93	0.93 (0.58, 1.48)	0.76	1.02 (0.84, 1.24)	0.87	0.81 (0.52, 1.28)	0.36
Vegetable per wk								
14+	Reference		Reference		Reference		Reference	
0-13	1.00 (0.82, 1.24)	0.93	0.84 (0.56, 1.25)	0.39	1.02 (0.84, 1.24)	0.87	1.03 (0.67, 1.57)	0.9
Smoking								
No	Reference		Reference		Reference		Reference	
Yes	0.86 (0.70, 1.07)	0.18	1.30 (0.59, 2.87)	0.52	1.02 (0.81, 1.29)	0.18	1.02 (0.39, 2.66)	0.97
Alcohol								
Never	Reference		Reference		Reference		Reference	
< 1 time per week	1.00 (0.72, 1.38)	0.99	1.64 (0.74, 3.67)	0.38	0.88 (0.66, 1.18)	0.39	0.49 (0.25, 0.90)	0.03
1-4time per week	1.07 (0.87, 1.33)	0.53	0.51 (0.31, 0.85)	0.01	0.81 (0.65, 1.00)	0.04	0.77 (0.48, 1.23)	0.28
5-6 time per week	0.73 (0.46, 1.16)	0.18	0.31 (0.07, 1.40)	0.21	0.87 (0.50, 1.52)	0.62	0.23 (0.03, 1.88)	0.17
Every day	0.68 (0.46, 1.00)	0.05	0.25 (0.06, 1.08)	0.06	0.73 (0.53, 1.02)	0.07	0.92 (0.40, 2.16)	0.84
HBP**								
Normal	Reference		Reference		Reference		Reference	
Hypertension	1.20 (1.01, 1.42)	0.04	1.11 (0.77, 1.60)	0.98	1.01 (0.86, 1.19)	0.87	0.92 (0.64, 1.30)	0.18

Note, all results adjusted for sex, age, education, and profession

*Burkina Faso excluded

**Ghana excluded

Results

Table 1 summarises the socio-demographic characteristics of study participants. Of the 15,520 respondents analysed, 44% were males and 56% were females. The sample size ranged from 2788 in Mali to 4570 in Burkina Faso. The mean and median age of the total sample was 40.4 years and 38 years respectively. The age group with the largest number of participants was between 24 and 34 years (38%) and the lowest was between 55 and 64 (17%) years. The BMI of women was significantly higher than that of men (mean in women = 25.7, mean in men = 23.5, $p < 0.001$) and men were more physically active than females ($p < 0.001$). The smoking and alcohol intake of males were significantly higher than those of females (smoking, $p < 0.001$ and alcohol consumption, $p < 0.001$), though consumption of both was small for most countries.

The RRs and 95% confidence intervals (CIs) of the association between the risk factors and both T2DM and IFG are shown in Table 2. Except for alcohol, and for fruit and vegetable consumption, all risk factors showed positive associations with T2DM and IFG both in the crude and adjusted analyses. As expected, associations were mostly stronger between the risk factors and T2DM compared to IFG. The analysis shows that the risk of T2DM increased with increasing age. The highest RR associated with T2DM was recorded among 55 to 64 years old [RR: 4.77, 95% CI: (3.77, 6.04)]. In contrast, for IFG the highest RR was recorded among participants who were obese, as defined by BMI [RR: 2.10, 95% CI: (1.70, 2.59)]. Physical inactivity was strongly associated with both T2DM [RR: 2.02 95% CI (1.68 2.42)] and IFG [RR: 1.87, 95% CI (1.87, 2.24)] in the adjusted analyses. Hypertension was significantly associated with T2DM but not with IFG.

The interactions with both age and sex for the association between risk factors and T2DM and IFG are presented in Table 3. The associations between most risk factors and both T2DM and IFG did not vary according to either age or sex. However, a statistically significant interaction with age was observed for a positive association between HBP and T2DM, WHtR and T2DM and a negative association between WHR and IFG.

Discussion

To our knowledge, this is the first study to explore the effect of age and sex on the relationship between diabetes risk factors and T2DM and IFG in West African countries. As expected, we found that the associations between all risk factors, and both T2DM and IFG were significant, even after adjusting for age, sex, occupation, and education. The general findings on the risk factors were concordant with those of several previous studies among different population groups, including those from Nigeria [10], Australia [22], Asia, and European countries [7, 8, 23, 24]. There was no evidence that these associations varied according to either age or sex in the current study.

In the present study, all obesity markers measured by BMI, WC, WHR, and WHtR were strongly associated with both T2DM and IFG in both sexes and among all age groups, confirming previous studies among Africans [10, 25], and other populations including Asians, Americans, and Europeans [7, 15, 26]. However, our findings are inconsistent with those from the Lasky et al. [9] study among Ugandan subjects. In that study a strong, direct relationship was observed between obesity defined by BMI and the development of T2DM among women only. This difference could be because in the Lasky

et al. study [9], male subjects were primarily lean (defined as BMI < 20 kg/m²) whereas in the current study, male participants ranged from normal BMI to obese.

In the present study, in both sexes, the strongest association between WC and WHtR with T2DM (compared to overall body fat as measured by BMI) in the adjusted models reinforces the importance of abdominal adiposity as an independent risk factor for the development of T2DM [27, 28]. Although obesity, as defined by BMI, has the strongest association with IFG, this is a transition state before T2DM, and it may be the case that those classified as obese based on markers of central obesity spend less time in the IFG category [19]. Of note, glycaemic profiles have been shown to differ by sex [13, 29], with studies among populations from Mauritius and Australia finding impaired glucose tolerance (IGT) to be more common in women (due to the greater glucose load taken relative to body size) and IFG more common in men [13, 29]. The fact that an oral glucose tolerance test (OGTT) was not used for diagnosis of T2DM or pre-diabetes in the current study means that the comparison of results with other studies that did use an OGTT should be interpreted with caution. Moreover, the thresholds used for defining obesity markers are not consistent across studies.

Overall physical activity in the present study was found to be associated with around a two-fold higher risk of both T2DM and IFG, among both sexes and age groups. Previous studies among African populations have reported similar findings independent of BMI [30], as have studies from Portugal [31], the United Kingdom, Canada, Australia, and Finland [26, 32]. In a study among European participants, however, low levels of leisure-time physical activity (e.g swimming, jogging) was associated with incident diabetes among European women only [7]. Although the GPAQ used in this study did include assessment of leisure-time physical activity, levels of leisure-time physical activity are consistently low across African countries [30].

Our findings that hypertension was associated with T2DM and IFG among sexes are in direct agreement with earlier studies in Kenya [33] and Europe [7]. An association between systolic blood pressure and diabetes was observed among men only, however, in various European prospective cohort studies [7, 34]. This difference was ascribed to the fact that women with hypertension controlled their level of blood pressure better than men [7], implying the importance of awareness and management of HBP among the West African populations [35]. However, our findings that age modified the association between hypertension and T2DM can be ascribed to the evidence that hypertension increases with age in some populations [36, 37].

Heavy alcohol consumption has been found to be associated with T2DM in both sexes and all age groups in previous reviews and meta-analyses [38, 39]. However, sex differences in the association between heavy alcohol users and insulin sensitivity are reported only in studies among predominantly European populations [7, 40], with the incident diabetes among men only [40]. The significance of heavy alcohol consumptions highlights the importance of the low percentage of alcohol consumption in the current study as it may be insufficient to detect any significant difference. Almost 70% of women in the current sample have never drunk alcohol, with this being due to religious and cultural factors in West Africa. Mali, for example, is predominately a Muslim country, and alcohol consumption is prohibited [41]. Additionally, socio-culturally, heavy alcohol drinkers and smokers are highly stigmatised in most African countries and

this may contribute to the low rate of alcohol consumption [41]. In the current study, drinking alcohol was found to be protective for T2DM and IFG, which is consistent with previous studies [42].

Smoking in this study was associated with T2DM and IFG and confirms earlier studies among South Africans and other populations [43]. Though the association between smoking and T2DM and IFG did not vary by sex or age in this study, some previous studies among European populations [6, 7] showed positive associations between cigarette smoking and incident diabetes in men only. An association was evident between cigarette smoking and incident diabetes in women however in the large American Nurses' Health Study [16]. The difference in the prevalence of smoking among women in these two studies (much higher in the Nurses' Health Study) may explain these findings [6, 7]. As such, the low percentage of female smokers (1.4% of women and 19.9% of men) in the present study means it is challenging to assess sex-specific differences in associations with T2DM and pre-diabetes.

Finally, earlier studies on dietary patterns conducted in urban Ghana [44] and Senegal [45] showed that inadequate fruit and vegetable consumption was associated with an increased risk of T2DM. In this study, lower fruit intake was associated with increased prevalence of T2DM but the association with IFG was not statistically significant. Lower vegetable intake had opposite associations with T2DM and IFG although none were statistically significant. The simple diet recall questions used limit the ability to generalise from these findings, but the results are consistent with previous evidence that fruit consumption alone is protective against T2DM [46].

The current study has several strengths, including the large sample size from five different West African countries. This ensured greater statistical power to detect age and sex interaction effects between potentially modifiable risk factors and both T2DM and IFG. The study, however, has several limitations, which need to be considered when interpreting the results. First, because the study is cross-sectional in design, results do not imply causal relationships between risk factors and T2DM. Secondly, only risk factors that were assessed in all the five countries were assessed. Therefore, important risk factors, such as high-density lipoprotein cholesterol levels, could not be included in this analysis, though studies have shown this factor to interact with sex [8]. Thirdly, since an OGTT was not used to define diabetes and pre-diabetes, the results may differ from those where this method was used, especially given the sex-specific impact of a glucose load due to differences in body size between males and females [29]. Fourthly, fruit and vegetable consumption measures were not coded as per the WHO guidelines of five servings per day due to the low level of fruit and vegetable consumption in this sub-population and may constitute a limitation when comparing to other studies. Lastly, the different years that the survey data were collected may have introduced some bias, however, this is not an important limitation for this study given the focus on associations between risk factors and health outcomes. These limitations notwithstanding, the findings from the current study have important policy implications.

Policy Implications

Since the association between T2DM risk factors and both T2DM and IFG do not appear to vary with age or sex, policies and interventions may be similar among adults of both sexes in West African populations. This is particularly advantageous given the low-income context in West Africa, with interventions likely to be both more cost-effective and simpler. While, in general, smoking and alcohol are more prevalent among men, obesity and physical inactivity are more prevalent among women in West Africa. Any policies targeting these risk factors should consider socio-cultural factors and beliefs [47]. These may include i) the commonly held belief in much of Africa that overweight is an outward manifestation of high socioeconomic standing, prosperity, and beauty, as well as good health among females and the preference for central obesity among some affluent men [48, 49]; ii) the fact that physical activity among women is often discouraged in most countries as it is culturally considered to be undesirable and unattractive and associated with a masculine physique [47], and iii) the fact that physical activity is usually not viewed through a health lens for men, but through the lens of sports [50]. Policies should target the persistently low levels of awareness regarding the importance of fruit and vegetable consumption, as well as the globalisation of food markets, particularly concerning alcohol and tobacco industries. Globalisation has been shown to exacerbate the use and increased the ease of access to alcohol and tobacco use among young adults in Africa

Conclusion

This study showed that, while obesity defined by BMI, WC, WHR, and WHtR, physical inactivity, smoking, and HBP were associated with both T2DM and pre-diabetes, the association did not vary by age or sex. Our findings, therefore, demonstrate that interventions and policies for treatment and prevention of T2DM and IFG may be similar among adults for both sexes in West Africa. Importantly, these findings could aid policymakers, government, non-government bodies, and health professionals in the development of specific guidelines at the individual, community-level educational programs in the prevention and treatment of T2DM.

Abbreviations

BMI: Body mass index; CI: Confidence interval; DALY: Disability-adjusted life years; GPAQ: Global Physical Activity Questionnaire; HBP: High blood pressure; IDF: International Diabetes Federation; IFG: impaired fasting glucose; IGT: Impaired glucose tolerance; NCD: Noncommunicable disease; OGTT: Oral glucose tolerance tests; OR: Relative risk; SD: Standard deviation; SSA: Sub-Saharan Africa; T2DM: Type 2 diabetes; WC: waist circumference; WHR: waist to hip ratio; WHtR: waist to height ratio.

Declarations

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Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available because they belong to third parties but are available from the corresponding author on reasonable request.

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Authors' contributions

AI and CS designed the study. AI assembled the data, analysed, and interpreted the data. CS and AC assisted in assembling the data. AI drafted the manuscript. CS, AC, WKB, YCNH and YP participated in the revision of the manuscript. JBK, CSW, DSH and DJPN read and approved the final manuscript.

Ethics approval and consent to participate

Each country obtained ethical approval from a local ethics committee, and all participants provided written informed consent. In Burkina Faso, the WHO STEPS survey protocol was approved by the Ethics Committee for Health Research (CERS) of the Ministry of Health, jointly with the Ministry of Scientific Research and Innovation (Deliberation No. 2012-12-092 on 5th December 2012). In Ghana, the study protocol was reviewed and approved by the Ghana Health Service Ethical Review Committee. (Reference number: GHS-ERC-7 on 30 March 2006). In Mali, the Ministry of Health and Public Hygiene ethical committee reviewed and approved the study in February 2007). In Liberia the protocol was approved by the University of Liberia-Pacific Institute for Research and Evaluation (UL PIRE), Liberia in January 2011, and in Benin, the study protocol was reviewed and approved by the Ministry of Health Ethics Committee (now, the National Ethics Committee for Health Research: Authorisation no. 2008/PNLMNT/DNSP/MS-Bénin). Study methods were carried out in accordance with relevant regulations and guidelines

Competing interests

The authors declare no conflict of interest

Consent for publication

Not applicable.

References

1. Kirigia JM, Sambo HB, Sambo LG, Barry SP: **Economic burden of diabetes mellitus in the WHO African region.** *BMC International Health and Human Rights* 2009, **9**(1):1-12.
2. Murray CJ, Vos T, Lozano R, Naghavi M, Flaxman AD, Michaud C, Ezzati M, Shibuya K, Salomon JA, Abdalla S, et al: **Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010.** 2012, **380**(9859):2197-2223.
3. Saeedi P, Salpea P, Karuranga S, Petersohn I, Malanda B, Gregg EW, Unwin N, Wild SH, Williams RJDR, Practice C: **Mortality attributable to diabetes in 20–79 years old adults, 2019 estimates: Results from the International Diabetes Federation Diabetes Atlas.** 2020:108086.
4. IDF Diabetes Atlas: **International Diabetes Federation, Brussels, 2019.** Available from: https://www.diabetesatlas.org/upload/resources/material/20200302_133351_IDFATLAS9e-final-webpdf Accessed: 08th May 2021.
5. Tabarés-Seisdedos R: **Health effects of overweight and obesity in 195 countries over 25 years.** *New England Journal of Medicine* 2017, **377**(1):13-27.
6. Feskens EJ, Kromhout D: **Cardiovascular risk factors and the 25-year incidence of diabetes mellitus in middle-aged men.** *American Journal of Epidemiology* 1989, **130**(6):1101-1108.
7. Meisinger C, Thorand B, Schneider A, Stieber J, Döring A, Löwel H: **Sex differences in risk factors for incident type 2 diabetes mellitus: the MONICA Augsburg cohort study.** *Archives of Internal Medicine* 2002, **162**(1):82-89.
8. Njølstad I, Amesén E, Lund-Larsen P: **Sex differences in risk factors for clinical diabetes mellitus in a general population: a 12-year follow-up of the Finnmark Study.** *American Journal of Epidemiology* 1998, **147**(1):49-58.
9. Lasky D, Becerra E, Boto W, Otim M, Ntambi J: **Obesity and gender differences in the risk of type 2 diabetes mellitus in Uganda.** *Nutrition and Health* 2002, **18**(5):417-421.
10. Ekpenyong CE, Akpan UP, Ibu JO, Nyebuk DE: **Gender and age specific prevalence and associated risk factors of type 2 diabetes mellitus in Uyo metropolis, South Eastern Nigeria.** *Diabetologia Croatica* 2012, **41**(1):17-28.
11. Alva ML, Hoerger TJ, Zhang P, Gregg EW, Care: **Identifying risk for type 2 diabetes in different age cohorts: does one size fit all?** *BMJ Open Diabetes Research* 2017, **5**(1):e000447.
12. Clausen TD, Mathiesen ER, Hansen T, Pedersen O, Jensen DM, Lauenborg J, Damm P: **High prevalence of type 2 diabetes and pre-diabetes in adult offspring of women with gestational diabetes mellitus or type 1 diabetes: the role of intrauterine hyperglycemia.** *Diabetes Care* 2008, **31**(2):340-346.
13. Sicree R, Zimmet P, Dunstan D, Cameron A, Welborn T, Shaw J: **Differences in height explain gender differences in the response to the oral glucose tolerance test—the AusDiab study.** *Diabetic Medicine* 2008, **25**(3):296-302.

14. Jackson AS, Stanforth P, Gagnon J, Rankinen T, Leon AS, Rao D, Skinner J, Bouchard C, Wilmore J: **The effect of sex, age and race on estimating percentage body fat from body mass index: The Heritage Family Study.** *International Journal of Obesity* 2002, **26**(6):789-796.
15. Tillin T, Hughes AD, Godsland IF, Whincup P, Forouhi NG, Welsh P, Sattar N, McKeigue PM, Chaturvedi N: **Insulin resistance and truncal obesity as important determinants of the greater incidence of diabetes in Indian Asians and African Caribbeans compared with Europeans: the Southall And Brent REvisited (SABRE) cohort.** *Diabetes Care* 2013, **36**(2):383-393.
16. Rimm EB, Manson JE, Stampfer MJ, Colditz GA, Willett WC, Rosner B, Hennekens CH, Speizer FE: **Cigarette smoking and the risk of diabetes in women.** *American Journal of Public Health* 1993, **83**(2):211-214.
17. Bonita R, Winkelmann R, Douglas KA, de Courten M: **The WHO Stepwise approach to surveillance (STEPS) of non-communicable disease risk factors.** In: *Global behavioral risk factor surveillance*. edn.: Springer; 2003: 9-22.
18. WHO. **WHO STEPS surveillance manual: the WHO STEPwise approach to chronic disease risk factor surveillance.** Geneva: World Health Organization. Available from: https://apps.who.int/iris/bitstream/handle/10665/43376/9241593830_eng.pdf; 2005. Accessed 08th May, 2021. In.
19. Issaka A, Cameron AJ, Paradies Y, Kiwallo JB, Bosu WK, Houehanou YCN, Wesseh CS, Houinato DS, Nazoum DJ, Stevenson C: **Associations between obesity indices and both type 2 diabetes and impaired fasting glucose among West African adults: results from WHO STEPS surveys.** *Nutrition, Metabolism Cardiovascular Diseases* 2021.
20. World HO: **World Health Organization–Diabetes country profiles.** Accessed from : <https://www.who.int/diabetes/country-profiles/en/> In.: Diakses; 2016.
21. Population Pyramids of the World from 1950 to 2100. Available from; <https://www.populationpyramid.net/africa/2019/>. Accessed 28th August.
22. Grant JF, Hicks N, Taylor AW, Chittleborough CR, Phillips PJ: **Gender-specific epidemiology of diabetes: a representative cross-sectional study.** *International Journal for Equity in Health* 2009, **8**(1):1-12.
23. Stampfer MJ, Colditz GA, Willett WC, Manson JE, Arky RA, Hennekens CH, Speizer FE: **A prospective study of moderate alcohol drinking and risk of diabetes in women.** *American Journal of Epidemiology* 1988, **128**(3):549-558.
24. Sattar N: **Gender aspects in type 2 diabetes mellitus and cardiometabolic risk.** *Best Practice Research Clinical Endocrinology Metabolism* 2013, **27**(4):501-507.
25. Africa Working Group. **Trends in obesity and diabetes across Africa from 1980 to 2014: an analysis of pooled population-based studies** *International Journal of Epidemiology* 2017, **46**(5):1421-1432.
26. Kodama S, Horikawa C, Fujihara K, Heianza Y, Hirasawa R, Yachi Y, Sugawara A, Tanaka S, Shimano H, Iida KT: **Comparisons of the strength of associations with future type 2 diabetes risk among anthropometric obesity indicators, including waist-to-height ratio: a meta-analysis.** *American Journal of Epidemiology* 2012, **176**(11):959-969.
27. Ashwell M, Gibson S: **Waist to height ratio is a simple and effective obesity screening tool for cardiovascular risk factors: analysis of data from the British National Diet and Nutrition Survey of adults aged 19–64 years.** *Obesity Facts* 2009, **2**(2):97-103.
28. Lee CMY, Huxley RR, Wildman RP, Woodward M: **Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis.** *Journal of Clinical Epidemiology* 2008, **61**(7):646-653.
29. Williams JW, Zimmet PZ, Shaw JE, De Courten M, Cameron AJ, Chitson P, Tuomilehto J, Alberti K: **Gender differences in the prevalence of impaired fasting glycaemia and impaired glucose tolerance in Mauritius. Does sex matter?** *Diabetic Medicine* 2003, **20**(11):915-920.
30. Guthold R, Louazani SA, Riley LM, Cowan MJ, Bovet P, Damasceno A, Sambo BH, Tesfaye F, Armstrong TPJAjopm: **Physical activity in 22 African countries: results from the World Health Organization STEPwise approach to chronic disease risk factor surveillance.** 2011, **41**(1):52-60.
31. Seabra AFTE, Maia JARR, Mendonca DM, Thomis M, Caspersen CJ, Fulton JE: **Age and sex differences in physical activity of Portuguese adolescents.** *Medicine Science in Sports Exercise* 2008, **40**(1):65-70.
32. Jeon CY, Lokken RP, Hu FB, Van Dam RM: **Physical activity of moderate intensity and risk of type 2 diabetes: a systematic review.** *Diabetes Care* 2007, **30**(3):744-752.
33. Ongosi AN, Wilunda C, Musumari PM, Techasrivichien T, Wang C-W, Ono-Kihara M, Serrem C, Kihara M, Nakayama T: **Prevalence and risk factors of elevated blood pressure and elevated blood glucose among residents of Kajiado County, Kenya: A population-based cross-sectional survey.** *International Journal of Environmental Research Public Health* 2020, **17**(19):6957.
34. Perry IJ, Wannamethee SG, Walker MK, Thomson A, Whincup PH, Shaper AG: **Prospective study of risk factors for development of non-insulin dependent diabetes in middle aged British men.** *Biomedical Journal* 1995, **310**(6979):560-564.
35. Bosu WK, Bosu DK: **Prevalence, awareness and control of hypertension in Ghana: A systematic review and meta-analysis.** *PLoS ONE* 2021, **16**(3):e0248137.
36. Qi S-F, Zhang B, Wang H-J, Yan J, Du P, Zhang W, Mi Y-J, Zhao J-J, Liu D-W, Tian Q-B: **Joint effects of age and body mass index on the incidence of hypertension subtypes in the China Health and Nutrition Survey: a cohort study over 22 years.** *Preventive Medicine* 2016, **89**:23-30.
37. Fujita M, Hata A: **Sex and age differences in the effect of obesity on incidence of hypertension in the Japanese population: a large historical cohort study.** *Journal of the American Society of Hypertension* 2014, **8**(1):64-70.
38. Baliunas DO, Taylor BJ, Irving H, Roerecke M, Patra J, Mohapatra S, Rehm J: **Alcohol as a risk factor for type 2 diabetes: a systematic review and meta-analysis.** *Diabetes Care* 2009, **32**(11):2123-2132.
39. Howard AA, Arnsten JH, Gourevitch MN: **Effect of alcohol consumption on diabetes mellitusA systematic review.** *Annals of Internal Medicine* 2004, **140**(3):211-219.
40. Flanagan D, Moore V, Godsland I, Cockington R, Robinson J, Phillips D: **Alcohol consumption and insulin resistance in young adults.** *European Journal of Clinical Investigation* 2000, **30**(4):297-301.

41. Martinez P, Røislien J, Naidoo N, Clausen T: **Alcohol abstinence and drinking among African women: data from the World Health Surveys.** *BMC Public Health* 2011, **11**(1):1-9.
42. Koppes LL, Dekker JM, Hendriks HF, Bouter LM, Heine R: **Moderate alcohol consumption lowers the risk of type 2 diabetes: a meta-analysis of prospective observational studies.** *Diabetes Care* 2005, **28**(3):719-725.
43. World Health Organization: **WHO report on global tobacco epidemic, 2011. Appendix VIII - Table Crude smokeless tobacco prevalence in WHO member states. Geneva- Table 8.2: World Health organization: 2011.**
http://www.who.int/tobacco/global_report/2011/en_tfi_global_report_2011_appendix_VIII_table_2.pdf. Accessed 21 March 2017.
44. Frank LK, Kröger J, Schulze MB, Bedu-Addo G, Mockenhaupt FP, Danquah I: **Dietary patterns in urban Ghana and risk of type 2 diabetes.** *British Journal of Nutrition* 2014, **112**(01):89-98.
45. Seck S, Dia D, Doupa D, Diop-Dia A, Thiam I, Ndong M, Gueye L: **Diabetes burden in urban and rural Senegalese populations: a cross-sectional study in 2012.** *International Journal of Endocrinology* 2015, **2015**.
46. Rasmussen M, Krølner R, Klepp K-I, Lytle L, Brug J, Bere E, Due P: **Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part I: quantitative studies.** *International Journal of Behavioral Nutrition and Physical Activity* 2006, **3**(1):1.
47. Goedecke JH, Mtintzila A, Dlamini SN, Kengne AP: **Type 2 diabetes mellitus in African women.** *Diabetes Research Clinical Practice* 2017, **123**:87-96.
48. Adeboye B, Bermano G, Rolland C: **Obesity and its health impact in Africa: a systematic review.** *Cardiovascular Journal of Africa* 2012, **23**(9):512.
49. Issaka A, Paradies Y, Stevenson C: **Modifiable and emerging risk factors for type 2 diabetes in Africa: a systematic review and meta-analysis protocol.** *Systematic Reviews* 2018, **7**(1):139.
50. Mbanya JCN, Motala AA, Sobngwi E, Assah FK, Enoru ST: **Diabetes in sub-Saharan Africa.** *Lancet (British edition)* 2010, **375**(9733):2254-2266.