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Which anthropometric measures best indicate type 2 diabetes among Russian, Somali and Kurdish origin migrants in Finland?

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Abstract

Objectives: To compare the performance of body mass index (BMI), waist-to-height ratio (WHtR), waist circumference (WC) and waist-to-hip ratio (WHR) in detecting type 2 diabetes among Russian, Somali and Kurdish (born in Iraq/Iran) origin migrants and Finns.

Design and participants: Cross-sectional study comparing health examination survey data of 30-64 year-old Russian, Somali and Kurdish origin migrants (n=917) who took part in the Migrant Health and Wellbeing Survey with the general Finnish population in the Health 2011 Survey (n=887). Participants were randomly selected from the National Population register.

Setting: Six cities in Finland, where a substantial majority of migrants live.

Outcome measures: Anthropometric measures included objectively measured BMI, WHtR, WC and WHR. Type 2 diabetes was defined based on self-report, laboratory measures of glycated haemoglobin (HbA1c) and register data. Test performance was assessed using receiver operating characteristics (ROC) curves, using area under the curve (AUC) as a measure of accuracy.

Results: Among Finns, test performance was highest for WC (AUC=0.81, 95%CI 0.74-0.87) and WHtR (AUC=0.81, 95%CI 0.75-0.87). Test performance was similar for BMI (AUC=0.80, 95%CI 0.67-0.92), WC (AUC=0.79, 95%CI 0.67-0.91) and WHtR (AUC=0.70, 95%CI 0.66-0.93) among Russians. WC and WHtR had highest test performance also among Somali (AUC=0.74, 95%CI 0.64-0.84 for WC and AUC=0.75, 95% CI 0.65-0.85 for WHtR) and Kurds (AUC=0.71, 95% CI 0.61-0.81 for WC and AUC=0.70, 95% CI 0.59-0.80 for WHtR).WHR had the poorest test performance among migrants.

Conclusion: WC and WHtR performed overall the best across all study groups, however accuracy of detection was lower particularly among Somali and Kurds. Currently used diabetes risk assessment tools assume a strong association between anthropometrics and diabetes. These tools need to be validated among non-Western populations.

Keywords: anthropometric; type 2 diabetes; migrant; African; Middle-Eastern; non-Western

Strengths and limitations of the study

- To our best knowledge, no previous studies have aimed at determining the best anthropometric measures for detecting type 2 diabetes among migrants of Eastern-European, African and Middle-Eastern origin.
- A substantial strength of the study is use of randomized study design and inclusion of several diverse migrant groups.
- A further strength is the use of several objective standardized anthropometric measures and supplementation of self-report data with register based-data and laboratory analyses.
- Use of anthropometric measures as continuous variables takes into account the lack of specific cut-offs for Middle-Eastern and African origin populations.
- One limitation could be the cross-sectional nature of the data, due to which we were unable to test causality by using follow-up data on diabetes diagnosis.

Abbreviations

AUC, Area under the curve

BMI, Body mass index

HbA1c, glycated haemoglobin

Maamu Survey, Migrant Health and Wellbeing Survey

ROC curves, Receiver operating characteristics curves

WC, waist circumference

WHR, waist-to-hip ratio

WHtR, waist-to-height ratio

1 Introduction

Non-Western origin migrants have a higher prevalence of glucose impairment and type 2 diabetes both compared with Europeans and compatriots in their country of origin[1-5]. Prevalence of type 2 diabetes has been reported to be 2-5 times higher among South Asians, 2-4 times higher among migrants from the Middle-East and Northern-Africa, and 2-3 times higher among the Sub-Saharan African origin populations compared with Europeans[6]. Non-Western origin migrants in Finland (Somali and Iranian/Iraqi Kurds) have also been reported to have a 3-5 times higher risk for glucose impairment and 2-3 times higher risk for diabetes compared with Finns[7]. There is therefore an urgent need for effective screening strategies to identify those at elevated risk for type 2 diabetes.

Weight gain, particularly abdominal obesity, is strongly associated with insulin resistance, which is a central precursor for diabetes[8,9]. Body mass index (BMI) and waist circumference (WC) are the most commonly used anthropometric measures for identifying populations at a higher risk for type 2 diabetes[10]. While BMI is an indicator of total body fat, it does not provide information on body fat distribution. WC reflects central fat deposition but does not take fully into account intra-individual and ethnic differences in lean body mass, body shape and height[11,12]. Body fat distribution, body shape and height may vary substantially according to country of origin, therefore anthropometric measures that are more sensitive to these variations across population groups may need to be considered[11]. Alternatives to BMI and WC include waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR). While WHR reflects relative fat distribution, it is rather an indicator of body shape than of excess fat[12]. Recently, WHtR was shown to be superior to BMI and WC in predicting future risk for type 2 diabetes by taking into account both central fat deposition and intra-individual differences in height [11,13].

In addition to the apparent need for considering more appropriate anthropometric measures for non-Western origin migrants, currently used classifications of obesity may need to be reconsidered. Generally, the association between obesity and glucose impairment is examined using cut-off points that have been established based on large-scale studies conducted among Caucasian populations[12]. Recent studies have demonstrated a weaker association between obesity and type 2 diabetes among migrants of South Asian[2], Middle-Eastern[14] and West African[15] origin migrants, which may be attributable to different mechanisms for developing type 2 diabetes. However, these findings may also be related to inappropriateness of current obesity classifications for non-Western origin migrants. There is increasing evidence that migrant populations have an increased risk of developing type 2 diabetes at lower BMI and WC levels than Western populations[16-18]. Considering that diabetes risk prediction tools assume a strong association between obesity and type 2 diabetes[10], use of obesity cut-offs for Western populations may lead to misclassification of those at higher risk for diabetes among non-Western origin populations.

The aim of this study was to compare the performance of BMI, WHtR, WC and WHR in detecting type 2 diabetes among Russian, Somali and Kurdish (born in Iraq/Iran) origin migrants and the general Finnish population.

2 Methods

2.1 Design and study population

This cross-sectional study was based on the data from the Migrant Health and Wellbeing Survey (Maamu), conducted between 2010 and 2012 in six cities in Finland. A more detailed description of survey methods has been provided elsewhere[7]. Briefly, a stratified random sample of 3000 Russian, Somali and Kurdish origin migrants (1000 per each group) aged 18-64 years was drawn from the National Population Register that contains information on all permanent residents in Finland. Inclusion criteria were country of birth (Russia/Former Soviet Union, Somalia and Iran/Iraq), mother tongue (Russian/Finnish and Sorani dialect of Kurdish) and residence in Finland for at least one year. Participants were invited for a structured face-to-face interview and a standardized health examination, conducted by trained fieldwork personnel.

The reference group were the general Finnish population (later referred to as Finns) who participated in the nationally representative Health 2011 Survey[19]. The reference group consisted of participants from the corresponding six cities of the Maamu Survey. Survey data was supplemented with register-based data from the Social Institution of Finland (Kela) and the Finnish Care Register for Health Care (Hilmo). The Social Institution of Finland grants reimbursement rights for medication based on diagnosis and severity of the long-term condition[20]. The Finnish Care Register for Health Care contains information on inpatient or outpatient hospital care[21].

The current study was limited to 30-64 year-old health examination participants, with participation rate of 48% for Russians, 40% for Somali, 59% for Kurds and 56% for Finns. Following exclusion of persons with type 1 diabetes (n=9), the study was based on health examination data of 917 migrants and 887 Finns. All participants gave written informed consent. Both surveys and record linkages were approved by the Coordinating Ethics Committee of the Helsinki and Uusimaa Hospital District.

2.2 Clinical measurements and interview data

The health examination included standardized measurements of weight and height as well as waist and hip circumferences according to the European Health Examination Survey standards[22]. Weight was measured wearing light clothing and no shoes with a balanced beam scale (Seca 709) in the Maamu Survey and as a part of the bioimpedance body composition analysis (Seca 514) in the Health 2011 Survey. In both studies, height was measured without shoes with a stand-alone stadiometer (Seca 213). WC was measured with a soft measuring tape half-way between the lowest rib and top of iliac crest on bare skin or wearing light clothing. Hip circumference was not measured in the Health 2011 Survey and is available for Maamu Survey participants only. Weight and WC were not measured if the participant was over 20 weeks pregnant.

Blood samples were taken by trained laboratory staff, centrifuged within an hour and frozen at -20°C on site. Samples were shipped packed in dry ice weekly in Helsinki, Espoo, and Vantaa, and monthly in other cities, to their final storage location in THL, where they were stored at -70°C. HbA1c was measured by immuno-turbidimetric method using Abbott Architect reagents. The inter-assay coefficient of variation for glycated haemoglobin was 3.9%. The laboratory (Disease Risk Unit at THL) conducting the analyses took part in the External Quality Assessment Schemes organized by Labquality, Helsinki, Finland.

2.3 Variable definition

Variable

Type 2 diabetes was determined based on: 1) interview data on self-reported previous diagnosis by a physician, 2) self-reported medication use, 3) register based diabetes defined by information on special medication reimbursement rights and/or inpatient or outpatient hospital care for diabetes and/or 4) glycated haemoglobin (HbA1c) levels ≥ 6.5% (48 mmol/mol). Diabetes type was not asked in the interviews, thus persons with type 1 diabetes were identified as those who had diabetes onset below the age of 35 years and simultaneously used only insulin as their diabetes medication.

Anthropometric measures included in this study were BMI, WC, WHtR and WHR. BMI was calculated as kg/m2. WHtR was calculated as WC in cm divided by height in cm. WHR was calculated as WC in cm divided by hip circumference in cm. Age was used as a categorical variable (< 45 years vs. ≥ 45 years).

2.4 Statistical analysis

All analyses accounted for the stratified sampling and finite population correction and were conducted using the Sudaan 11.0.1 and SAS 9.3 software packages[23]. Inverse probability weights, based on register information (age group, sex, study group, study location, and marital status), were used to correct for the effects of non-response and different sampling probabilities in all of the analyses[24].

Age-adjusted mean values and their 95% confidence intervals (95% CI) for continuous variables were calculated using linear logistic regression, whereas logistic regression was applied to categorical variables. Regression analyses were performed by study group stratified by sex using predictive margins based on regression models[25]. Statistical significance was assessed with Sattherthwaite F-statistic. Logistic regression was applied to test the interaction between anthropometrics and sex with type 2 diabetes as an outcome variable for each study group. No statistically significant sex interactions were found for any of the continuous anthropometric variables in any of the study groups, therefore analyses in Table 3 and Table 4 were performed jointly for men and women using the interaction of study group and sex.

Test performance of anthropometric measures was evaluated by receiver operating characteristics (ROC) curves[26]. Accuracy of the test was assessed by calculating area under the curve (AUC). The perfect test has an AUC of 1.0, whether random chance gives an AUC of 0.5. The AUC values are classified as: 0.5-0.6 fail, 0.6–0.7 poor, 0.7–0.8 fair, 0.8–0.9 good, and 0.9–1.0 excellent[27]. With exception of inverse probability weights, the sampling design was not accounted for in the statistical testing of the AUC differences.

3 Results

Age-adjusted anthropometric characteristics are presented in Table 1. Russian men were shorter, weighted less and had lower WC compared with Finns. Russian women were shorter, otherwise their anthropometric characteristics were similar to those of Finns. Somali men were shorter, weighted less and had lower WC compared with Finns. Somali women were also shorter but were simultaneously significantly heavier than Finns. Mean BMI and WHtR were significantly higher among Somali women compared with Finns, however mean WC did not differ significantly between the two groups. Compared with Finns, Kurdish men were significantly shorter, weighted less and had lower WC, however no statistically significant differences were observed with respect to BMI and WHtR. Kurdish women, on the other hand, were significantly shorter but had similar weight and WC as Finns, as reflected also in higher BMI and WHtR.

[Table 1 about here]

Prevalence of type 2 diabetes as well as prevalence of each individual component (self-report, registers and HbA1c) that were combined to form a joint "type 2 diabetes" variable are presented in Table 2. Prevalence of type 2 diabetes was significantly higher among Somali and Kurds, particularly among women. Register-based prevalence of type 2 diabetes was higher than self-report among men in all study groups and Finnish women, whereas it was lower among Russian, Somali and Kurdish women. Prevalence of HbA1c $\geq$ 6.5% (48 mmol/mol) was several times higher among Somali and Kurdish men and Somali women compared with Finns.

Supplementing self-reported diabetes diagnosis with register-based data on special medication reimbursement rights for diabetes medicine and/or inpatient or outpatient hospital care/physician visits for diabetes treatment, provided with altogether 17 new cases of diabetes (n=7 for Finns, n=1 for Russians, n=4 for Somali, n=5 for Kurds). Laboratory measures of HbA1c provided with an additional nine new cases of diabetes (n=2 for Finns, n=2 for Russians, n=5 for Somali) in addition to the information based on self-report and registers.

[Table 2 about here]

Mean BMI values varied significantly among persons with and without type 2 diabetes in Finnish and Russian groups, whereas the difference was less pronounced among Somali and Kurds (Table 3). Similar observations were made for WC, WHtR and WHR. Additionally, while mean BMI values were overall similar in corresponding diabetes categories across all groups, mean WC among Somali and Kurdish origin persons with type 2 diabetes was significantly lower compared with that of Russians and Finns. Somali origin migrants with type 2 diabetes had a significantly lower mean WHtR compared with Finns.

[Table 3 about here]

Results of the ROC curves are presented in Table 4 and in Figure 1. ROC curves showed that test performance was similar for WC and WHtR and significantly poorer for BMI among Finns. Accuracy of detection for WC and WHtR was good (AUC within the range of 0.80-0.90) and fair for BMI (AUC within the range of 0.70-0.80). Among Russians, test performance was similar for BMI, WC and WHtR (AUC ranging between 0.79 and 0.80), with fair to good accuracy of detection. For Somali, test performance was similar for WC and WHtR and poorer for BMI. Accuracy of detection for WC and WHtR was fair among the Somali group (AUC within the range of 0.70-0.80) and poor for BMI (AUC within the range of 0.60-0.70). As in all other groups, test performance was similar for WC and WHtR among

Kurds as well. However, accuracy of detection ranged between AUC 0.70 and 0.71, suggesting poor to fair test performance.

WHR (available for migrants only) performed the poorest across the examined anthropometric measures across all groups, with poor accuracy of detection (AUC ranging between 0.62 and 0.69 depending on migrant group).

[Table 4 and Figure 1 about here]

In addition to comparing test performance of continuous anthropometric measures in detecting type 2 diabetes, we also examined test performance of categorical anthropometric measures using established cut-off points for overweight and obesity (Supplement Table 1). These analyses showed a similar trend, however accuracy of detection was slightly lower for categorical anthropometric measures compared with corresponding continuous anthropometric measures within each study group.

[Link to Supplement Figure 1]

4 Discussion

Our results suggest that out of the four examined anthropometric measures, WC and WHtR performed the best in detecting type 2 diabetes in all study groups. However, accuracy of prediction was better among Finns and Russians, compared with Somali and Kurds. There was some discordance in the prevalence of type 2 diabetes using different sources of information (self-report, registers and laboratory measures), highlighting the benefits of taking different data sources into account. Highest proportion of cases of screen-detected diabetes, i.e. persons meeting the diabetes criteria of HbA1C ≥ 6.5% (48 mmol/mol) without previously known diabetes according to self-report or registers, was found among the Somali group (2.2%), compared with 0.2% of Finns and 0.6% of Russians. This finding suggests the need for more effective screening for type 2 diabetes especially among Somali migrants.

Abdominal obesity is considered to be a central precursor for diabetes[8,9]. Therefore our finding that WC and WHtR are the best anthropometric measures for detecting type 2 diabetes is in line with previous research. Out of these two abdominal measures, WC is more established and is used in diabetes risk assessment tools[10]. More recently, WHtR has been argued to be superior to a single measure of WC by taking into account intra-individual and ethnic differences in height[11,13]. While we did find substantial differences in anthropometrics across study groups, our findings show very similar accuracy of detection for WC and WHtR within each study group. This may be related to an overall lower degree of the association between anthropometric measures with type 2 diabetes among non-Western origin migrants.

We also found an overall weaker association between anthropometrics and type 2 diabetes among Somali and Kurds. This was reflected through less pronounced differences in mean anthropometric values according to diabetes category as well as poorer accuracy of detection for WC and WHtR. In consistency with this findings, several previous studies report a lower level of correlation between obesity indicators and diabetes among non-Western origin migrants compared with Western populations[2,6,15,28].

Higher prevalence of diabetes among South Asian origin migrants was not explained by obesity and other metabolic risk factors upon follow-up[2]. Middle-Eastern origin migrants from Iraq had a significantly higher prevalence of both obesity and diabetes, however high diabetes rates were only partly explained by abdominal obesity and other established risk factors for diabetes[28]. Similarly, the association between body composition measures and diabetes was weaker among Sub-Saharan African origin migrants compared with Western African origin migrants and persons in the Dutch general population[15]. These differences may be attributable to genetic and epigenetic factors[15,29], however there is also emerging evidence that there may be different biological mechanisms behind glucose impairment according to country of origin[30-33].

Glucose impairment among Sub-Saharan Africans from Ghana appears to be more strongly related to peripheral insulin resistance than to Beta cell dysfunction[32]. Middle-Eastern origin migrants (Lebanon, Iraq, Iran, Syria, Turkey) have been suggested to have an altogether different form of T2DM compared with Western populations due to a stronger genetic component, reflected in earlier age at onset, stronger family history and a more significant reduction in Beta cell function despite similar insulin resistance levels[28,31]. Family history of diabetes has been found to have a stronger association with poorer glucose control than with age, BMI and WC among Iraqi origin migrants without diabetes[33].

Non-Western origin migrants come from countries at an earlier stage of the epidemiological transition. Rapid epidemiological transition, with a notable change in diet and physical activity levels, may further contribute to a higher prevalence of glucose impairment and diabetes[32,34]. Rapid weight gain upon migration may be related to glucose impairment among migrants. Furthermore, it has been suggested that a rapid transition from normal weight to overweight may be sufficient to produce glucose impairment and increase the likelihood of developing type 2 diabetes[30,34-36].

We used continuous anthropometric measures as opposed to conventional categorical measures because of an increasing amount of literature questioning the appropriateness of currently used obesity cut-offs validated among Caucasian populations in diabetes risk assessment among non-Western origin populations[16-18,37]. Some studies have suggested that lower cut-offs for abdominal obesity among African men and higher cut-offs for African women may be more appropriate for detecting insulin resistance[16,17]. Our findings support this as among persons with type 2 diabetes, Somali and Kurds had on average approximately 10cm lower WC circumference compared with Finns and Russians. Lower cut-offs for BMI and WC may be more appropriate also for Middle-Eastern origin migrants. Insulin resistance index of Middle-Eastern origin (Iraqi) migrants at BMI 28.5 kg/m^2 for men and 27.5 kg/m^2 for women has been shown to correspond to that of Swedes with BMI 30 kg/m^2. Insulin sensitivity index among abdominally obese Swedes (WC ≥ 94cm for men and ≥ 80 cm for women) corresponded to 10 cm lower cut-offs among Iraqi migrants (≥ 84 cm for men and ≥71cm for women)[18].

In addition to calculating ROC curves for continuous anthropometric measures, we tested the performance of categorical measures in detecting type 2 diabetes. Test performance was poorer for categorical compared with continuous anthropometric measures. Taking into account the increasing amount of evidence suggesting poorer applicability of categorical anthropometric measures in detecting diabetes among non-Western origin populations[16-18,37], current use of categorical anthropometric measures in diabetes risk assessment may need to be reconsidered. Awareness of the limitations in the use of categorical anthropometric measures may facilitate development of more appropriate and sensitive tools for diabetes risk assessment among different population groups. Such have already been developed for cardiovascular risk prediction, which enable the use of continuous measures instead of the conventional cut-offs for cardiovascular risk factors[38,39]. Additionally, the observed overall lower degree of the association between anthropometrics and diabetes among non-Western origin migrants may lead to a higher degree of misclassification of those at risk for developing diabetes. Therefore, diabetes risk assessment tools need to be validated among different population groups.

Strengths and limitations

A significant strength of this study is the use of several objective standardized anthropometric measures and supplementing self-reported data with register data and blood samples. An advantage of using HbA1c is that it measures average glucose levels over the past several weeks and is not affected by fasting. Use of anthropometric measures as continuous variables takes into account the lack of specific cut-offs for Middle-Eastern and African origin populations. A further strength of this study is the randomized study design and inclusion of several migrant groups. Russian, Somali and Iranian/Iraqi Kurds are significant migrant groups not only in Finland but also in other Western countries. Kurds are a substantial refugee group in many European countries, United States and Canada but identification of Kurds in national statistics is particularly challenging as not all countries collect information on country of origin and mother tongue.

This study has also some limitations. Due to the cross-sectional nature of the data, we were unable to test causality by using follow-up data on diabetes diagnosis. Due to sample size restrictions, it was not feasible to calculate ROC curves for men and women separately. However, we did not observe interaction between sex and continuous anthropometric measures with respect to diabetes. Furthermore, type 2 diabetes risk assessment tools do not generally differentiate by sex and for this purpose as well, performing analyses jointly for men and women is plausible. Division of our study population according to country of origin has created relatively small study groups, resulting in widened confidence intervals. Our findings need to be confirmed in a larger sample.

In conclusion, WC and WHtR were the best anthropometric measures for detecting type 2 diabetes among both Western and non-Western origin populations in our study. Out of the two, WHtR may be more appropriate for use in diabetes risk assessment as it takes into account intra-individual and ethnic differences in height and body composition. Currently used diabetes risk assessment tools have been designed for Western populations and assume that there is a high level of correlation between anthropometrics, and particularly abdominal obesity, with incidence of type 2 diabetes. Accuracy of anthropometric measures in detecting type 2 diabetes was lower among non-Western origin migrants. This may lead to a higher degree of misclassification of diabetes risk among non-Western origin populations. Non-Western origin migrants have a substantially higher prevalence of glucose impairment and diabetes than Finns, and effective screening strategies are needed for identification of those at high risk for developing diabetes.

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Author contributions

Skogberg analyzed and interpreted the data and wrote the first draft of the manuscript. Koponen, Laatikainen and Lundqvist contributed to conceptualizing the study design, data interpretation and provided critical review of the manuscript. Härkänen and Lilja critically revised the statistical methods used in the study and contributed to data interpretation. All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and accuracy of the data analyses.

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Disclosure of interest

The authors declare that they have no competing interest.

Data sharing statement

The Migrant Health and Wellbeing (Maamu) Survey data can be shared with other researchers after a research plan has been compiled and accepted. More information on data sharing process can be accessed from: https://www.thl.fi/en/web/thlfi-en/research-and-expertwork/population-studies/migrant-health-and-wellbeing-study-maamu-/information-for-researchers.

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Table 1 Age-adjusted anthropometric characteristics of the study population

	Finnish	Russian	Somali	Kurdish
	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)
Men, N	395	119	85	181
Age ≥ 45 years, %	57.0 (50.7-63.1)	46.5 (37.0-56.4)	31.1 (21.7-42.3)	34.5 (28.5-41.0)
Weight, kg	86.4 (84.5-88.3)	82.9 (80.1-85.7)	74.6 (72.3-77.0)	80.9 (79.3-82.5)
Height, cm	179.6 (178.7-180.5)	176.6 (175.4-177.7)	174.5 (173.0-176.0)	171.6 (170.7-172.4)
Hip circumference, cm	N/A	100.3 (98.8-101.7)	100.0 (98.5-101.5)	97.2 (96.2-98.3)
Waist circumference, cm	96.0 (94.5-97.5)	92.9 (90.5-95.3)	87.1 (85.1-89.1)	93.3 (92.0-94.5)
Body mass index, kg/m^2	26.7 (26.2-27.3)	26.6 (25.8-27.4)	24.5 (23.8-25.3)	27.4 (26.9-27.9)
Waist-to-height ratio	0.54 (0.53-0.54)	0.53 (0.51-0.54)	0.50 (0.49-0.51)	0.54 (0.54-0.55)
Waist-to-hip ratio	N/A	0.92 (0.91-0.93)	0.87 (0.85-0.88)	0.95 (0.95-0.96)
Women	492	225	140	167
Age ≥ 45 years, %	55.2 (50.2-60.1)	60.6 (53.6-67.2)	35.3 (27.6-43.7)	31.1 (25.1-37.9)
Weight, kg	72.2 (70.8-73.6)	71.5 (69.5-73.4)	80.9 (78.4-83.3)	71.0 (69.5-72.6)
Height, cm	165.9 (165.2-166.5)	164.0 (163.1-164.8)	161.9 (161.0-162.9)	157.4 (156.7-158.2)
Hip circumference, cm	N/A	102.7 (101.2-104.2)	109.6 (107.8-111.4)	100.5 (99.2-101.8)
Waist circumference, cm	86.8 (85.4-88.1)	85.1 (83.3-86.9)	88.3 (86.5-90.1)	88.5 (86.9-90.0)
Body mass index, kg/m^2	26.3 (25.8-26.8)	26.6 (25.8-27.3)	30.8 (29.9-31.6)	28.6 (28.0-29.3)
Waist-to-height ratio	0.52 (0.52-0.53)	0.52 (0.51-0.53)	0.55 (0.54-0.56)	0.56 (0.55-0.57)
Waist-to-hip ratio	N/A	0.83 (0.82-0.83)	0.80 (0.79-0.82)	0.87 (0.87-0.88)

95% CI, 95% Confidence interval.

Table 2 Age-adjusted prevalence of type 2 diabetes

	Finnish	Russian	Somali	Kurdish
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Men, N	395	119	85	181
Type 2 diabetes[a]	6.2 (4.4-8.7)	4.3 (1.8-10.0)	15.5 (8.5-26.7)	10.5 (7.0-15.4)
Self-reported diabetes	5.1 (3.4-7.5)	3.5 (1.3-9.2)	8.2 (3.4-18.4)	8.8 (5.6-13.6)
Register-based diabetes[b]	6.0 (4.2-8.5)	4.3 (1.8-10.0)	12.3 (6.0-23.5)	9.7 (6.3-14.5)
HbA1c ≥ 6.5 % (48 mmol/mol)	2.0 (1.0-4.0)	0.7 (0.1-4.7)	8.2 (3.4-18.5)	4.7 (2.4-8.8)
Women	492	225	140	167
Type 2 diabetes[a]	3.5 (2.3-5.5)	6.0 (3.4-10.4)	16.4 (10.6-24.5)	11.8 (7.8-17.4)
Self-reported diabetes	2.6 (1.5-4.3)	4.6 (2.5-8.4)	14.6 (8.9-23.0)	11.2 (7.3-16.8)
Register-based diabetes[b]	3.1 (1.9-4.9)	3.3 (1.6-6.6)	10.5 (6.0-17.8)	8.1 (4.8-13.3)
HbA1c ≥ 6.5 % (48 mmol/mol)	1.7 (0.8-3.4)	1.8 (0.6-5.6)	5.1 (2.1-12.0)	2.5 (0.8-7.0)

95% CI, 95% Confidence interval; HbA1c, Glycated haemoglobin.

[a]Type 2 diabetes: self-reported diagnosis by a physician and/or self-reported diabetes medications and/or register-based diabetes and/or glycated haemoglobin ≥ 48 mmol/mol;

[b]Register-based diabetes: register-based data on special medication reimbursement rights for diabetes medicine and/or inpatient or outpatient hospital care/physician visits for diabetes treatment.

Table 3 Age-adjusted mean anthropometric measures according to the presence of type 2 diabetes

	Finnish		Russian		Somali		Kurdish	
	Type 2 diabetes[a]		Type 2 diabetes[a]		Type 2 diabetes[a]		Type 2 diabetes[a]	
	No (n=834)	Yes (n=53)	No (n=326)	Yes (n=18)	No (n=195)	Yes (n=30)	No (n=312)	Yes (n=36)
	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)
BMI, kg/m^2	26.3 (25.9-26.6)	30.7 (28.9-32.6)	26.3 (25.8-26.9)	32.8 (29.2-36.5)	27.6 (26.9-28.2)	29.7 (28.1-31.3)	27.8 (27.4-28.2)	30.0 (28.6-31.3)
WC, cm	90.3 (89.3-91.4)	104.9 (100.7-109.1)	87.9 (86.5-89.3)	105.8 (97.5-114.0)	86.9 (85.5-88.2)	92.7 (88.9-96.5)	89.9 (88.8-90.9)	96.5 (93.0-99.9)
WHtR	0.53 (0.52-0.53)	0.62 (0.59-0.64)	0.52 (0.51-0.53)	0.62 (0.57-0.68)	0.52 (0.51-0.53)	0.56 (0.54-0.57)	0.55 (0.54-0.55)	0.59 (0.57-0.61)
WHR	N/A	N/A	0.86 (0.86-0.87)	0.93 (0.90-0.96)	0.82 (0.81-0.84)	0.88 (0.85-0.91)	0.91 (0.90-0.91)	0.93 (0.91-0.95)

95% CI, 95% Confidence interval; BMI, Body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio.

[a]Type 2 diabetes: self-reported diagnosis by a physician and/or self-reported diabetes medications and/or register-based diabetes and/or glycated haemoglobin $\geq$ 48 mmol/mol.

Table 4 Receiver operating curve analysis area under the curve (AUC) for continuous anthropometric measures

	Finnish (n=887)		Russian (n=344)		Somali (n=225)		Kurdish (n=348)	
	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value
BMI	0.74 (0.67-0.81)	<0.001	0.80 (0.67-0.92)	0.869	0.68 (0.58-0.79)	0.065	0.66 (0.55-0.76)	0.107
WC	0.81 (0.74-0.87)	0.497	0.79 (0.67-0.91)	0.575	0.74 (0.64-0.84)	0.565	0.71 (0.61-0.81)	0.523
WHR	N/A	N/A	0.70 (0.58-0.81)	0.055	0.66 (0.55-0.77)	0.115	0.62 (0.52-0.73)	0.187
WHtR	0.81 (0.75-0.87)	ref.	0.80 (0.66-0.93)	ref.	0.75 (0.65-0.85)	ref.	0.70 (0.59-0.80)	ref.

95% CI, 95% Confidence interval; BMI, Body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio.

Figure legends

Figure 1 Age-adjusted receiver operating characteristics (ROC) curves for the association between anthropometrics and type 2 diabetes by study group

[Figure 1 should be preferably reproduced in colour]

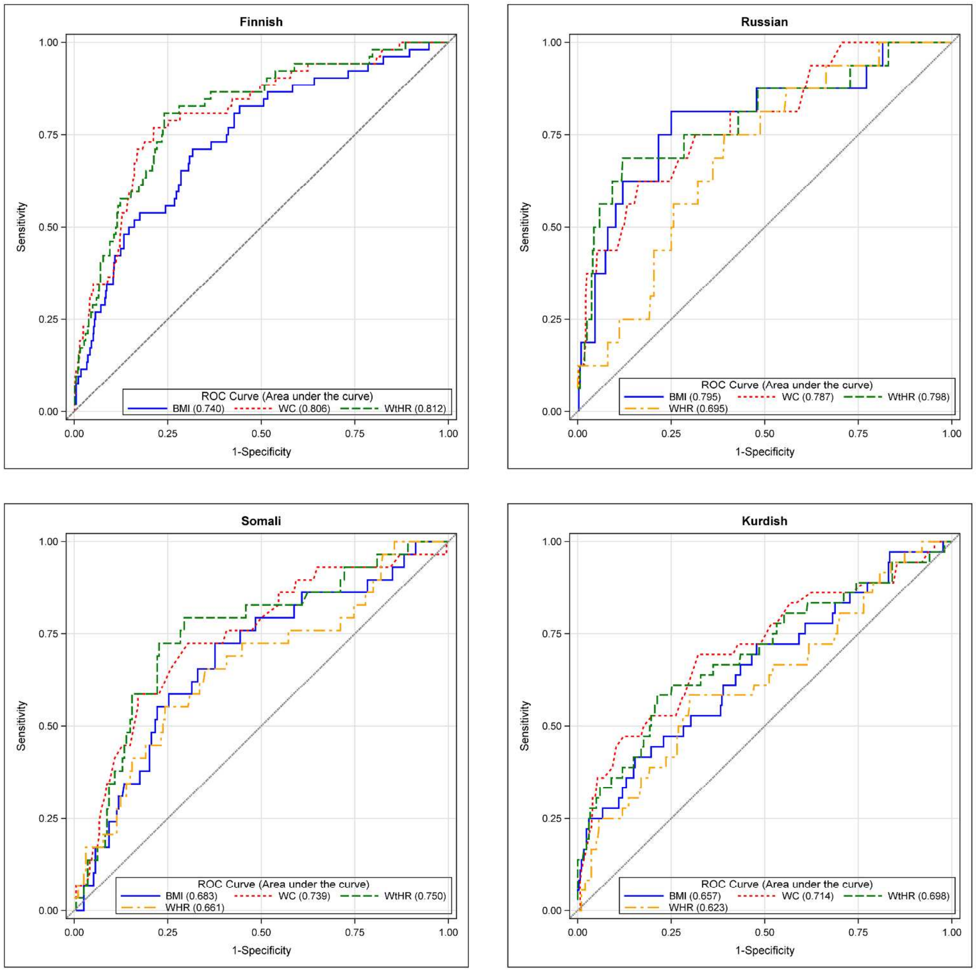

Figure 1 Age-adjusted receiver operating characteristics (ROC) curves for the association between anthropometrics and type 2 diabetes by study group

304x304mm (300 x 300 DPI)

Supplement Table 1 Receiver operating characteristics curves area under the curve (AUC) for categorical anthropometric measures

	Finnish (n=887)		Russian (n=344)		Somali (n=225)		Kurdish (n=348)	
	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value
BMI[a]	0.73 (0.66-0.79)	0.006	0.74 (0.62-0.87)	0.873	0.67 (0.57-0.77)	0.421	0.61 (0.51-0.71)	0.226
WC[b]	0.75 (0.69-0.81)	0.404	0.76 (0.67-0.86)	0.874	0.71 (0.61-0.81)	0.964	0.67 (0.58-0.77)	0.248
WHR[c]	N/A	N/A	0.68 (0.58-0.78)	0.348	0.65 (0.55-0.75)	0.229	0.54 (0.47-0.61)	0.025
WHtR[d]	0.77 (0.72-0.83)	ref.	0.75 (0.61-0.90)	ref.	0.71 (0.61-0.80)	ref.	0.64 (0.55-0.74)	ref.

95% CI, 95% Confidence interval; BMI, Body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio.

[a]BMI categories: normal BMI < 25 kg/m^2, overweight 25-29.9 kg/m^2, obese ≥ 30 kg/m^2;

[b]WC categories: normal WC < 94 cm (men)/ < 80 cm (women), overweight 94-102 cm (men)/ 80-88 cm (women), obese > 102 cm (men)/ > 88 cm (women);

[c]WHtR categories: normal < 0.50; overweight 0.50-0.59; obese ≥ 0.60;

[d]WHR categories: normal < 90 (men)/ < 0.85 (women), obese ≥ 90 (men)/ ≥ 0.85 (women).

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9,10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	10
		(*e*) Describe any sensitivity analyses	13
Results			

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	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, 24
		(b) Indicate number of participants with missing data for each variable of interest	24
Outcome data	15*	Report numbers of outcome events or summary measures	9, 24
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	11
		(*b*) Report category boundaries when continuous variables were categorized	9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
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	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information			
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	18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.

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Which anthropometric measures best indicate type 2 diabetes among Russian, Somali and Kurdish origin migrants in Finland? A cross-sectional study.

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Abstract

Objectives: To compare the performance of body mass index (BMI), waist-to-height ratio (WHtR), waist circumference (WC) and waist-to-hip ratio (WHR) in detecting type 2 diabetes among Russian, Somali and Kurdish (born in Iraq/Iran) origin migrants and Finns.

Design and participants: Cross-sectional study comparing health examination survey data of 30-64 year-old Russian, Somali and Kurdish origin migrants (n=917) who took part in the Migrant Health and Wellbeing Survey with the general Finnish population in the Health 2011 Survey (n=887). Participants were randomly selected from the National Population register.

Setting: Six cities in Finland, where a substantial majority of migrants live.

Outcome measures: Anthropometric measures included objectively measured BMI, WHtR, WC and WHR. Type 2 diabetes was defined based on self-report, laboratory measures of glycated haemoglobin (HbA1c) and register data. Test performance was assessed using receiver operating characteristics (ROC) curves, using area under the curve (AUC) as a measure of accuracy.

Results: Among Finns, test performance was highest for WC (AUC=0.81, 95%CI 0.74-0.87) and WHtR (AUC=0.81, 95%CI 0.75-0.87). Test performance was similar for BMI (AUC=0.80, 95%CI 0.67-0.92), WC (AUC=0.79, 95%CI 0.67-0.91) and WHtR (AUC=0.70, 95%CI 0.66-0.93) among Russians. WC and WHtR had highest test performance also among Somali (AUC=0.74, 95%CI 0.64-0.84 for WC and AUC=0.75, 95% CI 0.65-0.85 for WHtR) and Kurds (AUC=0.71, 95% CI 0.61-0.81 for WC and AUC=0.70, 95% CI 0.59-0.80 for WHtR).WHR had the poorest test performance among migrants.

Conclusion: WC and WHtR performed overall the best across all study groups, however accuracy of detection was lower particularly among Somali and Kurds. Currently used diabetes risk assessment tools assume a strong association between anthropometrics and diabetes. These tools need to be validated among non-Western populations.

Keywords: anthropometric; type 2 diabetes; migrant; African; Middle-Eastern; non-Western

Strengths and limitations of the study

- To our best knowledge, no previous studies have aimed at determining the best anthropometric measures for detecting type 2 diabetes among migrants of Eastern-European, African and Middle-Eastern origin.
- A substantial strength of the study is use of randomized study design and inclusion of several diverse migrant groups.
- A further strength is the use of several objective standardized anthropometric measures and supplementation of self-report data with register based-data and laboratory analyses.
- Use of anthropometric measures as continuous variables takes into account the lack of specific cut-offs for Middle-Eastern and African origin populations.
- One limitation could be the cross-sectional nature of the data, due to which we were unable to test causality by using follow-up data on diabetes diagnosis.

Abbreviations

AUC, Area under the curve

BMI, Body mass index

HbA1c, glycated haemoglobin

Maamu Survey, Migrant Health and Wellbeing Survey

ROC curves, Receiver operating characteristics curves

WC, waist circumference

WHR, waist-to-hip ratio

WHtR, waist-to-height ratio

1 Introduction

Non-Western origin migrants have a higher prevalence of glucose impairment and type 2 diabetes both compared with Europeans and compatriots in their country of origin(1-5). Prevalence of type 2 diabetes has been reported to be 2-5 times higher among South Asians, 2-4 times higher among migrants from the Middle-East and Northern-Africa, and 2-3 times higher among the Sub-Saharan African origin populations compared with Europeans(6). Non-Western origin migrants in Finland (Somali and Iranian/Iraqi Kurds) have also been reported to have a 3-5 times higher risk for glucose impairment and 2-3 times higher risk for diabetes compared with Finns(7). There is therefore an urgent need for effective screening strategies to identify those at elevated risk for type 2 diabetes.

Weight gain, particularly abdominal obesity, is strongly associated with insulin resistance, which is a central precursor for diabetes(8,9). Body mass index (BMI) and waist circumference (WC) are the most commonly used anthropometric measures for identifying populations at a higher risk for type 2 diabetes(10). While BMI is an indicator of total body fat, it does not provide information on body fat distribution. WC reflects central fat deposition but does not take fully into account intra-individual and ethnic differences in lean body mass, body shape and height(11,12). Body fat distribution, body shape and height may vary substantially according to country of origin, therefore anthropometric measures that are more sensitive to these variations across population groups may need to be considered(11). Alternatives to BMI and WC include waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR). While WHR reflects relative fat distribution, it is rather an indicator of body shape than of excess fat(12). Recently, WHtR was shown to be superior to BMI and WC in predicting future risk for type 2 diabetes by taking into account both central fat deposition and intra-individual differences in height (11,13).

In addition to the apparent need for considering more appropriate anthropometric measures for non-Western origin migrants, currently used classifications of obesity may need to be reconsidered. Generally, the association between obesity and glucose impairment is examined using cut-off points that have been established based on large-scale studies conducted among Caucasian populations(12). Recent studies have demonstrated a weaker association between obesity and type 2 diabetes among migrants of South Asian(2), Middle-Eastern(14) and West African(15) origin migrants, which may be attributable to different mechanisms for developing type 2 diabetes. However, these findings may also be related to inappropriateness of current obesity classifications for non-Western origin migrants. There is increasing evidence that migrant populations have an increased risk of developing type 2 diabetes at lower BMI and WC levels than Western populations(16-18). Considering that diabetes risk prediction tools assume a strong association between obesity and type 2 diabetes(10), use of obesity cut-offs for Western populations may lead to misclassification of those at higher risk for diabetes among non-Western origin populations.

The aim of this study was to compare the performance of BMI, WHtR, WC and WHR in detecting type 2 diabetes among Russian, Somali and Kurdish (born in Iraq/Iran) origin migrants and the general Finnish population.

2 Methods

2.1 Design and study population

This cross-sectional study was based on the data from the Migrant Health and Wellbeing Survey (Maamu), conducted between 2010 and 2012 in six cities in Finland. A more detailed description of survey methods has been provided elsewhere(7). Briefly, a stratified random sample of 3000 Russian, Somali and Kurdish origin migrants (1000 per each group) aged 18-64 years was drawn from the National Population Register that contains information on all permanent residents in Finland. Stratification was based on all combinations of the three migrant groups (Russian, Somali and Kurds) and the six cities where the study was conducted (Helsinki, Espoo, Vantaa, Turku, Tampere, Vaasa). Somali migrants were not recruited in the city of Vaasa because at the point of planning the survey, the Somali population size was very low. Stratification was therefore based on altogether 17 combinations (Russian x 6 cities)+(Somali x 5 cities)+(Kurdish x 6 cities). A random sample was drawn in each stratum based on predetermined sample sizes. Inclusion criteria were country of birth (Russia/Former Soviet Union, Somalia and Iran/Iraq), mother tongue (Russian/Finnish and Sorani dialect of Kurdish) and residence in Finland for at least one year. Participants were invited for a structured face-to-face interview and a standardized health examination, conducted by trained fieldwork personnel.

The reference group were the general Finnish population (later referred to as Finns) who participated in the nationally representative Health 2011 Survey(19). The reference group consisted of participants from the corresponding six cities of the Maamu Survey. Survey data was supplemented with register-based data from the Social Institution of Finland (Kela) and the Finnish Care Register for Health Care (Hilmo). The Social Institution of Finland grants reimbursement rights for medication based on diagnosis and severity of the long-term condition(20). The Finnish Care Register for Health Care contains information on inpatient or outpatient hospital care(21).

The current study was limited to 30-64 year-old health examination participants, with participation rate of 48% for Russians, 40% for Somali, 59% for Kurds and 56% for Finns. Following exclusion of persons with type 1 diabetes (n=9), the study was based on health examination data of 917 migrants and 887 Finns. All participants gave written informed consent. Both surveys and record linkages were approved by the Coordinating Ethics Committee of the Helsinki and Uusimaa Hospital District.

2.2 Clinical measurements and interview data

The health examination included standardized measurements of weight and height as well as waist and hip circumferences according to the European Health Examination Survey standards(22). Weight was measured wearing light clothing and no shoes with a balanced beam scale (Seca 709) in the Maamu Survey and as a part of the bioimpedance body composition analysis (Seca 514) in the Health 2011 Survey. In both studies, height was measured without shoes with a stand-alone stadiometer (Seca 213). WC was measured with a soft measuring tape half-way between the lowest rib and top of iliac crest on bare skin or wearing light clothing. Hip circumference was not measured in the Health 2011 Survey and is available for Maamu Survey participants only. Weight and WC were not measured if the participant was over 20 weeks pregnant.

Blood samples were taken by trained laboratory staff, centrifuged within an hour and frozen at -20°C on site. Samples were shipped packed in dry ice weekly in Helsinki, Espoo, and Vantaa, and monthly in other cities, to their final storage location in THL, where they were stored at -70°C. HbA1c was measured by immuno-turbidimetric method using Abbott Architect reagents. The inter-assay coefficient of variation for glycated haemoglobin was 3.9%. The laboratory (Disease Risk Unit at THL) conducting the analyses took part in the External Quality Assessment Schemes organized by Labquality, Helsinki, Finland.

2.3 Variable definition

Variable

Type 2 diabetes was determined based on: 1) interview data on self-reported previous diagnosis by a physician, 2) self-reported medication use, 3) register based diabetes defined by information on special medication reimbursement rights and/or inpatient or outpatient hospital care for diabetes and/or 4) glycated haemoglobin (HbA1c) levels ≥ 6.5% (48 mmol/mol). Diabetes type was not asked in the interviews, thus persons with type 1 diabetes were identified as those who had diabetes onset below the age of 35 years and simultaneously used only insulin as their diabetes medication.

Anthropometric measures included in this study were BMI, WC, WHtR and WHR. BMI was calculated as kg/m2. WHtR was calculated as WC in cm divided by height in cm. WHR was calculated as WC in cm divided by hip circumference in cm. Age was used as a categorical variable (< 45 years vs. ≥ 45 years).

2.4 Statistical analysis

All analyses accounted for the stratified sampling and finite population correction and were conducted using the Sudaan 11.0.1 and SAS 9.3 software packages(23). Inverse probability weights, based on register information (age group, sex, study group, study location, and marital status), were used to correct for the effects of non-response and different sampling probabilities in all of the analyses(24). The regression analyses were based on the generalized estimating equations, and all variance estimates on linearization(25).

Age-adjusted mean values and their 95% confidence intervals (95% CI) for continuous variables were calculated using linear regression, whereas logistic regression was applied to categorical variables. All regression analyses were stratified by study group and sex, with exception for estimation of age-adjusted mean anthropometric measures according to the presence of type 2 diabetes. All regression analyses were conducted using predictive margins based on regression models(26). Statistical significance was assessed with Sattherthwaite F-statistic. Logistic regression was applied to test the interaction between anthropometrics and sex with type 2 diabetes as an outcome variable for each study group. No statistically significant sex interactions were found for any of the continuous anthropometric variables in any of the study groups, therefore mean anthropometric measures according to the presence of type 2 diabetes and area under the curve (AUC) were calculated jointly for men and women using the interaction of study group and sex.

Test performance of anthropometric measures was evaluated by receiver operating characteristics (ROC) analyses(27). Accuracy of the test was assessed by calculating area under the curve (AUC). The perfect test has an AUC of 1.0, whether random chance gives an AUC of 0.5. The AUC values are classified as: 0.5-0.6 fail, 0.6–0.7 poor, 0.7–0.8 fair, 0.8–0.9 good, and 0.9–1.0 excellent(28). Stratified sampling design based on the 17 combinations of migrant groups and study locations were accounted for when calculating the AUC values but not when calculating confidence intervals for AUC and p-values for the difference in the performance of anthropometric measures within each migrant group. The reason for not accounting for stratified sampling design in these analyses is that we are unaware of any accessible statistical tools for assessing the differences of AUC in complex survey data. ROC analyses were performed for each study group separately.

3 Results

Age-adjusted anthropometric characteristics are presented in Table 1. Russian men were shorter, weighted less and had lower WC compared with Finns. Russian women were shorter, otherwise their anthropometric characteristics were similar to those of Finns. Somali men were shorter, weighted less and had lower WC compared with Finns. Somali women were also shorter but were simultaneously significantly heavier than Finns. Mean BMI and WHtR were significantly higher among Somali women compared with Finns, however mean WC did not differ significantly between the two groups. Compared with Finns, Kurdish men were significantly shorter, weighted less and had lower WC, however no statistically significant differences were observed with respect to BMI and WHtR. Kurdish women, on the other hand, were significantly shorter but had similar weight and WC as Finns, as reflected also in higher BMI and WHtR.

[Table 1 about here]

Prevalence of type 2 diabetes as well as prevalence of each individual component (self-report, registers and HbA1c) that were combined to form a joint “type 2 diabetes” variable are presented in Table 2. Prevalence of type 2 diabetes was significantly higher among Somali and Kurds, particularly among women. Register-based prevalence of type 2 diabetes was higher than self-report among men in all study groups and Finnish women, whereas it was lower among Russian, Somali and Kurdish women. Prevalence of HbA1c $\geq$ 6.5% (48 mmol/mol) was higher among Somali and Kurdish men and Somali women compared with Finns.

Supplementing self-reported diabetes diagnosis with register-based data on special medication reimbursement rights for diabetes medicine and/or inpatient or outpatient hospital care/physician visits for diabetes treatment, provided with altogether 17 new cases of diabetes (n=7 for Finns, n=1 for Russians, n=4 for Somali, n=5 for Kurds). Laboratory measures of HbA1c provided with an additional nine new cases of diabetes (n=2 for Finns, n=2 for Russians, n=5 for Somali) in addition to the information based on self-report and registers.

[Table 2 about here]

Among persons with type 2 diabetes, mean age upon arrival to Finland was 35 years for Russian, 32 years for Somali and 31 years for Kurds (detailed data not shown). Self-reported mean age at diagnosis was 48 years for Russians, 45 years for Somali, 41 years for Kurds and 45 years for Finns. The difference in age of diagnosis was statistically significant among Kurds (p=0.006) and approached statistical significance for Russians (p=0.058) when comparing with Finns. Type 2 diabetes was diagnosed in Finland in majority of the cases (72% among Russians, 59% among Somali and 70.5% of Kurds).

Mean BMI values varied significantly among persons with and without type 2 diabetes in Finnish and Russian groups, whereas the difference was less pronounced among Somali and Kurds (Table 3). Similar observations were made for WC, WHtR and WHR. Additionally, while mean BMI values were overall similar in corresponding diabetes categories across all groups, mean WC among Somali and Kurdish origin persons with type 2 diabetes was significantly lower compared with that of Russians and Finns. Somali origin migrants with type 2 diabetes had a significantly lower mean WHtR compared with Finns.

[Table 3 about here]

Results of the ROC curves are presented in Table 4 and in Figure 1. ROC curves showed that test performance was similar for WC and WHtR and significantly poorer for BMI among Finns. Accuracy of detection for WC and WHtR was good (AUC within the range of 0.80-0.90) and fair for BMI (AUC within the range of 0.70-0.80). Among Russians, test performance was similar for BMI, WC and WHtR (AUC ranging between 0.79 and 0.80), with fair to good accuracy of detection. For Somali, test performance was similar for WC and WHtR and poorer for BMI. Accuracy of detection for WC and WHtR was fair among the Somali group (AUC within the range of 0.70-0.80) and poor for BMI (AUC within the range of 0.60-0.70). As in all other groups, test performance was similar for WC and WHtR among Kurds as well. However, accuracy of detection ranged between AUC 0.70 and 0.71, suggesting poor to fair test performance.

WHR (available for migrants only) performed the poorest across the examined anthropometric measures across all groups, with poor accuracy of detection (AUC ranging between 0.62 and 0.69 depending on migrant group).

[Table 4 and Figure 1 about here]

In addition to comparing test performance of continuous anthropometric measures in detecting type 2 diabetes, we also examined test performance of categorical anthropometric measures using established cut-off points for overweight and obesity (Supplement Table 1). These analyses showed a similar trend, however accuracy of detection was slightly lower for categorical anthropometric measures compared with corresponding continuous anthropometric measures within each study group.

[Link to Supplement Table 1]

4 Discussion

Our results suggest that out of the four examined anthropometric measures, WC and WHtR performed the best in detecting type 2 diabetes in all study groups. However, accuracy of prediction was better among Finns and Russians, compared with Somali and Kurds. There was some discordance in the prevalence of type 2 diabetes using different sources of information (self-report, registers and laboratory measures), highlighting the benefits of taking different data sources into account. Highest proportion of cases of screen-detected diabetes, i.e. persons meeting the diabetes criteria of HbA1C ≥ 6.5% (48 mmol/mol) without previously known diabetes according to self-report or registers, was found among the Somali group (2.2%), compared with 0.2% of Finns and 0.6% of Russians. This finding suggests the need for more effective screening for type 2 diabetes especially among Somali migrants.

Abdominal obesity is considered to be a central precursor for diabetes(8,9). Therefore our finding that WC and WHtR are the best anthropometric measures for detecting type 2 diabetes is in line with previous research. Out of these two abdominal measures, WC is more established and is used in diabetes risk assessment tools(10). More recently, WHtR has been argued to be superior to a single measure of WC by taking into account intra-individual and ethnic differences in height(11,13). While we did find substantial differences in anthropometrics across study groups, our findings show very similar accuracy of detection for WC and WHtR within each study group. This may be related to an overall lower degree of the association between anthropometric measures with type 2 diabetes among non-Western origin migrants.

We also found an overall weaker association between anthropometrics and type 2 diabetes among Somali and Kurds. This was reflected through less pronounced differences in mean anthropometric values according to diabetes category as well as poorer accuracy of detection for WC and WHtR. In consistency with this findings, several previous studies report a lower level of correlation between obesity indicators and diabetes among non-Western origin migrants compared with Western populations(2,6,15,29).

Higher prevalence of diabetes among South Asian origin migrants was not explained by obesity and other metabolic risk factors upon follow-up(2). Middle-Eastern origin migrants from Iraq had a significantly higher prevalence of both obesity and diabetes, however high diabetes rates were only partly explained by abdominal obesity and other established risk factors for diabetes(29). Similarly, the association between body composition measures and diabetes was weaker among Sub-Saharan African origin migrants compared with Western African origin migrants and persons in the Dutch general population(15). These differences may be attributable to genetic and epigenetic factors(15,30), however there is also emerging evidence that there may be different biological mechanisms behind glucose impairment according to country of origin(31-34).

Glucose impairment among Sub-Saharan Africans from Ghana appears to be more strongly related to peripheral insulin resistance than to Beta cell dysfunction(33). Middle-Eastern origin migrants (Lebanon, Iraq, Iran, Syria, Turkey) have been suggested to have an altogether different form of T2DM compared with Western populations due to a stronger genetic component, reflected in earlier age at onset, stronger family history and a more significant reduction in Beta cell function despite similar insulin resistance levels(29,32). Family history of diabetes has been found to have a stronger association with poorer glucose control than with age, BMI and WC among Iraqi origin migrants without diabetes(34).

Non-Western origin migrants come from countries at an earlier stage of the epidemiological transition. Rapid epidemiological transition, with a notable change in diet and physical activity levels, may further contribute to a higher prevalence of glucose impairment and diabetes(33,35). Rapid weight gain upon migration may be related to glucose impairment among migrants. Furthermore, it has been suggested that a rapid transition from normal weight to overweight may be sufficient to produce glucose impairment and increase the likelihood of developing type 2 diabetes(31,35-37).

We used continuous anthropometric measures as opposed to conventional categorical measures because of an increasing amount of literature questioning the appropriateness of currently used obesity cut-offs validated among Caucasian populations in diabetes risk assessment among non-Western origin populations(16-18,38). Some studies have suggested that lower cut-offs for abdominal obesity among African men and higher cut-offs for African women may be more appropriate for detecting insulin resistance(16,17). Our findings support this as among persons with type 2 diabetes, Somali and Kurds had on average approximately 10cm lower WC circumference compared with Finns and Russians. Lower cut-offs for BMI and WC may be more appropriate also for Middle-Eastern origin migrants. Insulin resistance index of Middle-Eastern origin (Iraqi) migrants at BMI 28.5 kg/m^2 for men and 27.5 kg/m^2 for women has been shown to correspond to that of Swedes with BMI 30 kg/m^2. Insulin sensitivity index among abdominally obese Swedes (WC ≥ 94cm for men and ≥ 80 cm for women) corresponded to 10 cm lower cut-offs among Iraqi migrants (≥ 84 cm for men and ≥71cm for women)(18).

In addition to calculating ROC curves for continuous anthropometric measures, we tested the performance of categorical measures in detecting type 2 diabetes. Test performance was poorer for categorical compared with continuous anthropometric measures. Taking into account the increasing amount of evidence suggesting poorer applicability of categorical anthropometric measures in detecting diabetes among non-Western origin populations(16-18,38), current use of categorical anthropometric measures in diabetes risk assessment may need to be reconsidered. Awareness of the limitations in the use of categorical anthropometric measures may facilitate development of more appropriate and sensitive tools for diabetes risk assessment among different population groups. Such have already been developed for cardiovascular risk prediction, which enable the use of continuous measures instead of the conventional cut-offs for cardiovascular risk factors(39,40). Additionally, the observed overall lower degree of the association between anthropometrics and diabetes among non-Western origin migrants may lead to a higher degree of misclassification of those at risk for developing diabetes. Therefore, diabetes risk assessment tools need to be validated among different population groups.

Strengths and limitations

A significant strength of this study is the use of several objective standardized anthropometric measures and supplementing self-reported data with register data and blood samples. An advantage of using HbA1c is that it measures average glucose levels over the past several weeks and is not affected by fasting. Use of anthropometric measures as continuous variables takes into account the lack of specific cut-offs for Middle-Eastern and African origin populations. A further strength of this study is the randomized study design and inclusion of several migrant groups. Russian, Somali and Iranian/Iraqi Kurds are significant migrant groups not only in Finland but also in other Western countries. Kurds are a substantial refugee group in many European countries, United States and Canada but identification of Kurds in national statistics is particularly challenging as not all countries collect information on country of origin and mother tongue.

This study has also some limitations. Due to the cross-sectional nature of the data, we were unable to test causality by using follow-up data on diabetes diagnosis. Due to sample size restrictions, it was not feasible to calculate ROC curves for men and women separately. However, we did not observe interaction between sex and continuous anthropometric measures with respect to diabetes. Furthermore, type 2 diabetes risk assessment tools do not generally differentiate by sex and for this purpose as well, performing analyses jointly for men and women is plausible. Division of our study population according to country of origin has created relatively small study groups, resulting in widened confidence intervals. Our findings need to be confirmed in a larger sample.

In conclusion, WC and WHtR were the best anthropometric measures for detecting type 2 diabetes among both Western and non-Western origin populations in our study. Out of the two, WHtR may be more appropriate for use in diabetes risk assessment as it takes into account intra-individual and ethnic differences in height and body composition. Currently used diabetes risk assessment tools have been designed for Western populations and assume that there is a high level of correlation between anthropometrics, and particularly abdominal obesity, with incidence of type 2 diabetes. Accuracy of anthropometric measures in detecting type 2 diabetes was lower among non-Western origin migrants. This may lead to a higher degree of misclassification of diabetes risk among non-Western origin populations. Non-Western origin migrants have a substantially higher prevalence of glucose impairment and diabetes than Finns, and effective screening strategies are needed for identification of those at high risk for developing diabetes.

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Author contributions

Skogberg analyzed and interpreted the data and wrote the first draft of the manuscript. Koponen, Laatikainen and Lundqvist contributed to conceptualizing the study design, data interpretation and provided critical review of the manuscript. Härkänen and Lilja critically revised the statistical methods used in the study and contributed to data interpretation. All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and accuracy of the data analyses.

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Disclosure of interest

The authors declare that they have no competing interest.

Data sharing statement

The Migrant Health and Wellbeing (Maamu) Survey data can be shared with other researchers after a research plan has been compiled and accepted. More information on data sharing process can be accessed from: https://www.thl.fi/en/web/thlfi-en/research-and-expertwork/population-studies/migrant-health-and-wellbeing-study-maamu-/information-for-researchers.

Patient and Public Involvement

The research question was based on our previous finding that the prevalence of glucose impairment and diabetes as well as overweight and obesity are particularly high in some migrant groups and that it is a topic that needs to be further addressed. This study is an epidemiological study using health examination survey data and therefore no patients were directly involved in the design, recruitment or conduct of the current study. Results of the study will benefit the target group of the study through the use of the findings for developing risk assessment tools for different migrant groups.

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Table 1 Age-adjusted anthropometric characteristics of the study population

	Finnish	Russian	Somali	Kurdish
	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)
Men, N	395	119	85	181
Age ≥ 45 years, %	57.0 (50.7-63.1)	46.5 (37.0-56.4)	31.1 (21.7-42.3)***	34.5 (28.5-41.0)***
Weight, kg	86.4 (84.5-88.3)	82.9 (80.1-85.7)*	74.6 (72.3-77.0)***	80.9 (79.3-82.5)***
Height, cm	179.6 (178.7-180.5)	176.6 (175.4-177.7)***	174.5 (173.0-176.0)***	171.6 (170.7-172.4)***
Hip circumference, cm	N/A	100.3 (98.8-101.7)	100.0 (98.5-101.5)	97.2 (96.2-98.3)
Waist circumference, cm	96.0 (94.5-97.5)	92.9 (90.5-95.3)*	87.1 (85.1-89.1)***	93.3 (92.0-94.5)**
Body mass index, kg/m^2	26.7 (26.2-27.3)	26.6 (25.8-27.4)	24.5 (23.8-25.3)***	27.4 (26.9-27.9)
Waist-to-height ratio	0.54 (0.53-0.54)	0.53 (0.51-0.54)	0.50 (0.49-0.51)***	0.54 (0.54-0.55)
Waist-to-hip ratio	N/A	0.92 (0.91-0.93)	0.87 (0.85-0.88)	0.95 (0.95-0.96)
Women	492	225	140	167
Age ≥ 45 years, %	55.2 (50.2-60.1)	60.6 (53.6-67.2)	35.3 (27.6-43.7)***	31.1 (25.1-37.9)***
Weight, kg	72.2 (70.8-73.6)	71.5 (69.5-73.4)	80.9 (78.4-83.3)***	71.0 (69.5-72.6)
Height, cm	165.9 (165.2-166.5)	164.0 (163.1-164.8)***	161.9 (161.0-162.9)***	157.4 (156.7-158.2)***
Hip circumference, cm	N/A	102.7 (101.2-104.2)	109.6 (107.8-111.4)	100.5 (99.2-101.8)
Waist circumference, cm	86.8 (85.4-88.1)	85.1 (83.3-86.9)	88.3 (86.5-90.1)	88.5 (86.9-90.0)

Body mass index, kg/m^2	26.3 (25.8-26.8)	26.6 (25.8-27.3)	30.8 (29.9-31.6)***	28.6 (28.0-29.3)***
Waist-to-height ratio	0.52 (0.52-0.53)	0.52 (0.51-0.53)	0.55 (0.54-0.56)**	0.56 (0.55-0.57)***
Waist-to-hip ratio	N/A	0.83 (0.82-0.83)	0.80 (0.79-0.82)	0.87 (0.87-0.88)

95% CI, 95% Confidence interval.

* $p < 0.5$; ** $p < 0.001$; *** $p < 0.001$ P-value is presented for the difference between each migrant group and Finns.

Table 2 Age-adjusted prevalence of type 2 diabetes

	Finnish	Russian	Somali	Kurdish
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Men, N	395	119	85	181
Type 2 diabetes[a]	6.2 (4.4-8.7)	4.3 (1.8-10.0)	15.5 (8.5-26.7)*	10.5 (7.0-15.4)
Self-reported diabetes	5.1 (3.4-7.5)	3.5 (1.3-9.2)	8.2 (3.4-18.4)	8.8 (5.6-13.6)
Register-based diabetes[b]	6.0 (4.2-8.5)	4.3 (1.8-10.0)	12.3 (6.0-23.5)	9.7 (6.3-14.5)
HbA1c ≥ 6.5 % (48 mmol/mol)	2.0 (1.0-4.0)	0.7 (0.1-4.7)	8.2 (3.4-18.5)*	4.7 (2.4-8.8)
Women	492	225	140	167
Type 2 diabetes[a]	3.5 (2.3-5.5)	6.0 (3.4-10.4)	16.4 (10.6-24.5)***	11.8 (7.8-17.4)***
Self-reported diabetes	2.6 (1.5-4.3)	4.6 (2.5-8.4)	14.6 (8.9-23.0)***	11.2 (7.3-16.8)***
Register-based diabetes[b]	3.1 (1.9-4.9)	3.3 (1.6-6.6)	10.5 (6.0-17.8)**	8.1 (4.8-13.3)**
HbA1c ≥ 6.5 % (48 mmol/mol)	1.7 (0.8-3.4)	1.8 (0.6-5.6)	5.1 (2.1-12.0)	2.5 (0.8-7.0)

95% CI, 95% Confidence interval; HbA1c, Glycated haemoglobin.

[a]Type 2 diabetes: self-reported diagnosis by a physician and/or self-reported diabetes medications and/or register-based diabetes and/or glycated haemoglobin ≥ 48 mmol/mol;

[b]Register-based diabetes: register-based data on special medication reimbursement rights for diabetes medicine and/or inpatient or outpatient hospital care/physician visits for diabetes treatment.

* p < 0.5; ** p < 0.001; *** p < 0.001. P-value is presented for the difference between each migrant group and Finns.

Table 3 Age-adjusted mean anthropometric measures according to the presence of type 2 diabetes.

	Finnish		Russian		Somali		Kurdish	
	Type 2 diabetes[a]		Type 2 diabetes[a]		Type 2 diabetes[a]		Type 2 diabetes[a]	
	No (n=834)	Yes (n=53)	No (n=326)	Yes (n=18)	No (n=195)	Yes (n=30)	No (n=312)	Yes (n=36)
	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)	mean (95% CI)
BMI, kg/m^2	26.3 (25.9-26.6)	30.7 (28.9-32.6)***	26.3 (25.8-26.9)	32.8 (29.2-36.5)**	27.6 (26.9-28.2)	29.7 (28.1-31.3)*	27.8 (27.4-28.2)	30.0 (28.6-31.3)**
WC, cm	90.3 (89.3-91.4)	104.9 (100.7-109.1)***	87.9 (86.5-89.3)	105.8 (97.5-114.0)***	86.9 (85.5-88.2)	92.7 (88.9-96.5)**	89.9 (88.8-90.9)	96.5 (93.0-99.9)***
WHtR	0.53 (0.52-0.53)	0.62 (0.59-0.64)***	0.52 (0.51-0.53)	0.62 (0.57-0.68)***	0.52 (0.51-0.53)	0.56 (0.54-0.57)**	0.55 (0.54-0.55)	0.59 (0.57-0.61)**
WHR	N/A	N/A	0.86 (0.86-0.87)	0.93 (0.90-0.96)***	0.82 (0.81-0.84)	0.88 (0.85-0.91)**	0.91 (0.90-0.91)	0.93 (0.91-0.95)*

95% CI, 95% Confidence interval; BMI, Body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio.

[a]Type 2 diabetes: self-reported diagnosis by a physician and/or self-reported diabetes medications and/or register-based diabetes and/or glycated haemoglobin ≥ 48 mmol/mol.

* $p < 0.5$; ** $p < 0.001$; *** $p < 0.001$. P-value is presented for the difference within each study group, comparing mean anthropometric values among persons with type 2 diabetes to those witout type 2 diabetes.

Table 4 Receiver operating curve analysis area under the curve (AUC) for continuous anthropometric measures

	Finnish (n=887)		Russian (n=344)		Somali (n=225)		Kurdish (n=348)	
	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value
BMI	0.74 (0.67-0.81)	<0.001	0.80 (0.67-0.92)	0.869	0.68 (0.58-0.79)	0.065	0.66 (0.55-0.76)	0.107
WC	0.81 (0.74-0.87)	0.497	0.79 (0.67-0.91)	0.575	0.74 (0.64-0.84)	0.565	0.71 (0.61-0.81)	0.523
WHR	N/A	N/A	0.70 (0.58-0.81)	0.055	0.66 (0.55-0.77)	0.115	0.62 (0.52-0.73)	0.187
WHtR	0.81 (0.75-0.87)	ref.	0.80 (0.66-0.93)	ref.	0.75 (0.65-0.85)	ref.	0.70 (0.59-0.80)	ref.

95% CI, 95% Confidence interval; BMI, Body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio.

Figure legends

Figure 1 Age-adjusted receiver operating characteristics (ROC) curves for the association between anthropometrics and type 2 diabetes by study group

[Figure 1 should be preferably reproduced in colour]

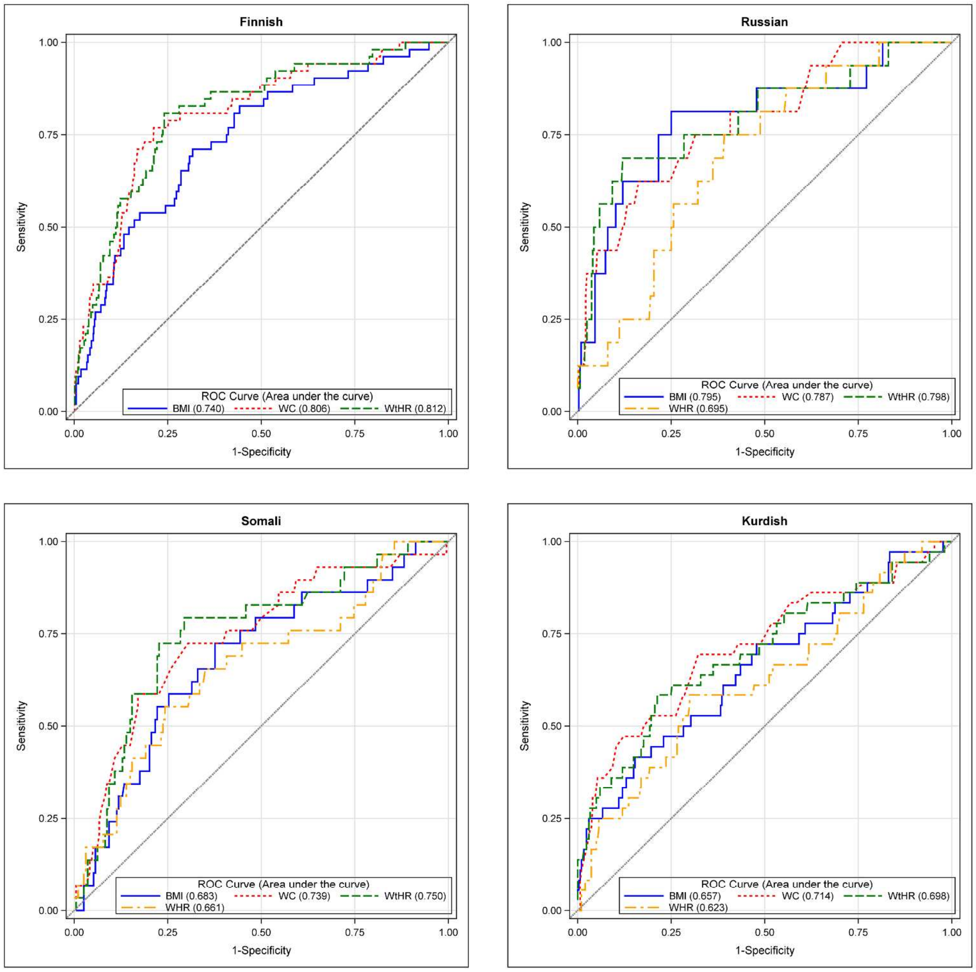

Figure 1 Age-adjusted receiver operating characteristics (ROC) curves for the association between anthropometrics and type 2 diabetes by study group

304x304mm (300 x 300 DPI)

Supplement Table 1 Receiver operating characteristics curves area under the curve (AUC) for categorical anthropometric measures

	Finnish (n=887)		Russian (n=344)		Somali (n=225)		Kurdish (n=348)	
	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value	AUC (95% CI)	*p*-value
BMI[a]	0.73 (0.66-0.79)	0.006	0.74 (0.62-0.87)	0.873	0.67 (0.57-0.77)	0.421	0.61 (0.51-0.71)	0.226
WC[b]	0.75 (0.69-0.81)	0.404	0.76 (0.67-0.86)	0.874	0.71 (0.61-0.81)	0.964	0.67 (0.58-0.77)	0.248
WHR[c]	N/A	N/A	0.68 (0.58-0.78)	0.348	0.65 (0.55-0.75)	0.229	0.54 (0.47-0.61)	0.025
WHtR[d]	0.77 (0.72-0.83)	ref.	0.75 (0.61-0.90)	ref.	0.71 (0.61-0.80)	ref.	0.64 (0.55-0.74)	ref.

95% CI, 95% Confidence interval; BMI, Body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio.

[a]BMI categories: normal BMI < 25 kg/m^2, overweight 25-29.9 kg/m^2, obese ≥ 30 kg/m^2;

[b]WC categories: normal WC < 94 cm (men)/ < 80 cm (women), overweight 94-102 cm (men)/ 80-88 cm (women), obese > 102 cm (men)/ > 88 cm (women);

[c]WHtR categories: normal < 0.50; overweight 0.50-0.59; obese ≥ 0.60;

[d]WHR categories: normal < 90 (men)/ < 0.85 (women), obese ≥ 90 (men)/ ≥ 0.85 (women).

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9,10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	10
		(*e*) Describe any sensitivity analyses	13
Results			

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	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, 24
		(b) Indicate number of participants with missing data for each variable of interest	24
Outcome data	15*	Report numbers of outcome events or summary measures	9, 24
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	11
		(*b*) Report category boundaries when continuous variables were categorized	9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
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	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information			
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	18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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.