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## ORIGINAL ARTICLE

# Patterns of physical activity determined by heart rate monitoring among diabetic children

M M Massin, M-C Lebrethon, D Rocour, P Gérard, J-P Bourguignon



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**Background:** Children with type 1 diabetes should be encouraged to participate in physical activity because exercise can benefit insulin sensitivity and improve known risk factors for atherosclerosis.

**Methods:** Physical activity patterns of 127 children and adolescents with stable type 1 diabetes were investigated by 24 hour continuous heart rate monitoring. The percentage of heart rate reserve was used to measure the amounts of physical activity at different intensities. The results were compared with normative data.

**Results:** Diabetic preschoolchildren accumulated 192.7 (78.1), 39.1 (24.3), and 21.3 (9.4) minutes/day (mean (SD)) of light, moderate, and vigorous physical activity, respectively. At the same activity levels, diabetic schoolchildren accumulated 168.9 (76.7), 37.9 (15.9), and 19.0 (14.8) minutes/day, and diabetic teenagers accumulated 166.3 (67.5), 45.6 (26.9), and 25.2 (15.3) minutes/day. Diabetic schoolchildren were significantly more active than healthy peers when considering moderate activity; diabetic teenagers were significantly more active when considering moderate and vigorous activity. There was a negative correlation between the most recent glycated haemoglobin and the time spent in light activities in schoolchildren, and a negative correlation between mean glycated haemoglobin for one year and time spent in light and moderate activities in schoolchildren.

**Conclusion:** The majority of our diabetic patients meet the classical paediatric guidelines for physical activity and compare favourably with their healthy peers.

Exercise is routinely recommended to children and adolescents with type 1 diabetes as a means of improving glycaemic control, limiting excessive weight gain, increasing sense of wellbeing, and helping in the prevention of later cardiovascular disease.<sup>1</sup> There have however been conflicting reports on the long term chronic effect of physical activity on metabolic control<sup>2–7</sup> and prevention of atherosclerosis.<sup>6, 8</sup> In this study the physical activity patterns of a large cohort of diabetic children and adolescents were analysed to study whether or not they differed from healthy subjects and to discover if their metabolic control is affected by the volume of physical activity.

## METHODS

### Subjects

In our department, diabetic patients are screened for cardiac autonomic neuropathy by analysis of heart rate variability as part of routine diabetes follow up.<sup>9</sup> During the autumn of 2003, Holter monitoring was recorded for 24 hours in a total of 131 children and adolescents recruited from the type 1 diabetes population that regularly attends our outpatient clinic. We investigated the physical activity patterns, defined by the continuous heart rate monitoring obtained from the 24 hour Holter recording, of the 127 patients who had no heart rate variability abnormalities.<sup>9</sup> Indeed, if present, cardiac autonomic neuropathy would affect physical activity tests based on heart rate. There were three age groups: preschoolchildren aged 3–6 years ( $n = 12$ ; seven boys, five girls); schoolchildren aged 7–12 years ( $n = 52$ ; 20 boys, 32 girls); and teenagers aged 13–16 years ( $n = 63$ ; 25 boys, 38 girls). All had a stable diabetes with an illness duration of one year or longer. Mean diabetes duration was 23.6 (16.1) months (mean (SD)) for the preschoolchildren, 55.0 (30.7) months for the schoolchildren, and 62.3 (43.4) months for the teenagers. The vast majority of patients had been treated with

combinations of short and intermediate acting human insulin injected subcutaneously twice a day. The glycated haemoglobin (GHb) at the time of the Holter recording was 7.0% (1.2%) (normal range 4–6%) for the preschoolchildren, 7.9% (1.3%) for the schoolchildren, and 8.0% (1.7%) for the teenagers. The mean GHb value during the one year period preceding the Holter recording was 6.8% (1.0%) for the preschoolchildren, 7.8% (1.3%) for the schoolchildren, and 7.8% (1.5%) for the teenagers. None of the subjects had any disorders other than diabetes or took any medication. None had any known problem that might limit normal physical activity. The diabetic children did not have any clinical complications or overt diabetic nephropathy, retinopathy, or neuropathy. Parental informed consent and child assent were obtained. The study protocol was approved by our institutional review board.

Physical activity patterns of our diabetic population were compared with those of 200 healthy peers.<sup>10</sup> The control subjects (59 preschoolchildren (28 boys, 31 girls), 105 schoolchildren (55 boys, 50 girls), and 36 teenagers (17 boys, 19 girls)) were recruited from a group of children referred to the outpatient clinic for assessment of a “new” functional heart murmur. Echocardiography confirmed that all murmurs were innocent.

### Methods

The volume of physical activity was estimated from continuous heart rate monitoring during normal weekdays. Physical activity is not directly measured in this way, but the relative stress placed on the cardiopulmonary system by the activity is monitored. For ease of exposition, however, it will be assumed that volume of heart rate response is indicative of volume of physical activity.

Heart rate monitoring was recorded using an MR45 Oxford recorder type (Oxford Instruments, Largo, FL). Since it was determined that parents would not be likely to allow their

**Table 1** Time spent in minutes/day at different levels of physical activity in diabetic and healthy age matched children

Levels of activity	Diabetic preschoolchildren	Healthy preschoolchildren	Diabetic schoolchildren	Healthy schoolchildren	Diabetic teenagers	Healthy teenagers
Light	192.7 (78.1)	184.3 (54.2)	168.9 (76.7)	165.6 (74.6)	166.3 (67.5)	159.2 (68.3)
Moderate	39.1 (24.3)	40.7 (16.1)	37.9 (15.9)*	32.1 (12.1)	45.6 (26.9)*	32.1 (23.5)
Vigorous	21.3 (9.4)	21.8 (12.3)	19.0 (14.8)	22.9 (11.5)	25.2 (15.3)*	19.1 (11.3)

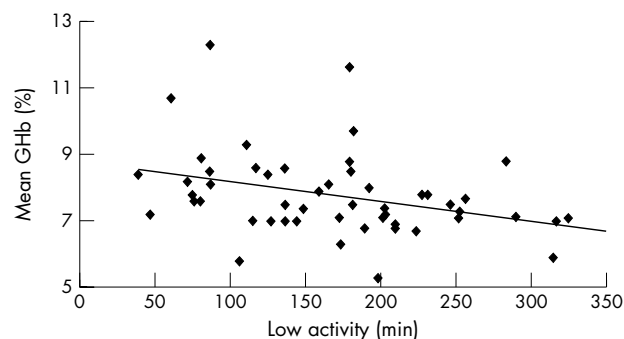
Data are given as mean (SD).

\*Significant difference between diabetic and healthy children.

children to be observed and monitored several days or all day on weekend days, all monitoring occurred Monday to Thursday over one 24 hour period. Parents were instructed to allow their child to engage in his or her normal daily activities, including sporting and other after school activities.

Heart rate was averaged every minute. Resting heart rate was obtained from an electrocardiogram performed in the early morning, without prior exercise, at rest for five minutes. The percentage of heart rate reserve (%HRR) was used to measure the amounts of physical activity at different intensities.<sup>11</sup> Resting heart rate was subtracted from 200 to calculate the heart rate reserve (HRR), and the percentage above resting heart rate was multiplied by HRR to estimate %HRR. There is general agreement that children who meet the 20–40% HRR criteria are not engaged in sedentary behaviour, that children who reach 40% HRR meet minimal guidelines for physical activity at intensities equivalent to at least 5 resting metabolic rates, and that the lower threshold for aerobic fitness effects is 50% HRR.<sup>11</sup> As in previous papers,<sup>10 11</sup> we therefore considered the time spent in light activity (corresponding to heart rate values between 20% and 40% HRR), moderate activity (corresponding to values between 40% and 50% HRR), and vigorous activity (corresponding to values above 50% HRR).

A two way ANOVA was performed on the whole population for each activity level with age group and diabetic status as classification factors together with their interaction. F tests were used to analyse the signification of both factors. A two way multivariate ANOVA was also performed, with the same classification factors and their interaction, on the vector of the time spent at each activity level. Wilks' tests were used to analyse the signification of the factors. Finally, Student's *t* test was used to compare data in healthy and diabetic children for each age group at each activity level. Statistical associations between the time spent in physical activity at different intensities and short term and mid term metabolic controls were established in the three age groups by linear regression analysis for continuous data. Statistical significance was fixed at  $p < 0.05$ .



**Figure 1** Correlation between mid-term metabolic control and time spent in light physical activity by schoolchildren.

## RESULTS

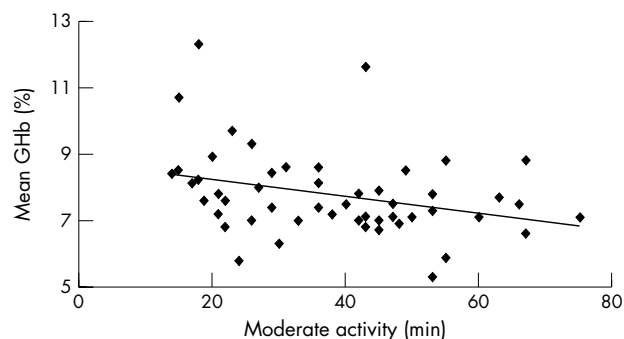
Diabetic preschoolchildren accumulated 192.7 (78.1), 39.1 (24.3), and 21.3 (9.4) minutes/day (mean (SD) of light, moderate, and vigorous physical activity, respectively; table 1). At the same activity levels, diabetic schoolchildren accumulated 168.9 (76.7), 37.9 (15.9), and 19.0 (14.8) minutes/day, and diabetic teenagers accumulated 166.3 (67.5), 45.6 (26.9), and 25.2 (15.3) minutes/day (table 1). No sex differences were observed. Sixty seven per cent of the preschoolchildren, 60% of the schoolchildren, and 65% of the teenagers engaged in more than 30 minutes/day of moderate activity; while 50% of the preschoolchildren, 29% of the schoolchildren, and 65% of the teenagers engaged in more than 20 minutes/day of vigorous activity.

The univariate analysis showed that the diabetic population is significantly more active than healthy peers when considering moderate ( $p < 0.03$ ) and vigorous activity ( $p < 0.02$ ). The multivariate analysis showed the independent effects of the intensity of the activity ( $p < 0.001$ ), age ( $p < 0.001$ ), and diabetic status ( $p < 0.001$ ) on the amount of physical activity. Finally, Student's *t* tests used in each age group for each activity level showed that diabetic schoolchildren were significantly more active than healthy peers when considering moderate activity ( $p < 0.02$ ), and that diabetic teenagers were significantly more active than healthy peers when considering moderate ( $p < 0.02$ ) and vigorous activity ( $p < 0.01$ ) (table 1).

Our data showed a significant negative correlation between the most recent GHb value and time spent in light activity in schoolchildren ( $p < 0.05$ ) and a negative correlation with a *p* value just above 0.05 between the most recent GHb value and time spent in moderate activity in the same age group. They also showed a significant negative correlation between mean GHb for one year and time spent in light (fig 1) and moderate activity (fig 2) in schoolchildren ( $p < 0.01$  and  $p < 0.05$  respectively), but not in other groups.

## DISCUSSION

Understanding the physical activity behaviour requires a valid, reliable, and practical method of assessing activity



**Figure 2** Correlation between mid-term metabolic control and time spent in moderate physical activity by schoolchildren.

levels which is appropriate for use in large groups.<sup>12–14</sup> The self-report of activity by children is difficult because they are less conscious of time than adults and tend to engage in physical activity that is chaotic, both in time and intensity. Classical pedometers are insensitive to non-locomotor forms of movement and are unable to record the magnitude of the movement detected.<sup>12–14</sup> New accelerometers are useful<sup>14–17</sup> but expensive, and only reliable with cooperating subjects (children may mimic the movements detected by the sensors during periods of inactivity). A classical alternative is to measure activity with heart rate, which is an indirect estimate of physical activity that makes assumptions based on the linearity that exists through most of the heart rate–energy expenditure relation. Heart rate monitoring can be implemented in large groups with multiple monitors; it has been the most popular objective measurement of physical activity in children,<sup>10 11 18–22</sup> and the technique has been validated against direct measures of energy expenditure, including oxygen consumption or doubly labelled water.<sup>11 12 23–25</sup> Moreover, Holter recordings are regularly performed in our diabetic population for early detection of cardiac autonomic neuropathy.<sup>9</sup> For these reasons, we decided to use this technique. Even if heart rate monitoring is popular, it has limitations because it is an indirect estimate of physical activity. Wearing a heart rate monitor may also influence the amount of physical activity and children may not habituate as rapidly to wearing a recorder in comparison with less intrusive accelerometers. A last source of error is the fact that our children were monitored during only 24 hours. One week of monitoring would probably be necessary to produce more accurate estimates of daily activities and to account for differences in weekday and weekend activity. Non-compliance of children and limited availability of expensive monitors make it not realisable when large cohorts of people are included; many previous studies suffered the same limitation.<sup>11</sup> For these reasons, data must be carefully interpreted.

Regular physical activity is an essential component of a healthy lifestyle for all children and adolescents,<sup>26</sup> including those with diabetes.<sup>27</sup> Early education and experience help establish life-long physical activity habits. To encourage adoption of active lifestyles, different experts panels developed guidelines for the amount of physical activity required to produce health benefits. They all recommend 30 minutes of daily moderate activity to be accumulated over short bouts,<sup>28</sup> and some recommend that all children aged 5 and older also perform at least 20 minutes of vigorous activities at least 3–4 days each week. Recommendations about exercise for the general population must be applied carefully to diabetic patients because exercise can have both positive and negative consequences in this population. Participating in physical activity helps them increase energy expenditure and obtain and maintain a healthy body weight, preserve or increase muscle mass, and become more sensitive to insulin and therefore be able to function with less insulin.<sup>1 27</sup> Type 1 diabetes is associated with a markedly increased risk of atherosclerotic disease<sup>29</sup> and the benefit of physical activity in improving risk factors for atherosclerosis is also to be highly valued. With careful guidance, all levels of exercise can be performed by diabetic patients who do not have complications and are in good blood glucose control.<sup>27</sup> Our diabetic children accumulated 35–45 minutes/day of moderate activity and 20–25 minutes/day of aerobic vigorous activity. Contrary to other studies,<sup>30–33</sup> they compare favourably with their healthy peers.<sup>10</sup> As the healthy subjects received no educational programme with promotion of physical activity, it suggests that our educational programme for diabetic patients may influence their physical activity behaviour. In our department a personal diabetes plan ensures that a daily

schedule is in place to keep the child's diabetes under control. The plan shows the young patient how to follow a healthy meal plan, check blood glucose levels, take insulin as prescribed, deal with potential problems related to a child's or teen's diabetes, and also achieve regular physical activity. Healthcare providers encourage regular physical activity in a positive manner at clinic or office visits. The ways to reduce barriers to exercise as well as a review of the benefits of exercise are also discussed in a chapter of a support book that provides extensive information on the illness and is given to every patient. Finally, the paediatric diabetologists organise diabetes camps during which the young patients may learn about the effects of different types of physical activity on their glucose levels. However, as all diabetic children received the programme before they were included in this study, we cannot show the influence of the educational programme on their behaviour.

Moderate sustained exercise in diabetic patients may be used to help regulate glucose on a day-to-day basis. The potential benefits of exercise include lower blood glucose concentrations during and after exercise, and improved insulin sensitivity.<sup>34</sup> Some previous studies failed to show an independent effect of physical activity training.<sup>3 6</sup> Others suggested an association between activity and glycaemic control in children,<sup>2 4 5 7</sup> but suffered from inadequate randomisation and controls, and were confounded by associated lifestyle changes.<sup>27</sup> Our study suggests that light and moderate physical activity improves metabolic control in schoolchildren, but not in teenagers. During puberty, hormonal changes contribute to the difficulty in controlling blood glucose levels. Because of the fear of hypoglycaemia in such a period of instability, diabetic teenagers may tend to increase their food intake during periods of increased activity, and as a result often remain hyperglycaemic.<sup>3</sup> It is therefore not surprising that glycaemic control is not found to improve with increased physical activity during adolescence. Most studies have concentrated on physical fitness rather than patterns of activity. Sackey and Jefferson<sup>7</sup> suggested that only activity in the morning appears to influence glycaemic control. The reason for this effect is likely to be due to the importance of hypoglycaemic factors in the morning when blood glucose levels are generally highest and to the fact that compensatory eating is probably less likely to accompany activity early in the morning compared to later in the day. Vranic and Berger<sup>35</sup> suggested that the effect of exercise on glucose homeostasis is dependent on the balance between tissue uptake and hepatic release of glucose, and this balance is influenced by the levels of insulin and counter-regulatory hormones. When the insulin level is high, exercise induces a hypoglycaemic effect; when insulin concentrations are very low, exercise may result in hyperglycaemia. Since most of the patients inject about two thirds of their insulin dose in the morning, the hypoglycaemic effect of exercise is likely to be more pronounced during that period. One day of monitoring is not enough to produce accurate estimates of individual patterns of physical activity, but it could be that the metabolic control is not influenced by physical activity in our teenagers because, contrary to younger patients, they have no opportunity for physical activity in the morning during school periods.

## Conclusion

Children with diabetes should be encouraged to participate in physical activity because exercise can benefit insulin sensitivity and improve known risk factors for atherosclerosis. Our diabetic patients met the classical paediatric guidelines for physical activity and compared favourably with our healthy population.



### What is already known on this topic

- Exercise is routinely recommended to children and adolescents with type 1 diabetes as a means of improving glycaemic control, limiting excessive weight gain, increasing sense of wellbeing, and helping in the prevention of later cardiovascular disease

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Competing interests: none declared

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### What this study adds

- Young diabetic patients meet the classical paediatric guidelines for physical activity and compare favourably with the healthy population. Educational programmes for diabetic patients may influence their physical activity behaviour
- Light and moderate physical activity may improve the metabolic control in schoolchildren

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