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Original Article

Associations between physical activity, sedentary behavior, and glycemic control in a large cohort of adolescents with type 1 diabetes: the Hvidoere Study Group on Childhood Diabetes

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Background: The Hvidoere Study Group on Childhood Diabetes has demonstrated persistent differences in metabolic outcomes between pediatric diabetes centers. These differences cannot be accounted for by differences in demographic, medical, or treatment variables. Therefore, we sought to explore whether differences in physical activity or sedentary behavior could explain the variation in metabolic outcomes between centers.
Methods: An observational cross-sectional international study in 21 centers, with demographic and clinical data obtained by questionnaire from participants. Hemoglobin A1c (HbA1c) levels were assayed in one central laboratory. All individuals with diabetes aged 11–18 yr (49.4% female), with duration of diabetes of at least 1 yr, were invited to participate. Individuals completed a self-reported measure of quality of life (Diabetes Quality of Life - Short Form [DQOL-SF]), with well-being and leisure time activity assessed using measures developed by Health Behaviour in School Children WHO Project.
Results: Older participants ($p < 0.001$) and females ($p < 0.001$) reported less physical activity. Physical activity was associated with positive health perception ($p < 0.001$) but not with glycemic control, body mass index, frequency of hypoglycemia, or diabetic ketoacidosis. The more time spent on the computer ($r = 0.06$; $p < 0.05$) and less time spent doing school homework ($r = -0.09$; $p < 0.001$) were associated with higher HbA1c. Between centers, there were significant differences in reported physical activity ($p < 0.001$) and sedentary behavior ($p < 0.001$), but these differences did not account for center differences in metabolic control.
Conclusions: Physical activity is strongly associated with psychological well-being but has weak associations with metabolic control. Leisure time activity is associated with individual differences in HbA1c but not with intercenter differences.

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The Hvidoere Study Group (HSG) on Childhood Diabetes has investigated metabolic control in large cohorts of adolescents from more than 20 pediatric diabetes centers worldwide. Studies have shown that although the mean hemoglobin A1c (HbA1c) was not much higher than that in the intensively treated adolescent group in the Diabetes Control and Complications Trial (DCCT), few of the adolescents achieved glycated hemoglobin levels in an optimal range (29% of adocescents with HbA1c<8%) (1). Better metabolic control was associated with better quality of life with no increased rate of hypoglycemia (2, 3), contrary to the results of the DCCT for adolescents (4, 5). Substantial and persistent differences in treatment outcome have been observed between centers in the study group (2, 6, 7), but we have been unable to explain these differences in terms of demographic and medical characteristics (2, 6, 7), or differential use of insulin regimens (2, 6, 7), despite major changes in therapeutic strategies during recent years (7). Cultural differences in food consumption and physical and leisure activities vary substantially between adolescents from different countries (8, 9), which suggests that these factors could explain differences in metabolic outcome in adolescents with type 1 diabetes mellitus (T1DM).

The aim of the present study was to investigate whether such lifestyle factors such as physical activity and inactivity are associated with glycemic control and psychological well-being in adolescents with T1DM and if these factors might explain the difference in metabolic outcome between centers of the HSG.

Research design and methods

An observational multicenter, cross-sectional study involving 21 pediatric diabetes departments from 19 countries in Europe, Japan, Australia, and North America was performed between March 2005 and October 2005 (7). Adolescents (aged 11–18 yr; diabetes duration >12 months) were invited to participate. The Case Report Form (CRF) included information on gender, age, height, weight, duration of diabetes, number of severe hypoglycemic events, and diabetic ketoacidosis (DKA). Information regarding insulin treatment and concomitant medical conditions was obtained. Language difficulties causing communication problems and comorbid conditions specified as celiac disease, thyroid disease, asthma, epilepsy, or others were asked for by the diabetes nurse. Parental employment and parental cohabitation were reported by the adolescents in the questionnaire. If the adolescent was accompanied by a parent to the clinic was reported by the adolescents, meaning the parent was following into the room during consultation.

Diabetes-specific quality of life was assessed using a short version of the Diabetes Quality of Life - Short Form (DQOL-SF) questionnaire, which has been developed by the HSG (2). Psychological well-being and health perception were assessed by questions from The Health Behavior in School-aged Children Questionnaires (HBSC survey 2001), a WHO study conducted in 3-yr cycles in over 30 countries (8, 9).

The questionnaires for the adolescents included five questions on physical activity and sedentary lifestyle, HBSC survey 2001 (8, 9). These were questions regarding number of days during the last week being moderately physically active for more than 60 min (defined as an activity causing increased heart rate and/ or breathlessness), the usual number of hours watching television during 1 d, and the usual daily number of hours doing school homework, and finally the usual daily hours with the computer during spare time (for playing games, e-mailing, and chatting or surfing the internet).

A capillary blood sample for HbA1c was provided by participants and analyzed at Steno Diabetes Center, Gentofte, Denmark, with the Tosoh method (normal range 4.4–6.3% and an inter assay SD of 0.15%) as described elsewhere (1, 7).

The study was performed according to the criteria of the Helsinki II Declaration and was approved by the local ethics committee at each center.

Statistical analysis

All data were double entered at an independent data management center, and ambiguous data on CRFs were resolved by direct liaison with relevant center. All analysis was undertaken using SPSS v 13. Summary statistics are expressed as means ± SD or number and percentage. Test of differences for categorical variables were undertaken using analysis of variance, where the dependent variables was HbA1c, frequency of hypoglycemia, and DKA. For associations between continuous variables, we used Pearson's product moment correlation coefficients. Where both variables were ordinal, we used the Spearman's rho correlation coefficient. When correlated variables were of mixed level (e.g., one ordinal and one continuous), or where substantial differences in ranges would have resulted in a non-monotonic relationship, Kendall's tau correlation coefficients were used. Where regression analysis was undertaken, all categorical variables such as insulin regiment were dummy coded. All analysis was initially completed with one factor entered separated for each analysis, with additional factors and covariates added sequentially as appropriate.

Results

Sample characteristics

Of a total of 2269 eligible patients with insulin-treated T1DM, 2093 (92%) completed a questionnaire and 2036 (89%) provided a blood sample. The mean age of the 2093 adolescents was 14.5 ± 2.1 yr (14.5 ± 2.2 yr for males and 14.5 ± 2.1 yr for females; $p = 0.96$), and the mean daily insulin dose was 1.0 ± 0.3 U/kg body weight. Insulin pump therapy was used by 334 (15.9%) patients, basal bolus insulin therapy was used by 926 (44.2%) patients, and twice- or thrice-daily insulin injection therapy was used by the remaining 833 (39.8%) adolescents. Body mass index (BMI) was 22.8 ± 4.2 in females and 21.7 ± 3.7 in males ($p < 0.001$) and did not correlate with HbA1c or insulin regimen. The grand mean HbA1c for the whole sample was 8.2 ± 1.4% (males 8.1 ± 1.3% and females 8.3 ± 1.5%). HbA1c was positively but modestly correlated to age ($r = 0.09$; $p < 0.001$) and duration of diabetes ($r = 0.29$; $p < 0.001$). Adolescents whose families had language problems had significantly higher HbA1c (8.5%) than those from families without language problems (8.2%) ($p < 0.05$) (7).

Physical activity and sedentary behavior in individuals

Table 1 provides the mean level of activity by gender for the sample. Boys reported being more physically active ($t = 7.51$; $p < 0.001$), doing less school homework ($t = 8.47$; $p < 0.001$), and spending more time on a computer ($t = 6.49$; $p < 0.001$) than girls, but there was no difference for time spent watching television. Older respondents were less physically active ($r = -0.17$; $p < 0.001$) but did more school homework ($r = 0.11$; $p < 0.001$) and spent more time on the computer ($r = 0.17$; $p < 0.001$). Similarly, longer duration of diabetes correlated with less physical activity ($r = 0.06$; $p < 0.001$) and less time watching television ($r = -0.05$; $p < 0.001$) but more time spent doing schoolwork ($r = 0.11$; $p < 0.001$) and more time on computers ($r = 0.06$; $p < 0.001$).

Physical activity was not significantly correlated with the amount of time spent watching television or doing school homework but was negatively correlated with amount of time spent on computer ($r = -0.12$; $p < 0.001$). Time spent watching television was positively correlated with time spent on a computer ($r = 0.10$; $p < 0.001$) with no other significant correlations between activity measures.

Physical activity, sedentary behavior, and glycemic outcome

Physical activity was not associated with metabolic outcome, frequency of hypoglycemia, DKA, or BMI (Table 2). However, the number of hours spent doing school homework or on a computer was associated with HbA1c such that the more schoolwork adolescents report doing and the less time on computers for personal use, the lower the HbA1c. In contrast, physical activity is positively correlated with nearly all markers of psychological health, with more activity associated with greater well-being, fewer symptoms, less worry, greater perception of health, and general quality of life. Conversely, the more time spent on the computer, the more worry and the more symptoms were reported. Given the confounding effects of demographic variables with activity, the correlations were repeated controlling for age, gender, comorbidity, parental employment, cohabitation, and presence at clinic. After controlling for these, the number of days physical activity in a week remained correlated with well-being ($r = 0.05$; $p < 0.05$), physical symptoms ($r = 0.05$; $p < 0.05$), psychological symptoms ($r = 0.06$; $p < 0.05$), perception of health ($r = 0.15$; $p < 0.001$), and quality of life ($r = 0.10$; $p < 0.001$) but not with diabetes-related worry. Furthermore, when controlling for these factors, more time spent doing school homework ($r = -0.09$; $p < 0.001$) and less time spent on computer ($r = 0.06$; $p < 0.05$) remained associated with lower HbA1c. There was no association between insulin regimens and physical activity or sedentary behavior.

Physical activity, sedentary behavior, and center differences

There were significant differences between centers for physical activity (last week: $F = 8.5$; $df = 20$; $p < 0.001$ and typical week: $F = 7.7$; $df = 20$; $p < 0.001$), watching television ($F = 3.4$; $df = 20$; $p < 0.001$), playing on computer ($F = 10.6$; $df = 20$; $p < 0.001$), and time spent doing school homework ($F = 16.4$; $df = 20$; $p < 0.001$) (Fig. 1). As time spent doing school homework showed a robust inverse relationship with glycemic control, the relationship

Table 1. Mean and standard deviation for activity measures by gender

Activity	Male (n = 1016) Mean	Male (n = 1016) SD	Female (n = 991) Mean	Female (n = 991) SD
Last 7 d, physically active for at least 60 min (d)	4.1	2.5	3.3	2.4
Over a typical or usual week, physically active for at least 60 min (d)	4.2	2.4	3.6	2.2
Hours a day do you usually watch television on week day	2.0	1.5	2.1	1.4
Hours a day do you usually watch television on hours television weekend	2.8	1.7	2.8	1.7
Hours a day spent doing school homework out of school hours on a week day	1.2	1.0	1.6	1.2
Hours a day spent doing school homework out of school hours on a weekend	0.9	1.1	1.4	1.5
Hours a day use a computer (for playing games, e-mailing, and chatting or surfing the internet) in your free time on week day	1.5	1.6	1.2	1.4
Hours a day use a computer (for games, e-mailing, and chatting, or surfing the internet) in your free time on weekend	2.1	2.0	1.5	1.6

Table 2. Correlations of activity with metabolic and psychological outcomes

	Number of days last week physically active for at least 60 min	Number of days in typical week active for at least 60 min	Total hours watching television in a week	Total hours doing schoolwork in a week	Total hours on a computer in a week
Body mass index	−0.01	−0.05	0.01	0.02	0.01
Hypos	0.04	0.04	−0.02	−0.01	0.02
Diabetic ketoacidosis	0.02	0.04	−0.02	0.03	0.01
Hemoglobin A1c	−0.02	−0.01	0.04	−0.09*	0.06†
Well–being	0.05	0.07‡	0.01	0.01	0.07*
Impact	−0.03	−0.02	−0.02	0.04	0.01
Worry	−0.09*	−0.09*	0.03	0.12*	0.06†
Physical symptoms	0.06‡	0.08*	−0.02	−0.03	−0.08*
Psychological symptoms	0.06‡	0.10*	−0.02	−0.07‡	−0.06‡
Health perception	0.17*	0.15*	0.01	0.01	−0.02
Life ladder	0.11*	0.10*	−0.03	0.01	−0.03

*Correlation is significant at the 0.001 level (two tailed).
†Correlation is significant at the 0.01 level (two tailed).
‡Correlation is significant at the 0.005 level (two tailed).

between doing school homework and centers differences in metabolic control was explored. Further analysis of variance, with planned comparison, indicated that HbA1c center rank showed a linear association with amount of school homework reported ($F = 58.3$; $p < 0.001$) and center rank correlated weakly with amount of school homework reported ($r = -0.21$; $p < 0.001$). Regression analysis was undertaken to determine whether the amount of school homework accounted for any of the impact of center differences in glycemic control. With HbA1c as the dependent variable, demographic details (age, gender, parental cohabitation, attendance at clinic, and employment) and medical factors (diabetes duration, comorbidity, and insulin regimen) were entered first ($F = 9.9$; $df = 6$; $R^2 = 0.03$). Thereafter, center rank was entered, followed by amount of school homework ($F = 46.0$; $df = 7$; $R^2 = 0.151$). Addition of amount of school homework resulted in a small drop in the beta coefficient for center rank, from 0.35 to 0.34, but was a significant predictor of HbA1c in the final regression ($F = 46.0$; $df = 7$; $R^2 = 0.153$). This suggests that differences between centers in school homework does not account for the center differences in metabolic outcomes but rather contribute to variation within centers. Similar results were generated when using analysis of variance and covarying for confounding factors.

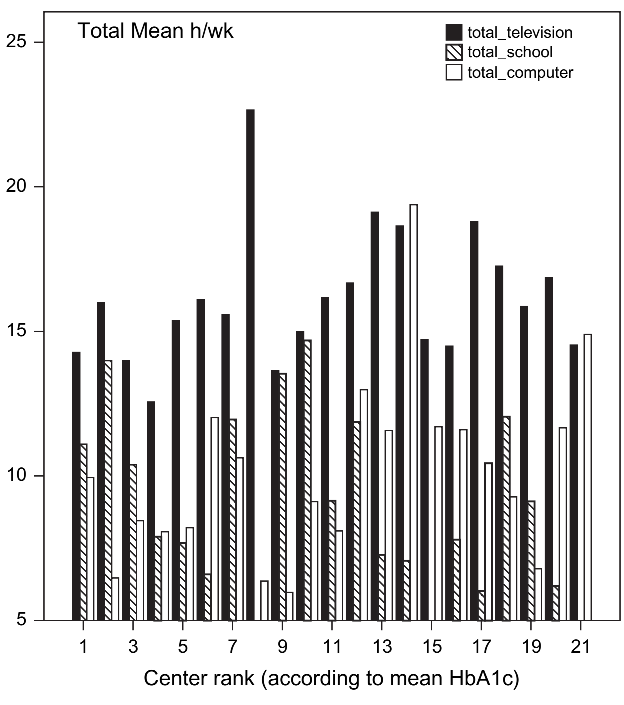

Fig. 1. Mean total hours spent in each activity for each participating center. HbA1c, hemoglobin A1c.

Discussion

Physical activity is considered to be one of the corner stones in the treatment of T1DM, and moderate physical activity should be performed in agreement with the recommendations for healthy children and adolescents. It has also been suggested that sedentary behavior, especially time watching television and time on computers, should be limited in children and adolescents. The time viewing television should, according to the American Academy of Pediatrics, be limited to no more than 2 h per day (10).

Physical activity is associated with improved insulin sensitivity, an increase in lean body mass, improved physical and psychological well-being, and improved lipid profile (11). However, several studies have been unable to demonstrate any association between physical activity and glycemic control in adolescents with T1DM (12, 13). In more intensive training activities, the diabetes treatment is affected and must be adjusted with regard to both diet and insulin management, and self-monitoring of blood glucose is needed to avoid hypoglycemia and hyperglycemia (14, 15).

In the present study, we used validated questionnaires from the WHO HBSC survey 2001 (8, 9). The WHO study is conducted in 3-yr cycles in over 30 countries. The questionnaire for the adolescents included five questions on physical activity and sedentary lifestyle. Physical activity was estimated as the number of days being physically active for more than 60 min. Sedentary behavior was assessed from the total hours watching television during 1 wk and the total number of hours being in front of the computer. Concerns have been raised against questionnaire-based methods of estimating physical activity and sedentary lifestyle (16). In the present study, we had no possibility of making objective measurements of physical activity levels using accelerometers or other methods (13, 17).

As expected, we found significantly less physical activity, fewer hours using the computers, and more hours spent doing school homework in girls with T1DM compared with boys. We could also demonstrate significantly less physical activity in older respondents. These associations are well known also in the general population (18) and from previous studies in T1DM children and adolescents (13). The glycemic control in females in this and other studies is also significantly poorer (1, 7).

Not surprisingly, however, we did not find any relationship between the number of days being physically active and HbA1c, which is in agreement with findings in previous studies (12, 13). In contrast, total hours doing school homework was inversely related to HbA1c, and a weak positive association was also found between number of computer hours and higher HbA1c. This may reflect the association seen between personality and health, particularly conscientiousness (19–21), but the explanation for these associations is complex and needs further evaluation. In contrast to a recent study, no association was found between hours watching television and HbA1c (22).

It was encouraging to observe the positive relationships between physical activity and markers of psychological health, with more activity associated with greater well-being, fewer symptoms, less worry, greater perception of health, and better general quality of life. Objective methods used in a previous study showed minor difference in the total amount of physical activity between adolescents with T1DM and healthy age-matched controls (13). This is a positive message indicating that T1DM adolescents can and should be as physically active as their healthy peers to support their quality of life.

Regarding the persistent center differences in metabolic control found in previous HSG studies (1, 3, 6, 7), it seems that differences in physical activity and sedentary behavior are of no major importance in explaining those center differences.

The strength of this study is the large number of participants with an excellent response rate. The weakness is the use of a questionnaire method, although it is widely used in healthy adolescents within the WHO HBSC survey (8, 9). It is possible that the results would have been modified if more objective methods had been used for the evaluation of physical activity.

In conclusion, this study in adolescents has demonstrated a positive association between physical activity and markers of psychological health, with greater well-being, fewer symptoms, less worry, greater perception of health, and better general quality of life. It has shown an inverse relationship between time spent doing school homework and HbA1c as well as an association between more time spent on the computer and higher HbA1c. We were unable to demonstrate significant relationships between reporting of moderate physical activity or total hours watching television and glycemic control. Levels of physical activity and sedentary behaviour did not explain the differences in HbA1c between participating centers of the HSG. Evaluation of other factors is therefore needed.

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