Habitual Physical Activity in Adult IDDM Patients

A study with portable motion meters

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The objective of this study was to assess the habitual physical activity of insulin-dependent diabetes mellitus (IDDM) patients on intensive insulin therapy. This case-control study consisted of 34 IDDM patients (14 on multiple injection therapy, 20 on continuous subcutaneous insulin infusion [CSII], and control subjects matched for sex, age, weight, height, body mass index, smoking behavior, and occupational status). Seven IDDM patients were studied before and after changing from multiple injection to CSII therapy. All patients were well controlled according to HbA_{1c}. Portable motion meters were used to assess habitual physical activity during 7 consecutive days with appreciable reproducibility (coefficient of variation 1.24%) and agreement to standardized activity protocols ($r = 0.96$, $P < 0.001$). Habitual physical activity was similar in IDDM patients on injection treatment and in controls, respectively. CSII-treated patients exhibited on the average 17% less habitual physical activity than control subjects ($P < 0.05$). Changing from multiple injection therapy to CSII lowered habitual physical activity insignificantly in seven patients. There was no indication of decreasing physical exercise (e.g., sports) by CSII in this patient group. No correlations were found between habitual physical activity and HbA_{1c} or body mass index, respectively. Habitual physical activity is similar in IDDM patients on multiple injection therapy and control subjects, but may decrease by CSII therapy.

Diabetic patients often experience impaired physical functioning (1), either because they are poorly controlled and, thus, too weak to exercise (2,3), or because they fear medication-related hypoglycemia (3,4). It is unknown whether diabetic patients with antidiabetic drugs or insulin therapy reduce habitual physical activity (HPA) (un-)intentionally, or minimize planned physical activity in order to prevent harmful lowering of blood glucose. If so, near-normoglycemic patients with insulin-dependent diabetes mellitus (IDDM), who may carry a special risk of hypoglycemia, would exhibit less spontaneous and planned physical activity than nondiabetic subjects. Furthermore, IDDM patients with continuous subcutaneous insulin infusion (CSII) therapy (5) might be hindered from physical activity even more because of the insulin pump and the indwelling subcutaneous catheter. To investigate these issues, adult IDDM patients with and without CSII and nondiabetic control subjects were studied by the use of portable motion meters.

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STUDY PARTICIPANTS

Control subjects

A control group of 53 healthy subjects was set up from the study patients' environment, with various occupations and sedentary and nonsedentary life-styles. Among them were students, medical personnel, technicians, teachers, retirees, and housekeepers. They served to validate the motion meter. Furthermore, from this pool of subjects, samples were selected to match according to sex, age, weight, height, body mass index, smoking behavior, and occupational status with study patients.

Patients

A total of 41 free-living, nonobese patients with IDDM (6) for 4 to 26 yr volunteered for the study. They were in good metabolic control; i.e., their HbA_{1c} was <8.5% (normal mean 4.9 [SD = 0.3])% of total hemoglobin; 7). All of them came from industrialized, urban districts in and around Düsseldorf.

Patients with CSII therapy

Twenty patients with long-term CSII treatment were studied after >1 yr of CSII.

Patients with intensive insulin injection therapy

Fourteen patients were studied after performing intensive insulin therapy with >3 injections/day for more than 1 yr.

Patients with intensive insulin injection therapy switching to CSII

Seven patients were studied twice, 1 mo before and 1 mo after switching from intensive insulin injection therapy to CSII. Anthropometric data of all of the

Table 1—*Anthropometric data of the study participants*

	IDDM patients, permanently on		IDDM patients changing from injections to CSII	Control subjects
	Injections	CSII		
No.	14	20	7	53
Male/female	10/4	13/7	4/3	29/24
Age (yr)	28 ± SD 5	32 ± SD 11	31 ± SD 8	30 ± SD 8
Height (cm)	177 ± SD 9	175 ± SD 8	177 ± SD 9	173 ± SD 8
Weight (kg)	71.6 ± SD 10.2	71.8 ± SD 9.6	71.2 ± SD 13	66.3 ± SD 10.1
BMI (kg/m²)	22.8 ± SD 2.4	23.4 ± SD 1.8	22.5 ± SD 2.4	22.0 ± SD 2.4

Values are means ± SD.
IDDM, insulin-dependent diabetes mellitus; CSII, continuous subcutaneous insulin infusion; BMI, body mass index.

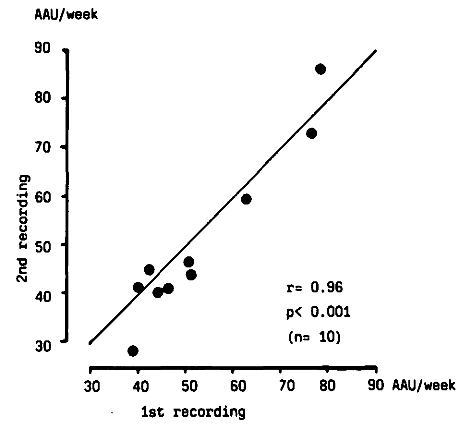

Figure 2—*Repeated recordings of habitual physical activity by motion meter, given in arbitrary activity units (AAU)/wk (n = 10 subjects).*

study participants are summarized in Table 1.

Methods

Intensive insulin injection therapy and CSII therapy were self-selected by the patients, and conducted as previously described (7,8). HPA was recorded with a motion meter (9). We used an electronic, battery-powered device (Kenz Calorie Counter, Suzuken, Ltd., Japan), obtained from Domobell, Inc. (Wiesbaden, Germany), weighing 70 g. The meter was worn at a waist belt. According to the manufacturer, the meter senses and records nine different grades of acceleration. It can be programmed with anthropometric data from the user. However, for the purpose of this study, each motion meter was programmed to measure only body movements, without regard to the individuals' age, weight, height, or sex, according to Kriska et al. (10). The participants of this study were advised not to wear the motion meter when performing heavy planned physical activity like swimming or wrestling. The motion meter was validated before using it for the study (e.g., by checking its performance against standardized activity protocols according to the literature [11,12]), by checking the within-subject reproducibility of the meter recordings, and by assessing the precision of the meters, respectively. Motion meter and standardized activity protocol results agreed significantly during 24 h of observation ($r = 0.95$, $P < 0.001$, $n = 29$; see Fig. 1), confirming previous reports (9,10). The reproducibility of 1-wk meter recordings within subjects was excellent, too ($r = 0.96$, $P < 0.001$; Fig. 2). The precision of the meters ($n = 6$, during 41 h of use) was appreciably high, with a coefficient of variation of 1.24%.

STUDY DESIGN— The motion meters were worn during the day; they were to be taken off before performing particular sports (e.g., swimming, boxing, football, etc.), when undressing, and during sleep at night, respectively.

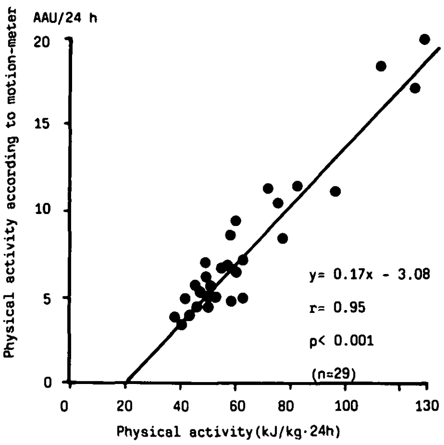

Figure 1—*Habitual physical activity as recorded in 29 subjects by standardized activity protocol according to refs. 11 and 12 (x – axis), plotted against the recordings by motion meter [given in arbitrary activity units (AAU)/24 h, y-axis].*

Control studies

To obtain a pool of control data on HPA, 53 healthy subjects used motion meters for 1 wk (5 work days and 2 holidays) each.

Patient studies

All of 34 diabetic patients (20 patients on CSII and 14 patients on insulin injection treatment) used motion meters for seven consecutive days. Seven patients on injection treatment were studied during a 1-wk period 1 mo before and 1 mo after changing over to CSII. At variance to the other study participants, these seven patients were asked to record separately type, frequency, and duration of planned physical exercise (13) during the period of motion recording.

STATISTICAL ANALYSES— Motion meter results are reported in arbitrary activity units (AAU). Data are given as means ± SD, or as means with 95% confidence intervals. Validation results were analyzed according to Gardener and Altman (14), and with linear regression analysis. $P < 0.05$ was considered statistically significant.

RESULTS — In control subjects, HPA ranged between 22.37 and 91.06 AAU/wk, with a mean of 44.67 (SD = 15.94) AAU/wk. Among the employed control subjects (n = 36), those with office work for an estimated >70% of working hours (n = 12) experienced HPA of 37.37 (SD = 7.81) AAU/wk, compared with more physically working subjects (n = 24) with 49.32 (SD = 16.66) AAU/wk (P < 0.05). The student control subjects (n = 15) exhibited an average HPA of 44.26 (SD = 18.4) AAU/wk, as did the unemployed subjects (n = 2). In the controls, HPA was unrelated to sex (see Table 1), age (r = 0.10), weight (r = −0.17), height (r = −0.05), or body mass index (r = −0.20) according to regression analyses (P > 0.05). Taken together, all of the 34 IDDM patients exhibited a mean of 38.9 (SD = 11.47) AAU/wk, with a difference of 5.77 [95% confidence interval (CI), −0.17 to 11.71] AAU/wk vs. all 53 controls (not significant). There was no sex difference in HPA. Matched insulin-injecting IDDM patients vs. control subjects exhibited 42.4 (SD = 12.0) vs. 44.6 (SD = 13.3) AAU/wk (not significant; see Table 2). However, IDDM patients on CSII exhibited significantly less HPA (36.4 [SD = 11.1] AAU/wk) compared with matched control subjects (43.9 [SD = 12.3] AAU/wk; Table 3). The difference was 7.5 (95% CI, 3.7 to 11.3) AAU/wk for all subjects on CSII and 5.7 (95% CI, 1.6 to 9.8) and 10.8 (95% CI, 1.5 to 20.1) AAU/wk for men and women on CSII vs. controls, respectively. HPA differed between CSII-treated and injection-treated patients by 6.0 (95% CI, −1.96 to 7.96) AAU/wk (not significant). HbA_{1c} and body mass index in patients on injections (r = 0.29 and r = 0.32) and patients on CSII (r = −0.06 and r = −0.26) were unrelated to HPA (not significant). In patients changing from injections to CSII treatment, HPA and planned physical activity were assessed. HPA decreased from 46.7 (SD = 9.1) to 37.7 (SD = 16.1) AAU/wk (not significant), and planned physical activity increased from 13.7 (SD = 21.5) to 18 (SD = 21.5) min/day (not significant).

Table 2—*Comparison of IDDM patients on injection therapy and matched healthy control subjects*

	IDDM patients on injection therapy	Matched healthy control subjects
Sex (m/f, n)	10/4	10/4
Age (yr)	28 ± 5	29 ± 4
Weight (kg)	72 ± 10	1 ± 8
Height (cm)	177 ± 9	178 ± 8
Occupation		
Medical personnel (n)	5	5
Students (n)	2	3
Technicians (n)	1	1
Office workers (n)	6	5
HbA_{1c} (% of total Hb)	6.8 ± 1.1*	4.9 ± 0.3
Habitual physical activity (AAU/wk)	42.4 ± 12.0	44.6 ± 13.3

Values are means ± SD, unless otherwise indicated. IDDM, insulin-dependent diabetes mellitus; Hb, hemoglobin; AAU, arbitrary activity units.
*P < 0.05 vs. controls.

Table 3—*Comparison of IDDM patients on insulin pump therapy (CSII) and matched healthy control subjects*

	IDDM patients on CSII therapy	Matched healthy controls
Sex (m/f, n)	13/7	13/7
Age (yr)	32 ± 11	30 ± 9
Weight (kg)	72 ± 10	69 ± 11
Height (cm)	175 ± 8	176 ± 8
Occupation		
Medical personnel (n)	4	5
Students (n)	3	3
Technicians (n)	3	2
Office workers (n)	7	7
Teachers (n)	2	1
Retirees (n)	1	1
Housekeepers (n)	0	1
HbA_{1c} (% of total Hb)	7.0 ± 1.0*	4.9 ± 0.3
Habitual physical activity (AAU/wk)	36.4 ± 11.1*	43.9 ± 12.3

Values are means ± SD, unless otherwise indicated. IDDM, insulin-dependent diabetes mellitus; CSII, continuous subcutaneous insulin infusion; Hb, hemoglobin; AAU, arbitrary activity units.
*P < 0.05 vs. controls.

DISCUSSION — This study indicates that HPA is comparable in IDDM patients and healthy control subjects in an industrialized, urban setting. There was no significant difference in HPA between near-normoglycemic IDDM patients on injection treatment and healthy control subjects; thus, good diabetes control was not associated with avoiding physical activity. However, patients on CSII treatment exhibited less HPA than control subjects or patients on injection treatment, suggesting the impact of continuously wearing the insulin pump and the catheter tubing. Changing from injection treatment to CSII therapy also reduced HPA. However, the difference failed to reach statistical significance because of the small sample size. To confirm a difference in means of 6 AAU/wk (with a SD of ~12 AAU/wk), ~100 probands are needed to achieve a power of 80% at P < 0.05 (15).

The reduction in HPA might be related to the (in-)compatibility of CSII and some sports disciplines, such as swimming or ball games. In some patients, problems like this may be crucial for adherence to CSII therapy, as shown by Wolf et al. (16). Patients who like swimming may feel particularly hampered because CSII has to be interrupted before swimming (insulin pumps are not waterproof). It would also be appropriate to take off the pump when performing other sports disciplines, such as wrestling, boxing, or football. However, short-term, nonexhaustive exercise, such as bicycling, can be well managed with the pump running on basal rate mode, as shown by Trovati et al. (17). When CSII-treated patients are planning moderate exercise after a meal, the prandial insulin bolus needs to be reduced to prevent hypoglycemia (18). Long-term exercise like cross-country skiing or mountaineering may also be performed on CSII, but in such cases, the basal rate should be reduced appropriately (3). Short-term exhaustive exercise can successfully be handled with the pump on, as shown by Mitchell et al. (19). These authors stress that different insulin strategies are required for intense compared with moderate exercise in IDDM patients.

Is a reduction in HPA of 6 AAU/wk clinically relevant for IDDM patients on insulin pump therapy? According to Fig. 1, this amount of HPA would relate to ~53 kJ (12.8 kcal)/kg body wt/wk. In a 72 kg person, this would mean a reduction in HPA by 545 kJ/day [i.e., <6% of all energy expenditure, apparently too little to impair his/her level of physical fitness (20)]. We believe that the decreased HPA in CSII-treated patients is more likely to represent another benign molestation of this otherwise beneficial (5,7,16) therapy, rather than another harmful predisposition for unfitness (21). This assumption is supported by the fact that the subgroup of patients switching from injections to CSII felt unrestricted in doing planned, vigorous exercise as they liked. Thus, insulin-pumping, unlike TV-watching (22), is compatible with a healthy, nonsedentary life-style (23). Because spontaneous physical activity accounts for a substantial proportion of 24-h energy expenditure (24), reduction of HPA could promote weight gain by decreasing energy expenditure. Weight gain occurring in some IDDM patients after starting CSII (25) has indeed been reported e.g., by the Diabetes Control and Complications Trial (DCCT; 26). However, in the DCCT study, weight gain was also observed with multiple injection therapy (26) and was closely related to the decline in HbA_{1c} achieved by either therapy. Thus, the energy-saving effect of improved metabolic control (26) rather than a reduction in HPA by CSII is most likely to be the cause of weight gain in those patients. We found no correlation between HPA and body mass index among our patients (all of whom were nonobese). This is consistent with previous observations on spontaneous physical activity in extremely obese or thin, nondiabetic subjects (24). There was neither correlation between HPA and actual HbA_{1c} value in our study, probably because only well-controlled IDDM patients had been recruited. Thus, the extent to which body weight and glycemic control affect HPA (and vice versa) in normal weight patients with IDDM remains to be elucidated.

In summary, we have studied habitual, spontaneous physical activity in IDDM patients on injections and CSII treatment, and in matched healthy control subjects. It was found that injection-treated IDDM patients exhibited about the same physical activity as the controls, whereas physical activity in CSII-treated patients was reduced by about 17%. The clinical significance of these findings remains to be established.

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