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Determinants of postprandial triglyceride and glucose responses after two consecutive fat-rich or carbohydrate-rich meals in normoglycemic women and in women with type 2 diabetes mellitus: the Hoorn Prandial Study

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Abstract

Both postprandial hyperglycemia and hypertriglyceridemia have been identified as risk markers for cardiovascular disease, but parameters associated with these postprandial responses are largely unknown. The objective was to assess whether usually measured clinical and biochemical parameters can predict postprandial glucose and triglyceride responses and whether these responses are associated with each other. Postmenopausal women, 76 with normal glucose metabolism (NGM) and 41 with type 2 diabetes mellitus (T2DM), received 2 consecutive fat-rich meals and carbohydrate-rich meals on separate occasions. Blood samples were taken before and at $t = 1$, 2, 4, 6, and 8 hours after breakfast; lunch was given at $t = 4$ hours. Regression analysis was performed with incremental area under the postprandial triglyceride curve (triglyceride-iAUC) and glucose curve (glucose-iAUC) after fat-rich and carbohydrate-rich meals, respectively. In women with NGM, fasting triglycerides, hemoglobin A_{1c}, total cholesterol, and, inversely, high-density lipoprotein cholesterol were independently associated with triglyceride-iAUC; and age and fasting triglycerides were independently associated with glucose-iAUC. In women with T2DM, fasting triglycerides were independently associated with triglyceride-iAUC, whereas hemoglobin A_{1c} and fasting glucose were stronger than fasting triglycerides associated with glucose-iAUC. Glucose-iAUC and triglyceride-iAUC were associated with each other in women with T2DM, but not in those with NGM. The association between glucose-iAUC and triglyceride-iAUC in women with T2DM and the association of fasting triglycerides with both glucose-iAUC and triglyceride-iAUC in NGM and T2DM suggest a common underlying mechanism for postprandial increments in glucose and triglycerides, especially in T2DM. Commonly measured clinical and biochemical parameters can only partly explain postprandial glucose and triglyceride excursions.

1. Introduction

In 1979, Zilversmit [1] postulated that atherogenesis might be a postprandial phenomenon. Since then, both postprandial hyperglycemia and hypertriglyceridemia have been identified as risk markers for cardiovascular disease [2]. These risk markers do especially but not uniquely apply to patients with type 2 diabetes mellitus (T2DM) [3]. We recently demonstrated that postprandial glucose levels were more strongly associated with carotid intima-media thickness than fasting levels in women with normal glucose metabolism (NGM) [4]. Others have shown that, in T2DM [5] and also in healthy subjects [6], postprandial hypertriglyceridemia is more strongly related to carotid intima-media thickness than fasting triglyceride levels.

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The determinants of these postprandial glucose and triglyceride responses are not well known, but insulin resistance may underlie both metabolic abnormalities. Impaired glucose tolerance has been attributed to peripheral insulin resistance [7]. In addition, postprandial triglyceride responses in T2DM patients have been shown to be associated with insulin resistance [8].

Parameters associated with postprandial triglyceride and glucose concentrations might, at least in part, overlap but have not been described in one single study population before. Furthermore, most postprandial studies to date used a single, often artificially composed liquid fat or carbohydrate load. Because a first meal can affect the glucose and triglyceride responses to a second meal, we chose to apply 2 consecutive meals to reflect daytime postprandial responses [9,10]. Postmenopausal women were invited for the present study because postprandial triglyceride responses increase in the menopause [11] and it is known that T2DM confers a higher relative risk for cardiovascular disease in women as compared with men [12].

In light of the above considerations, we assessed whether clinical and biochemical variables (including surrogate markers of insulin resistance) can predict postprandial triglyceride and glucose day profiles in postmenopausal women. We furthermore investigated whether postprandial hypertriglyceridemia and hyperglycemia were related with each other.

2. Subjects and methods

2.1. Study population

The study population has been described in detail previously [13]. In brief, women with T2DM were randomly selected from the registry of the Diabetes Care System in the city of Hoorn, the Netherlands. Women with NGM were randomly selected from the municipal registry of the city of Hoorn. All women were between 50 and 65 years of age; were postmenopausal; were nonsmokers; had no untreated endocrine disorder other than T2DM; had no liver or renal impairment (ie, alanine aminotransferase [ALT] <2.5 times the upper limit of the reference range and creatinine <120 μmol/L); had fasting triglycerides ≤4.0 mmol/L and cholesterol ≤8.0 mmol/L; and did not use short-acting insulin analogues, peroxisome proliferator–activated receptor α or γ agonists, oral corticosteroids, or hormone replacement therapy. Women without known T2DM underwent an oral glucose tolerance test and were selected on NGM status [14]. Women with T2DM were excluded if they had hemoglobin A_{1c} (HbA_{1c}) >9.0%. For the present analysis, we also excluded T2DM patients who used hydroxymethylglutaryl–coenzyme A reductase inhibitors (statins) because these drugs affect several of the potential determinants of the metabolic responses we assessed.

Finally, 76 women with NGM and 41 women with T2DM completed the study protocol. All women gave written informed consent. The study was approved by the ethics committee of the VU University Medical Center, Amsterdam, The Netherlands.

2.2. Study protocol

The study consisted of a screening visit and 2 separate visits for the test meals, with a minimum interval of 1 week and a maximum interval of 1 month between visits. On the screening visit, blood samples were drawn after a 12-hour overnight fast to determine levels of HbA_{1c}, plasma glucose, total cholesterol, triglycerides, ALT, and creatinine. Women who were selected from the municipal registry underwent an oral glucose tolerance test.

Blood pressure was measured at the left upper arm 3 times with 5-minute intervals using an oscillometric blood pressure measuring device (Collin Press-mate BP-8800; Colin, Komaki City, Japan) after a 15-minute supine rest. Weight and height were measured twice in barefooted participants wearing light clothes only. Body mass index (BMI) was calculated as weight (in kilograms) divided by the square of height (in meters). Waist circumference was measured twice at the level midway between the lowest rib margin and the iliac crest, and hip circumference was measured at the widest level over the greater trochanters. Medical history, medication, (former) smoking, and alcohol use were assessed by a questionnaire [15]. Finally, habitual physical activity was assessed by the Short Questionnaire to Assess Health-Enhancing Physical Activity of which reproducibility and relative validity were described previously [16].

On the second and third visits, women arrived at the test facility in the morning after a 12-hour overnight fast. They had abstained from exercise 24 hours before the study visit. Blood samples were taken before (twice) and at $t = 1$, $t = 2$, $t = 4$, $t = 6$, and $t = 8$ hours after ingestion of the first test meal. The second test meal was given at $t = 4$ hours, immediately after the blood sample was taken.

2.3. Test meal composition

Postprandial meal responses were examined after the consumption of 2 standardized test meals (breakfast and lunch) on 2 randomized separate occasions, either with a high-fat content or high-carbohydrate content. The nutrient composition of the meals was calculated from the Dutch Food Composition Tables [17]. The fat-rich meals (both breakfast and lunch) consisted of 2 croissants, 10 g of butter, 40 g of fat-rich cheese, and 300 mL of fat-rich milk (3349 kJ; 50 g fat, 56 g carbohydrates, and 28 g proteins). The carbohydrate-rich meals (both breakfast and lunch) consisted of 2 slices of bread, 25 g of marmalade, 30 g of cooked chicken breast, 50 g of ginger bread, and 300 mL of drinkable yogurt enriched with 45 g of soluble sugars (3261 kJ; 4 g fat, 162 g carbohydrates, and 22 g of proteins). Both meals were eaten within 10 minutes. Apart from the test meals and water (ad libitum), participants refrained from food and drinks and had only limited physical activity.

2.4. Laboratory analysis

All laboratory analyses were performed at the VU University Medical Center (Department of Clinical Chemistry) in Amsterdam, the Netherlands. Serum total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides were measured by enzymatic colorimetric assays (Roche, Mannheim, Germany). Low-density lipoprotein cholesterol was calculated according to the Friedewald formula [18]. Alanine aminotransferase was determined by an enzymatic assay (Roche) according to the methods proposed by the International Federation of Clinical Chemistry and Laboratory Medicine [19]. Plasma glucose concentration was determined with a glucose hexokinase method (Gluco-quant, Roche), and HbA_{1c} was measured with cation-exchange chromatography (Menarini Diagnostics, Florence, Italy). The interassay coefficients of variation for the triglyceride and glucose measurements were <1.8% and <2.2%, respectively. Immunospecific insulin was measured in serum by an immunometric assay in which proinsulin does not cross-react (ACS Centaur, Bayer Diagnostics; Mijdrecht, the Netherlands). The inter- and intraassay coefficients of variation for insulin were 6% and 3%, respectively.

2.5. Statistical analyses

Analyses were performed by SPSS for Windows 12.0.1 (SPSS, Chicago, IL). Postprandial responses were calculated as incremental area under the curve (iAUC) with the trapezoid method [20]. Missing values for a given time point (0.5% of all the glucose and triglyceride values) were imputed by interpolation.

Insulin resistance was estimated by homeostasis model assessment (HOMA-IR), calculated as [mean fasting insulin (in microunits per milliliter) × mean fasting glucose (in millimoles per liter)]/22.5 [21]. Mean glucose and insulin concentrations were derived from fasting measurements on 2 separate study days.

Firstly, to study the associations of possible determinants of postprandial triglyceride and glucose responses, linear regression analysis was performed with adjustment for age. As independent variables, we considered age, T2DM duration, BMI, waist circumference, hip circumference, fasting glucose, HbA_{1c}, fasting insulin, HOMA-IR, total cholesterol, HDL cholesterol, fasting triglycerides, ALT, systolic blood pressure, alcohol intake, and habitual physical activity. As dependent variables, postprandial triglycerides (iAUC) after the fat-rich meals and postprandial glucose concentrations (iAUC) after the carbohydrate-rich meals were used. Secondly, multivariable models that included age and all variables that were associated with the outcome variables at $P < .10$ were composed. The associations were expressed as standardized regression coefficients (95% confidence interval) by dividing the dependent and independent variables by the SD derived from the entire study population. A regression coefficient of 0.5 means that, if the independent variable increases by 1.0 SD, the dependent variable increases by 0.5 SD. All associations were tested for interaction with T2DM. For interaction terms, $P < .10$ was considered statistically significant; and for other analysis, we used a 2-sided P value < .05 to indicate statistical significance.

3. Results

3.1. Characteristics of the study population

Clinical and biochemical characteristics of the participants are listed in Table 1. Fig. 1 shows the 8-hour time courses of triglyceride and glucose concentrations after 2 consecutive fat-rich and 2 consecutive carbohydrate-rich meals. Triglyceride-iAUC after the fat-rich meals was similar in the 2 groups ($P = .33$) (Table 2). After the carbohydrate-

Table 1
Clinical and biochemical characteristics of the 117 participants

	NGM	T2DM
n	76	41
Age (y)	60.1 (4.0)	58.9 (3.7)
Duration of T2DM (y)	NA	5 (3-9)
Anthropometry		
BMI (kg/m^2)	26.3 (3.6)	32.7 (6.0)*
Waist (m)	0.88 (0.10)	1.04 (0.14)*
Hip (m)	1.04 (0.08)	1.12 (0.12)*
Glucose metabolism		
HbA_{1c} (%)	5.6 (0.3)	6.6 (0.6)*
Fasting insulin (pmol/L)[a]	33.2 (25.5-47.5)	82.7 (38.8-122.5)*
HOMA-IR[a]	1.29 (0.94-1.95)	4.05 (1.92-7.07)*
Lipids (mmol/L)		
Total cholesterol	6.0 (0.9)	5.6 (1.0)
HDL cholesterol	1.80 (0.49)	1.51 (0.34)*
LDL cholesterol	3.7 (0.9)	3.2 (1.0)*
Blood pressure (mm Hg)		
Systolic	131 (15)	143 (16)*
Diastolic	72 (8)	79 (7)*
Liver enzyme (U/L)		
ALT	20 (16-26)	27 (20-40)*
Medication (%)		
Antihypertensive medication	16	66*
Blood glucose–lowering medication	NA	71
Use of insulin	NA	17
Lifestyle		
Former smoking (%)	49	39
Habitual physical activity (h/wk)	35 (23-46)	35 (22-46)
Alcohol >0 g/d (%)	78	37*

Data are presented as mean values (SD) or percentages. In case of skewed distribution, data are presented as median (interquartile range); and Ln-transformed values were tested. Differences between groups were tested with t test for continuous variables and with χ^2 test for dichotomous variables. NA indicates not applicable; LDL, low-density lipoprotein.

[a] Subjects using insulin were excluded for these variables, and insulin was calculated as mean of 2 measurements.

* $P < .05$.

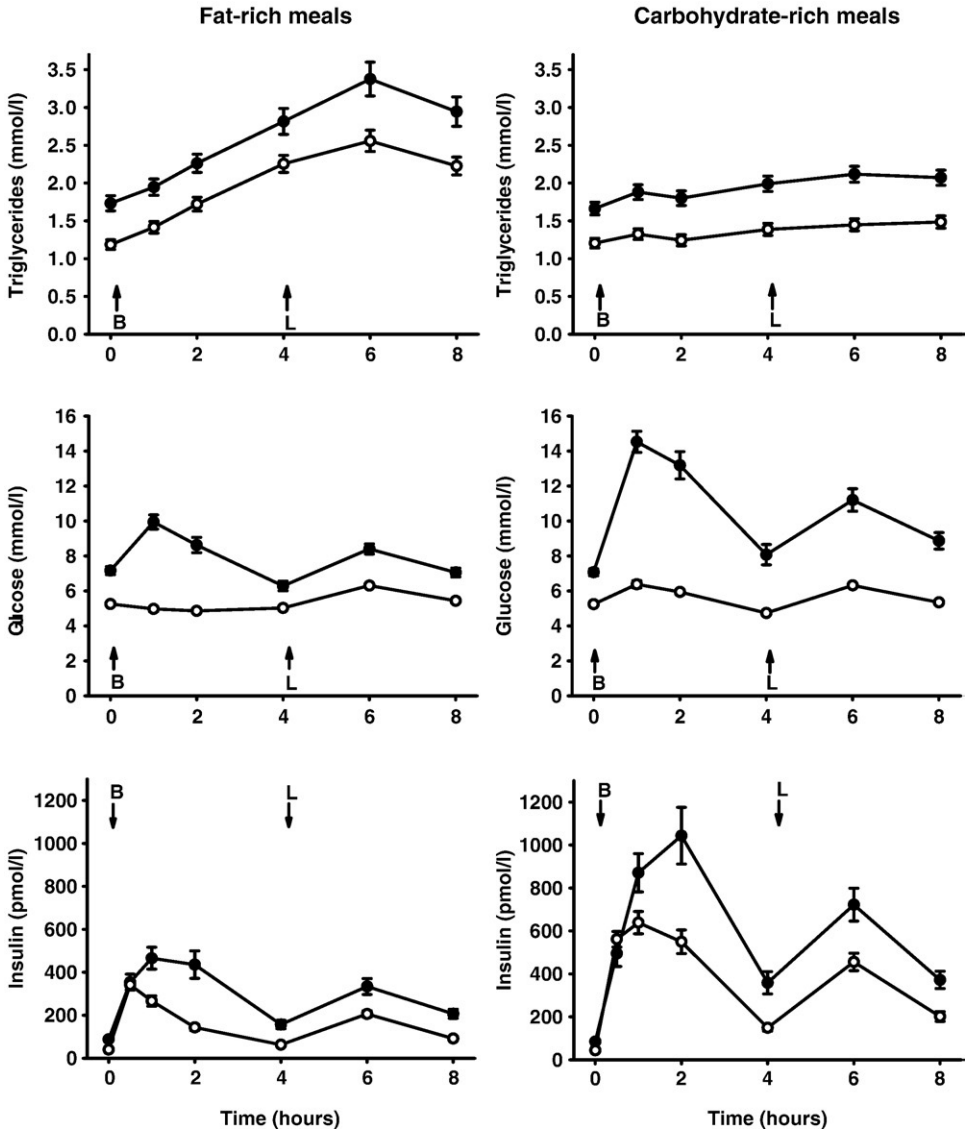

Fig. 1. Triglyceride, glucose, and insulin concentrations (mean ± SEM) after ingestion of 2 consecutive meals. For insulin figures, patients who use insulin (n = 7) were excluded. B indicates breakfast; L, lunch. NGM (○), T2DM (●).

rich meals, triglyceride-iAUC was most marked in women with T2DM compared with NGM women (P = .01). As expected, glucose-iAUC and insulin-iAUC after the fat-rich and the carbohydrate-rich meals were most marked in the women with T2DM (all $P < .01$).

3.2. Associations with postprandial triglycerides

Linear regression analyses with triglyceride-iAUC after the fat-rich meals were performed with each of the variables considered as independent variables (statistical analysis section) and with adjustment for age. Because of interaction of some variables (HDL cholesterol and physical activity) with diabetic state, we performed the analysis for NGM and T2DM women separately. In the NGM group, when adjusted for age only, fasting triglycerides were associated with triglyceride-iAUC; also, HbA_{1c}, fasting insulin, HOMA-IR, and total cholesterol were positively associated whereas HDL cholesterol and hip circumference were negatively associated with triglyceride-iAUC (data not shown).

To study whether potential determinants of triglyceride-iAUC were independent of fasting triglyceride levels, we made a multivariable model as presented in Table 3. For women with NGM, we included fasting triglycerides, hip circumference, HbA_{1c}, fasting insulin, total cholesterol, and HDL cholesterol and adjusted for age and BMI (R^2 = 0.52); and all these variables, except fasting insulin (P = .08) and hip circumference (P = .07), remained statistically significantly associated with triglyceride-iAUC.

In the T2DM group, fasting triglycerides, HbA_{1c} (both adjusted for age), and age were the strongest predictors of

Table 2
Fasting and postprandial glucose and triglyceride levels after fat-rich meals and after carbohydrate-rich meals

	NGM	T2DM
Fat-rich meals		
Fasting triglycerides (mmol/L)	1.2 (0.6)	1.7 (0.7)*
Triglyceride-iAUC (mmol/L)	0.9 (0.5)	1.0 (0.5)
Fasting glucose (mmol/L)	5.3 (0.4)	7.2 (1.5)*
Glucose-iAUC (mmol/L)	0.1 (0.5)	0.7 (1.5)*
Carbohydrate-rich meals		
Fasting triglycerides (mmol/L)	1.2 (0.6)	1.7 (0.6)*
Triglyceride-iAUC (mmol/L)	0.2 (0.3)	0.3 (0.3)*
Fasting glucose (mmol/L)	5.2 (0.4)	7.1 (1.3)*
Glucose-iAUC (mmol/L)	0.4 (0.8)	3.6 (2.9)*

Data are presented as mean values (SD). Triglyceride-iAUC and glucose-iAUC are presented as mean iAUC during the day.
* t test $P < .05$.

triglyceride-iAUC. In a multivariable model with fasting triglycerides, HbA_{1c}, and age ($R^2 = 0.29$), fasting triglycerides were the only independent determinant of triglyceride-iAUC (Table 3).

3.3. Associations with postprandial glucose

Linear regression analyses for postprandial glucose (glucose-iAUC) after the carbohydrate-rich meals were performed with each of the variables considered as independent variables (statistical analysis section) and with adjustment for age. Interaction with T2DM status for almost all independent variables (BMI, waist and hip circumference, fasting glucose, HbA_{1c}, fasting insulin, HOMA-IR, total cholesterol, fasting triglycerides, ALT, alcohol intake, and physical activity) prompted us to perform the analyses for NGM and T2DM women separately. In the NGM group, age was associated with higher glucose-iAUC. Furthermore, when adjusted for age only, waist circumference and fasting triglycerides were positively associated and HDL-cholesterol was inversely associated with glucose-iAUC. In a multivariable model containing age, waist circumference, BMI, HDL cholesterol, and fasting triglycerides ($R^2 = 0.24$), fasting triglycerides were still associated with glucose-iAUC; and age became significantly associated with glucose-iAUC (Table 3).

In women with T2DM, HbA_{1c}, fasting insulin, HOMA-IR, and fasting triglycerides were positively associated with glucose-iAUC. For this reason, fasting insulin was part of the multivariable model; and we excluded women with T2DM who used insulin (n = 7). In this model, only HbA_{1c} remained associated with glucose-iAUC when adjusted for age, fasting glucose, fasting insulin, total cholesterol, triglycerides, and habitual physical activity in a multivariable model ($R^2 = 0.68$, Table 3). Because HbA_{1c} is not considered as a determinant but rather as a consequence of glucose-iAUC, we also made a multivariable model including the above-mentioned variables except HbA_{1c}. In this model ($R^2 = 0.51$), fasting glucose was the strongest determinant of glucose-iAUC ($\beta = .49$ [0.19; 0.82]).

3.4. Association between postprandial triglyceride and glucose responses

We additionally assessed the age-adjusted association of glucose-iAUC with triglyceride-iAUC. In NGM women, no statistically significant association was found between these

Table 3
Multivariable linear regression analysis of clinical and biochemical parameters with postprandial triglycerides after fat-rich and postprandial glucose concentrations after carbohydrate-rich meals

Variables (SD)[a]	NGM		T2DM	
	Triglyceride-iAUC	Glucose-iAUC	Triglyceride-iAUC	Glucose-iAUC
Age (3.9 y)	−0.05 (−0.22; 0.11)	0.07 (0.01; 0.14)*	0.29 (−0.06; 0.65)	−0.13 (−0.45; 0.19)
BMI (5.4 kg/m^2)[b]	−0.06 (−0.54; 0.41)	−0.15 (−0.33; 0.04)	–	–
Waist (0.14 m)	–	0.13 (−0.05; 0.31)	–	–
Hip (0.10 m)	−0.35 (−0.73; 0.03)	–	–	–
Fasting glucose (1.2 mmol/L)	–	–	–	0.20 (−0.12; 0.52)
HbA_{1c} (0.7%)	0.40 (0.02; 0.78)*	–	0.27 (−0.06; 0.60)	0.58 (0.25; 0.91)*
Fasting insulin (ln) (0.67)[c]	0.29 (−0.04; 0.61)	–	–	−0.10 (−0.53; 0.33)
Total cholesterol (1.0 mmol/L)	0.24 (0.04; 0.44)*	–	–	0.16 (−0.15; 0.47)
HDL cholesterol (0.47 mmol/L)	−0.21 (−0.40; −0.03)*	−0.06 (−0.14; 0.01)	–	–
Fasting triglycerides (0.6 mmol/L)	0.39 (0.15; 0.62)*	0.10 (0.01; 0.19)*	0.35 (0.02; 0.69)*	0.34 (−0.05; 0.73)
Habitual physical activity (18 h/wk)	–	–	–	−0.31 (−0.66; 0.05)

[a] Standardized regression coefficients (95% confidence interval) in SD increase in dependent variable (0.5 mmol/L for triglyceride-iAUC and 2.3 mmol/L for glucose-iAUC) per 1-SD increase in independent variable (see table).
[b] Body mass index was added as a covariable in models with waist and hip circumference.
[c] Patients with T2DM who use insulin were excluded (n = 7) when the model includes fasting insulin.
* Variable significant at level $P < .05$ in multivariable model.

metabolic responses (β = .39 [−0.31; 1.08]). In contrast, for women with T2DM, glucose-iAUC and triglyceride-iAUC were associated (β = .26 [0.002; 0.53]). The latter association was in part dependent of fasting triglycerides; the regression coefficient was reduced to 0.18 (−0.10; 0.45) when fasting triglycerides were added to the model with age and glucose-iAUC.

4. Discussion

The present study assessed both postprandial triglyceride and glucose responses at 2 separate occasions in 1 study population. These responses were found to be associated with each other in women with T2DM, but not in women with NGM. We furthermore demonstrated that fasting triglycerides were associated with both triglyceride-iAUC and glucose-iAUC, but other potential determinants of triglyceride-iAUC and glucose-iAUC differed.

We expected a more markedly prolonged triglyceride response especially after the second meal in patients with T2DM [9,22]. The relative lack of exaggerated triglyceride response in women with T2DM might be the result of the meal composition. The substantial amount of carbohydrates in the fat-rich mixed meal might suffice to elicit a high insulin response. Indeed, attenuation of the triglyceride response was previously shown when glucose was added to a liquid fat load [23]. Furthermore, the patients with T2DM included in the present study were well controlled, possibly contributing to an ameliorated response of the liver to the meal-induced insulin response. Finally, we cannot exclude the possibility that a prolonged triglyceride response in patients with T2DM might have become evident with a longer observation period [24].

4.1. A common mechanism for elevated postprandial triglyceride and glucose responses?

Insulin resistance or central obesity, both components of the metabolic syndrome, might contribute to increased postprandial triglyceride and glucose levels [22,25]. We found that fasting insulin and HOMA-IR, as a reflection of insulin resistance and in particular of hepatic insulin resistance, were associated with triglyceride-iAUC in women with NGM. This association was in part confounded by fasting triglycerides. Similarly, in women with T2DM, not HOMA-IR but fasting triglycerides were associated with triglyceride-iAUC. Nevertheless, fasting triglycerides are a recognized component of the metabolic syndrome [26]; and the association between fasting triglycerides and triglyceride-iAUC might, at least in part, be the result of underlying hepatic insulin resistance. Alternatively, the lack of association between markers of insulin resistance and postprandial triglycerides in NGM and T2DM may refer to a relatively preserved insulin secretion in both populations. A preserved insulin secretion has been found to be associated with normal postprandial triglycerides responses, even in patients with T2DM [27].

Central obesity as a component of the metabolic syndrome is accompanied by an increased flux of free fatty acids and elevation of proinflammatory adipocytokines. Both result in so-called ectopic fat depositions in liver, muscle, and β-cells contributing to the development of hepatic and peripheral insulin resistance, and β-cell dysfunction [28]. Studies in men reported an association between visceral obesity and triglyceride-iAUC [29,30]. In line with these observations, a study among obese women showed that abdominal obesity, but not obesity as such, was associated with triglyceride-iAUC. In the present study, the association between waist circumference and triglyceride-iAUC was, although not statistically significant, stronger than the association between BMI and triglyceride-iAUC. Furthermore, we found that hip circumference was inversely associated with triglyceride-iAUC in women with NGM. An inverse relationship between larger hip circumference and fasting triglycerides has previously been found [31,32] and may reflect an enhanced buffering capacity for triglycerides in fat tissue [33].

The present data also suggest that an elevated postprandial triglyceride response might be part of a dyslipidemic lipid profile in women with NGM. Independent of fasting triglycerides, total cholesterol was positively associated and fasting HDL cholesterol concentration was inversely associated with triglyceride-iAUC. Postprandial lipemia might be a feature of “diabetic” dyslipidemia, involving high triglyceride and low HDL cholesterol concentrations [34].

We found that the triglyceride-iAUC was associated with the glucose-iAUC in women with T2DM, but not in NGM. This illustrates that the underlying mechanisms, for example, hepatic insulin resistance and β-cell dysfunction, are common in T2DM, but not in NGM. In line with this, fasting and postprandial glucose levels were associated with each other in T2DM only. This also suggests that both underlying mechanisms [7] are present in T2DM, but not in NGM.

4.2. Other potential mechanisms for postprandial triglyceride and glucose responses

The proportion of variance explained by the multivariable model for triglyceride-iAUC is lower for patients with T2DM (R^2 = 0.29) compared with women with NGM (R^2 = 0.52). In T2DM, insulin resistance, only partly reflected by fasting triglycerides, possibly plays an important role in increasing postprandial triglycerides, including a decreased lipoprotein lipase activity. It is well known that the lipoprotein lipase–mediated clearance of triglyceride-rich lipoproteins is hampered when insulin action and/or secretion is inadequate [35].

The proportion of variance explained (R^2) by the multivariable model for glucose-iAUC was 0.51 for the T2DM group and 0.24 for the NGM group. Obviously, the range in postprandial glucose excursions is much smaller in women with NGM. Furthermore, we did not consider the effect of gut hormones (incretins), rate of gastric emptying,

and peripheral insulin resistance on postprandial glucose, which play important roles in glucose regulation. In summary, the present parameters analyzed cannot completely explain the variation in postprandial glucose and triglyceride excursions.

4.3. Study limitations

A number of potential limitations of this study should be considered. First, the population consisted of white postmenopausal women aged 50 to 65 years; and caution should be exercised to generalize our findings to other populations. Second, the cross-sectional design limits us to assess causal relationships. Third, as a result of the smaller sample size of the T2DM population as compared with the NGM study population, less associations in the T2DM study population might have reached statistical significance. Fourth, the relatively few postprandial measurements after the second meal ($t = 6$ and $t = 8$) may have led to an underestimation of the postprandial glucose and triglyceride responses to the meals. Fifth, the use of diabetic medication during the study may have resulted in weaker postprandial responses and possibly to weaker associations.

4.4. Conclusion

In summary, glucose-iAUC and triglyceride-iAUC were interrelated in women with T2DM; and fasting triglycerides were associated with both glucose-iAUC and triglyceride-iAUC in women with NGM and T2DM. These findings suggest, at least partly, a common underlying mechanism for postprandial increments in glucose and triglycerides, especially occurring in women with T2DM. However, commonly measured clinical and biochemical variables can only partly explain the variation in postprandial glucose and triglyceride excursions.

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