Assessing and targeting key lifestyle cardiovascular risk factors at the workplace: Effect on hemoglobin A1c levels

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ABSTRACT

Purpose Despite the key role played by lifestyle habits in the epidemic of type 2 diabetes (T2D), nutritional quality and physical activity are not systematically considered in clinical practice. The project was conducted to verify whether assessing/targeting lifestyle habits could reduce hemoglobin A1c (HbA1c) levels of employees.

Methods The intervention consisted of a 3-month competition among teams of five employees to favor peer-based support in the adoption of healthier lifestyle habits (Eat better, Move more, and Quit smoking) (n = 900). A comprehensive cardiometabolic/cardiorespiratory health assessment was conducted before and after the contest (nutrition/physical activity questionnaires, blood pressure, anthropometric measurements, lipid profile, HbA1c, fitness). HbA1c levels were used to identify individuals with prediabetes (5.7%–6.4%) or T2D (>6.5%).

Results At baseline, 51% of the employees had increased HbA1c levels (>5.7%). The HbA1c levels were associated with waist circumference, independently of body mass index. Subjects with prediabetes showed a higher waist circumference as well as a more deteriorated cardiometabolic profile compared to workers with normal HbA1c levels. After the intervention, employees with elevated HbA1c significantly reduced their HbA1c levels.

Conclusion Results suggest that assessing/targeting key lifestyle correlates of the cardiometabolic profile represents a relevant approach to target abdominal obesity and fitness with a significant impact on HbA1c levels.

KEY MESSAGES

- The prevalence of employees with prediabetes or undiagnosed type 2 diabetes (T2D) was rather high in our cohort, suggesting that, from a public health standpoint, identification of those individuals is not optimal.
- Employees with prediabetes or T2D showed a higher waist circumference and a more deteriorated cardiometabolic risk profile compared to those with normal HbA1c levels.
- The significant reduction in HbA1c levels observed in response to the 3-month intervention supports the notion that a program which assesses and manages cardiometabolic risk at the workplace by also focusing on key lifestyle factors (nutritional quality and physical activity levels) represents an interesting option to reduce the risk of developing diabetes among high-risk individuals or to improve glycemic control and related cardiometabolic risk in patients with T2D.

Introduction

The prevalence of type 2 diabetes (T2D) is increasing worldwide, with a significant proportion of patients being undiagnosed (1). Poor glycemic control is known to predict development of micro- and macrovascular complications associated with diabetes (2). The American Diabetes Association (ADA) recommends that patients with T2D should have glycated hemoglobin (HbA1c) levels less than 7% for the prevention of chronic complications associated with diabetes (3). Furthermore, the ADA now recommends using HbA1c to diagnose T2D using a cut-off value of ≥6.5%. Individuals with HbA1c levels of 5.7%–6.4% are considered as having suboptimal glucose levels (prediabetes) and as being at increased risk for diabetes and cardiovascular diseases. In the United States, the total annual cost of diabetes is estimated to represent 245 billions of dollars (4), with a large proportion spent to treat the chronic complications of diabetes. Diabetes not only has financial...
consequences on the health care system, but it also has consequences on the competitiveness of the private sector as it is an important cause of absenteeism and productivity losses (4).

It is well established that abdominal obesity and physical inactivity are two major risk factors for the development of T2D and cardiovascular diseases (5). In addition, healthy eating habits and increased physical activity level are the cornerstone of the management and treatment of patients with T2D. Several studies have shown that lifestyle modification programs, combining improved dietary habits and increased physical activity, are effective to reduce abdominal adiposity and to improve insulin sensitivity and glycemic control, independently of weight loss (6,7). Unfortunately, very few cardiometabolic risk evaluation and management programs assessing and targeting nutritional quality, physical activity, abdominal adiposity, and cardiorespiratory fitness are used in clinical practice. There has been a major shift in recent nutritional guidelines with more emphasis placed on healthy food patterns rather than on macronutrient composition such as the lipid content of the diet (US nut guidelines) (8). Accordingly, we have recently reported in a 1-year lifestyle modification program that it was the global quality of the diet rather than changes in macronutrient composition which was predictive of improvements in the cardiometabolic risk profile (9). Thus, we have been interested in assessing and targeting overall nutritional quality rather than focusing on the calorie and fat content of the diet.

Accordingly, despite the fact that numerous guidelines have shown the tremendous health benefits of 150 minutes of moderate-intensity aerobic exercise per week, there is still almost one-third of our population who are physically inactive (10). In that regard, it has been documented that despite the fact that family physicians are aware of the importance of nutrition and physical activity in the management of patients with T2D (11), less than one-third of them raise the issue of nutrition, while 17% address the importance of physical activity when they manage their patients with T2D (12). Thus, the current clinical model does not efficiently assess and target lifestyle factors which are the basis of the optimal management of patients with T2D. It is with this problem in mind that we wanted to test the potential of a cardiometabolic risk evaluation/management program which was not only designed for the workplace, but which also aimed at key behaviors such as nutritional quality and level of physical activity.

The objective of this pilot study was therefore to test whether assessing and targeting lifestyle habits at the workplace could have an impact on HbA1c levels of employees involved in a cardiometabolic risk assessment/management program.

Material and methods

Employees (n = 900) from six different companies (mostly union blue-collar workers producing goods) were recruited on a voluntary basis in a pilot project of the ‘Grand Défi Entreprise’. No exclusion criteria were applied. They were invited to participate in a 3-month in-house competition among teams of five employees in order to favor peer-based support in the adoption of healthier lifestyle habits (Eat better, Move more, and Quit smoking) (13). The participation rate was 68% of the workforce. Details of this workplace cardiometabolic risk evaluation/management program have been published elsewhere (13). Briefly, a cardiometabolic risk profile including cardiorespiratory fitness was assessed at baseline and after a 3-month intervention focusing on improving overall nutritional quality and on increasing the level of physical activity (13). The assessment was performed by health care professionals in a mobile risk assessment unit at the workplace during working hours. The evaluation included standardized questionnaires on medical history and lifestyle habits (including nutritional quality and physical activity level), hemodynamic and anthropometric measurements, waist circumference, lipid profile, cardiorespiratory fitness, and glucose control. Before the project was initiated, the comprehensive cardiometabolic risk assessment had been previously presented and endorsed by both the top management and the workers’ unions. The study was approved by ethics committee of the Quebec Heart and Lung Institute (IUCPQ), and all subjects signed a written informed consent to participate in this study.

Lifestyle habit questionnaires

Physical activity index

The physical activity level was assessed by a validated short questionnaire used in the EPIC study, which has been shown to be related to the risk of cardiovascular disease (14). The questionnaire estimated physical activity level at work and during leisure time over the last year by season. Physical activity level was expressed as time spent being active during leisure time per week. The questionnaire was completed before the contest for the evaluation of physical activity level at baseline as well as after the 3-month competition which targeted lifestyle habits.
**Nutritional quality index**

The quality of diet was evaluated using the validated Dietary Screening Tool (DST) composed of 25 questions focusing mainly on eating behaviors for the assessment of a nutritional quality score which can vary from 0 to 100 (15). The nutritional quality index (NQI) allows classifying individuals into three categories of risk: 1) low risk (a score ≥75), 2) moderate risk (a score of 60–74), and 3) high risk (a score <60). It takes approximately 10 minutes to complete the questionnaire. Significant correlations were found between NQI and cardiovascular risk markers (–0.14 ≤ r ≤ –0.26; p ≤ 0.0001).

**Prediction of cardiovascular risk**

To estimate the 10-year cardiovascular risk, the Framingham risk score was calculated using the weighted risk factors: age, gender, total cholesterol, HDL-cholesterol, smoking history, blood pressure, and diabetes mellitus (16). Vascular age was also calculated according to the definition of D’Agostino et al. (17). The Diabetes Risk Score, designed to identify high-risk subjects for T2D in the population, was also calculated using the validated model (18).

**Anthropometric measurements**

Height, weight (19), and waist circumference (WC) (20) were measured according to standardized procedures, and body mass index (BMI) was calculated from weight and height. Individuals with a BMI between 18.5 and 24.9 kg/m² were classified as having normal weight, whereas individuals with a BMI ranging from 25 to 29.9 kg/m² and ≥30 kg/m² were classified as overweight and obese, respectively (20).

**Hemodynamic measurements**

Blood pressure and pulse rate measurements were taken on both arms with an automated sphygmomanometer (Suntech 247, Suntech Medical, Morrisville, NC, USA) after the patient had been resting in the sitting position for at least 5 minutes. Left arm blood pressure measurements were used for the analyses.

**Blood glucose control**

To evaluate blood glucose control and also to identify individuals with T2D or at high risk of T2D (3), glycated hemoglobin (HbA1c) levels were measured with the standardized procedure using the Cobas Integra 400/800 system (Roche, Ontario, Canada), based on the turbidimetric inhibition immunoassay (TINIA) (21). The final result is expressed as percent HbA1c.

**Plasma lipid profile**

Blood samples were collected from the forearm vein into lithium heparin tubes containing EDTA (Miles Pharmaceuticals, Rexdale, Ontario, Canada) for the measurement of plasma lipid and lipoprotein levels using standardized procedures with an Abaxis Piccolo Xpress Chemistry Analyzer (22).

**Submaximal treadmill test**

Cardiorespiratory fitness (CRF) was assessed using a submaximal treadmill test according to a homemade protocol on a TMX 425 treadmill (Trackmaster, Newton, KS, USA) linked to a Tango+ digital sphygmomanometer (SunTech Medical, Morrisville, NC, USA). The protocol began with a warm-up workload of 2.5 mph with a 0% slope. The second stage was performed at a speed of 3.5 mph with a 2% slope. The third stage was adjusted in an attempt to reach 75% of the age-estimated maximal heart rate (HR). If necessary, a fourth stage was performed. Estimated VO₂max was predicted by extrapolation to age-predicted maximal heart rate (23). HR at a standardized submaximal treadmill stage (3.5 mph, 2% slope) and estimated maximal oxygen consumption (VO₂max) were the variables considered as indicators of CRF in the present study.

**Lifestyle risk score**

Questions on lifestyle habits (nutritional quality and physical activity level), as well as waist circumference and estimated VO₂max data were combined to generate a lifestyle risk score. This score was calculated by generating quartiles for each of these four variables, and points were allocated as follows: more points were awarded when physical activity level (Q1: 4 points; Q2: 3 points; Q3: 2 points; Q4: 1 point), nutritional quality index (Q1: 4 points; Q2: 3 points; Q3: 2 points; Q4: 1 point), and estimated VO₂max (Q1: 4 points; Q2: 3 points; Q3: 2 points; Q4: 1 point), were lower and when waist circumference (Q1: 1 point; Q2: 2 points; Q3: 3 points; Q4: 4 points) was higher. Therefore, the lifestyle risk score could range from 4 (low estimated risk) to 16 points (high estimated risk).

**Lifestyle intervention**

All information from the cardiometabolic/cardiorespiratory evaluation was collected with an iPad and
automatically stored on a server. The evaluation lasted about one hour per participant, and employees received a printed confidential report at the end of their 1-hour evaluation. The employees received an individualized presentation of their health report along with printed recommendations (healthy eating and physical activity) explained by a health care professional.

Following the initial evaluation, a friendly in-house competition was conducted within each company independently and promoted the adoption of healthier lifestyle habits (Eat better, Move more, and Quit smoking). Employees had to regroup in teams of five employees. They had the opportunity to select their teammates.

Using their personalized recommendations, each member of a team had to target three to four food habits that they agreed to work on (e.g. increase fruit and vegetable intake or reduce soft drink intake) in order to improve their nutrition quality. Points were allowed for every target achieved per day. For physical activity, one point was given for each 15 minutes of continuous physical activity completed during leisure time. A day without smoking also gave one point for employees who engaged themselves to quit smoking. Each team had access to the Grand Défi Entreprise website to record points on the personalized profile of each team. The website worked as a diary to account for achievements during the 3-month period which could be shared with the other team members (added points of the teams are listed in a TOP achievers list). During the contest, the employees received information capsules to help them develop healthy eating habits and physical activity as well as help them find reliable resources in their respective communities. At the end of the 3-month period, points were given to each team as a function of improved risk variables such as stopping smoking during the whole period and reducing the waistline. Teams who globally improved their lifestyle habits the most had more chances to win a major prize offered by the top management such as gift certificates (sport equipment), travel packages, helicopter tours with gourmet meals, VIP show tickets with gourmet meals, as well as spa and massage packages with accommodation. Although the concept of the incentive was part of the intervention, there was no requirement on the investigators’ side regarding the form and the magnitude of the incentive provided.

Statistical analyses
Data are presented as means ± SD in the tables and as means ± SE in the figures. The Shapiro–Wilk test was used to examine the distribution of each variable, and logarithmic transformations were applied to variables showing abnormal distribution. Paired t tests were performed to compare baseline and post 3-month intervention levels of anthropometric parameters and cardiometabolic risk (CMR) markers. Subjects were classified into four subgroups according to their blood glucose homeostasis status assessed by HbA1c: group 1, normal glucose homeostasis (HbA1c < 5.7%); group 2, suboptimal glucose homeostasis or prediabetes (5.7% ≤ HbA1c < 6.5%); group 3, untreated T2D (de novo) (HbA1c ≥ 6.5%); and group 4, diagnosed and treated T2D. A one-way ANOVA was performed to compare cardiometabolic risk profile between subgroups of glucose homeostasis status and to compare HbA1c levels between quartiles of WC. A p value < 0.05 was considered statistically significant. All statistical analyses were performed with the SAS package (SAS 9.2 Institute, Cary, NC, USA).

Results
Nine hundred workers, including 736 men and 164 women, participated in the 3-month friendly competition aiming at the adoption of healthier lifestyle habits. At baseline, the mean age of our population was 44.8 years, and average BMI was 27.8 kg/m². More than 44% of employees were overweight, and 27% were considered obese. Furthermore, 63% of men and 72% of women had WC values exceeding the cut-off levels proposed by the International Diabetes Federation (IDF), namely, 94 cm and 80 cm in men and women, respectively. Only 49% of the sample had desirable HbA1c levels (less than 5.7%). A large proportion of employees (46%) had suboptimal HbA1c levels (prediabetes) (5.7% ≤ HbA1c < 6.5%), whereas almost 6% had HbA1c ≥ 6.5% or diagnosed and treated T2D. Among employees with T2D, 37 reported to be treated, while 14 subjects were found to have HbA1c levels greater than 6.5%. Mean HbA1c levels according to blood glucose homeostasis status at baseline are shown in Figure 1A. Table I shows baseline and post-3 month characteristics of employees according to their plasma glucose homeostasis status at baseline. BMI, blood pressure, VLDL-cholesterol, non-HDL-cholesterol, and triglyceride levels increased across categories of blood glucose control, while HDL-cholesterol, NQI, and estimated VO₂max decreased. However, employees with treated T2D had lower levels of LDL-cholesterol and non-HDL-C than those with normal blood glucose homeostasis or prediabetes. Among employees with untreated and treated T2D, more than 42% and 67% reported being treated with lipid-lowering drugs, respectively, while the prevalence of individuals on such drugs was lower in
subjects with normal or impaired glucose homeostasis (7% and 20%, respectively). At the baseline evaluation, employees with T2D showed higher HR at a submaximal workload during the exercise test than the other subgroups (p < 0.05). Finally, WC increased across categories of blood glucose levels at baseline (Figure 1B).

In order to explore the relationship between WC and HbA1c levels, subjects were classified into quartiles (Q) of WC measured at baseline (not shown). HbA1c levels increased across waist circumference quartiles (Q1, Q2, Q3, Q4).

Blood glucose homeostasis improved in response to the 3-month intervention with a significant decrease in mean HbA1c (Figure 1A). Thus, prevalence of prediabetes decreased from 45.7% to 42.3%, while prevalence of individuals with normal HbA1c levels increased from 48.7% to 52.2% after the 3-month intervention. After the 3-month lifestyle intervention, significant reductions in BMI, blood pressure, and submaximal HR were observed within each subgroup of glucose homeostasis status, while nutritional quality index increased (Table I). Increases in the global nutritional quality index were mainly explained by changes in the consumption of fruits and vegetables, whole-grain products, less added sugar and fat content of the diet, p < 0.0001 (results not shown). Moreover, WC decreased within each glucose homeostasis group after the intervention (Figure 1B). Subjects with normal glucose homeostasis and prediabetes also significantly improved their lipid profile as well as their estimated VO2max. Whereas no significant change was observed in estimated VO2max among employees with untreated or treated T2D, these individuals nevertheless showed a reduced HR at a standardized submaximal workload, suggesting improved capacity to perform prolonged endurance exercise in response to the intervention (Table I).

At baseline, subjects with treated and untreated T2D had a higher lifestyle risk score (worse) than subjects with normal blood glucose homeostasis or prediabetes. Subjects with prediabetes also had a higher lifestyle risk score than normoglycemic subjects. Figure 3 shows HbA1c level according to quartiles of lifestyle risk score at baseline. Employees with T2D using hypoglycemic drugs were excluded from the analyses. HbA1c levels at baseline increased across quartiles of lifestyle risk score. Subjects in the two top quartiles improved their glucose control after the intervention. Similarly, additional analyses in subjects with treated T2D showed that employees in the two upper tertiles of lifestyle risk score significantly reduced their HbA1c after the intervention.

Figure 1. A: HbA1c levels at baseline and after the 3-month workplace lifestyle intervention among the four groups classified on the basis of blood glucose homeostasis at baseline. B: Waist circumference at baseline and after the 3-month workplace lifestyle intervention across the four groups classified on the basis of blood glucose homeostasis at baseline. Thresholds used for categories were: 1 = normal blood glucose homeostasis (HbA1c < 5.7%); 2 = prediabetes (6.5% < HbA1c < 5.7%); 3 = newly diagnosed type 2 diabetes (untreated) (HbA1c ≥ 6.5%); and 4 = diagnosed and treated type 2 diabetes. Significantly different from baseline: †P < 0.01, ‡P < 0.0001. Data are presented as mean ± SE, n = 900. HbA1c = glycated hemoglobin; T2D = type 2 diabetes.

5.55%±0.28%; Q2, 5.62%±0.35%; Q3, 5.68%±0.30%; Q4, 5.78%±0.51%). Compared to employees in other quartiles, subjects in the top waist quartile had significantly higher HbA1c levels (p < 0.05).

To investigate further the specific contribution of abdominal adiposity to HbA1c levels, subjects were first stratified according to categories of BMI (normal weight, overweight, and obese) and then further classified on the basis of the 50th percentile of WC (above or below) within each BMI category (Figure 2). Compared to subjects with a WC below the 50th percentile in the same BMI category, overweight and obese employees with a WC above the 50th percentile showed significantly higher HbA1c (Figure 2).
Table I. Participant's characteristics at baseline and after the 3-month intervention according to their blood glucose homeostasis status at baseline.

|                        | Normal (n = 438) | Prediabetes (n = 411) | T2D untreated (n = 14) | T2D treated (n = 37) |
|------------------------|------------------|-----------------------|------------------------|---------------------|
|                        | Baseline Post-3 months | Baseline Post-3 months | Baseline Post-3 months | Baseline Post-3 months |
| Age (years)            | 41.6 ± 10.0 (±0.3**) | 41.9 ± 10.0 (±0.3**) | 47.3 ± 9.3 (±0.3**)    | 46.6 ± 9.3 (±0.3**)  |
| BMI (kg·m⁻²)           | 26.9 ± 4.2 (±0.7**) | 26.2 ± 3.9 (±0.7**)   | 28.0 ± 4.4 (±0.8**)    | 27.2 ± 4.2 (±0.8**)  |
| Systolic BP (mmHg)     | 129 ± 13 (±5**)    | 124 ± 12 (±5**)       | 133 ± 14 (±7**)        | 126 ± 14 (±7**)      |
| Diastolic BP (mmHg)    | 81 ± 9 (±7**)      | 78 ± 9 (±7**)         | 83 ± 10 (±7**)         | 79 ± 9 (±7**)        |
| Lipid profile          |                  |                       |                        |                     |
| VLDL-C (mmol·L⁻¹)      | 0.80 ± 0.40 (–0.10**) | 0.71 ± 0.40 (–0.10**) | 0.84 ± 0.39 (–0.14**) | 0.73 ± 0.38 (–0.14**) |
| LDL-C (mmol·L⁻¹)       | 2.50 ± 0.67 (–0.07**) | 2.43 ± 0.65 (–0.07**) | 2.58 ± 0.75 (–0.12**) | 2.46 ± 0.67 (–0.12**) |
| HDL-C (mmol·L⁻¹)       | 1.32 ± 0.33 (–0.02**) | 1.34 ± 0.32 (–0.02**) | 1.28 ± 0.32 (–0.02**) | 1.31 ± 0.32 (–0.02**) |
| Triglycerides (mmol·L⁻¹) | 1.87 ± 1.04 (–0.25**) | 1.61 ± 0.94 (–0.25**) | 2.07 ± 1.17 (–0.40**) | 1.67 ± 0.95 (–0.40**) |
| Non-HDL-C (mmol·L⁻¹)  | 3.34 ± 0.75 (–0.18**) | 3.16 ± 0.72 (–0.18**) | 3.50 ± 0.84 (–0.28**) | 3.21 ± 0.77 (–0.28**) |
| Nutritional quality index | 61.5 ± 12.8 (+8.2**) | 69.8 ± 11.2 (+8.2**) | 59.8 ± 13.0 (+9.5**)  | 62.9 ± 12.1 (+9.5**)  |
| Submaximal HR (3.5 mph, 2%) (bpm) | 114 ± 15 (–3**)  | 110 ± 15 (–3**)       | 114 ± 14 (–4**)        | 109 ± 14 (–4**)      |
| Estimated VO₂max       | 43.6 ± 11.9 (+1.1**) | 44.6 ± 11.6 (+1.1**)  | 40.8 ± 11.8 (±0.20++)  | 42.6 ± 12.0 (±0.20++) |
| Time of physical activity/ week (h) | 5.3 ± 4.9 (±0.7)  | 5.0 ± 5.2 (±0.7)      | 4.5 ± 4.2 (±1.3)       | 5.8 ± 5.7 (±1.3)     |

Data are presented as mean ± SD, n = 900. Significant change:
*P < 0.05, **P < 0.01.
*Significantly different from normal glucose tolerance subgroup at baseline.
**Significantly different from prediabetes group at baseline.
Significantly different from untreated T2D group at baseline.
BMI = body mass index; BP = blood pressure; HR = heart rate; T2D = type 2 diabetes.

(Supplementary Figure, available online). Furthermore, correlation analyses revealed that the lifestyle risk score was significantly associated with HbA1c (r = 0.22, p < 0.0001), as well as with the Framingham risk score (r = 0.20, p < 0.0001), the Framingham vascular age (r = 0.30, p < 0.0001), and with the diabetes risk score (r = 0.48, p < 0.0001) (data not shown).

Finally, we examined the correlations between changes in the individual components of the lifestyle risk score and changes in HbA1c levels in the four subgroups (Supplementary Table, available online). In the rather large (n = 411) subgroup of individuals with prediabetes, significant correlations were found between changes in two out of the four individual components of our lifestyle risk score (waist circumference and estimated VO₂max) and changes in HbA1c levels.

**Discussion**

We designed the present pilot study to test the added value of measuring/targeting lifestyle risk factors (nutritional quality, physical activity, waist circumference, and cardiorespiratory fitness) in a cardiometabolic risk management program designed for the workplace. Details of the intervention and overall findings of this pilot intervention have been recently published (13). The present analyses, which focused on HbA1c levels, aimed at: 1) testing the hypothesis that lifestyle risk factors were key determinants of HbA1c levels among workers; and 2) targeting these lifestyle risk factors which could have beneficial effects on HbA1c levels and related cardiometabolic risk variables.

Results of the present study show that more than 51% of workers had prediabetes or T2D based on HbA1c levels. Among workers with T2D, 28% were newly diagnosed and therefore not treated for their diabetes. Results of our pilot study suggest that an intervention targeting the improvement of nutritional quality and increasing physical activity for only 3 months appears as a promising approach to reduce WC, improve cardiorespiratory fitness, and significantly improve glycemic control, regardless of the glucose tolerance status at baseline.

We also found that the four lifestyle variables considered in our study were indeed very significant effects of physical activity on HbA1c levels.
correlates of circulating HbA1c levels. With the current worldwide epidemic of T2D, our results suggest that it may also be relevant to screen for these lifestyle variables in order to implement approaches (such as the pilot intervention conducted in the present study) aiming at the prevention of T2D or at the optimal management of patients with T2D.

Analyses presented in the current study also showed a high prevalence of subjects with a WC exceeding the IDF recommendations. It is well documented that excess abdominal adiposity is associated with ‘diabetogenic’ metabolic abnormalities (5). As expected, WC increased across categories of plasma glucose homeostasis in the present study. Furthermore, higher HbA1c levels were associated with an overall deterioration in the cardiometabolic risk profile. Our results also indicate that HbA1c levels increased across categories of WC, irrespective of the BMI categories considered. This finding is concordant with the diabetes risk associated with an increased WC within each BMI category (24).

As reported in many lifestyle modification programs (25–27), the present pilot intervention produced significant reductions in waist circumference and HbA1c levels. The large benefits associated with regular exercise in patients with T2D are well established (7,28–30). The American College of Sport Medicine (ACSM) and the ADA both recommend that patients with T2D should perform at least 150 minutes of moderate-intensity aerobic physical activity per week and resistance training three times per week (31,32). It has been suggested that exercise-associated metabolic benefits could be mediated, in part, by the mobilization of visceral/ectopic fat (6,33). Accordingly, employees involved in the present program significantly decreased their WC by more than 4 cm after only 3 months, regardless of their glucose tolerance status at baseline. Borel et al. have recently shown that reduction in abdominal visceral fat could lead to an enhancement in insulin sensitivity in viscerally obese men with metabolic syndrome, independently of the change in total body fat (6).

In addition to the beneficial effects of endurance exercise to mobilize visceral/ectopic fat, regular exercise has been reported to have weight/adiposity-independent hypoglycemic effects which may contribute to the improved glycemic control (34,35). In a meta-analysis, Boule et al. showed that exercise training reduces HbA1c by approximately 0.66% in patients with T2D (28). Although advice to increase physical activity alone seems to decrease HbA1c to a lesser extent than structured exercise training, it is associated with a better glycemic control when combined with a dietary intervention (36). A modest overall absolute reduction of 0.07% HbA1c was observed in our population after our 3-month lifestyle program. However, our cohort included subjects with normal HbA1c levels at baseline. Employees with prediabetes as well as with untreated or

Figure 2. HbA1c levels of participants with low versus high waist circumference values (below or above 50th percentile) within each BMI category. Patients with T2D using hypoglycemic drugs were excluded from analyses (n = 37). Data are presented as mean ± SE. *Significantly different from normal BMI with a waist circumference below 50th percentile; †Significantly different from overweight with a waist circumference below 50th percentile. HbA1c = glycated hemoglobin; BMI = body mass index.

Figure 3. HbA1c levels at baseline and after the 3-month lifestyle intervention across the quartiles of lifestyle risk score assessed at baseline. Data are presented as mean ± SE. Patients with T2D using hypoglycemic drugs were excluded from analyses (n = 37). 1,2,3Baseline HbA1c levels significantly different from the corresponding quartiles. Significantly different from baseline: *P < 0.05, †P < 0.01.
treated T2D reduced their HbA1c levels by 0.13%, 0.64%, and 0.69% respectively. Such changes, which were similar to what has been observed in previous lifestyle intervention studies with baseline HbA1c similar or higher than ours (≥5.70%) (25,37), confirm the clinical relevance of targeting lifestyle to improve glucose control in patients with prediabetes or T2D.

Exercise training/physical activity and weight loss induced by diet are both associated with improved glycemic control and insulin sensitivity by partly distinct mechanisms. To assess the impact of WC and fitness, as well as behaviors on glycemic control, we generated a lifestyle risk score combining nutritional quality, physical activity habits, estimated VO2max. and WC. The higher the lifestyle risk score was, the greater was the risk. This score was significantly associated with HbA1c, as well as with the diabetes risk score and the Framingham risk score. These results highlight the importance of targeting CRF and WC through improved nutritional quality and physical activity, in order to improve glycemic control. Indeed, substantial differences in this lifestyle score were observed across our four groups of workers with progressively increasing HbA1c levels. As observed in previous lifestyle intervention studies, employees in quartiles with a higher lifestyle score at baseline were those who benefited the most from this workplace intervention (38). Such findings are encouraging and should pave the way to the development of large trials testing the added value of measuring/targeting key behaviors in the optimal management of individuals with T2D or at high risk of developing this condition.

Similarly to what has been observed in previous studies, prevalence of prediabetes and undiagnosed diabetes was rather high in our population (1), suggesting that screening and management of diabetes is far from being adequate. It is well established that a poor glycemic control is associated with the development of several micro- and macrovascular complications associated with diabetes (2), which increase comorbidities as well as reduce survival and quality of life. These are very expensive health conditions (39), the costs of which could be reduced by prevention (7). Previous studies have suggested that each 1% drop in HbA1c could reduce the risk of major cardiovascular events by 20% and the risk of microvascular complications by 37% (2,40). Vuori recently discussed the feasibility and the effectiveness of advising on physical activity in ‘real-life’ conditions to reduce chronic diseases, such as cardiovascular diseases and T2D, as well as to reduce health costs (41). Growing evidence supports the notion that the workplace could become a privileged environment for the early detection of established CVD risk factors and to promote healthy lifestyle habits (42–44). Several workplace lifestyle intervention programs have shown that nutritional and PA programs are effective to improve nutritional quality, fitness, and weight management (45). Our pilot study provides evidence that targeting both CRF and WC, through regular PA/exercise and improving nutritional quality, can indeed improve the CMR profile (13). Simple tools must be implemented in clinical practice to help high-risk patients to implement physical activity in their lifestyle. Results of the present study support the notion that a program which assesses and manages CMR at the workplace, by also targeting key lifestyle factors (nutritional quality and physical activity levels), represents an interesting option for the assessment/management of individuals with diabetes or at increased risk for the development of this costly chronic disease.

Our study documents the feasibility of improving glycemic control through a 3-month lifestyle modification intervention designed for the workplace. The present study was not a randomized trial. Our program was offered to all employees within each company with no exclusion criteria. We acknowledge the fact that numerous confounding factors (sex, age, socio-economic status, employee status, initial health status, smoking or not, initial health, and risk factor status) could modulate the response to this cardiometabolic/ cardiorespiratory health evaluation and management program that we designed for the workplace. However, the study was not designed to isolate the contribution of these confounding factors, and further studies will have to be conducted to address their influence on the employees’ response. The advantage, however, of the present intervention is that it reflects a study conducted in a ‘real-world’ setting, no employee having been excluded from the evaluation/management program. Finally, the duration of the intervention was relatively short. Although these preliminary results were encouraging and document the relevance of assessing and targeting some key lifestyle features in a clinical setting, long-term data are needed. We are planning to conduct further studies with longer follow-up.

Although the focus of the present intervention was HbA1c, the overall cardiometabolic risk profile assessed in our study clearly shows that although this variable (HbA1c) has advantages/disadvantages, there was a clear gradient in the deterioration of overall cardiometabolic risk (as well as of lifestyle variables) going from normal HbA1c to prediabetes, newly diagnosed diabetes, and treated diabetes. Considering how easy it is to obtain this marker of glucose control (non-fasting, no need for a costly glucose tolerance test), our results suggest that it may be relevant to consider this marker of plasma glucose homeostasis in a cardiometabolic risk
assessment/management program which also focuses on assessing and targeting lifestyle habits.

Conclusion

In conclusion, results from this pilot project indicate that: 1) lifestyle predicts HbA1c levels; 2) lifestyle habits can be improved by a simple intervention designed for the workplace; and 3) improving cardiorespiratory fitness and reducing waist circumference appear as promising new targets to reduce HbA1c levels and related cardiometabolic risk.

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Declaration of interest

All authors declare that there are no conflicts of interest.

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Supplementary material available online