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Leisure time and occupational physical activity in relation to obesity and insulin resistance: a population-based study from the Skaraborg Project in Sweden

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ABSTRACT

The objective was to study obesity and insulin resistance in relation to leisure time physical activity (LTPA) and occupational physical activity (OPA) in a Swedish population, with particular focus on sex differences. Using a cross-sectional design, waist circumference, body mass index (BMI), glucose/insulin metabolism, blood pressure, heart rate, self-reported education, smoking, alcohol consumption, LTPA, and OPA were assessed in 1745 men and women (30-74 years) randomly chosen from 2 municipalities in southwestern Sweden. In both men and women, LTPA was inversely associated with BMI, waist circumference, and the homeostasis model assessment of insulin resistance (HOMA-IR), respectively. These associations remained statistically significant after adjustments for age, OPA, education, alcohol consumption, smoking, and study area, and also for BMI in the analyses concerning waist circumference and HOMA-IR. A statistically significant interaction term ($P = .030$), adjusted for multiple confounders, revealed a stronger association between LTPA and HOMA-IR in women compared with men. Occupational physical activity was positively associated with BMI ($P < .001$), waist circumference ($P < .001$), and HOMA-IR ($P = .001$), however, only in women. These associations remained when adjusting for multiple confounders. The sex differences were confirmed by statistically significant interaction terms between sex and OPA in association with BMI, waist circumference, and HOMA-IR, respectively. The observed sex differences regarding the strength of the association between LTPA and insulin resistance, and the positive association between OPA and obesity and insulin resistance found solely in women, warrant further investigation. Although exploration of the metabolic effects of OPA appears to be needed, thorough measurement of potential confounders is also vital to understand contextual effects.

Author contributions: Charlotte A Larsson prepared the data, performed most of the statistical analyses, drafted the manuscript, and took part in conceiving the study. Lotte Krøll and Louise Bennet helped in conceiving the study and drafting the manuscript. Bo Gullberg offered statistical expertise and performed some of the statistical analyses. Lennart Råstam conceived the study and acquired the data. Ulf Lindblad conceived and coordinated the study, and acquired the data. All authors took part in the design of the study, the interpretation of data, the revision of the manuscript, and read and approved the final manuscript.

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1. Introduction

Obesity is a growing public health hazard that has already reached epidemic proportions in Western society [1]. Because obesity greatly increases the risk for serious disorders, such as type 2 diabetes mellitus and cardiovascular disease [1,2], the negative implications for public health are evident. Obesity is associated with several risk factors for type 2 diabetes mellitus and cardiovascular disease, such as insulin resistance [1,2], hypertension [1,3], and dyslipidemia [1,3]. These risk factors (including obesity) tend to cluster and are often collectively referred to as the *metabolic syndrome*, which has been linked to coronary heart disease [4]. When clusters of risk factors for coronary heart disease have been evaluated for principal components, abdominal [5,6]/general obesity [6,7] and insulin resistance [6,7] have often been found to be of major importance.

Physical inactivity is a major risk factor for obesity [8] and insulin resistance [9], and numerous studies have confirmed an inverse association between leisure time physical activity (LTPA) and obesity [10,11]. However, as most adults spend a large proportion of their daily life in a work environment, it is also important to consider the physical activity that is work related, which is often referred to as *occupational physical activity* (OPA). In comparison to studies concerning LTPA and obesity, corresponding studies regarding OPA are generally less consistent in their conclusions, with some showing no associations with obesity in either sex [10,12-16] and others showing inverse associations in both sexes [17-19]. In addition, a few previous studies have found a positive association between OPA and obesity in women only [20-22]. Yet another study has found a positive association in women and an inverse association in men [11]. Furthermore, whereas LTPA is well known to have a protective effect on insulin resistance [23], few studies have studied the association between OPA and insulin resistance [24,25]. Also, to our knowledge, no previous investigation has looked at the association between OPA and insulin resistance in a large unselected sample of both men and women using a robust marker for insulin resistance such as the homeostasis model assessment of insulin resistance (HOMA-IR). The primary aim of the present study was thus to study OPA and LTPA in relation to obesity and insulin resistance in a Swedish adult population, with particular focus on potential sex differences.

2. Methods

2.1. Subjects

The Skaraborg Project was initially launched in 1977 in the former county of Skaraborg, southwestern Sweden, aiming to improve blood pressure control in the population and to reduce the risk of cardiovascular disease. In all primary health care settings in the program area, special outpatient clinics for hypertension were established, and guidelines for detection, workup, treatment, and control of men and women with hypertension were drawn up. Over the years, the project evolved to also include diabetic patients, and numerous studies on these patients, as well as on the general population in the area, have been performed.

Vara is a small rural municipality with approximately 16 000 inhabitants. The nearest larger town is Skövde, with approximately 50 000 inhabitants and a university and a hospital. Between 2001 and 2005, a computer-generated random sample was obtained from the population census register regarding Vara and Skövde and surveyed as part of a new population study within the Skaraborg Project [26]. Participants were selected and stratified by sex and 5-year age groups from all individuals (no exclusion criteria) between 30 and 74 years of age, with intentional oversampling (3-fold) in the age group of 30 to 50 years as compared with those older than 50 years. There were 1811 subjects from the Vara population (81% participation rate) and 1005 subjects from the Skövde population (70% participation rate) who fulfilled all requirements for participation. Those requirements included visiting the study nurse, completion of the questionnaires, and having venous blood samples drawn. Pregnant women (n = 9) were excluded, as well as those participants who had worked less than 20 h/wk or less than 10 months during the past year (n = 994) and those without full information on LTPA, OPA, body weight, and waist circumference (n = 68). This left 1745 subjects for further analyses.

2.2. Procedures

Study participants were assessed in the morning after an overnight fast (10 hours) by specially educated and trained nurses. Body weight and height were measured while participants were wearing light clothing and no shoes. Blood pressure was measured, blood samples were drawn, and an oral glucose tolerance test was performed with an intake of 75-g standard glucose load [27]. A physical examination was performed, and participants filled in questionnaires regarding smoking habits, alcohol consumption, civil status, educational level, psychosocial stress, OPA, and LTPA. Detailed information on medical history and ongoing medication was also collected.

2.3. Measures

Body mass index (BMI) was calculated by the body weight in kilograms divided by the square of the height in meters, and *obesity* was defined as BMI of at least 30 kg/m^2. Waist circumference was measured between the lowest rib margin and iliac crest, and a waist circumference greater than 88 cm in women and greater than 102 cm in men was defined as *abdominal obesity*. Fasting plasma insulin was analyzed by enzyme immunoassay [28]. Fasting blood glucose was analyzed by the laboratory at the local hospital (Kärnsjukhuset, Skövde), and serum insulin was analyzed at the Wallenberg Laboratory (Malmö University Hospital). The HOMA-IR was calculated by the following formula: fasting insulin × fasting blood glucose/22.5 [29].

Leisure time physical activity was categorized on the basis of 4 alternative answers to the question “How much physical activity do you engage in during your leisure time?” The question referred to the past year, and the alternatives were as follows:

1. Sedentary leisure time: reading, TV, stamp collecting, or other sedentary activity.
2. Light LTPA: walking, cycling, or other physical activity under at least 4 hours per week.

Table 1 – Characteristics in men and women in the Vara and Skövde cohorts, the Skaraborg Project 2001-2005, Sweden

Characteristics	Women		Men		P value
	Mean [a]	SD/CV[a] (Q1-Q3)	Mean [a]	SD/CV[a] (Q1-Q3)	
	n = 774		n = 971		
Age, y	44.5	8.1	43.8	8.1	.103
Waist circumference, cm	84	11	94	11	<.001
BMI, kg/m^2	26.1	4.1	26.7	4.1	.004
Fasting plasma glucose, mmol/L	5.2	0.8	5.4	0.8	<.001
2-h plasma glucose, mmol/L	5.4	1.8	5.2	1.8	.029
Fasting insulin, mmol/L	4.7	64	5.4	61	<.001
HOMA-IR	1.09	67	1.29	69	<.001
Systolic blood pressure, mm Hg	115	13	121	13	<.001
Diastolic blood pressure, mm Hg	68	9	71	9	<.001
Resting heart rate, beat/min	64	8.2	62	8.2	<.001
Alcohol consumption, g/wk [b]	27	(7-37)	63	(17-84)	<.001 [c]
	n	%	n	%	P value
LTPA, low [d]	529	68	567	58	<.001
Category 1 (sedentary LTPA)	36	5	73	8	
Category 2 (low LTPA)	493	64	494	51	
Category 3 (moderate LTPA)	227	29	357	37	
Category 4 (high LTPA)	18	2	47	5	
OPA, high [e]	399	52	575	59	.002
Category 1 (sedentary OPA)	249	32	285	29	
Category 2 (low OPA)	126	16	111	11	
Category 3 (moderate OPA)	262	34	283	29	
Category 4 (high OPA)	128	17	223	23	
Category 5 (very high OPA)	9	1	69	7	
Daily smoking	164	21	131	14	<.001
Primary school only	104	14	211	22	<.001

Age-adjusted differences between men and women were analyzed by general linear model with regard to means and by logistic regression analysis with regard to proportions.
[a] For alcohol consumption, data are means and quartile 1 to quartile 3 (Q1-Q3); for insulin and HOMA-IR, data are geometric means (anti-log) and CV (expressed as percentage); and for all other variables, data are means and SD.
[b] Ten grams of alcohol is equivalent to approximately 1 glass of wine or 1 small beer.
[c] The *P* value accounted for the generally higher physiological tolerance for alcohol in men as compared with women.
[d] Low = categories 1 and 2.
[e] High = categories 3 to 5.

3. Moderate LTPA: running, swimming, tennis, aerobic, heavier gardening, or similar physical activity during at least 2 hours a week.
4. Heavy training or competitive sport: heavy training or competition in running, skiing, swimming, football, etc, which is performed regularly and several times a week.

Occupational physical activity was measured by the question “Is your daily work physically light or heavy?” The 5 alternative answers were as follows:

1. Very light: sitting work (eg, driving a vehicle, reading, office work, teaching).
2. Light: standing with little muscle activity (eg, feeding, distribution of medication in a health care setting, washing up, precision mechanical work).
3. Moderate intensity: muscular activity with moderate intensity (eg, walking around, lifting/carrying less than 5 kg, washing, making beds, cleaning, carpenter's work, child care).
4. Heavy: muscular work with quite high intensity and increased breathing (eg, maintenance, heavier service work, handling patients within medical care, sweeping streets, heavier gardening, freighting/unloading goods).
5. Very heavy: muscular activity with high intensity and highly increased breathing (eg, casting concrete, timbering, shoveling soil/sand, lifting/carrying more than 25 kg).

Alcohol consumption was assessed by questions concerning the number of days during the past 30 days that the subjects had consumed beer, wine, and strong liquor, respectively. Each of these questions was followed by questions concerning how many cans, glasses, and/or bottles were normally consumed on such days. The total number of grams of alcohol consumed per week was then calculated by multiplying the number of days of alcohol consumption by the number of grams of alcohol contained in the consumed alcoholic beverage.

Current smoking was defined as daily smoking (yes/no), and educational level was assessed by a question with 10 alternatives ranging from primary school to PhD degree. *Total physical activity* refers to the combined measure of LTPA and OPA.

2.4. Statistical analyses

SPSS (Chicago, IL) Base System for Macintosh 17.0 was used for data analyses, and all analyses were performed separately by sex. Sex differences were examined by general linear model for continuous variables and by logistic regression analyses for proportions. Differences between categories of LTPA and OPA with regard to BMI, waist circumference, HOMA-IR, and heart rate were examined by general linear model, and tests for trends between categories were performed. Associations with regard to OPA and LTPA were also examined using logistic regression analyses with BMI, waist circumference, and HOMA-IR, respectively, as dependent variables and OPA and LTPA, respectively, as independent variables. For these analyses, BMI was dichotomized as less than 30/greater than or equal to 30, waist circumference was dichotomized as less than or equal to 88/greater than 88 cm in women and less than or equal to 102/greater than 102 cm in men, and HOMA-IR was dichotomized at the 90th percentile. Because of low numbers, the fifth and highest category of OPA was merged with the fourth category, leaving 4 OPA categories (sedentary, low, moderate, high). The first of the 4 categories of OPA and LTPA (sedentary) was used as the reference in all analyses, except for the logistic regression analyses of LTPA. For these analyses, the fourth category was merged with the third category because of low numbers, and this last category was then used as the reference category. Logistic regression analyses for the association between OPA and BMI, waist circumference, and HOMA-IR, respectively, were also performed stratified by high (categories 3 and 4) and low (categories 1 and 2) LTPA. Sex differences regarding OPA/LTPA were examined by 2-way interaction terms with BMI, waist circumference, and HOMA-IR, respectively, as dependent variables. For these analyses BMI, waist circumference, and HOMA-IR were dichotomized as described above for the logistic regression analyses. In the analyses between HOMA-IR and OPA/LTPA, all subjects with diabetes were excluded (n = 50). In all analyses with fasting insulin and HOMA-IR, log transformation (natural logarithm) was used to induce normality, and coefficient of variation (CV) was used to describe dispersion. Confounding was controlled for by multivariate analyses and stratification. All tests were 2-sided, and statistical significance was accepted at $P < .05$.

Table 2 – Comparisons of means of metabolic risk factors through different levels of LTPA in the Vara and Skövde cohorts, the Skaraborg Project 2001-2005, Sweden

Women	Categories of LTPA								
	Sedentary		Low		Moderate		High		
	n = 36		n = 493		n = 227		n = 18		
	M	SD (CV)	M	SD (CV)	M	SD (CV)	M	SD (CV)	P for trend
Model 1 [a]									
BMI	28.2	4.7	26.6 ‡	4.7	24.9 *	4.7	24.4 ‡	4.7	<.001
WC, cm	89.8	12.2	85.2 ‡	12.2	80.9 *	12.2	80.2 ‡	12.2	<.001
Heart rate	67	7.9	65	7.9	63 ‡	7.9	60 ‡	7.9	<.001
HOMA-IR	1.42	(61)	1.15 ‡	(62)	0.89 *	(62)	0.77 *	(61)	<.001
Model 2 [b]									
BMI	28.0	4.7	26.5	4.7	25.0 †	4.7	24.0 †	4.7	<.001
WC, cm	89.1	12.1	85.1	12.0	81.2 *	12.1	78.5 †	12.1	<.001
Heart rate	66	8.0	65	7.9	63 ‡	8.0	60 ‡	7.9	<.001
HOMA-IR	1.41	(61)	1.15 ‡	(61)	0.90 *	(60)	0.73 *	(60)	<.001
Men	n = 73		n = 494		n = 357		n = 47		
Model 1 [a]									
BMI	28.1	3.4	26.9 †	3.4	26.2 *	3.4	25.2 *	3.4	<.001
WC, cm	98.1	9.2	94.9 ‡	9.3	92.3 *	9.2	88.6 *	9.4	<.001
Heart rate	64	8.3	63	8.3	61 †	8.3	58 *	8.4	<.001
HOMA-IR	1.54	(68)	1.34	(66)	1.17 *	(66)	0.83 *	(66)	<.001
Model 2 [b]									
BMI	28.0	3.3	26.8 †	3.3	26.3 *	3.3	25.3 *	3.3	<.001
WC, cm	97.8	9.1	94.6 ‡	9.1	92.4 *	9.1	88.8 *	9.2	<.001
Heart rate	64	8.2	63	8.2	61 ‡	8.2	59 *	8.3	<.001
HOMA-IR	1.53	(65)	1.32	(66)	1.18 †	(65)	0.82 *	(66)	<.001

Means for HOMA-IR are geometric (anti-log) and based on subjects without diabetes. Differences in means between levels of LTPA were examined by general linear model. M indicates mean; SD, standard deviation; CV, coefficient of variation (expressed as per cent); BMI, body mass index; WC, waist circumference.

[a] Model 1 = adjusted for age.

[b] Model 2 = adjusted for age, OPA, education, alcohol consumption, smoking, and study area.

* $P < .001$, with the sedentary category used as reference.

† $P < .005$, with the sedentary category used as reference.

‡ $P < .050$, with the sedentary category used as reference.

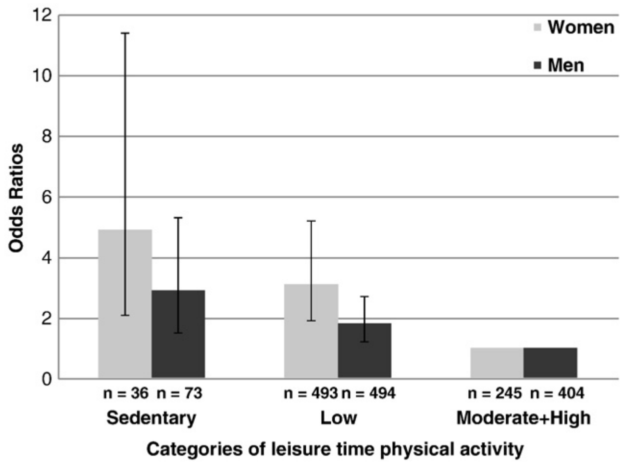

Fig. 1 – Age-adjusted odds ratios and confidence intervals of obesity (BMI ≥ 30 vs BMI < 30) in association with LTPA in the Vara and Skövde cohorts, the Skaraborg Project 2001-2005, Sweden.

2.5. *Statement of ethics*

We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research. All participants gave informed signed consent before being enrolled for the study, and the Ethical Committee of Gothenburg University, Sweden, approved the study.

3. Results

Compared with women, men were slightly but significantly more often obese and had significantly higher fasting insulin levels (Table 1). Men also had higher blood pressure than women, and they consumed more alcohol, reported higher levels of OPA, and had more often only primary school education (Table 1). Women were more often smokers and reported lower levels of LTPA (Table 1). Leisure time physical activity and OPA were significantly, but weakly and inversely, correlated in women ($r = -0.075$, $P = .036$) but not at all in men ($r = -0.024$, $P = .451$). When adjusting for multiple confounding factors (age, alcohol consumption, smoking, education, study area, and BMI), the correlation coefficient in women between LTPA and OPA became even weaker ($r = -0.027$) and was no longer statistically significant ($P = .462$).

3.1. *Leisure time physical activity*

As shown in Table 2, LTPA was inversely associated with BMI, waist circumference, and HOMA-IR in both men and women after adjusting for age (model 1), as well as for age, OPA, education, alcohol consumption, smoking, and study area (model 2). The significant associations with regard to waist circumference and HOMA-IR also remained after BMI was entered into the model (model 3, data not shown). Moreover, the age-adjusted odds ratio for general obesity was also significantly increased in both men and women in the 2 lowest categories of LTPA, respectively, compared with the 2 highest combined (Fig. 1). This pattern remained statistically significant when adjusting for model 2 (data not shown). Consistent associations were also seen for waist circumference and HOMA-IR (data not shown). Furthermore, cross-product interaction analyses between LTPA and sex in association with HOMA-IR revealed protective effects of being physically active in women in all models (model 3: $P = .030$). This association was not seen with regard to BMI or waist circumference.

Leisure time physical activity was also significantly associated with low resting heart rate in both men and women, and this association remained in both model 2 (Table 2) and model 3 (data not shown).

3.2. *Occupational physical activity*

Occupational physical activity in women was positively associated with both general and abdominal obesity, as well as with HOMA-IR, when adjusting for models 1 and 2 (Table 3). However, when BMI was also entered into the model (model 3) in the analysis of waist circumference and HOMA-IR, the association disappeared (data not shown). Furthermore, a logistic regression model revealed a statistically significantly higher odds ratio of general obesity in women exposed to the highest level of OPA as compared with the lowest (Fig. 2). This pattern remained in model 2 and was generally robust when stratifying for high and low LTPA (data not shown). The corresponding analyses for waist circumference and HOMA-IR showed similar associations, albeit somewhat weaker (data not shown).

In contrast to women, no associations between OPA and obesity (whether general or abdominal) were observed in men, whereas the association with insulin resistance was in an opposite and dose-dependent direction and statistically significant in model 2 (Table 3) but not in model 3 (data not shown). The logistic regression analyses also showed a statistically significant inverse association between HOMA-IR and the highest level of OPA in models 1 and 2 (data not shown). Sex differences were confirmed by statistically significant age-adjusted interaction terms between sex and OPA in association with all aforementioned effect variables (BMI, $P = .018$; waist circumference, $P = .041$; HOMA-IR, $P = .006$). The interactions remained statistically significant in model 2, but not in model 3, for waist circumference and HOMA-IR (data not shown).

In men, resting heart rate was significantly increased with increasing levels of OPA in both models 1 and 2 (Table 3), as well as in model 3 for HOMA-IR (data not shown). No such association was seen in women.

All aforementioned associations remained when also adjusting for self-reported sleep disturbances and daily life stress (data not shown).

In a subanalysis, LTPA and OPA were combined into 8 categories, which were then reduced to 4 categories of total physical activity. In general linear models, a consistent pattern of inverse associations was found in both men and women between the highest and the lowest category of total physical activity with regard to BMI, waist circumference, and HOMA-IR, respectively (data not shown). All these associations were statistically significant apart from that with regard to HOMA-IR

Table 3 – Comparisons of means of metabolic risk factors through different levels of OPA in the Vara and Skövde cohorts, the Skaraborg Project 2001-2005, Sweden

Women	Categories of OPA								
	Sedentary		Low		Moderate		High		
	n = 249		n = 126		n = 262		n = 137		
	M	SD (CV)	M	SD (CV)	M	SD (CV)	M	SD (CV)	P for trend
Model 1 [a]									
BMI	25.4	4.7	25.9	4.7	26.1	4.7	27.7*	4.7	<.001
WC, cm	82.3	12.2	82.8	12.2	84.2	12.2	88.2*	12.2	<.001
Heart rate	64	7.9	64	7.9	64	7.9	65	7.9	.152
HOMA-IR	1.02	(63)	1.01	(63)	1.07	(63)	1.24†	(62)	.004
Model 2 [b]									
BMI	25.5	4.7	26.1	4.7	26.0	4.7	27.4*	4.8	.001
WC, cm	82.6	12.2	83.0	12.2	83.9	12.1	87.4*	12.2	.001
Heart rate	64	8.0	64	7.9	64	8.0	65	8.1	.416
HOMA-IR	1.03	(60)	1.02	(61)	1.05	(60)	1.20‡	(62)	.041
Men	n = 285		n = 111		n = 283		n = 292		
Model 1 [a]									
BMI	26.7	3.4	26.4	3.4	26.3	3.4	26.9	3.4	.680
WC, cm	94.5	9.4	92.7	9.4	93.1	9.4	94.5	9.4	.939
Heart rate	61	8.4	61	8.4	63†	8.4	63‡	8.4	.001
HOMA-IR	1.31	(67)	1.29	(67)	1.20	(67)	1.24	(66)	.194
Model 2 [b]									
BMI	26.9	3.4	26.6	3.3	26.2‡	3.3	26.7	3.4	.363
WC, cm	94.8	9.4	93.0	9.1	92.7‡	9.1	94.0	9.3	.225
Heart rate	61	8.5	62	8.3	63‡	8.3	63‡	8.4	.008
HOMA-IR	1.34	(69)	1.31	(66)	1.18‡	(63)	1.22	(68)	.036

Means for HOMA-IR are geometric (anti-log) and based on subjects without diabetes. Differences in means between levels of OPA were examined by general linear model.

[a] Model 1 = adjusted for age.

[b] Model 2 = adjusted for age, LTPA, education, alcohol consumption, smoking, and study area.

* $P < .001$, with the sedentary category used as reference.

† $P < .005$, with the sedentary category used as reference.

‡ $P < .050$, with the sedentary category used as reference.

in women, which was of borderline significance. There was no statistically significant association between total physical activity and resting heart rate in either men or women.

4. Discussion

In this cross-sectional study, LTPA was inversely associated with obesity and insulin resistance in both men and women, whereas the corresponding analyses with regard to OPA revealed considerable sex differences. In women, OPA was positively associated with both general and abdominal obesity and with insulin resistance. No such association was seen in men, and the sex difference was confirmed by statistically significant interaction terms.

4.1. *Leisure time physical activity*

Our inverse results with regard to LTPA in both men and women were expected, insofar as a protective effect of LTPA on general obesity [10,11,30,31], abdominal obesity [10,11], and insulin resistance [23,32-36] is well established. Furthermore, the associations found here for insulin resistance and waist circumferences were independent of BMI, which is also in

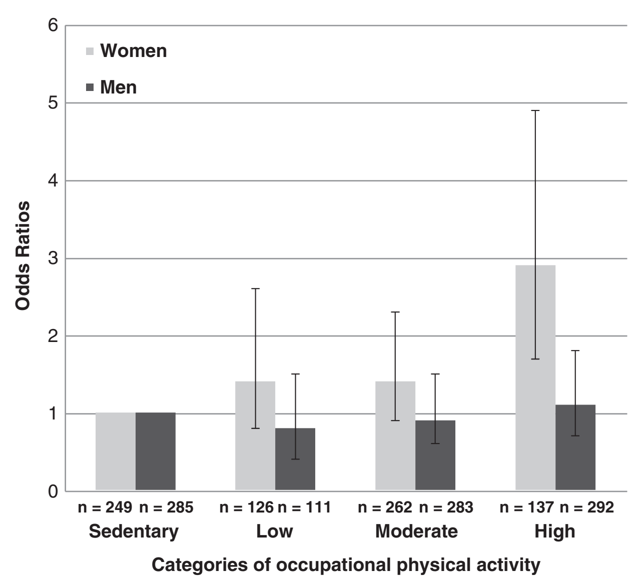

Fig. 2 – Age-adjusted odds ratios and confidence intervals of obesity (BMI ≥ 30 vs BMI < 30) in association with OPA in the Vara and Skövde cohorts, the Skaraborg Project 2001-2005, Sweden.

agreement with previous studies [11,23,32-36]. Thus, LTPA seems to have a beneficial effect on abdominal obesity and insulin sensitivity irrespective of a subject's BMI. Whereas most previous studies have found this association in both men and women [34-36], no study has, to our knowledge, tested for differences between sexes. When sex differences were explored in the current study, a significant interaction between female sex and high LTPA was found in association with HOMA-IR. This is in contradiction with 2 previous studies [37,38] where associations between physical activity and fasting insulin were found only in men. However, the authors of those studies attribute their lack of similar findings in women to probable methodological aspects. Although the reason for the findings concerning the effect of LTPA in women in the present study is not clear, the results are consistent with women having more insulin-sensitive muscle tissues than equally fit men [39,40]. This was further confirmed here when comparing means of HOMA-IR for men and women adjusted for age, BMI, and LTPA (data not shown). Also, in a previous study [35], women similarly showed higher insulin sensitivity irrespective of physical activity energy expenditure and percentage of body fat. However, those findings would still not explain the higher protective effect of physical activity on insulin resistance found here in women compared with men, and neither would the level of LTPA as women in the present study reported less LTPA than men.

In both men and women, high levels of LTPA were found to be associated with low resting heart rate, which is a well-known indicator for physical fitness. These findings indicate a high internal validity of the LTPA questionnaire and also point to a good external validity of the results.

4.2. *Occupational physical activity*

Occupational physical activity was positively associated with both general and abdominal obesity in women in this study. These associations were robust when adjusting for multiple confounding factors, except for when BMI was entered into the model in the analysis of waist circumference, where the association disappeared. However, this might be due to overadjustment as BMI and waist circumference are closely associated. Previous studies on the association between OPA and obesity have yielded differing results with regard to the direction of association and to sex [10-22]. Some studies have found results that are similar to ours, with a few studies showing positive associations between OPA and obesity in women only [20-22] and one study showing a positive association in women and an inverse association in men [11].

In correspondence with the findings between OPA and BMI/waist circumference, a positive association between OPA and insulin resistance was also found in women in the present study. The latter findings might have been expected as insulin resistance is closely associated with obesity [1,2] and the association in our study did indeed disappear when adjusting for BMI. Measurement of HOMA-IR has, to our knowledge, never been used before to study insulin resistance in relation to OPA. However, 2 previous studies have looked at the association between OPA and fasting insulin as a marker of insulin resistance. One of these, a Chinese study in women [24], found a U-shaped association between occupational energy expenditure and fasting insulin resistance index, whereas the other study found no association at all between OPA and fasting insulin in either men or women [25].

None of the positive associations in women with regard to OPA were replicated in men. On the contrary, OPA was even inversely associated with HOMA-IR in men. The differences between men and women with regard to BMI, waist circumference, and HOMA-IR were indeed confirmed in cross-product interaction analyses, which to our knowledge have not been performed in previous studies. Although a biological causal pathway is the most plausible explanation for the association found here and elsewhere with regard to LTPA [30,41], confounding by lifestyle factors is a more likely explanation for the association with regard to OPA in women. Consequently, differences in these confounding factors between men and women might explain why the positive association was seen solely in women. For example, women in occupations with high OPA might differ from men in corresponding occupations with regard to some aspect that could counteract the presumed biological benefits of their physically active work. Still, the associations in our study between OPA and obesity/insulin resistance were only marginally affected by education, study area, LTPA, smoking, alcohol consumption, sleep deprivation, and daily life stress. However, other potential confounders were not accounted for in the present study, such as irregular working hours and dietary habits/caloric intake, which are factors that might plausibly have affected the results and which might differ in men and women. However, the present results were adjusted for education, and low socioeconomic status has been associated with obesity in previous studies, especially in women [42,43]. Furthermore, differences in unhealthy diet, psychosocial stress, and reproductive history have been found to explain most of this association [42], and it might therefore seem somewhat surprising that adjustment for education did not affect any of the associations found here with regard to OPA. However, education might not completely capture all of the effects related to socioeconomic status in the present sample, and other socioeconomic differences between men and women might still indirectly explain some of the sex differences seen here. Moreover, although different types of physical activity (aerobic vs anaerobic types) might have differing effects on metabolism and cardiovascular function [44], it seems unlikely that low frequency of "beneficial" types of OPA among women would do more than attenuate an expected inverse association with obesity/insulin resistance. The validity of the self-reported data of OPA could also possibly differ between men and women, as for example has been seen with regard to self-reported weight [45]. Furthermore, the disparities shown across studies concerning the association between OPA and obesity might also, to some extent, be due to differences with regard to study populations, assessment of OPA, exclusion criteria, and year of data collection.

The analyses of total physical activity showed significant inverse associations with general and abdominal obesity in both sexes and also with insulin resistance in men. Thus, the inverse associations were found in women despite the different directions of associations in the separate analyses of OPA and LTPA, and these findings reflect the stronger association for obesity with regard to LTPA as compared with OPA. It is thus evident that measures of total physical activity can completely mask different directions of association between the separate measures of physical activity.

4.3. *Strengths and weaknesses*

The main strengths of the present study are the large sample size, the random selection, and the high participation rate, which are aspects that enhance the representativeness of the study sample, albeit some selection bias can never entirely be ruled out. Another strength is the use of exclusion criteria to ensure that the amount of OPA (or lack of OPA) reported by the subjects would actually be sufficient to have an impact on obesity and insulin resistance. However, some limitations may have had implications for the results obtained. The data on LTPA and OPA are self-reported and, to differing extents, lack details regarding frequency, duration, intensity, and context. Still, the LTPA question used has shown good internal validity with regard to physical fitness both in the present study and elsewhere [46,47], which also indicates good external validity. However, the validity and reliability of the OPA question are unknown and thus potential weaknesses. The generalizability of the results may also be limited because of differences in level of education and in the prevalence of obesity in our study sample compared with more urbanized areas in Sweden. Nonetheless, our study sample may in these respects still be regarded as representative of a national sample of Sweden, and the results should thus also be generalizable to other countries that are similar to Sweden as a whole and also perhaps to other settings. The study lacks information on some potentially important confounding factors, such as dietary habits and other lifestyle factors. Lastly, the cross-sectional design of this study does not allow us to determine causality.

5. Conclusions

The present study found conflicting results with regard to the beneficial aspects of LTPA and OPA in men and women, with sex differences apparent especially in the findings concerning OPA. Although further exploration of the metabolic effects of OPA appears warranted, more thorough measurement of potential confounders is also vital to understand contextual effects. Our results also indicate that the work setting may be an important context to consider in cardiovascular prevention, especially in women. The stronger association between LTPA and insulin resistance in women than in men also warrants further investigation.

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Conflict of Interest

The authors declare no conflict of interest.

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