CLINICAL RESEARCH

Reduction in postprandial energy expenditure during pregnancy

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Abstract

Energy expenditure was measured during pregnancy in seven primigravid women at 12-15, 25-28, and 34-36 weeks and after the cessation of lactation. On each occasion the resting metabolic rate and the increase in metabolic rate after ingestion of a liquid test meal were measured by indirect calorimetry. In absolute terms the resting metabolic rate increased steadily during pregnancy but when expressed per unit of body weight no change was found. The energetic response to a mixed constituent meal was significantly reduced by 28% in the middle trimester of pregnancy.

These findings suggest a possible maternal adaptation to increase energetic efficiency at a time when the energy demands of the fetus are high.

Introduction

Current estimates of energy requirement during pregnancy recommend an increase in energy intake over the normal non-pregnant non-lactating intake of 0·63 MJ/day in the first trimester and 1·47 MJ/day in the second and third trimesters in order to cover the additional energy demands of pregnancy.[1] These estimates are based largely on the theoretical calculations of Hytten and Leitch.[2] By contrast, several recent studies have found that healthy women eating to appetite may show little or no increase in energy intake above the prepregnancy level with no evident adverse effect on either the outcome of pregnancy or maternal nutritional state.[3-5] This apparent disparity suggests that there may be an increased efficiency of maternal metabolism during pregnancy. In order to investigate this phenomenon further we have measured energy expenditure both at rest and in response to a test meal in the first, second, and third trimesters of pregnancy and compared these measurements with those in the postlactational state.

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Patients and methods

Serial measurements of energy expenditure were performed on seven healthy normotensive women (mean age 28·2 (SD 2·9) years) both during and after uncomplicated pregnancies. Patients were recruited at the initial antenatal booking visit. All subjects were in their first pregnancy and none smoked. All were delivered vaginally between 39 and 42 weeks of gestation and birth weights were between 2800 and 3900 g (mean 3350 (SD 340) g). The subjects had a mean prepregnant weight (obtained by recall) of 63·1 (SD 8·2) kg and a mean height of 162 (SD 6) cm. Weight gain during pregnancy was obtained by subtracting the weight before pregnancy from the last recorded weight in the antenatal clinic. The mean postlactational weight was 63·3 (7·9) kg.

Measurements of energy expenditure were performed on each subject on four occasions: between 12 and 15 weeks of gestation, between 25 and 28 weeks of gestation, between 34 and 36 weeks of gestation, and after lactation. All subjects breast fed their babies and the postpartum measurements were therefore carried out six weeks after the complete disappearance of lactation with a medium time of eight months after delivery (range six to 11 months). Postpartum measurements were performed during the follicular phase of the cycle.

Energy expenditure was measured by an indirect ventilated hood technique[6] with oxygen consumption and carbon dioxide output monitored by paramagnetic (Taylor, Servomex) and infrared (SS-200, Analytical Development Company) analysis, respectively. From these data energy expenditure was calculated using the formula of Weir[7] and expressed in equivalent units (kJ/min).

On each occasion two components of energy expenditure were measured —namely, resting metabolic rate and the increase in metabolic rate in response to a test meal. After an overnight fast of 12 hours the subject rested supine for 40 minutes at a thermoneutral temperature of 25-27°C, after which resting metabolic rate was measured for 20 minutes. The subject then received a liquid test meal (Carnation Build-up) reconstituted with milk to contain protein, carbohydrate, and fat with a ratio of 1·5:3·3:2·2 in an amount calculated to give 41 kJ/kg of ideal body weight. This provided a meal with a mean energy content of 2·23 (SD 0·17) MJ. Ideal body weight was defined as that given as an acceptable average weight in a report of the Royal College of Physicians of London[8] based on the weight for height tables of the Metropolitan Life Insurance Company.[9] The subsequent increase in metabolic rate in response to this meal was measured for two hours. Metabolic rate is expressed both in absolute terms and as per unit of body weight, the second measurement being used to try to take into account the rise in lean body mass during pregnancy.

An indwelling cannula (Abbott 19 gauge) was inserted 40 minutes before the metabolic rate measurement and kept patent with 3·8% (wt/vol) sodium citrate. Venous blood was collected just before and at 30, 60, 90, and 120 minutes after ingestion of the meal and analysed for glucose and insulin concentrations. Plasma glucose concentration was assayed by an enzymatic-colorimetric method adapted from the method of Trinder,[10] and insulin concentration was measured with a double antibody radioimmunoassay kit (Cambridge Medical Diagnostics Inc).

The cumulative incremental response was calculated from the area under the response curve. Statistical analysis was by Student's paired t test with 95% confidence intervals (CI) being shown where applicable, degrees of freedom being 6 for each result. Except where stated otherwise results are expressed as means and one standard deviation (SD). Ethical approval for the study was obtained from the ethical committee of the Tayside Health Board and fully informed consent obtained from each subject.

Results

Weight changes—During pregnancy all subjects accumulated weight (11·9 (2·1) kg), which was subsequently lost after delivery. Six of the seven subjects had regained their prepregnancy weight by the time of the repeat measurement after the disappearance of lactation.

Resting metabolic rate (table I) was increased at each trimester of pregnancy and when compared with that in the postlactational state was significantly higher both in the second trimester (CI 0·04 to 0·034 kJ/min; t=3·16, p<0·02) and in the third trimester (CI 0·14 to 0·53 kJ/min; t=3·97, p<0·01). When resting metabolic rate was expressed per kg of body weight, however, there was no difference between measurements obtained during pregnancy and in the postlactational state.

Energy response to test meal—After ingestion of the mixed constituent meal metabolic rate increased in all subjects investigated at all stages of pregnancy (fig 1). The metabolic response to the meal (table I) was significantly reduced in the second trimester compared with that after lactation (CI 5·5 to 39·2 kJ; t=3·24, p<0·02). This effect was particularly pronounced during the second hour after ingesting the meal (CI 4·3 to 26·9 kJ; t=3·37, p<0·02). This reduction in energy expenditure during the second trimester was shown by all subjects. There was no difference in the cumulative incremental rise in the first trimester compared with that in the postlactational state. During the third trimester, however, postprandial energy expenditure was significantly reduced when measured at 105 and 120 minutes, though the cumulative incremental rise for the second hour and the total response were not significantly reduced.

TABLE I—*Energy expenditure resting and in response to test meal. Values are means (SD in parentheses)*

	Resting metabolic rate		Incremental metabolic response to test meal (kJ)		
	(kJ/min)	(kJ/kg/min)	Rise in 1st hour	Rise in 2nd hour	Total rise
12-15 Weeks	4·23 (0·34)	0·064 (0·007)	35·7 (10·8)	43·3 (14·7)	79·0 (24·7)
25-28 Weeks	4·37 (0·24)**	0·063 (0·008)	29·8 (7·9)*	27·9 (5·8)**	57·7 (12·4)**
34-36 Weeks	4·50 (0·29)***	0·063 (0·008)	33·9 (9·7)	34·1 (9·0)	68·0 (17·5)
After lactation	4·17 (0·29)	0·066 (0·005)	36·6 (10·3)	43·5 (10·6)	80·2 (20·5)

Compared with value after lactation: *p<0·05; **p<0·02; ***p<0·01.

Responses of glucose and insulin concentrations to meal—When compared with the mean fasting glucose concentration in the postlactational state (5·4 (0·3) mmol/l) that during pregnancy was significantly lower in the first (4·7 (0·3) mmol/l (CI 0·3 to 1·1); t=4·49, p<0·01), second (4·5 (0·3) mmol/l (CI 0·5 to 1·14); t=6·65, p<0·001), and third (4·2 (0·3) mmol/l (CI 0·6 to 1·6); t=6·28, p<0·001) trimesters. The glucose response to the meal was significantly greater during pregnancy than in the postlactational state (fig 2). There was no difference between the fasting insulin concentration (fig 3) in the postlactational state (9·6 (2·9) mIU/l) and that in the first (9·9 (2·9) mIU/l), second (9·4 (2·6) mIU/l), or third (11·0 (1·8) mIU/l) trimester of pregnancy. As pregnancy advanced, however, the insulin response to the mixed meal became progressively greater with a delayed peak. The concentration 60 minutes after the meal was significantly raised in both the second (mean 73·9 mIU/l (CI 12·2 to 33·2); t=5·29, p<0·01) and third (mean 154·9 mIU/l (CI 76·6 to 131·6); t=9·26, p<0·001) trimesters when compared with the postlactational value. The insulin to glucose ratio (table II) therefore showed a pronounced increase in the second and third trimesters, the ratio being significantly greater than the postlactational value at 60 (CI 1·3 to 5·4; t=3·94, p<0·01), 90 (CI 0·1 to 5·9; t=2·45, p<0·05), and 120 minutes (CI 1·0 to 4·3; t=3·90, p<0·01) after ingestion in the second trimester and 60 (CI 10·5 to 16·6; t=10·85, p<0·001), 90 (CI 5·2 to 11·4; t=6·52, p<0·001), and 120 minutes (CI 4·2 to 8·7; t=7·03, p<0·001) in the third trimester.

TABLE II—*Insulin to glucose ratio before and in response to test meal. Values are means (SD in parentheses)*

	Insulin: glucose ratio				
	0 min	30 min	60 min	90 min	120 min
12-15 Weeks	2·1 (0·7)	11·1 (4·1)	9·1 (2·7)	7·1 (1·8)	5·4 (2·0)
25-28 Weeks	2·1 (0·6)	12·2 (2·6)	11·1 (1·8)**	10·2 (2·0)*	8·3 (2·1)**
34-36 Weeks	2·5 (0·3)	13·1 (2·6)	23·3 (2·6)***	15·6 (3·0)***	12·1 (2·8)***
After lactation	1·8 (0·7)	11·9 (4·4)	7·7 (2·9)	7·3 (2·3)	5·6 (1·5)

Compared with value after lactation: *p<0·05; **p<0·01; ***p<0·001.

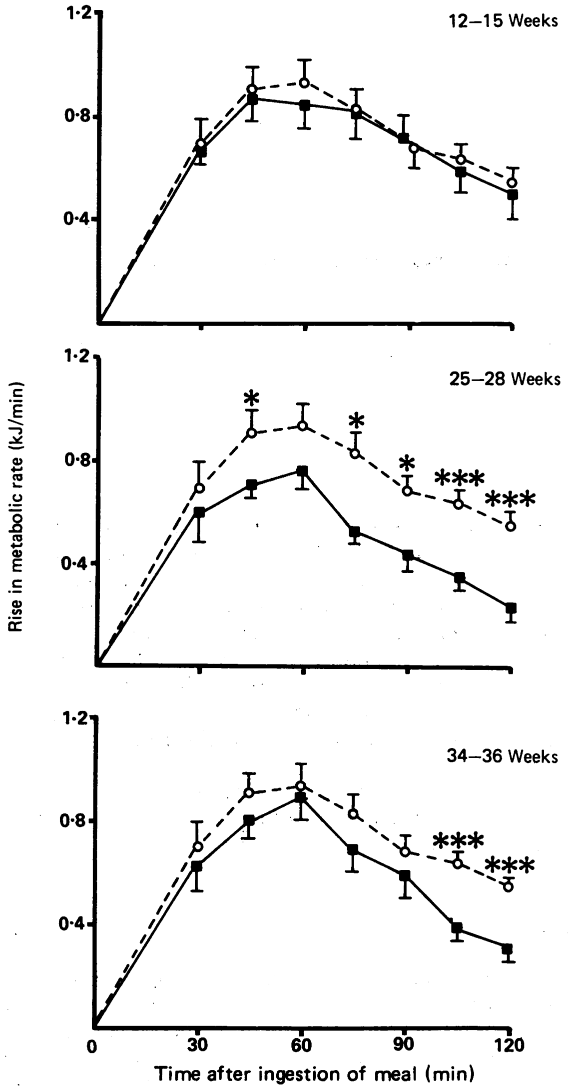

FIG 1—Rise in metabolic rate in response to test meal in subjects after lactation (– – –) and at 12-15 weeks of pregnancy, 25-28 weeks of pregnancy, and 34-36 weeks of pregnancy (———). Points are means. Bars are SEM. *p<0·05; ***p<0·01.

Discussion

In pregnancy, as in the non-pregnant state, energy is required for basal metabolic requirements, growth, physical activity, and the metabolic response to food.[1] Clearly the main factor differentiating energy balance during pregnancy from that in the non-pregnant state is the extra allowance necessary for the additional growth of fetal and maternal tissues as well as the extra energy required for maintaining this increased tissue mass. The total amount of energy required for this growth was calculated by Hytten and Leitch in 1964 by separating weight gain in pregnancy into the different chemical components on the basis of existing data and calculating the energy equivalents of these components from the heat of combustion.[2] By this method the energy cost of 335 MJ (80 000 kcal)

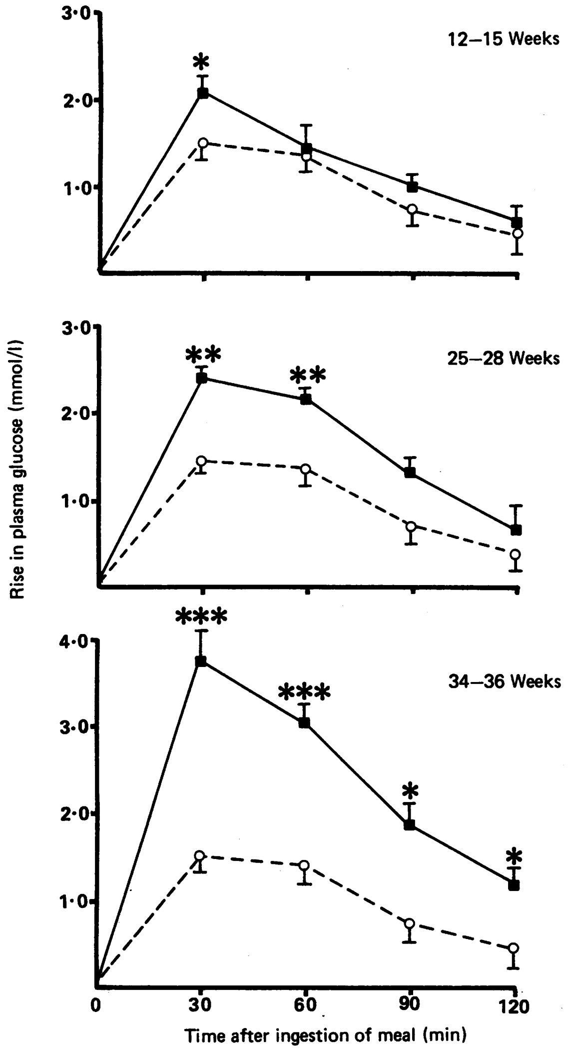

FIG 2—Absolute rise in plasma glucose concentration after test meal in subjects after lactation (— — —) and at 12-15 weeks of pregnancy, 25-28 weeks of pregnancy, and 34-36 weeks of pregnancy (———). Points are means. Bars are SEM. *$p<0·05$; **$p<0·02$; ***$p<0·01$.

for the whole pregnancy was reached. In view of this supposed increase in energetic demand the recent finding that pregnant women do not significantly increase their energy intake above the non-pregnant level[3-5] has aroused considerable interest. The original calculation of Hytten and Leitch remains valid, and it seems more likely that the apparent energetic discrepancy is due to a physiological adaptation during pregnancy rather than any inherent error in the Hytten calculation. In attempting to investigate this problem different aspects of energy expenditure in pregnancy have been measured.

The principal component of energy expenditure—that is, the basal metabolic rate—has been extensively investigated in pregnancy,[11-14] though none of these studies has included longitudinal measurements throughout pregnancy. These studies have concluded that in absolute terms the basal metabolic rate rises during the course of pregnancy but that when expressed per unit of weight no increase is found when compared with the prepregnant state. Considerable interest has recently been aroused by two studies on nutritionally different populations, including serial measurements throughout pregnancy, which suggest that there may be a fall in the basal metabolic rate per unit of weight during early pregnancy.[5 15] We found no such fall and our data agree with the earlier studies in showing a constant resting metabolic rate per unit of weight throughout pregnancy.

Energy spent on physical activity is another potential source of physiological adaptation in pregnancy. In a wide ranging survey of different population groups Houdek-Jimenez and Newton found that most of the women questioned showed very little change in the amount of physical work performed during pregnancy.[16] More detailed estimates of physical work have been obtained from 24 hour activity diaries but results have been conflicting[3 17] and reporting of activity by this method is notoriously inaccurate. The energetic efficiency of mechanical work during pregnancy has been assessed by measuring the energy cost by short term indirect calorimetry of set tasks. Pernoll *et al* found in late pregnancy an increase of oxygen consumption during exercise on a bicycle ergometer[18]; conversely, Seitchik found no difference[11] and Banerjee *et al* reported a decrease in oxygen consumption in pregnant women performing household tasks.[12] Nagy and King[14] found that such differences as existed for energy expenditure during walking were solely attributable to the alteration in body weight. The contradictory results in these studies may be related to the difficulties inherent in standardising such tasks. Such standardisation is particularly difficult as any changes in posture act as a potent stimulus for the release of noradrenaline, which will itself promote a significant increase in metabolic rate.[19] In view of the difficulties inherent in measuring the energetic cost of physical activity our study was constructed to examine another component of energy expenditure—namely, the thermic effect of food.

The physiological relevance of the increase in metabolic rate after food remains controversial,[20 21] but several studies have shown a diminished thermic response to food in some obese subjects, suggesting that subtle metabolic alterations may occur in certain people to promote weight gain.[22-24] The effect of pregnancy, a notable stimulus for weight gain, on the thermic role of food has never previously been examined. We found a significant diminution in the metabolic response to the mixed meal during the second trimester of pregnancy. Though the response was reduced in the third trimester at 105 and 120 minutes after ingestion, the cumulative rise failed to reach statistical significance. It is not clear why the diminution in metabolic response to food should be maximal in the second trimester but it is notable that this is the period of maximal deposition of maternal fat stores. We think that the post-lactational response probably represents the prepregnant response; in a previous study of non-pregnant women of similar age, height, weight, and resting metabolic rate we found a similar energy response (80·1 (20·5) kJ) to an identical meal.[6]

Insulin is central to the regulation of energy expenditure in man,[25] though the exact role of insulin in the thermic effect of food remains controversial. An increase in serum insulin concentration leads to an increase in energy expenditure,[26] but Schwartz *et al* found no correlation between the insulin response to a meal and the thermic response.[27] In this study we also found no correlation between the insulin response to the meal and either the increase in metabolic rate after the meal or the degree of suppression of postprandial energy expenditure in either the second or third trimester. These findings in association with the observation that the two phenomena of suppressed energy expenditure and increasing insulin resistance are maximal at different times in the pregnancy suggest that the two processes are not causally related. Our findings of a lower fasting glucose concentration throughout pregnancy and increased insulin resistance during the third trimester accord with earlier data.[28]

In conclusion our study shows that at the time of maximal energy demand in pregnancy women reduce energy expenditure by diminishing the metabolic response to a mixed constituent meal.

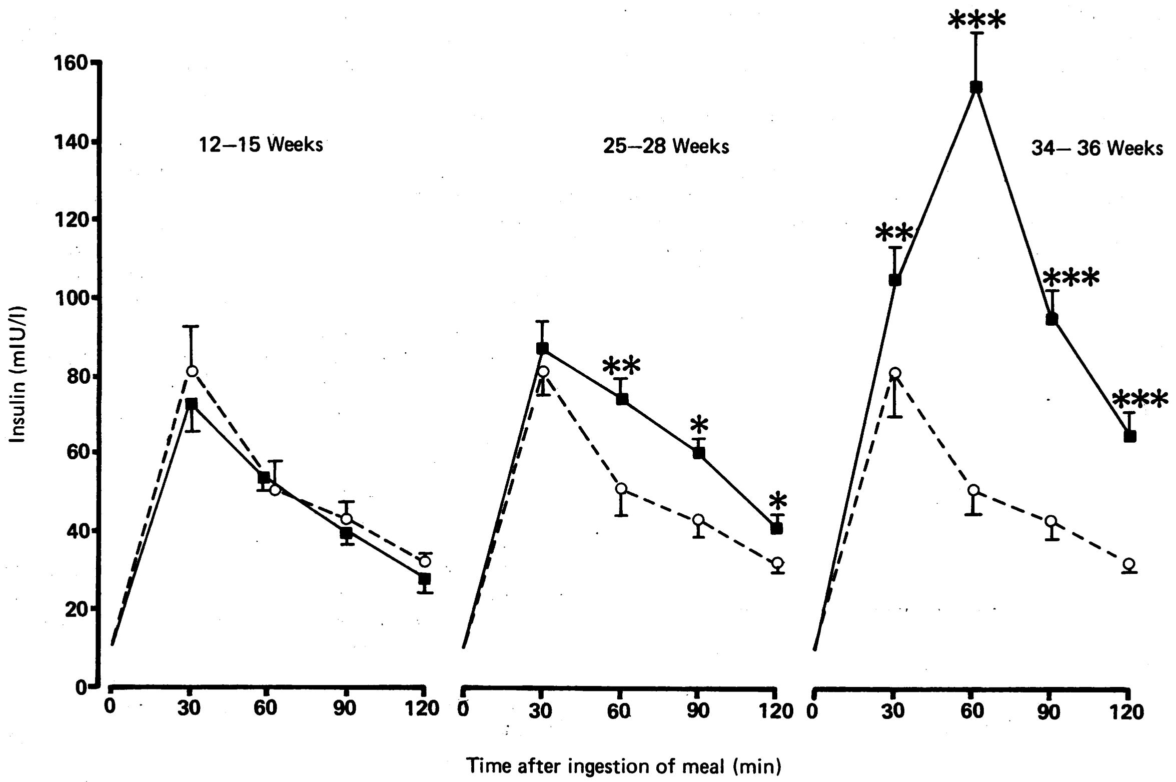

FIG 3—Plasma insulin concentration after test meal in subjects after lactation (– – – –) and 12-15 weeks of pregnancy, 25-28 weeks of pregnancy, and 34-36 weeks of pregnancy (———). Points are means. Bars are SEM. *$p<0.05$; **$p<0.01$; ***$p<0.001$.

The increased energetic efficiency inherent in this adaptation may play some part in making energy available for fetal nutrition without the need for maternal energy intake appreciably to increase.

We thank all our volunteers, the consultant obstetricians of this hospital for allowing us to study patients under their care, Mrs Jean Baty for expert biochemical help, Mr Simon Ogston for statistical advice, the Medical Research Council Dunn Nutrition Unit for advice on constructing a calorimeter, and Miss Beverly Reid for expert typing. This work was supported by a research grant from Tayside Health Board. PJI was in receipt of a grant from Birthright, Royal College of Obstetricians and Gynaecologists.

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(Accepted 15 April 1987)