

Slow postmeal walking reduces postprandial glycemia in middle-aged women

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Abstract: Postprandial blood glucose concentration is a risk factor for the development of cardiovascular diseases and diabetes, even at states well below hyperglycemic levels. A previous study has shown that postmeal exercise of moderate intensity blunts the blood glucose increase after carbohydrate intake (Høstmark et al. *Prev. Med.* **42**(5): 369–371). The objective of the present study was to examine whether even postmeal slow walking would have a similar effect. Fourteen healthy women aged >50 years participated in 3 experiments in a random crossover design: after a carbohydrate-rich meal, either they were seated (control experiment) or they performed slow postmeal walking for 15 min (W15) or 40 min (W40). Blood glucose concentration was determined prior to the meal (fasting), and at 11 time points throughout each experiment. The W15 trial lowered the blood glucose values during walking and delayed the peak blood glucose value ($p = 0.003$). In W40, the postmeal blood glucose increase during walking was blunted, the peak glucose value was delayed ($p = 0.001$), and the incremental area under the 2-h blood glucose curve (IAUC) was reduced ($p = 0.014$). There was a negative relationship between IAUC and walking time ($p = 0.016$). The individual reducing effect of walking on IAUC correlated strongly with IAUC on the control day ($p < 0.001$). We conclude that even slow postmeal walking can reduce the blood glucose response to a carbohydrate-rich meal. The magnitude of this effect seems to be related to the duration of walking and to the magnitude of the postprandial blood glucose response when resting after a carbohydrate-rich meal.

Key words: blood glucose, physical activity, walking, postprandial period, women.

Résumé : Qu'importe le niveau d'hyperglycémie, la concentration sanguine postprandiale de glucose est un facteur de risque de développement des maladies cardiovasculaires et du diabète. D'après une étude récente, un exercice d'intensité modérée pratiqué après un repas limite l'augmentation de la concentration sanguine de glucose consécutive à l'apport de sucres (Høstmark et al. *Prev. Med.* **42**(5) : 369–371). La présente étude se propose de vérifier si une marche lente pratiquée après un repas entraîne un effet semblable. Quatorze femmes en bonne santé et âgées de plus de 50 ans participent à trois expériences selon un schéma expérimental en chassé-croisé; après un repas riche en sucres, on les invite à s'asseoir (contrôle) ou à marcher lentement durant 15 min (W15) ou 40 min (W40). On évalue la concentration de glucose avant le repas (à jeun) et à 11 moments donnés dans chacune des expériences. Dans la condition W15, la concentration de glucose diminue au cours de la marche et son pic est retardé ($p = 0,003$). Dans la condition W40, l'augmentation de la concentration de glucose au cours de la marche est atténuée et son pic est retardé ($p = 0,001$); on observe aussi une diminution de la surface incrémentielle sous la courbe (IAUC) de concentration du glucose sur une période de 2 h ($p = 0,014$). De plus, on note une corrélation négative entre l'IAUC et la durée de l'exercice de marche ($p = 0,016$). L'effet atténuant de la marche sur l'IAUC est corrélé étroitement avec la valeur de l'IAUC enregistrée lors de la journée de contrôle ($p < 0,001$). En conclusion, même une marche lente pratiquée après un repas riche en sucres peut diminuer l'augmentation de la concentration de glucose associée à ce repas. L'ampleur de l'effet semble associée à la durée de l'exercice de marche et à l'importance de la réponse du glucose sanguin lors de la période de repos suivant le repas riche en sucres.

Mots-clés : glucose sanguin, activité physique, marche, période postprandiale, femmes.

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Introduction

The magnitude of postprandial blood glucose elevation seems to be of major importance in the development of cardiovascular diseases (Chiasson et al. 2003; Coutinho et al.

1999; Hanefeld et al. 2004; Sasso et al. 2004; Temelkova-Kurktschiev et al. 2000; DECODE study group 1999, 2001, 2003b). Blood glucose values after a glucose challenge predict the risk for, and mortality of, such diseases better than

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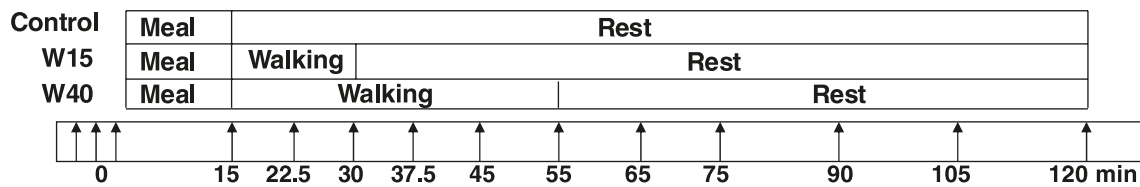
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Fig. 1. Schematic presentation of the protocol. Top row: the control day. Middle row: the day with 15 min of postmeal walking (W15). Bottom row: the day with 40 min of postmeal walking (W40). ↑, Blood glucose measurements.



fasting blood glucose values (Sasso et al. 2004; Temelkova-Kurktschiev et al. 2000; DECODE study group 1999, 2001). The association between postprandial blood glucose levels and cardiovascular mortality shows no threshold level and starts well below diabetic glucose values (Coutinho et al. 1999; DECODE study group 2003b).

As demonstrated by Høstmark et al. (2006), physical activity has the potential to blunt postprandial blood glucose responses. They observed that there was an acute blood glucose reducing effect during 30 min of bicycling following the consumption of a carbohydrate-rich meal. The exercise was done at about 70% of the subjects' maximal heart rate. This observation raises the question of whether even very light physical activity might have a similar effect, and whether the magnitude of the effect is related to the duration of such activity. We accordingly have investigated the blood glucose responses to a carbohydrate-rich meal, as influenced by slow postmeal walking for 15 and 40 min, respectively. Additionally, we examined whether the effect of such activity was related to the magnitude of the postmeal blood glucose response observed when resting after carbohydrate intake.

Materials and methods

Subjects and experimental conditions

Healthy women over the age of 50 years were included in the study. Exclusion criteria were hyperglycemia (fasting blood glucose levels above 6.0 mmol·L⁻¹, known diabetes, or known glucose intolerance), cardiovascular disease, other diseases or medications affecting the blood glucose levels, and abuse of alcohol or drugs. Fourteen females of Caucasian ancestry volunteered for the study. One subject was excluded because she had impaired fasting glucose concentration (6.4 mmol·L⁻¹). Thus, 13 healthy subjects were included in the analysis. Three of these subjects were premenopausal and 10 were postmenopausal, of whom 2 were on estrogen replacement therapy. There were no changes in medication during the study. Subject characteristics are given in Table 1. All participants had relatively sedentary work in a local community authority administration in Norway. The experiments were performed at their workplace, which had spacious indoor areas suitable for walking. The study was approved by the Regional Ethics Committee (reference no. S-07270b). All subjects gave their written informed consent.

General design

The study had a random crossover design. Each subject carried out 3 experiments on 3 separate days, a minimum of 4 and a maximum of 30 days apart. They were not informed about their own results until all tests were completed. The

Table 1. Subject characteristics.

Variable	Value
Height (cm)	166±6
Body mass (kg)	67±9
BMI (kg·m ⁻²)	24±3
Physical activity (min·wk ⁻¹) ^a	225±196

Note: Values are means ± SD (*n* = 13). BMI, body mass index.

^aWalking and bicycling included.

subjects were asked to avoid physical activity the last 2 days prior to each experiment, and were not allowed to walk or bicycle to work on test days. We emphasized that diet should be as similar as possible on the days before the different test days. To facilitate this requirement, the subjects were given written simplified diet recommendations. The onset of the experiments was between 0700 and 0830 hours after a 12-h fast. Subject characteristics were collected prior to the first test.

Experimental protocol

The experiments started with ingestion of Cornflakes (Kellogg's, Deutschland) and milk corresponding to 1 g carbohydrate per kilogram body mass (Cornflakes: 84 g carbohydrate, 7 g protein, and 1 g fat per 100 g; skimmed milk: 4.7 g carbohydrate, 3.3 g protein, and 0.7 g fat per 100 g). The meal took place in the time period 0–15 min. On the control day, the meal was followed by seated office work. The intervention days were similar to the control day, with the exception that 15 min (W15) or 40 min (W40) of slow walking was carried out immediately after the meal (Fig. 1). Blood glucose was determined in triplicate before the meal, and at 11 points of time throughout each experiment. Walking was done indoors on a flat surface. Subjects were instructed to walk slowly at their own pace, which corresponded to level 9 (i.e., very light) on Borg's rate of perceived exertion scale (Borg 1998). The seated office work involved routine tasks such as reading, writing, computer work, and telephone conversation.

Measurements

Capillary blood from finger punctures was used to determine the blood glucose concentration. Analyses were done with a glucometer (Ascensia Contour, Bayer HealthCare, Mishawaka, Ind.), and using blood glucose strips (Ascensia Microfill, Bayer HealthCare). All blood glucose strips had the same serial number. During walking, blood glucose was determined at different places in the building, depending on the location of each subject at the time of measurement. Each measurement was completed in about 10 s. The equip-

ment was carried along in a pouch. Heart rate was recorded with heart rate monitors (Polar Vantage nv, Polar Electro Oy, Kempele, Finland) throughout the experiments. Electrode gel (Beckman Instruments Inc., Schiller Park, Ill.) was used to obtain a steady heart rate recording.

Calculations

Incremental areas under the blood glucose curve (IAUC) were calculated using the trapezoid rule (FAO/WHO 1997). Means of blood glucose values at each time of measurement were calculated. The mean with the highest value is referred to as the “highest mean value”. Means of the individual peak glucose values are referred to as “peak blood glucose values”.

Statistical analyses

All data were tested for normality and analysed using SPSS for Windows, version 15.0 (SPSS Inc., Chicago, Ill.). Within subjects, analysis of variance (ANOVA) was used to determine the main effects of time and type of intervention on blood glucose values, and the effect of walking time on 2-h IAUC. Linear regression was used to determine the slope of the regression line for walking time vs. IAUC, and a 1-sample *t* test was used to assess whether the slope was different from zero. Differences between corresponding mean values of the 3 experiments were assessed using paired *t* tests. Wilcoxon’s paired samples test was used when evaluating corresponding means of “time to peak” because these values did not meet the criteria for parametric tests. Correlations were estimated with Pearson’s method. A *p* value < 0.05 was considered statistically significant, except for multiple comparisons, where *p* ≤ 0.016 was considered significant due to Bonferroni correction. Data are presented as means ± SEM unless otherwise stated. Figures were produced by SPSS 15.0 for Windows and SigmaPlot 10.0, Systat Software Inc.

Results

Heart rate

Mean heart rate during the 15 min walking period was 14 beats above the value on the control day. Mean heart rate during the 40-min walking period was 16 beats above the value on the control day (Table 2).

Blood glucose responses to Cornflakes intake, as influenced by postmeal slow walking

There was a main time effect of the carbohydrate-rich meal on blood glucose values (Fig. 2; repeated-measures ANOVA; *F* = 33.38, *p* < 0.001), and of type of intervention (*F* = 5.80, *p* = 0.017). There was also a significant interaction between time and type of intervention (*F* = 10.07, *p* < 0.001).

The mean fasting blood glucose value on the control day was 4.9 ± 0.1 mmol·L⁻¹ (Fig. 2). The blood glucose concentration increased during and after the meal, reaching the highest mean value, i.e., 8.3 ± 0.4 mmol·L⁻¹, after 45 min. Then the curve decreased, reaching a minimum value of 6.1 ± 0.2 mmol·L⁻¹ after 120 min. In the W15 experiment, the increase in blood glucose values during walking was attenuated as compared with the control day. Maximum dif-

Table 2. Heart rate.

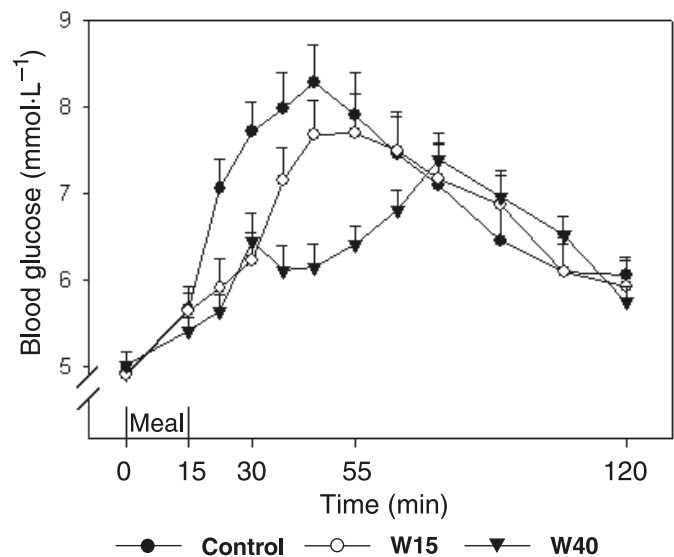
Experiment	Walking heart rate ^a	Resting heart rate ^b
Control	—	74.4±10.3
W15	88.6±13.2	74.8±10.7
W40	90.6±12.8	78.5±10.7

Note: Values are means ± SD (*n* = 13). HR, heart rate; W15, slow postmeal walking for 15 min; W40, slow postmeal walking for 40 min.

^aWalking HR represents the HR during the periods of walking, i.e., 15 min for W15 and 40 min for W40.

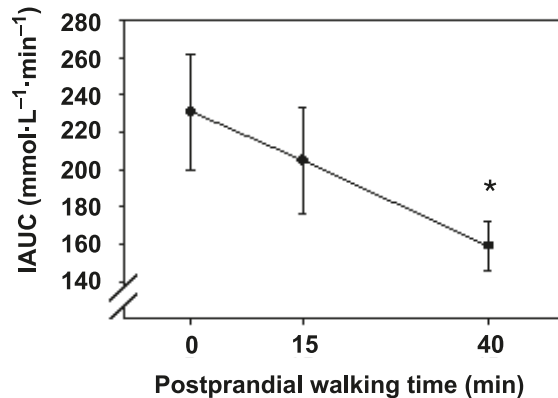
^bFor the control experiment, resting HR values represent the HR for the complete control period after the meal (from 15 to 120 min after commencing the experiment); for W15 and W40, the resting period was from 30 to 120 min and from 55 to 120 min, respectively.

Fig. 2. Glycemic responses to intake of Cornflakes (1 g carbohydrate per kilogram body mass), ingested in the time period 0–15 min. On the control day (closed circles) subjects were seated, doing office work after the meal. W15 (open circles) and W40 (closed triangles) were similar to control, but included 15 (W15) or 40 (W40) min of slow walking immediately after the meal. Mean values ± SEM (*n* = 13); *p* = 0.017 for the effect on blood glucose values of type of intervention (repeated-measures ANOVA).



ference between control and W15 occurred at the end of the walking period (i.e., 1.5 ± 0.3 mmol·L⁻¹; *p* < 0.001). After walking, the curve increased to 7.7 ± 0.5 mmol·L⁻¹, observed after 55 min. Then the curve decreased in a manner similar to the one on the control day, reaching the lowest value of 5.9 ± 0.3 mmol·L⁻¹ at 120 min. During walking in the W40 experiment, the blood glucose increase was attenuated appreciably. Maximum difference between control and W40 occurred at 45 min (2.1 ± 0.4 mmol·L⁻¹; *p* < 0.001). At the end of the walking period, the difference was 1.5 ± 0.4 mmol·L⁻¹ (*p* = 0.002). The slope of the blood glucose curve was steeper during the first 15 min of the walking period (0.07 ± 0.02 mmol·L⁻¹·min⁻¹) than during the last 25 min (0.00 ± 0.12 mmol·L⁻¹·min⁻¹; *p* < 0.001 for the difference). After walking for 40 min, the curve increased to obtain the highest mean value of 7.4 ± 0.3 mmol·L⁻¹ at 75 min. Then the glucose concentration decreased as in the 2 other experiments.

Fig. 3. Two-hour incremental area under the blood glucose curve (IAUC) as related to postprandial walking time. *, Different from 0 min walking (control); $p = 0.014$. Values are means \pm SEM ($n = 13$).



Two-hour incremental area under the blood glucose curve, as related to postprandial walking time

Using ANOVA, we observed a main effect of walking time (0, 15, and 40 min) on the 2-h IAUC ($F = 5.48$, $p = 0.011$). The slope of the regression line between postprandial walking time and 2-h IAUC values differed significantly from zero (-1.8 ± 0.6 ; $p = 0.016$). The relationship between mean IAUC values and walking time seemed to be approximately linear (Fig. 3). The mean 2-h IAUC values were 231 ± 31 mmol·L⁻¹·min for control, 205 ± 29 mmol·L⁻¹·min for W15, and 159 ± 13 mmol·L⁻¹·min for W40, corresponding to a 31.2% decrease from control to W40 ($p = 0.014$). The decreases from control to W15 (11.0%) and from W15 to W40 (22.7%) did not attain statistical significance.

Peak blood glucose concentration and time to peak

Compared with control, peak blood glucose value was 0.8 mmol·L⁻¹ ($p = 0.013$) lower as a result of 40 min of walking (Table 3). There were no significant differences between control and W15 (0.4 mmol·L⁻¹) or between W40 and W15 (0.5 mmol·L⁻¹).

Time to peak blood glucose was prolonged as a result of both W15 and W40 (Table 3). Compared with control, peak value for W15 came 11.5 min later ($p = 0.003$) and peak value for W40 came 24.2 min later ($p = 0.001$), with no significant difference between W15 and W40 (12.7 min).

Reduction in blood glucose by slow postmeal walking as related to the magnitude of the postmeal blood glucose without physical activity

Subjects with the largest 2-h glucose IAUC on the control day demonstrated the greatest reduction in postprandial glucose response when walking 40 min after the meal (Fig. 4). There was a positive correlation between 2-h IAUC on the control day and the difference between the control day and W40 ($r = 0.909$, $p < 0.001$). There was no significant correlation between the 2-h IAUC on the control day and the reduction in IAUC caused by 15-min postmeal walking ($r = 0.380$; Fig. 4).

Fig. 4. Glycemic response (incremental area under the blood glucose curve (IAUC)) to Cornflakes ingestion without postmeal walking (abscissa) as related to the reduction in IAUC caused by postmeal slow walking (ordinate). (A) Scatter-plot of IAUC on the control day vs. decrease in IAUC caused by 15-min postmeal slow walking (W15). (B) Scatter-plot of IAUC on the control day vs. decrease in IAUC caused by 40 min postmeal slow walking (W40) ($r = 0.909$, $p < 0.001$, $n = 13$).

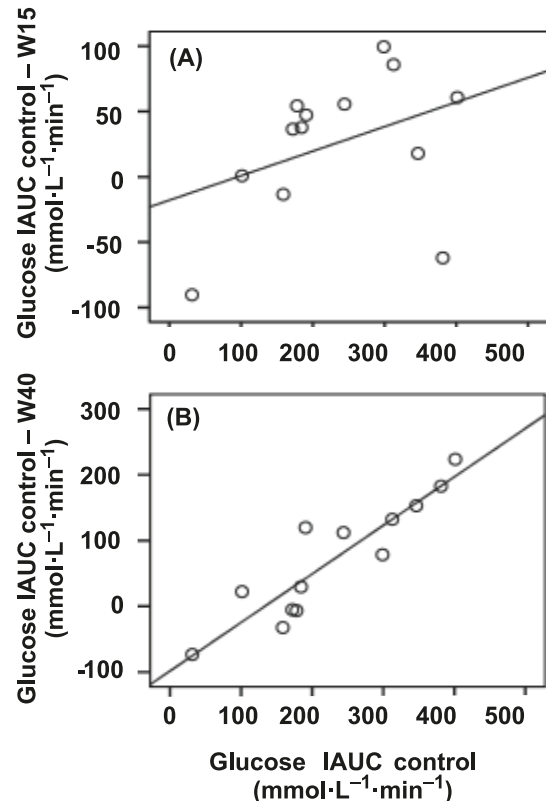


Table 3. Peak blood glucose concentration and time to peak.

Experiment	Peak blood glucose (mmol·L ⁻¹)	Time to peak (min)
Control	8.6 \pm 0.4	44.2 \pm 3.7
W15	8.3 \pm 0.4	55.8 \pm 2.7
W40	7.8 \pm 0.2	68.5 \pm 5.8

Note: Peak blood glucose concentration and time to peak are for the day without walking (control), the day with 15 min of postmeal walking (W15), and the day with 40 min of postmeal walking (W40). Time to peak is the mean of the individual periods of time from the start of the meal to the peak value. Values are means \pm SEM ($n = 13$).

Discussion

The present study strongly suggests that even slow postmeal walking can attenuate the increase in blood glucose levels after a carbohydrate-rich meal, and that this effect takes place with only a minor increase in the heart rate.

Duration and intensity of physical activity

The finding that there were no significant differences in the blood glucose lowering effect between the 2 durations of postmeal walking, i.e., 15 and 40 min, is probably due to

the limited number of subjects. On the other hand, the relationship between postmeal walking time and the blunting effect of such walking on postprandial glycemia indicates a dose-response influence of postmeal walking. This contention is supported by the observed linear relationship between the 2-h IAUC mean values and walking time. Furthermore, the blunting influence caused by walking seems to be increased when carried out for more than 15 min, as indicated by the difference in the slope of the blood glucose curve between the first 15 and the last 25 min of 40-min walking. Thus, it seems that the duration of postmeal walking is a crucial factor for attenuating the increase in the postprandial blood glucose concentration. Previously, the blunting effect on postprandial glycemia of 30-min bicycling at 70% of maximal heart rate (Høstmark et al. 2006) and 45-min bicycling at 57% of maximal oxygen consumption (Nelson et al. 1982) have been demonstrated. Despite the very low intensity of the present work, the blood glucose reducing effect obtained by 40 min of slow walking seemed to be approximately of the same magnitude as that observed in the previous studies. This would suggest that the duration of postmeal physical activity may be at least as important as the intensity in lowering postprandial glycemia. This suggestion is in accordance with a recent study by Aadland and Høstmark (2008) on healthy subjects, and is consistent with the recommendations of Galbo, Tobin, and van Loon (Galbo et al. 2007) in those with type 2 diabetes, that overall energy expenditure, rather than peak exercise intensity, is the primary determinant for reduction in postprandial blood glucose and insulin with physical activity.

Despite higher glucose utilization in high-intensity exercise, the acute effect on postprandial glycemia obtained by moderate or very low-intensity physical activity may be as beneficial as the effect of vigorous activity. Endogenous glucose production is affected by plasma catecholamine levels, which will increase with increasing severity of muscular exertion (Von Euler 1974). However, the aim of the present study was not to explore mechanisms of action.

Individual responses to postmeal walking

The finding that subjects with the largest 2-h glucose IAUC on the control day demonstrated the greatest reduction in postprandial glucose response when walking for 40 min after the meal illustrates the potential of slow walking as a method to obtain reductions in postprandial glycemia. Thus, it would seem that subjects most in need of lowering postprandial glycemia are also those obtaining the greatest blood glucose reduction when walking after a carbohydrate-rich meal. Previously, similar observations were made when comparing the postprandial glycemia after intake of high-glycemic vs. low-glycemic carbohydrates (Høstmark 2007), and in the exercise study of Aadland and Høstmark (2008).

Recommendation of walking

The benefit of lowering postprandial glycemia has been estimated with the use of drugs, in subjects with impaired glucose tolerance. Treatment with the α -glucosidase inhibitor acarbose showed an appreciable decrease in the risk of developing diabetes (Chiasson et al. 2002) and cardiovascular diseases (Chiasson et al. 2003). Oral hypoglycemic

agents are, however, associated with adverse effects (Bolen et al. 2007). The acute effect on postprandial glycemia of different doses of α -glucosidase inhibitors has been tested in healthy humans (Kageyama et al. 1997). Indeed, the reduction in postmeal blood glucose by walking for 40 min after a carbohydrate-rich meal is comparable to the drug effects. With reference to the clinical studies using α -glucosidase inhibitors, it is conceivable that light postmeal walking could have a preventive potential, but future clinical studies are needed to corroborate this suggestion.

The present study was performed in a setting aimed to extend its external validity and generalizability. Postprandial glycemia is associated with some age- and sex-specific differences (DECODE study group 2003a) that might influence the effect of slow walking. On the other hand, and in contrast to oral hypoglycemic agents, walking is associated with multifarious benefits and minimal adverse effects. It can be done by almost everyone, except for the seriously disabled (Morris and Hardman 1997). As a consequence of this, walking can be recommended safely for lowering postprandial glycemia.

Given that postprandial glycemia is a risk factor for cardiovascular disease and diabetes, our study provides scientific evidence for the health benefit of going for a walk after a meal. Such a practice may be an important public health message to prevent development of these conditions, although this would need to be confirmed in future research.

Conclusion

Our study demonstrates that slow postmeal walking can reduce the blood glucose response to a carbohydrate rich meal. These data suggest a dose response relationship between the duration of slow walking and the reduction in postprandial glycemia. In addition, the reduction in postprandial glycemia seems to be proportional to the individual blood glucose responses at rest.

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