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Vigorous physical activity may be important for the insulin sensitivity in immigrants from the Middle East and native Swedes

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Abstract

Purpose: To compare physical activity measures and their associations with insulin sensitivity, β-cell function and body mass index (BMI) between Iraqi immigrants and native Swedes. **Methods:** A cross-sectional study of 493 Iraqis (58% men) and 469 Swedes (54% men) aged 30-75 years living in the city of Malmö, Sweden. Accelerometry was used for physical activity measures (sedentary time, breaks in sedentary time, moderate and vigorous physical activity, total counts). Insulin sensitivity index and oral disposal index were determined from an oral glucose tolerance test and BMI by body weight and height. **Results:** Iraqi men were less physically active than Swedish men, while the physical activity was more similar in the women. BMI was a strong predictor of insulin sensitivity and β-cell function and frequently associated with the physical activity measures. BMI modified the associations of insulin sensitivity and β-cell function with the physical activity measures to such extent that only VPA and total counts show direct associations with insulin sensitivity in addition to the indirect associations via BMI. Iraqi women demonstrated weaker associations compared to Swedish women. **Conclusions:** Physical activity and performed at vigorous intensity may be important mainly for the insulin sensitivity in Iraqi immigrants and native Swedes.

Introduction

Type 2 diabetes (T2D) is increasing rapidly worldwide and nearly 90% of its incidence can be attributed to the five lifestyle factors overweight/obesity, diet, physical inactivity, smoking and alcohol consumption.[1] The Middle East is one of the regions in the world with the highest prevalence of T2D.[1] The reduction in the number of new cases of T2D and gain in life expectancy is estimated to be larger in this region compared to other regions in the world if the population met recommended physical activity.[2] In the Nordic countries, a higher prevalence of diabetes has been reported among immigrants from the Middle East compared to natives.[3] The Migration and Ethnicity on Diabetes In Malmö (MEDIM) study was developed to target healthy behaviors in Iraqi immigrants in Sweden to prevent T2D.

Insulin sensitivity and β-cell function both play a part in the progression of T2D.[4-6] Proposed mechanisms are that excessive food intake, physical inactivity and onset of obesity cause metabolic overload/alterations and accumulation of lipid-derived metabolites in the cells decreasing insulin sensitivity. A compensating increase in β-cell mass and insulin secretion occurs to maintain glucose homeostasis, to a degree and duration that varies greatly between individuals (up to several years in some individuals without notable alterations in the levels of circulating glucose or lipids). Eventually, β-cell dysfunction occurs with reduced cell mass and insulin secretion interfering with maintenance of glucose homeostasis, finally ending in T2D. Previous research suggests that body fatness is a major predictor of metabolic function,[7-9] but that regular exercise improves insulin sensitivity by reestablish the oxidative capacity of the cells and preserves/increases β-cell mass and secretion.[4] This is performed independently from changes in body fatness. A relevant question concerns what type of physical activity behavior (sedentary time, breaking sedentary time, moderate physical activity, vigorous physical activity or total physical activity) most favorably improves insulin sensitivity, β-cell function (or other measures of glucose regulation) and body fatness, as previous research provides various suggestions.[10-20] Interventions studies propose insulin sensitivity to be dependent on exercise intensity, but the results are inconsistent due to differences in factors such as participant characteristics and study conditions.[21-24] In addition, how daily vigorous physical activity relates favorably to insulin sensitivity and β-cell function is rather uninvestigated. Individual characteristics such as ethnic background may also influence the responsiveness of insulin sensitivity, T2D and body fatness to physical activity.[4,25]

We analyzed baseline data from the MEDIM study with the novel contribution of using accelerometers for objective physical activity in a large sample of Iraqi immigrants and native Swedes. The aims were to compare various physical activity measures in Iraqi immigrants with native Swedes, and their associations with insulin sensitivity, β-cell function and body mass index (BMI).

Methods

Study design

This is a cross-sectional investigation conducted within the MEDIM study framework. Data were collected from February 2011 to September 2012. The Ethics committee at Lund University approved the study (approval nos. 2009/36 and 2010/561) and written informed consent was given by all participants.

Study participants

Malmö is a multicultural city with approximately 300,000 residents, 9,000 of whom have their origins in Iraq. Of those aged 30 to 75 years, over 4,000 were born in Iraq. In the present study, residents born in Iraq (N=1,647) and native Swedes (N=2,293) aged 30 to 75 years were randomly selected from the census register and invited by phone and mail to participate. After excluding those with serious physical and mental illness, 1,627 Iraqis (61% men) and 2,285 Swedes (52% men) were eligible. The stepwise attrition and the response rate are shown in Figure 1.

Procedures

Trained research nurses conducted the physical examination and oral glucose tolerance test (OGTT). The participants came to the research laboratory in the morning following an overnight 10-h fast. A standard 75g OGTT was performed and blood samples were collected at 0, 30, 60 and 120 min. Blood glucose in capillary whole blood was measured immediately after sampling using a photometer (HemoCue AB, Ängelholm, Sweden). Serum insulin levels were determined using a radioimmunoassay kit (Access© Ultrasensitive Insulin, Beckman Coulter, USA). During the visit, the participants completed the study questionnaire in Swedish or Arabic. The latter was translated and back-translated by two independent authorised translators with Arabic as a native language. Participants were provided with an ActiGraph with an elastic belt together with oral and written instructions, a simple diary for reporting wearing of the activity monitor, and a prepaid padded envelope for returning the activity monitor and diary. Oral and written instructions and support during the research laboratory visit were provided in Swedish or Arabic.

Physical activity measures

ActiGraph GT1M accelerometers (firmware 4.4 and 7.5) and ActiLife data analysis software 6.4.3 (ActiGraph™, Pensacola, FL, USA) were used to derive the physical activity measures. The GT1M model is a small (4.0 × 3.9 × 1.8 cm), non-obstructive light (26.7 g) unit worn on an elastic belt round the waist. It registers movement intensity at the body's center of mass with a primary output "activity counts", which shows a linear increase with increasing physical activity intensity across a broad range of activity intensities.[26] GT1M has high inter-monitor reliability.[27] Study participants were instructed to wear the activity monitor on the left hip during 7 consecutive days, except during sleep, showering and swimming, from the day after the visit to the research laboratory. The epoch length was set to 1 minute.

Downloaded data were graphically screened in ActiLife to confirm "true" wearing days. The definition of a non-wear period was set to ≥60 minutes of consecutive zero counts, which has shown high validity.[28] As in most studies, 10 hours was determined to be adequate wearing for a valid day.[29] We included participants with at least three valid days with one of those days being a weekend day. This cut-point was a compromise between including sufficient number of days and preserving the representativeness of the sample. Differences in numbers of valid days according to sociodemographics, cardiometabolic risk markers and health have been reported.[30] Physical activity variables commonly reported in the literature were included in the analyses, such as sedentary time ($min \cdot d^{-1}$), breaks in sedentary time ($counts \cdot d^{-1}$), moderate-and-vigorous physical activity (MVPA, $min \cdot d^{-1}$), vigorous physical activity (VPA, $min \cdot d^{-1}$) and total physical activity ($counts \cdot d^{-1}$).[10-20] The cut-point of <100 $counts \cdot min^{-1}$ was used to define sedentary time,[31] and a break of sedentary time occurred at ≥100 $counts \cdot min^{-1}$. Although the ActiGraph cut-point of 100 $counts \cdot min^{-1}$ may show limitations for the assessment of sedentary time and breaks in sedentary time,[31,32] it is commonly applied in research and therefore used. Freedson´s cut-points for moderate (1952-5724 $counts \cdot min^{-1}$) and vigorous (≥5725 $counts \cdot min^{-1}$) physical activity were used to investigate both non-bouts and bouts (≥10 min duration) of physical activity.[33]

Body mass index

Body height was measured to the nearest cm and weight to the nearest kg with participants wearing light clothes but not shoes. BMI was calculated as weight (kg) / height $(m)^2$. It is a widely used measure to represent body fatness and shows strong relationship with T2D.[9]

Insulin sensitivity and β-cell function

Insulin sensitivity index (ISI) and oral disposal index (DIo) are widely used indirect measures of insulin sensitivity and β-cell function, respectively,[6] and were calculated from fasting glucose and fasting insulin from the OGTT as follow:

- ISI = 10,000 / √ [(fasting glucose (mmol/L) × fasting insulin (mIE/L)) × (mean OGTT glucose concentration (mmol/L) × mean OGTT insulin concentration (mIE/L))][34]
- CIR = (100 × insulin at 30 min (mIE/L)) / (glucose at 30 min (mmol/L) × (glucose at 30 min (mmol/L) - 3.89))[35]
- DI_O = ISI × CIR[36]

Corrected insulin resistance (CIR) provides an estimation of β-cell function and its calculation requires that the glucose concentration at 30 minutes is >4.44 mmol/l and is greater than the fasting glucose concentration.[37] DI_O provides an estimate of β-cell function adjusted for insulin sensitivity.

Sociodemographic characteristics

Age, sex, education level and financial situation were the sociodemographic charcteristics considered. In the study questionnaire, the participants had to choose between four categories of highest attained education level: 1) no education; 2) elementary school or high school; 3) college; and 4) university. For the statistical analyses, education level was dichotomized by merging categories 1 and 2 and categories 3 and 4. Financial situation was assessed from the study questionnaire using a question about whether the participant had had problems during the previous 12 months meeting payments for rent, food and other expenses. There were three categories to choose between: 1) yes, on several occasions; 2) yes, on one occasion; and 3) no. For the statistical analyses, this variable was dichotomized by merging categories 1 and 2.

Statistics

ISI and DI_O showed skewed distribution and their base 10-logarithmic values were therefore used in the association analyses. The MVPA in 10-min bouts and VPA both showed skewed distribution with many zero-values which did not allowed logarithmic transformation. The MVPA in 10-min bouts was therefore dichotomized into reaching or not reaching at least 30 $min \cdot d^{-1}$ of MVPA which is in line with the physical activity recommendation for adults,[38] while the VPA was dichotomized into zero or at least one $min \cdot d^{-1}$ of VPA. Although these transformations improved the use of the two physical activity variables, analyze results for the non-transformed values are presented as well. All other variables in the analyses did not need transformations.

All analyses were performed separated by gender. An independent samples t-test (parametric) or Mann-Whitney U Test (non-parametric) for continuous variables or chi-square test for categorical variables was used for group comparisons of sociodemographic characteristics, BMI, insulin sensitivity, β-cell function and accelerometer wear time. Sociodemographic characteristics and accelerometer wear time were considered potential covariates in the following analyses. General linear model (which includes analysis of variance and linear regression) was used for group comparisons of continuous physical activity variables and for investigating associations. Logistic regression was used for testing group difference in categorical physical activity variables. For the association analyses, three models were investigated using linear regression: Model A1 included the physical activity variable as explanatory variable and insulin sensitivity or β-cell function as response variable to investigate the overall association; Model A2 added BMI as explanatory variable to assess the remaining association of insulin sensitivity or β-cell function with the physical activity variable; and Model B assessed the association of BMI with the physical activity variable. For all regression models, a second analysis was performed introducing the interaction with country of origin to test whether the associations differed between Iraqis and Swedes. Significance was considered when $p<0.05$. Statistical analyses were performed with SPSS Statistics version 20.0 (IBM Corporation, NY, USA).

Results

Sociodemographic characteristics and accelerometer wear time (Table 1)

Iraqis were somewhat younger with a higher proportion having financial constraints. The Iraqi women showed a lower proportion with secondary school or higher education than the Swedish women. Iraqis had higher BMI and lower insulin sensitivity than Swedes, and the Iraqi men also showed lower β-cell function compared to the Swedish men. The β-cell function was also reduced in the Iraqi women but not significantly different from the Swedish women. Iraqis had a lower accelerometer wear time than the Swedes. Differences in socioeconomic characteristics and accelerometer wear time were accounted for in the following analyses.

Physical activity measures (Table 2)

The Iraqis men broke sedentary time more often but had less MVPA, VPA and total physical activity than the Swedish men. The difference in the dichotomized measure of VPA was not significant. The Iraqi women showed less sedentary time and broke sedentary time more often than the Swedish women but had the same level of MVPA and total physical activity. VPA 1-min was significantly lower in the Iraqi women, although its dichotomized measure did not differed significantly.

Association analyses (Table 3 insulin sensitivity, Table 4 β-cell function)

In general, the physical activity variables and BMI showed stronger associations with insulin sensitivity than with β-cell function (Table 3 versus Table 4). Also, the associations of insulin sensitivity and β-cell function were stronger with BMI than with the physical activity variables (Model A2, coefficient *b* versus coefficient *a*). BMI influenced the associations of the physical activity variables as only some of them showed a significant direct association with insulin sensitivity (Table 3, Model A2, coefficient *a*). Differences in associations occurred between Iraqi and Swedish women (interaction; Table 3).

In the men, higher insulin sensitivity showed significant overall association with less sedentary time and more MVPA 1-min in the Iraqis, and with more VPA (both measures) and total physical activity in both Iraqis and Swedes (Table 3, Model A1). When BMI was introduced into the model the association remained significant for VPA 1-min and total physical activity in the Iraqis and for the dichotomized measure of VPA in both groups (Table 3, Model A2, Coefficient *a*). BMI was significantly associated with the dichotomized measure of VPA and total physical activity in both groups, but also with MVPA 1-min in the Iraqis and with VPA 1-min in the Swedes (Table 3, Model B). No significant interactions with country of origin occurred in the men. Although, the association of insulin sensitivity with BMI showed lower β-coefficients in the Iraqis than in the Swedes with the significance level of $P_{interaction}$=0.05 to $P_{interaction}$=0.08 depending on the physical activity measure included in the model.

In the women, insulin sensitivity in the Iraqis showed an overall significant association only with breaks in sedentary time, but was in the Swedes significantly associated with all physical activity measures except sedentary time (Table 3, Model A1). The overall associations of insulin sensitivity with MVPA 1-min and total physical activity reached significant difference between Iraqis and Swedes (MVPA 1-min $P_{interaction}$=0.04 and Total physical activity $P_{interaction}$=0.02). When BMI was introduced in the model the associations of insulin sensitivity with the physical activity measures remained significant only for total physical activity in the Swedish women (Table 3, Model A2, Coefficient *a*). BMI was significantly associated only with breaks in sedentary time in the Iraqi women and with all MVPA and VPA measures in the Swedish women (Table 3, Model B). The associations of BMI with MVPA 1-min and 10-min and with the dichotomous measure of VPA reached significant difference between Iraqis and Swedes ($P_{interaction}$=0.04, all three physical activity measures).

β-cell function showed an overall significant association with VPA in the Iraqi men and with the dichotomous measure of VPA in the Swedish men, and with breaks in sedentary time in Iraqi women (Table 4, Model A1). None of the associations remained significant after BMI was introduced into the model (Table 4, Model A2, Coefficient a). No interactions with country of origin were found for the associations of β-cell function.

Discussion

Key findings were that the Iraqi men were less physically active than the Swedish men, while the Iraqi women showed similar physical activity levels as the Swedish women although with less time in VPA. BMI was strongly associated with insulin sensitivity and β-cell function and frequently associated with the physical activity measures. BMI modified the associations of the physical activity variables to such extent that the results suggest that more physical activity is associated mainly with increased insulin sensitivity and indirectly via BMI. However, direct associations with insulin sensitivity were found for VPA and total physical activity. Differences in the associations of the physical activity variables were discovered between Iraqi and Swedish women.

Our study adds to previous research demonstrating BMI/body fatness is a major predictor of insulin sensitivity and metabolic risk.[7-9] Weight reduction may therefore be an important target in lifestyle behavior interventions to reduce the risk for T2D in Iraqis as they showed higher BMI than the Swedes. The results indicated a difference in the association of insulin sensitivity with BMI between the Iraqis and the Swedes among the men, with borderline significance. It is possible that it requires a larger reduction in BMI in Iraqis to improve their insulin sensitivity. BMI was also an important predictor of β-cell function but to a lower degree than of insulin sensitivity. One explanation to this difference may lie in the β-cell compensation that occurs as a response to decreased insulin sensitivity.[5,6] While increased body fatness reduces insulin sensitivity, the degree of body fatness may not be related to the β-cell function which in obese and insulin resistant individuals can be remained or even increased for long periods.

Increasing physical activity may be an important target behavior to reduce body fatness. Less sedentary time, breaking sedentary time and more MVPA have been consistently associated with lower BMI or waist circumference.[10-12,16-20] The present study supports MVPA to be favorably associated with BMI only in Iraqi men and Swedish women, but presents the interesting finding of favorable associations with VPA in Iraqi men and Swedish women as well as in Swedish men. Hence, VPA seems to be an important for reducing BMI. However, BMI was not associated with MVPA or VPA in the Iraqi women which differed from the results seen in the Swedish women. BMI was only associated with breaks in sedentary time in the Iraqi women, indicating different response to physical activity in this group.

Previous studies have investigated associations of physical activity measures mostly with insulin sensitivity and the results have been inconsistent.[12-15,17] We found few associations of β-cell function with these physical activity measures. Sedentary time was not an important predictor of insulin sensitivity or β-cell function, and breaks in sedentary time was associated with insulin sensitivity and β-cell function only in Iraqi women. Sedentary time, but not breaks of sedentary time, has shown to be associated with insulin sensitivity and β-cell function in the general population,[12] but sedentary time was not associated with insulin sensitivity in individuals with risk for T2D.[14,15] We found insulin sensitivity to be associated with MVPA in the Iraqi men and the Swedish women only. As mention previously, Iraqi women seem to respond differently to physical activity as there was no association of insulin sensitivity with MVPA in this group, which differed from the response in the Swedish women. Insulin sensitivity has shown to be associated with MVPA in the general population,[13,17] but inconsistent results have been found in individuals with risk for T2D.[14,15] In the later, higher insulin sensitivity was associated with more MVPA independent of waist circumference only in one of the studies.[14] Hence, it seems that the responsiveness of insulin sensitivity and β-cell function as well as BMI to sedentary time, breaks in sedentary time and MVPA may vary depending on the population investigated (characteristics, conditions ethnicity etc) as has been suggested previously.[4,25]

Our results indicate that the influence of physical activity on insulin sensitivity and β-cell function goes to a large extent via BMI. Previous studies demonstrated that physical activity energy expenditure assessed from heart rate monitoring had a small direct association with insulin sensitivity/metabolic function compared to body fatness.[7,8] A novel contribution of the present study was to show that insulin sensitivity was associated both directly and indirectly via BMI with VPA in the Iraqi and Swedish men. Also, associations of β-cell function with VPA were found in the men that seemed to go to a certain extent via BMI. In the women, associations were found only for the Swedes and the influence of VPA on insulin sensitivity seemed to go to a large extent via BMI. Previous exercise intervention studies give some support to the importance of VPA for improving insulin sensitivity, although the results have been inconsistent.[21-24] However, increasing VPA may be a greater challenge than increasing moderate physical activity or reducing sedentary time in overweight and obese individuals at risk for T2D. As the Iraqis showed higher BMI and lower insulin sensitivity and β-cell function than the Swedes, it is important to target the type of physical activity behavior that has most influence on reducing the risk of T2D in this group. In Iraqi men, less sedentary time and more MVPA, VPA and total physical seem all to have influence on insulin sensitivity and VPA also on β-cell function, while breaking sedentary was the only physical activity behavior of importance for insulin sensitivity and β-cell function in the Iraqi women. These results need to be followed-up in longitudinal studies.

Our study has both strengths and limitations. The strengths include the use of accelerometers for objective physical activity measures, as well as the use of OGTT to assess insulin sensitivity and β-cell function. Furthermore, our findings are based on a large sample of immigrant Iraqis and native Swedes. The cross-sectional design pose a limitation to draw conclusions concerning the effect of physical activity on insulin sensitivity, β-cell function and BMI, which requires a longitudinal study design. In addition, the large attrition proportion (larger in Swedes than in Iraqis) may have resulted in non-response bias, as non-participants may have differed from participants in terms of certain characteristics (e.g. individuals who consider themselves as healthy with no interest in participation, or individuals with the most unfavorable insulin sensitivity, β-cell function, BMI and physical activity behaviors with low motivation/ability to participate). However, there were only minor changes in gender distribution across the attrition steps in both groups. Larger samples may have been needed to reach significance for some of the associations, where the beta-coefficients were similar to other significant associations. The fact that the Iraqis and Swedes differed in terms of physical activity, BMI, insulin sensitivity and β-cell function may have contributed to some of the variation in the outcomes of the analyses.

Conclusions

Physical activity and performed at vigorous intensity may be important for the insulin sensitivity and to a less extent for the β-cell function in Iraqi immigrants and native Swedes. Their influence may be exerted directly and indirectly via BMI. Iraqi women may show different responses to physical activity compared to Swedish women. Intervention programs targeting physical activity behaviors that reduce body fatness and the risk of T2D may be needed in Iraqis, as they show higher BMI, lower insulin sensitivity and β-cell function and less physical activity to some extent than Swedes.

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Figure capture

Stepwise attrition and response rate of Iraqis and Swedes.

Table 1. Comparisons of participant characteristics by gender.

N=962		Men			Women		
		Iraq	Sweden	*p-value*	Iraq	Sweden	*p-value*
Variable		N=287 (58%)	N=254 (54%)		N=206 (42%)	N=215 (46%)	
Age (years), mean (sd)		47 (10)	49 (11)	*0.02*	44 (9)	49 (11)	*<0.001*
Secondary school or higher, n (%)	yes	227 (79)	211 (83)	*0.27*	134 (65)	179 (83)	*<0.001*
	no	60 (21)	43 (17)		72 (35)	36 (17)	
Financial constraints, n (%)	yes	159 (55)	31 (12)	*<0.001*	90 (44)	30 (14)	*<0.001*
	no	128 (45)	223 (88)		116 (56)	185 (86)	
Body mass index ($kg·m^{-2}$)	mean (sd)	28.8 (4.1)	27.0 (3.8)	*<0.001*	29.5 (5.0)	27.0 (5.2)	*<0.001*
Insulin sensitivity index (ISI)	median (IR)	70 (61)	90 (86)	*<0.001*	92 (72)	113 (83)	*<0.001*
Oral disposal index (DIo)	median (IR)	11483 (15961)	13932 (15516)	*0.04*	14031 (18146)	16536 (16709)	*0.25*
Accelerometer wear time ($min·d^{-1}$)	mean (sd)	864 (112)	898 (96)	*<0.001*	854 (95)	878 (80)	*0.005*

Group differences (within gender) were tested by independent samples t-test (parametric) or Mann-Whitney U Test (non-parametric) for continuous variables and chi-square test for categorical variables.

Higher values for the insulin sensitivity index and the oral disposal index indicates higher insulin sensitivity and better β-cell function, respectively.

Table 2. Comparison of physical activity, body mass index, insulin sensitivity and β-cell function by gender.

N=962	**Men**			**Women**		
	Iraq	Sweden	*p-value*	Iraq	Sweden	*p-value*
	N=287	N=254		N=206	N=215	
Variable	Mean (95% CI)	Mean (95% CI)		Mean (95% CI)	Mean (95% CI)	
Sedentary time, $min \cdot d^{-1}$	576 (566; 586)	565 (554; 576)	*0.17*	521 (509; 532)	542 (531; 553)	*0.01*
Breaks in sedentary time, $counts \cdot d^{-1}$	89 (87; 91)	86 (84; 88)	*0.01*	95 (93; 97)	88 (86; 90)	*<0.001*
MVPA 1-min, $min \cdot d^{-1}$	33 (30; 35)	38 (35; 41)	*0.01*	30 (28; 33)	30 (27; 33)	*0.92*
MVPA 10-min, $min \cdot d^{-1}$	11 (8; 13)	15 (13; 17)	*0.004*	12 (9; 14)	13 (11; 15)	*0.43*
MVPA 10-min ≥30 $min \cdot d^{-1}$, Yes, n (%)	27 (9.4)	46 (18.1)	*0.03*	25 (12.1)	33 (15.3)	*0.83*
No, n (%)	260 (90.6)	208 (81.9)		181 (87.9)	182 (84.7)	
VPA, $min \cdot d^{-1}$	1.2 (0.6; 1.7)	2.5 (1.9; 3.1)	*0.003*	0.7 (0.1; 1.3)	2.0 (1.4; 2.5)	*0.004*
VPA ≥1 $min \cdot d^{-1}$, Yes, n (%)	124 (43.5)	129 (50.6)	*0.08*	72 (35.0)	85 (39.5)	*0.36*
No, n (%)	161 (56.5)	125 (49.4)		134 (65.0)	130 (60.5)	
Total physical activity, $10{,}000 \cdot counts \cdot d^{-1}$	25 (24; 27)	30 (28; 31)	*<0.001*	26 (25; 28)	27 (25; 28)	*0.69*

Values are means (95% CI), except for MVPA 10-min ≥30 min/d and VPA ≥1 $min \cdot d^{-1}$ where proportions are presented. Means are adjusted for age, education level and financial situation; the means for the physical activity variables are also adjusted for wear time. One-way ANOVA was used to test group differences based on adjusted means. Logistic regression was used to compare dichotomous variables, adjusted for age, educational level, financial situation and wear time.

MVPA 1-min, all accumulated moderate and vigorous physical activity; **MVPA 10-min**, moderate and vigorous physical activity in bouts of at least 10 minutes duration; **MVPA 10-min ≥30 $min \cdot d^{-1}$**, reaching recommended physical activity of 30 $min \cdot d^{-1}$ of MVPA in bouts of at least 10 min duration; **VPA 1-min**, all accumulated vigorous physical activity; **VPA ≥1 min·d^{-1}**, having VPA or not.

Table 3. Overall associations of *insulin sensitivity* with physical activity variables (Model A1), independent associations of *insulin sensitivity* with physical activity variables (Coeff. *a*, Model A2) and BMI (Coeff. *b*, Model A2), and associations of BMI with physical activity variables (Model B).

N=962		**Standardized regression coefficient beta** ***p-value***							
		Response: *insulin sensitivity*						**Response: *BMI***	
		Men			**Women**			**Men**	**Women**
		Model A1	Model A2		Model A	Model A2		Model B	Model B
Physical activity variable	**Country of origin**	Coeff. *a*	Coeff. *a*	Coeff. *b*	Coeff. *a*	Coeff. *a*	Coeff. *b*	Coeff. *c*	Coeff. *c*
Sedentary time, $min \cdot d^{-1}$	Iraq	**-0.18**	-0.14	**-0.46**	0.05	0.02	***-0.45***	0.07	-0.07
		0.04	*0.06*	***<0.001***	*0.60*	*0.82*	***<0.001***	*0.40*	*0.46*
	Sweden	-0.14	-0.09	**-0.57**	-0.12	-0.13	**-0.50**	0.08	-0.02
		0.09	*0.16*	***<0.001***	*0.14*	*0.07*	***<0.001***	*0.34*	*0.82*
Breaks in sedentary time, $counts \cdot d^{-1}$	Iraq	0.003	-0.03	**-0.47**	**0.21**	0.11	**-0.43**	-0.07	**-0.23**
		0.97	*0.62*	***<0.001***	***0.006***	*0.12*	***<0.001***	*0.31*	***0.001***
	Sweden	0.06	0.08	**-0.58**	0.11	0.07	**-0.49**	0.03	-0.10
		0.43	*0.19*	***<0.001***	*0.16*	*0.34*	**<0.001**	*0.63*	*0.23*
MVPA 1-min, $min \cdot d^{-1}$	Iraq	**0.17**	0.11	**-0.46**	-0.02[a]	-0.004	**-0.45**	**-0.13**	-0.04[c]
		0.005	*0.05*	***<0.001***	*0.77*	*0.95*	***<0.001***	***0.03***	*0.59*
	Sweden	0.09	0.02	**-0.57**	***0.20***	0.11	**-0.48**	-0.12	**-0.18**
		0.16	*0.70*	***<0.001***	***0.004***	*0.07*	***<0.001***	*0.06*	***0.008***
MVPA 10-min, $min \cdot d^{-1}$	Iraq	0.09	0.05	**-0.46**	0.06	0.06	**-0.45**	-0.09	-0.006[d]
		0.12	0.32	***<0.001***	*0.37*	*0.33*	***<0.001***	*0.15*	*0.93*
	Sweden	0.05	0.002	**-0.58**	**0.20**	0.10	**-0.48**	-0.09	**-0.20**
		0.39	*0.97*	***<0.001***	***0.003***	*0.08*	***<0.001***	*0.16*	***0.003***

MVPA 10-min ≥30 min·d^{-1}, yes vs. no	Iraq	0.07	0.05	**-0.47**	0.05	0.04	**-0.45**	-0.04	-0.03
		0.26	0.34	**<0.001**	*0.43*	*0.51*	***<0.001***	*0.56*	*0.63*
	Sweden	0.10	0.03	**-0.57**	**0.14**	0.06	**-0.49**	-0.12	**-0.16**
		0.12	*0.56*	***<0.001***	***0.04***	*0.28*	***<0.001***	*0.06*	***0.02***
VPA, min·d^{-1}	Iraq	**0.16**	**0.12**	**-0.46**	0.01	0.04	**-0.45**	-0.08	0.06
		0.007	***0.02***	***<0.001***	*0.86*	*0.55*	***<0.001***	*0.21*	*0.39*
	Sweden	**0.14**	0.04	**-0.57**	**0.17**	0.09	**-0.48**	**-0.17**	**-0.18**
		0.03	*0.43*	***<0.001***	***0.01***	*0.16*	***<0.001***	***0.007***	***0.01***
VPA ≥1 min·d^{-1} , yes vs. no	Iraq	**0.22**	**0.15**	**-0.44**	0.05	0.06	**-0.45**	**-0.16**	0.02[e]
		<0.001	***0.006***	***<0.001***	*0.44*	*0.31*	***<0.001***	***0.009***	*0.74*
	Sweden	**0.31**	**0.16**	**-0.53**	**0.20**	0.08	**-0.48**	**-0.27**	**-0.24**
		<0.001	***0.003***	***<0.001***	***0.005***	*0.18*	***<0.001***	***<0.001***	***0.001***
Total physical activity, 10,000·counts·d^{-1}	Iraq	**0.20**	**0.14**	**-0.45**	-0.06[b]	-0.01	**-0.45**	**-0.12**	-0.10
		0.001	***0.008***	***<0.001***	*0.42*	*0.86*	***<0.001***	***0.05***	*0.13*
	Sweden	**0.13**	0.06	**-0.57**	**0.20**	**0.15**	**-0.48**	**-0.13**	-0.12
		0.03	0.27	***<0.001***	***0.005***	***0.02***	***<0.001***	***0.03***	*0.11*

Model A1 includes physical activity variable as explanatory variable; Model A2 adds BMI as explanatory variable, where the coefficient *a* is the standardized regression coefficient for the associations of the physical activity variables, and the coefficient *b* is the standardized regression coefficient for the associations of BMI; in Model B, the physical activity variable is the explanatory variable and BMI the response variable; all models adjust for age, education level, financial situation and wear time.

Bold values indicate significant associations (p<0.05). Superscript letter indicate significant interaction (p<0.05) with country of origin, i.e. significant different associations between Iraqis and Swedes (within gender): [a]p=0.04, [b]p=0.02, [c]p=0.04, [d]p=0.04, [e]p=0.04.

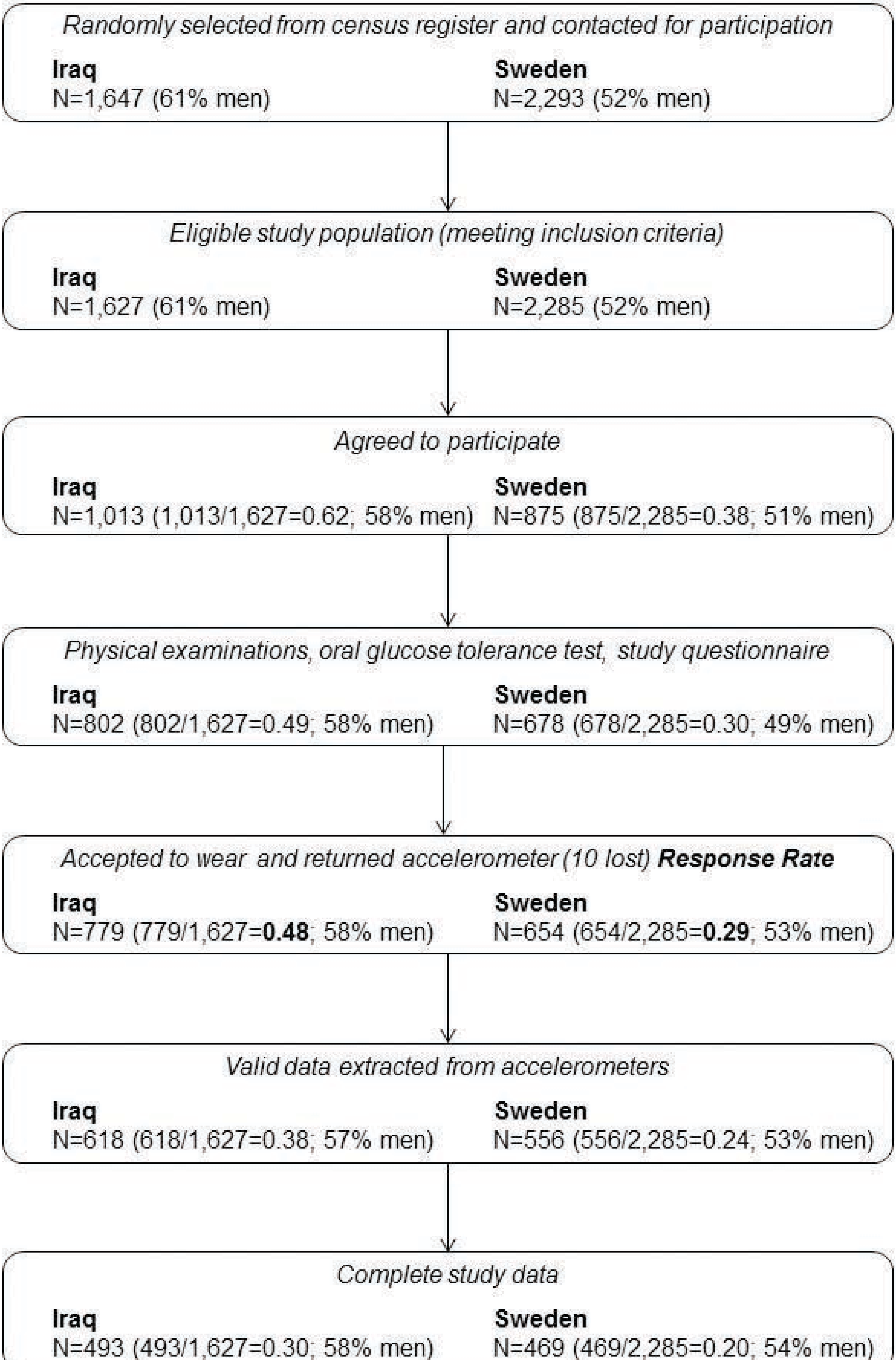
Table 4. Overall associations of *β-cell function* with physical activity variables (Model A1), and independent associations of β-cell function with physical activity variables (Coeff. *a*, Model A2) and BMI (Coeff. *b*, Model A2).

N=962		**Standardized regression coefficient beta** ***p-value***					
		Response: *β-cell function*					
		Men			**Women**		
		Model A1	Model A2		Model A1	Model A2	
Physical activity variable	**Country of origin**	Coeff. *a*	Coeff. *a*	Coeff. *b*	Coeff. *a*	Coeff. *a*	Coeff. *b*
Sedentary time, $min \cdot d^{-1}$	Iraq	0.006	0.02	**-0.23**	-0.17	-0.19	**-0.24**
		0.94	*0.78*	***<0.001***	*0.08*	*0.05*	***0.001***
	Sweden	0.05	0.06	**-0.17**	-0.04	-0.05	**-0.32**
		0.53	0.42	***0.006***	*0.58*	*0.51*	***<0.001***
Breaks in sedentary time, $counts \cdot d^{-1}$	Iraq	0.03	0.01	**-0.23**	**0.15**	0.11	**-0.21**
		0.70	*0.88*	***<0.001***	***0.04***	*0.17*	***0.006***
	Sweden	-0.02	-0.01	**-0.17**	0.07	0.04	**-0.31**
		0.77	0.83	***0.006***	*0.38*	*0.60*	***<0.001***
MVPA 1-min, $min \cdot d^{-1}$	Iraq	0.06	0.03	**-0.23**	0.10	0.10	**-0.23**
		0.28	*0.57*	***<0.001***	*0.17*	*0.12*	***0.001***
	Sweden	0.04	0.02	**0.16**	0.10	0.04	**-0.31**
		0.53	*0.80*	***0.008***	*0.16*	*0.55*	***<0.001***
MVPA 10-min, $min \cdot d^{-1}$	Iraq	-0.001	-0.02	**-0.23**	0.12	0.12	**-0.23**
		0.99	0.72	***<0.001***	*0.08*	*0.08*	***0.002***
	Sweden	0.08	0.06	**-0.16**	0.06	-0.001	**-0.32**
		0.20	*0.29*	**0.009**	*0.35*	*0.99*	***<0.001***
MVPA 10-min ≥30 $min \cdot d^{-1}$, yes vs. no	Iraq	0.001	-0.007	**-0.23**	0.10	0.09	**-0.22**
		0.98	*0.90*	***<0.001***	*0.15*	0.17	***0.002***

	Sweden	0.08	0.06	**-0.16**	0.05	-0.003	**-0.32**
		0.21	*0.34*	***0.01***	*0.48*	*0.96*	***<0.001***
VPA 1-min, min·d^{-1}	Iraq	**0.12**	0.11	**-0.23**	0.05	0.06	**-0.23**
		0.03	*0.06*	***<0.001***	*0.47*	0.35	***0.001***
	Sweden	0.04	0.01	**-0.16**	0.08	0.03	**-0.31**
		0.51	*0.84*	***0.01***	*0.23*	0.66	***<0.001***
VPA ≥1 min·d^{-1}, yes vs. no	Iraq	0.10	0.07	**-0.22**	0.06	0.06	**-0.23**
		0.08	0.25	***<0.001***	*0.39*	*0.34*	***0.002***
	Sweden	**0.13**	0.09	**-0.14**	0.11	0.04	**-0.31**
		0.04	*0.16*	***0.03***	*0.11*	*0.59*	***<0.001***
Total physical activity, 10,000·counts·d^{-1}	Iraq	0.06	0.03	**-0.23**	0.10	0.12	**-0.24**
		0.31	0.57	***<0.001***	*0.15*	*0.07*	***0.001***
	Sweden	-0.001	-0.02	**-0.17**	0.07	0.04	**-0.31**
		0.98	*0.69*	***0.006***	0.29	*0.57*	***<0.001***

Model A1 includes physical activity variable as explanatory variable; Model A2 adds BMI as explanatory variable, where the coefficient *a* is the standardized regression coefficient for the associations of the physical activity variables, and the coefficient *b* is the standardized regression coefficient for the associations of BMI; all models adjust for age, education level, financial situation and wear time.

Bold values indicate significant associations (p<0.05).


Randomly selected from census register and contacted for participation
Iraq
N=1,647 (61% men)
Sweden
N=2,293 (52% men)
Eligible study population (meeting inclusion criteria)
Iraq
N=1,627 (61% men)
Sweden
N=2,285 (52% men)
Agreed to participate
Iraq
N=1,013 (1,013/1,627=0.62; 58% men)
Sweden
N=875 (875/2,285=0.38; 51% men)
Physical examinations, oral glucose tolerance test, study questionnaire
Iraq
N=802 (802/1,627=0.49; 58% men)
Sweden
N=678 (678/2,285=0.30; 49% men)
Accepted to wear and returned accelerometer (10 lost) Response Rate
Iraq
N=779 (779/1,627=0.48; 58% men)
Sweden
N=654 (654/2,285=0.29; 53% men)
Valid data extracted from accelerometers
Iraq
N=618 (618/1,627=0.38; 57% men)
Sweden
N=556 (556/2,285=0.24; 53% men)
Complete study data
Iraq
N=493 (493/1,627=0.30; 58% men)
Sweden
N=469 (469/2,285=0.20; 54% men)