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Are active sun exposure habits related to lowering risk of type 2 diabetes mellitus in women, a prospective cohort study?

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ABSTRACT

Aim: An inverse relationship exists between vitamin D levels and diabetes mellitus. However, little is known about the correlation of sun exposure habits and type 2 diabetes mellitus (DM).
Methods: A South Swedish cohort study comprising 1000 women from each age group between 25 and 64 ($n = 40{,}000$) drawn from the Southern Swedish population registry 1990–1992. At the inception of the study 74% answered the inquiry ($n = 29{,}518$) and provided detailed information on their sun exposure habits and other variables. A follow-up inquiry was sent 2000–2002 which 24,098 women answered. The mean follow-up time was 11 years. Logistic regression analysis was used and the main outcome was the relationship between type 2 DM and sun exposure habits.
Results: Our findings indicated that women with active sun exposure habits were at a 30% lower risk of having DM, as compared to those with non-active habits. There was an inverse relation between this risk reduction and BMI.
Conclusion: Our investigation gives possible epidemiological explanation to ethnic and seasonal differences in type 2 DM and metabolic control. The study supports that sunlight is involved in the glucose metabolism.

1. Introduction

Vitamin D deficiency has also been shown to be common in type 2 DM [1–3]. Vitamin D levels are inversely related to body mass index (BMI), waistline, and HbA1c [4]. In addition, there are seasonal variations of HbA1c levels and incidental type 2 DM [5,6]. The supplementation of calcium and vitamin D at 800 I.U. daily, instead of the prior recommendation of 400 I.U. decreased the risk of type 2 DM by 33% [7].

Human subjects obtain vitamin D from sunlight exposure, diet, or dietary supplements [8]. Since most dietary products contain low levels of vitamin D, the major source is the skin production by ultraviolet B (UVB) radiation. UVB radiation, wavelength from 290 to 315 nm, penetrates the skin and convert 7-dehydrocholesterol to pre-vitamin D, which is converted to 25-hydroxicholecalciferol vitamin D $_3$ (25(OH)D) [8]. The hydroxylation of 25(OH)D to its active form 1α,25$(OH)_2$ vitamin D $_3$ (1,25(OH2)D) take place in different parts of the

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body, such as the endothelium, the pancreas, but mainly in the kidney [8]. A high proportion of the population in the Nordic countries maintain adequate levels of vitamin D (i.e., >75 mmol/L) *only* during summer [9,10].

Thus, an inverse relationship exists between vitamin D levels and the frequency of type 2 DM. However, little is known about the relation between sun exposure habits and DM. In the Melanoma Inquiry of Southern Sweden (MISS) study, we followed 40,000 women for a mean period of 11 years and obtained detailed information on their sun exposure habits, as well as such established risk factors for diabetes as age, BMI, and hormonal treatment. This longitudinal cohort study was then used in order to assess how women's sun exposure habits influence their risk of type 2 DM.

2. Materials and methods

One thousand Swedish-born women having no history of malignancy from each age group between 25 and 64 (n = 40,000) drawn from the Southern Swedish population registry 1990–1992 by computerized random selection. This represented 20% of the South Swedish female population in the selected age groups. The prospective cohort is called the Melanoma Inquiry of Southern Sweden (MISS) study. At the inception of the study 74% answered the written inquiry (n = 29,518) and provided detailed information on their sun exposure habits and other variables focussed on risk factors for malignant melanoma. A follow-up inquiry was sent 2000–2002 which 24,098 women answered. The mean follow-up time was 11 years. The questionnaire probed several items of potential interest for DM, including socioeconomic variables, such as education level and marital status, as well as BMI, and sun exposure habits. The latter were explored in detail. The wording of the sun exposure questions at the inception of the study were: (1) How often do you sunbathe during the summer? (never/1–14 times/15–30 times/>30 times); (2) Do you sunbathe during the winter in the mountains or the Alps? (no/1–3 days/4–10 days/>10 days); (3) Do you use a sun tanning bed? (never/1–3/4–10/>10 times per year); (4) Do you work outdoors during the summer (no/yes); (5) Do you vacation abroad where you swim and sunbathe? (never/annually/twice or more per year). The five questions were dichotomized into no/yes in the analysis, with a division established between no/never and sometimes. All data, except BMI, exercise, DM, and the presence of cancer during the study period were collected from the initial written inquiry.

Women who had answered that they had DM at follow-up inquiry were considered to have diabetes. We also used the National Discharge Registry, the Outpatient Care Registry and the National Prescription Register to classify type of DM. Women who only used insulin were classified as type 1 DM, while women who had ever being prescribed per oral antidiabetics (with or without insulin) or on no medication were classified as type 2 DM. Self-reported weight and height were obtained from the second questionnaire, through which subjects with DM were identified by self-reported lists of their diseases and medications (such as antidiabetics). Women that had answered that they took antidiabetic medication at inception were excluded from analysis of type 2 DM.

Hormonal use at the inception of the study, i.e., use of combined oral contraceptives (COC) or hormone replacement therapy (HRT), was introduced as a dichotomized variable (never-use [reference], ever-use). The questions were posed as: Have you ever used/are you currently using combined oral contraceptives? Women not answering the question (n = 16) were considered never-users. Smoking habits were also recorded at the inception of the study. They were categorized into the following subgroups: non-smokers (reference); those who had smoked less than 100,000 cigarettes in their lifetime; and those who had smoked 100,000 cigarettes or more (based on how participants had characterized their cigarette smoking in mean consumption at 5-year intervals). The level of regular exercise was estimated at the second interview by answers to the question—''In addition to your usual work, do you exercise regularly?'': No; Do you go for a walk once a week?; Do you go for a walk several times a week?; Do you bicycle, swim, participate in gymnastics, dancing, or similar activities one or more times a week (i.e., strenuous exercise)? Physical exercise was than divided into three categories: none; take walks one or more times a week; or strenuous exercise.

2.1. Statistics

Characteristics and analysis of selected variables were performed with binary logistic regression analysis, using 95% confidence intervals for odds ratios. The presence of type 2 DM was used as a dependant variable and the other variables as independent risk factors. As increasing age is a strong risk factor for type 2 DM, it was included for adjustment of all risk estimates. Age by decade was introduced as a categorized variable (25–34, 35–44, 45–54, 55–64 years at inclusion). Missing sun exposure variables were omitted from analysis and missing adjusting variables was entered in multivariable analysis as a dummy variable. All calculations were performed using SPSS software version 16 (Statistical Package for the Social Sciences, SPSS Inc., Chicago IL, USA) and p values <0.05 were considered statistically significant.

3. Results

Table 1 presents the characteristics of the women in the study cohort. A greater prevalence of DM was found among women with less than 9 years of schooling and among those with early menarche. Ever-users of COC were at 20% lower risk of DM, as compared to never-users. All women who participated in the second interview were included in the study (n = 24,098), which represented 262,429 woman years. A total of 794 women had DM, 599 with type 2 DM, and 537 were classified as getting type 2 DM after inception 1990.

Table 2 indicates the age-adjusted analysis of sun exposure habits and risk of DM. Those who either used a tanning bed, sunbathed during the summer or during winter vacations, or who sunbathed on trips abroad, were approximately 30% less likely to have type 2 DM (Models 1–4). Heavy smoking was related to 30% significantly increased risk of type 2 DM ($p < 0.05$) and strenuous exercise was related to 40% significantly decreased risk ($p \leq 0.005$) of type 2 DM. There were only minor changes in risk estimates when adjusting for

Table 1 – Demographic characteristics at inclusion of women with and without diabetes.

	Women with diabetes ($n = 537$)	Women without diabetes ($n = 23,425$)	Age-adjusted	
			OR	95% CI
Women's characteristics and habits[a]				
Education				
<9 years	165	3946	1.4	1.1–1.7
9 years	59	2270	0.9	0.6–1.2
10–12 years	112	6166	1.0	Reference
>12 years	116	8140	0.7	0.5–0.9
Other	85	2903	1.2	0.9–1.6
Marital status				
Unmarried	40	1931	1.2	0.9–1.7
Married	420	18,531	1.0	Reference
Divorced	42	2048	0.8	0.6–1.1
Widow	34	842	1.1	0.9–1.6
[a]	1	73		
Parity				
0	114	3826	1.1	0.9–1.4
1–2	416	13,117	1.0	Reference
>3	264	6361	1.2	0.8–1.6
Menarche				
<10	14	378	1.8	1.0–3.1
11–13	312	12,743	1.0	Reference
>14	206	9951	0.5	0.2–1.2
*	7	353		
Combined oral contraceptives				
Never-use	282	8272	1.0	Reference
Ever-use	255	15,153	0.8	0.6–0.9
Hormone replacement therapy				
Never-use	443	20,444	1.0	Reference
Ever-use	94	2981	0.9	0.7–1.2
Cancer during study period				
No	496	22,329	1.0	Reference
Yes	41	1096	1.3	0.9–1.8

All information, except cancer (follow-up data) was gathered at inclusion of study and analysed with logistic regression analysis with age-adjustment.

[a] Some women did not answer all questions.

demographic characteristics (Model 2). The Odds ratios (OR) did not change substantially when DM was used as dependable variable (data not shown).

Table 3 indicates lower risk of type 2 DM by sun exposure habits for those with lower BMI. An inverse relationship between this risk reduction and BMI was found, ranging from 40% to 60% for those with BMI < 25, 20% to 40% for those with BMI between 25 and 30, and no decrease in risk for obese women (BMI 30+).

4. Discussion

Our study showed that women with active sun exposure habits were at a lower risk of getting type 2 DM, as compared to those with non-active habits. These differences remained unaffected after adjustment for known socioeconomic and demographic risk factors. Since UVB radiation in sunlight is the major source of vitamin D, sun exposure habits can provide a good estimation of vitamin D status [9,10]. To the best of our knowledge, ours is the first large prospective cohort study where a relation between standardised measurements of sun exposure and prevalence of type 2 DM is demonstrated. Our findings are in agreement with prior studies reporting an inverse relationship between vitamin D levels and incidence of DM [1–3]. The fact that people with colored skin have a higher risk of DM and worse metabolic control in terms of HbA1c levels supports the sunlight/vitamin D hypothesis [11,12].

In the search for mechanisms by which sun exposure might lower the risk of DM type 2, there are several possibilities. HbA1c levels also show a seasonal pattern, with higher levels in winter and lower levels in spring/summer, indicating improved glucose control in summer [5]. Vitamin D deficiency impairs insulin secretion of the pancreatic β-cells and increase the insulin resistance [13]. Factors of importance for the metabolic syndrome may be affected by levels of vitamin D. Vitamin D has also been shown to improve endothelial function by reducing blood pressure [14], by decreasing vascular resistance [14], by acting as a immunomodulator preventing excessive expression of inflammatory cytokines (TNFα, IL6)[15] or by increasing IL10 [16].

Table 2 – Sun exposure habits and risk of diabetes, multivariate analysis.

	Women without diabetes	Women with diabetes	Model 1		Model 2		Model 3		Model 4	
			OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Use of sun beds?[a]										
No	12,049	357	1.0	Ref	1.0	Ref	1.0	Ref	1.0	Ref
Yes	11,031	172	0.7	0.5–0.8	0.7	0.6–0.9	0.8	0.6–0.9	0.7	0.6–0.9
Sunbathing during winter vacation?[a]										
No	18,550	480	1.0	Ref	1.0	Ref	1.0	Ref	1.0	Ref
Yes	4563	48	0.5	0.3–0.6	0.6	0.4–0.8	0.7	0.5–0.9	0.6	0.5–0.9
Working outdoor in summer?[a]										
No	17,408	376	1.0	Ref	1.0	Ref	1.0	Ref	1.0	Ref
Yes	5466	132	1.1	0.9–1.3	1.0	0.8–1.2	1.0	0.8–1.2	1.0	0.8–1.0
Sunbathing during summer?[a]										
No	1036	62	1.0	Ref	1.0	Ref	1.0	Ref	1.0	Ref
Yes	21,995	456	0.5	0.4–0.6	0.6	0.5–0.8	0.7	0.5–0.9	0.6	0.5–0.8
Sunbathing during vacation abroad?[a]										
No	9574	271	1.0	Ref	1.0	Ref	1.0	Ref	1.0	Ref
Yes	13,663	261	0.7	0.6–0.8	0.8	0.7–1.0	0.9	0.7–1.0	0.8	0.7–1.0

Logistic regression analysis: Model 1 age-adjustment, Model 2 age and BMI adjustment. Model 3 adjustment for age, BMI, education level, parity, and oral contraceptive use. Model 4 adjustment for age, BMI, smoking, and physical exercise.
[a] Not all women answering the questions.

The lower risk of DM among those with active sun exposure habits might not be an effect mediated by vitamin D, but rather the impact of sunlight on the melatonin system. Melatonin is involved in the bodýs circadian rhythms. Production of melatonin by the pineal gland is under the influence of the suprachiasmatic nuclei of the hypothalamus, which receive information from the retina about the daily pattern of light and darkness. The level of melatonin production is low during the day and high at night. It was recently reported that a polymorphism in the melatonin receptor 1B gene was related to DM by causing an inhibition of insulin release [17]. Carriers of the melatonin receptor 1B receptor polymorphism show increased expression of the receptor in the pancreatic islets.

4.1. *Variables affecting vitamin D levels*

Several factors affect the ability to form 25(OH)D via the skin. Melanin is extremely efficient in absorbing UVB radiation:

Table 3 – Sun exposure habits and risk of diabetes, stratified for BMI.

	No diabetes mellitus (n = 23,425)	Diabetes mellitus (n = 537)	Odds ratio (OR) (No = reference)	95% CI
Use of sun beds?				
Yes and BMI <25	6566	26	0.4	0.3–0.7
Yes and BMI 25–30	3028	64	0.7	0.5–0.9
Yes and BMI 30+	846	65	1.1	0.8–1.5
Sunbathing during winter vacation?				
Yes and BMI <25	3047	11	0.5	0.2–0.9
Yes and BMI 25–30	1029	20	0.6	0.4–1.0
Yes and BMI 30+	234	14	0.9	0.5–1.5
Working outdoor in summer?				
Yes and BMI <25	2821	22	1.0	0.6–1.7
Yes and BMI 25–30	1626	45	0.9	0.7–1.3
Yes and BMI 30+	592	43	0.9	0.6–1.2
Sunbathing during summer?				
Yes and BMI <25	12,375	85	0.4	0.2–0.8
Yes and BMI 25–30	6138	172	0.6	0.4–1.0
Yes and BMI 30+	2025	156	0.9	0.6–1.4
Sunbathing during vacation abroad				
Yes and BMI <25	8026	47	0.6	0.4–0.9
Yes and BMI 25–30	3721	100	0.8	0.6–1.1
Yes and BMI 30+	1075	92	1.0	0.8–1.4

Logistic regression analysis age-adjusted analysis.

increased skin pigmentation markedly reduces 25(OH)D synthesis [15]. Sun block with sun protection factor (SPF) 15 absorbs 93% of the incident UVB radiation, thus preventing most 25(OH)D synthesis [18]. African-Americans with very dark skin have an equivalent SPF of 15, i.e., their ability to synthesize vitamin D is reduced by 93% [15]. In addition, the angle at which sunlight strikes the earth has a major effect on the amount of UVB light that reaches the surface. In the Nordic countries, only small amounts of vitamin D result from UVB radiation in winter [15], and during the summer a limited amount of vitamin D is synthesized in the morning and late afternoon. Furthermore, the capacity to synthesize 25(OH)D from the skin declines with age (a 70-year-old $\approx$ 25% of a young adult) [15]. Tanning beds with UVA radiation also produce a small amount of UVB light have also been shown to increase vitamin D levels [19,20].

The finding that active sun exposure habits showed an inverse relationship between BMI and risk of type 2 DM is difficult to interpret. A possible explanation is that obesity per se involves such a high risk of type 2 DM that the level of sun exposure does not matter. Two studies have explored the relation between sun exposure, 25(OH)D, and body fat, but failed to find differences in sun exposure explaining the inverse relationship between 25(OH)D and % body fat [10,21]. The latter discussed if excess body fat resulted in sequestration and low availability, as a reason for low serum 25(OH)D levels in obese [10]. A recent prospective study from Japan showed no independent association between type 2 DM and Vitamin D consumption [22]. However, the combination of high vitamin D and calcium intake showed a significant inverse relationship (odds ratio = 0.6). Vitamin D deficiency in Japan was shown to be rare possible due to the prevalent fish (>3 times a week) and/or egg consumption, habits which improves vitamin D levels by 10–15 nmol/L [23]. If there is a relation between vitamin D and type 2 DM it is reasonable to assume that those with deficiency have more advantage than those not.

4.2. *Strengths and weaknesses*

A strength of the present paper is its use of an unselected large population-based cohort drawn from the Swedish national population registry and followed for 11 years. The information on sun exposure habits was gathered at the inception of the study. Thus, there is no recall bias. Because our data was collected at baseline, it was assumed that sun exposure habits did not change over time; consequently information from only one assessment was used in the models. This is a common assumption in cohort studies and tends to underestimate any differences found. Therefore, it is highly unlikely that these faults have been subject to bias of any way regarding sun exposure habits and, if so, they would have tended to underestimate any differences. Our study indicates that women who described themselves as having more active sun exposure habits were at a significantly lower risk of getting type 2 DM. Nevertheless, type 2 DM is a disease that is strongly linked to lifestyle factors, including high food intake, lack of physical activity, and obesity. High levels of Vitamin D have been associated with a healthy lifestyle, as has recently been shown in a study among women whose serum levels of 25(OH)D were closely related to indices of physical fitness, such as lean mass, balance, and handgrip strength [24]. A possible explanation of our findings could be that subjects with low sun exposure generally lead a more unhealthy life, resulting in a greater risk of type 2 DM. Unfortunately, we did not have access to exercise habits and BMI from the inception and only from the follow-up inquiry. Another limitation is that we limited the study to those who not were on antidiabetic medication at inclusion. However, we do not know if they had diet treated DM.

We believe our findings may be of interest not only with regard to type 2 DM, but may also prove useful in studying other conditions having seasonal and latitude variations such as MS and rheumatic disease [25]. In addition, our study is part of a larger project exploring risks and benefits of UVB exposure, which may have relevance for future sun exposure recommendations [26,27]. Our study makes available novel epidemiological data and a hypothesis calling attention to possible sunlight effects on type 2 DM. Finally, it offers a hypothesis that possibly explains ethnic differences in the prevalence of DM and in glucose control that, if confirmed, may have profound public health implications.

Ethical approval

The study was approved by the Ethics Committee at Lund University (LU 632-03 and 849/2005).

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Conflict of interest

The authors declare that they have no conflict of interest.

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