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MATERNAL CHARACTERISTICS RELATED TO POST PARTUM BODY COMPOSITION CHANGES AMONG LACTATING AND NON-LACTATING MOTHERS.

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Thesis submitted for the degree of Master of Science (M.Sc.)

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SUMMARY

A group of 32 breast-feeders and 30 bottle-feeders was followed for a six month period in order to compare their patterns of weight change after delivery.

Women were recruited at the Queen Mother's Hospital in Glasgow a few days after delivery. The sample included non-obese healthy women, aged between 20 and 35 years having a singleton birth at term.

Pre-pregnant weight, fat and weight gains during pregnancy were estimated from the booking weight.

Anthropometric measurements including body weight, four limb circumferences and four skinfold thicknesses were carried out every two weeks for the first two months and once a month from the third to the sixth month *post partum*.

Maternal characteristics such as pre-pregnant weight, fat and weight gains during pregnancy were similar in both groups. Breast-feeders came from a higher social class than bottle-feeders and smoking was more common among bottle-feeders.

Mothers started the study at two weeks *post partum* with a residual weight gain (the difference between the weight at two weeks *post partum* and the estimated pre-pregnant weight) of 5.3 kg for breast-feeders and 5.0 kg for bottle-feeders. By the end of six months *post partum*, both groups had lost weight, with a total of 3.66 kg for breast-feeders and 1.98 kg for bottle-feeders. The difference between the two weight losses being statistically significant with a $p<.01$.

Changes in skinfold and circumferences measurements were not statistically different between the two groups. From these measurements it appeared that fat was lost mainly over the trunk rather than over the limbs.

Although weight loss was significantly different between both groups, changes in fat mass as measured by skinfolds were not statistically different. It is possible that skinfold measurements might not be sensitive enough to provide an accurate estimate of fat mass during the *puerperium*. Or perhaps that *post partum* changes in a fat-free component, the excess breast tissue deposited during pregnancy, have concealed the real changes in fat mass.

An analysis of variance and a stepwise regression were carried out to identify which maternal characteristics had an influence on weight change *post partum*. Four factors were shown to be significant. They are in decreasing order of importance, time, residual weight gain, method of infant feeding and smoking.

A total of 50.9% of the variance was explained by the presence of these factors in the analysis.

The effect of residual weight gain on breast-feeders, who were almost exclusively non-smokers, and bottle-feeders non-smokers led to interesting results. As a rule, the smaller the residual weight gain, the greater the proportion of this weight that would be lost by six months *post partum*. The proportion of this residual weight gain lost by breast-feeders was always greater than for bottle-feeders non-smokers. The pattern of weight change among bottle-feeders smokers was erratic and therefore difficult to interpret.

An equation of regression is given to predict weight loss after delivery. The type of woman having the best chances to lose all the weight gained in pregnancy by six months *post partum* is a breast-feeder, non-smoker who gained less than 12 kg during pregnancy.

INTRODUCTION

Energy balance in man is achieved when energy intake matches energy expenditure. It is not possible though, to expect this perfect match on a day to day basis but in the long term, energy balance, as reflected by a stable body weight, should be attained (1).

The body is in a positive energy balance when energy intake is in excess of energy expenditure and that an increase in body weight is the resulting effect. On the other hand, negative energy balance prevails when energy expenditure is in excess of energy intake and body weight decreases as a result.

Lactation is a physiological state during which an increase in metabolic activity and cell synthesis involves greater energy needs. A traditional view of energy balance would predict the energy costs of lactation to be met by higher energy intake, lower energy expenditure and/or increased fat utilisation from adipose maternal stores. This fat mobilisation, if not offset by increased energy intake, should be reflected in weight changes.

The recommendations set by the FAO/WHO/UNU (2) for energy intake for lactating women are based on the assumption that a normal body composition should be re-established within six months by utilizing this reserve of fat, accounting for about 4 kg, to provide an energy release of 200 kcal/day. Another 500 kcal/day, in addition to the recommended dietary intake for a non-pregnant, non-lactating woman, is to be supplied by diet.

Although the theory seems quite logical, no one knows exactly how much fat is used for breast-feeding and how long does it take to the maternal body to get back to its pre-pregnant weight. Moreover, many breast-feeding populations appear to have successful lactational performance on energy intakes below these recommendations.

One way of looking at the effect of lactation upon maternal body weight is to compare a group of breast-feeders with a group of controls, in this case bottle-feeders, in their pattern of *post partum* weight loss. Very few scientists have attempted to compare these two groups and the results obtained were highly contradictory. Some investigators found that breast-feeders had lost more weight (3), some found that they had lost less weight (4), and others found no difference at all between both groups (5,6).

However, some of these studies and other studies made with breast-feeding women only have been done for short periods of time, less than 3 months, and it is possible that a longer period of observation is needed to show the effect of breast-feeding on maternal body weight.

All these uncertainties about breast-feeding plus the fact that the fat gained in pregnancy has often been blamed by some women to be the major cause of their obesity (7) have raised an interesting field of research.

The present descriptive longitudinal study has been undertaken, firstly, to investigate the differences in the pattern of *post partum* weight loss between a group of breast-feeders and a group of bottle-feeders; secondly, to see whether the maternal body will be back at its pre-pregnant weight by the end of six months *post partum*; and thirdly, to identify which factors influence weight loss in this particular sample.

Changes in body composition evaluated by body weight and four skinfold thicknesses measurements were measured regularly for a period of six months. There was no planned intervention by the recorder to influence the subjects concerning their energy intake and expenditure.

The first chapter of the thesis is a literature review of the most relevant (from the point of view of this study) studies on the subject of weight change during pregnancy and after delivery.

The methods used to carry out this project and analyse the data are detailed in chapter 2.

In chapter 3, the sample of subjects is described and some important maternal characteristics are presented.

Results from the data analysis and a following discussion are presented in chapters 4, 5 and 6. In chapter 4, the effect of infant feeding method on *post partum* weight loss is investigated by an analysis of variance. Chapter 5 is concerned with changes in maternal skinfolds and circumferences measurements.

Chapter 6 presents a multiple analysis of variance on *post partum* weight loss with the following factors: residual weight gain, method of infant feeding, smoking habit, parity and social class.

Finally, the conclusion emphasizes the main findings of the study and gives some possible suggestions for future research.

I

LITERATURE REVIEW

1.1 Weight change during pregnancy.

1.1.1 Importance of weight gain

Weight gain during pregnancy has been extensively studied because of its importance for monitoring the well-being of the mother and the fetus.

A century ago, it was a current practice for the obstetricians to recommend their patients to restrict their weight gain as much as possible to permit an "easy" delivery. These attempts to reduce the size of the fetus by dieting the mother were largely unsuccessful and were abandoned. The practice of restricting weight gain reappeared when sometime later, one realized that a sudden increase in weight gain might be related to a serious disease of the mother, eclampsia.

Fortunately, nowadays the well-being of the fetus is certainly as important as the well-being of the mother and no such restriction in weight gain is still recommended. The reversal in views on weight gain started in the sixties when some studies demonstrated that an increase in pregravid weight as well as a progressive increase in weight during pregnancy resulted in an increase in mean birth weight of the infant (see, for example, 8, 9). Since then it has become a well accepted fact that these two maternal variables, pregravid weight and weight gain are related to birthweight, although a direct causal effect between weight gain and birthweight seems improbable.

Recognition of the importance of adequate weight gain during pregnancy has been brought to light when some studies in the United States and the United Kingdom have found that perinatal mortality rates are lowest when maternal pregnancy weight gains are between eleven and thirteen kilograms (10). This is why these values are now accepted to be the *normal* range of weight gain during pregnancy for a group of healthy women eating to appetite. However, some evidence indicate that the amount of weight a woman should put on during pregnancy to optimize its outcome is largely influenced by her pre-pregnant weight. Naeye in 1979 (11) suggested a weight gain ranging from 9 to 14 kg depending on the pre-pregnant weight of the mother. The optimal weight gain during pregnancy for an overweight woman would be lower than for an underweight woman. Rosso in 1985 (12) had the same views but went further in recommending a minimum weight gain of 7 kg for overweight women.

1.1.2 Components of weight gain

Total weight gain has been separated in several components including the products of conception, i.e. fetus, placenta and amniotic fluid; and the increased maternal body fluids and tissues.

The important work by Hytten and Leitch (10) made possible the quantification of each component of weight gain during pregnancy. For a normal pregnancy, the total amount of weight gained by a healthy woman eating to appetite has been estimated at 12.5 kg. The products of conception on average can be accounted for 4.8 kg and maternal components such as extra blood volume, extracellular extravascular fluid, breast and uterus tissues add an extra 4.2 kg to the weight gain. The remainder, 3.5 kg, appears to be depot fat laid down mostly during the second trimester of pregnancy.

Studies among well-nourished women showed some difference in the amount of fat laid down, varying from 2.3 kg (13) up to 5.8 kg (14).

It is thought that this stored body fat might be used as an energy reserve during the last trimester when the fetus is the most vulnerable to an energy shortage or during lactation to meet its high energy cost (10). However, little is known about the pattern of fat mobilization *post partum.* Among women having liberal access to food as in developed countries, it is improbable that this energy reserve will be of much use during the last trimester. It is more realistic to expect this fat being used during lactation.

1.2 Weight change after delivery.

Weight change during the *post partum* period is a neglected area of research but it is certainly a matter of much concern to the mother. When women have been studied for body weight change after delivery, it has been done usually for a very short period of time (during the immediate *puerperium*) or as a follow-up study for a few months starting after the immediate *puerperium.*

1.2.1 Immediate *puerperium*

To obtain physiologically standard conditions, the studies made during the lying-in period were designed to achieve maximum accuracy: the subjects were weighed at the same time each day, after emptying their bladder, before breakfast and in light nightdress. Using the same weighing machine, body weight was recorded daily for about a week or until the patients were discharged which ever came first. Results are conflicting regarding the pattern of weight change and the factors influencing it (15-17). Some early studies (18,19) showed a continuing weight loss during the early *puerperium.* But the patients were weighed only at the time of discharge and not daily until discharge. More recent studies, certainly better designed to assess changes in the early *puerperium,* found that a great proportion of patients actually gained weight for the first few days and thereafter showed a gradual loss in weight (16,17).

The factors which were mostly investigated in relation to weight loss include parity, oedema or hypertension during pregnancy, initiation of lactation, type of delivery and gestation time. *Primiparae* were found to lose more weight than *multiparae* by some investigators (15-17). Bray (18) and Stander and Pastore (19) did not observe any difference between groups of different parity.

Women who had oedema in late pregnancy or suffered from hypertension were shown to lose more weight than women who did not show any sign of these two conditions (16,17,19). Singh (15) observed that oedema was a more common condition among *primiparae* than among *multiparae.* Weight loss during the early *puerperium* was shown to be slightly increased by the length of gestation (17), by vaginal delivery (16), and by initiation of lactation (16,17). Studies made in the early *puerperium* have certainly an interest from a physiological point of view, but the majority of factors influencing weight change in this particular period are of no importance when considering weight change after delivery on a longer period.

1.2.2 Longitudinal studies

Hytten and Chamberlain (10) mentioned that: "on the average, any weight gained in pregnancy in excess of 8.6 kg is retained after the immediate *puerperium.* The average woman who gains 12.5 kg in pregnancy is about 4.4 kg above her pre-pregnant weight when she leaves hospital after the lying-in period." These statements need some explanations. In section 1.1.2, we saw that a woman, in addition to the tissues and fluids directly concerned with reproduction, gained some reserve of fat. At parturition, a woman loses weight in the form of the products of conception and fluids. During the few days following delivery a great deal of body fluids are lost and the uterus starts its involution, decreasing rapidly in size and weight. After this lying-in period, a woman is left with about 4.4 kg of fat and excess breast and uterus tissues. Once the immediate *puerperium* is over, about two weeks after delivery, the total amount of weight lost from parturition is around 8.6 kg. Any additional weight is assumed to be fat plus some excess breast tissue.

Studies on *post partum* weight change with well-nourished women that have lasted for more than three months are scanty and the results reported contradictory.

Let us consider now what are the factors that have been studied for their possible effects on weight change after delivery.

A. Effect of infant feeding method

Few investigators attempted to compare breast-feeders and bottle-feeders in their pattern of weight loss. Naismith and Ritchie (4) found that in their sample of 42 healthy *primiparae*, the 20 bottle-feeders lost more weight by six months *post partum* (4.4 kg), than the 22 breast-feeders (2.7 kg). However, nothing is said about the significance of these results. Half of the bottle-feeders were consciously dieting whereas only one breast-feeder admitted to dieting. They reported unusually high energy intakes for their group of breast-feeders. The daily energy intake, estimated over the first three months by a monthly recall and a three day recorded food intake, gave a figure of 2930 kcal. If their estimate is right, it is not surprising that breast-feeders did not lose much weight since they did not need to derive a great deal of energy from their body fat reserve.

Olsen and Mundt (5) studied 182 women for a period of six weeks after delivery. These investigators initiated the study because of the clinical observation that most women had not returned to their pre-pregnant weight at their six week *post partum* visit, and the concern voiced by many women about their failure to lose weight. They found no statistically significant difference in weight loss between breast-feeders and bottle-feeders. The weight loss was calculated from the last weight taken just before delivery. There was a tendency for bottle-feeders to have lost more weight (10.7 kg), than breast-feeders (9.7 kg). The period of study, however, is certainly too short to attach too much importance to their finding. English and Hitchcock (6) also failed to observe any difference in weight loss by six months *post partum* between a group of 16 breast-feeders and a group of 10 bottle-feeders.

In a very well designed study, Bradshaw and Pfeiffer (3) did not report any significant difference in weight loss between 4 lactators and 7 bottle-feeders followed for six months. However, in opposition to the other studies mentioned above, the group of breast-feeders showed a greater weight loss by six months *post partum* (7.0 kg) than the bottle-feeders (5.2 kg). Nevertheless, one must be careful about the conclusion that can be drawn from a small sample such as this. In a study made by Dennis and Bytheway (16), they found that 94 days after delivery the only group still losing weight was that consisting of 28 breast-feeders.

Results from studies designed to evaluate lactational performance or to investigate different aspects of body composition among well-nourished lactating women, have all shown a reduction of body weight with time.

An average weight loss between 2.0 kg to 4.0 kg can be expected for the first three months *post partum* (14,20-22). By six months *post partum*, the average weight loss can be around 4.0 - 5.0 kg (14,22), showing that the greater rate of weight loss occurs during the first three months.

B. Effect of weight gain during pregnancy

There are two questions that might interest an investigator when looking at the effect of weight gain during pregnancy upon weight loss after delivery. Does a greater weight gain imply a greater weight loss? and, will the women return to their pre-pregnant weight (or in other words, will the weight gained be entirely lost *post partum*)?

According to some studies, on average the total amount of weight gained during pregnancy is not lost within the first six months *post partum* (3,5,14,20,21). By six months *post partum* a woman can expect to be, at least, 1 or 2 kg heavier than before pregnancy (3,14).

Weight gain during pregnancy seems to be positively correlated to weight loss after delivery (3,5,20). Therefore, a woman who puts on more weight during pregnancy will tend to lose a greater amount of weight after delivery than a woman who gained less weight.

On the other hand, it was shown that women who gained weight above the "norm" tended to retain large amounts of weight after delivery (5,23).

Greene et al (23) analysed data of 7116 women selected from an initial group of more than 58000 women who had participated in a study made in the United States between 1959 and 1965 on pregnancy outcome. Subjects selected enrolled for more than one pregnancy and had two singleton births within a six year period. Cases of complications during pregnancy were included.

Interpregnancy weight change was defined as the difference between pre-pregnant weights in the second and first studies pregnancies. These pre-pregnant weights were recalled by the women at the time of enrolment in the study.

Some of their results showed that 73% of the sample was heavier by the start of their second study pregnancy; 12% gained 6.8 kg or more, and 12% lost more than 2.3 kg.

Interpregnancy weight change correlated positively with weight gain in pregnancy and interpregnancy interval, and negatively with cigarette smoking and initiation of breast-feeding in hospital.

When the mean interpregnancy weight change was adjusted for some covariates (among them, interpregnancy interval and maternal age), women gaining more than 9.1 kg in their first study pregnancy were heavier by the start of their second study pregnancy. The range of weight retention was between 2.6 and 4.6 kg, regardless of their first pre-pregnant weight.

Two weaknesses have been identified in this study. Firstly it is impossible to make a difference between a woman who lost all her excess weight from the first pregnancy and subsequently put on weight and a woman who stayed heavier because of the first pregnancy. Secondly, the two weights on which is based the whole analysis have been recalled and not measured. Nevertheless, in view of the impressive size of the sample and the seemingly well conducted analysis, the main finding which is that prenatal weight gain in excess of 9.1 kg is associated with *post partum* weight retention is certainly reliable.

C. Effect of age and parity

The effect of parity is not easily discernible from the effect of age since older women are likely to be of a greater parity as well.

This problem is readily overcome as these variables are quite simple to control. Indeed, usually women who have participated in longitudinal studies have been selected among specific age and parity groups.

Consequently, few studies have attempted to investigate the effect of these two variables on weight loss *post partum.* Some results showed that six weeks after delivery, *primigravidae* had lost significantly more weight than *multigravidae* (5,24).

However, age and parity were not significantly correlated with weight change calculated between two successive pregnancies in a sample of 7116 subjects (23).

In view of all these uncertainties about the effect of age and parity, it would be wise to recommend that women participating in longitudinal studies on *post partum* energy balance should be controlled for these two variables.

It will make comparisons easier when analysing other variables in case age and parity have a real effect on body composition. And women of a same parity tend to have similar pattern of daily activities which might allow to control, at least in part, differences in energy expenditure.

II

METHODOLOGY

2.1 Recruitment and subjects.

All subjects but two were recruited in the maternity wards of the Queen Mother's Hospital in Glasgow a few days after delivery. The subjects who were not recruited there had manifested an interest to participate in another study conducted in the department of Physiology. All subjects were recruited by personal contact between May 1988 and January 1989.

The subjects were not chosen at random. They were chosen according to the following criteria of selection:

-aged between 20 and 35 years.

-having a single delivery at term (between 37 and 42 weeks of gestation).

-with the baby's birthweight of 2500g or more.

-without any illness.

-not obese prior to pregnancy.

An initial group of 65 women started the study but data for 62 of them were analyzed. Data for one lady were removed from the analysis because of a lack of follow-up data. The other two women decided not to continue the study, in one case, the baby had died of cot death and in the other, the baby was diagnosed as severely handicapped.

Of the 62, 32 were intending to breast-feed their baby at the time of recruitment. Of these, 26 women breast-fed their baby at least partially for 26 weeks post-partum, two women breast-fed for 22 weeks and three women breast-fed for 12 weeks. Only one woman breast-fed exclusively for the entire period of study. Among the 30 bottle-feeders, 26 did not breast-feed at all and four breast-fed for less than two weeks.

2.2 Data collection.

2.2.1 Anthropometry

A. Body weight

This measure was recorded to the nearest 0.1 kg with the subjects dressed in underwear or in a light nightdress. A set of portable electronic scales (SECA alpha, model 770) was used. The scales were checked regularly for accuracy against a beam balance.

B. Skinfold thicknesses

Four skinfold thicknesses were used to calculate the fat mass by using the regression equations calculated by Durnin and Womersley (25).

These were all measured on the right side of the body. They were all recorded to the nearest 0.5 mm with a Holtain caliper. The pressure of the caliper jaws was calibrated to give a constant pressure of 10 g/mm^2. The procedure for performing the skinfold measurements was the following: a fold of skin and subcutaneous tissue was picked up between the thumb and the forefinger and pinched away from the underlying muscle; the caliper jaws were applied about 1 cm below the pinch point and just then the fingers released the fold. After the full pressure of the caliper jaws was applied, the actual measurement was read at the time the readings started to stabilize, usually after two or three seconds. Every skinfold was measured three times and an average value was recorded (25).

Specific skinfold measurements:

1. Biceps:

the skinfold was picked up on the front of the arm directly above the center of the cubital fossa. The calipers were applied at the level of the midpoint of the biceps muscle.

2. Triceps:

the calipers were applied at the back of the arm on the middle point between the inferior border of the acromiom process and the tip of the olecranon process, and directly in line with the point of the elbow and acromion process.

3. Subscapular:

the skinfold was picked up immediately below the tip of the scapula at an angle of about 45° downwards from the spine.

4. Supra-iliac:

the vertical skinfold was picked up immediately above the anterior superior iliac crest in the mid-axillary line.

C. Limb circumferences:

These were recorded with a measuring tape made from non elastic material to the nearest 0.1 cm. The subject was standing with her weight evenly distributed on both legs for all the circumferences except for the calf where she was sitting. The circumferences were all measured on the right side of the body. The levels for the circumferences were:

1. Middle upper arm:

the measuring tape was applied on the middle point between the inferior border of the acromion process and the tip of the olecranon process (as for triceps skinfold).

2. Buttocks:

this was the maximum circumference over the buttocks, with the feet drawn together.

3. Upper thigh:

this was the circumference of the upper thigh at gluteal fold.

4. Calf:

this was the maximum circumference of the calf muscle.

D. Height

This measure was recorded to the nearest cm with a measuring tape made from a non elastic material. The subject was standing against a wall, without shoes, with the heels put together. The subject was asked to reach up to a maximum height with the legs streched but the feet flat on the ground.

2.2.2 Other information

Information concerning the type of delivery, parity, birthweight of baby, booking weight, health and age of the subject was gathered from her medical record.

A questionnaire was filled in to obtain information about some socio-economic characteristics of the subject, such as marital status, occupation and number of years of education, and other characteristics (smoking habit, the reason why she chose to breast-feed or bottle-feed and what she intended to do about her diet and exercise during the study).

2.2.3 Visits to subjects

Eight visits per subject were scheduled as follow: every two weeks for the first two months and every month from the third to the sixth month *post partum*. So the visits were made at weeks 2, 4, 6, 8, 12, 17, 22, and 26 after delivery.

For the visits at every fortnight, each measurement was taken at plus or minus four days of its planned day. For the monthly visits, measurements were taken at plus or minus seven days of their planned days.

Each visit took place at the subject's home, usually during the morning. Each time body weight, four skinfold thicknesses and four limb circumferences were measured. In addition to these measurements, during the first visit (at two weeks *post partum*) a questionnaire was filled in and the height was recorded.

A table summarizing the data collection procedure follows:

Table 1. Data collection procedure

Week after delivery	Place	Information collected
Less than 1	Maternity ward	Participation of the subject Information in medical record
2	Subject's home	Questionnaire / Anthropometry
4, 6, 8, 12, 17, 22	,, ,,	Anthropometry
26	,, ,,	Anthropometry / Dieting and exercising during the study

2.3 Data analysis.

Pre-pregnant weight and weight gain during pregnancy of the subjects were estimated from the booking weight taken at the very first antenatal clinic attended by the subjects, which is usually at about twelve weeks of gestation.

This weight recorded in kg was measured by the nursing staff of the clinic with a beam balance (Avery), with the subject in everyday clothing but without shoes.

2.3.1 Estimation of pre-pregnant weight

The pre-pregnant weight was estimated by the booking weight adjusted for clothing and week of pregnancy. The equation used is:

Estimated pre-pregnant weight = Booking weight
- Adjustment for clothing
- Adjustment for week of pregnancy

where adjustment for clothing was taken as 1kg

and adjustment for week of pregnancy was:

0.5kg for up to 10 weeks of pregnancy and

0.39kg per week for the next 30 weeks of pregnancy.

So, if for example a woman was weighed at week 14 of pregnancy, the adjustment would be 2.1kg $(0.5 + (14-10)\times 0.39)$.

Those adjustments for week of pregnancy follow from the results of a study which investigated energy requirements of pregnancy in a sample of 180 Glasgow mothers (13). They found that the average weight gain from conception to week 10 for the 20 women recruited before conception was 0.5kg. The average weight gain between week 10 and week 40 was 11.7kg.

A booking weight was not available for three women. Instead, a recalled pre-pregnant weight was used in the analysis.

2.3.2 Estimation of residual weight gain and fat gain during pregnancy

The residual weight gain was assumed to be the difference between the first weight measured after delivery (at two weeks *post partum*) and the estimated pre-pregnant weight. As seen in 1.2.2, this weight gain represents presumably the adipose tissue deposited during pregnancy plus some excess breast tissue (10,13).

The fat gain was estimated as follows:

Estimated fat gain = (residual weight gain - 0.4kg) x .8

where the value of 0.4kg represents the increased breast mass among breast-feeders (10) and the value of 0.8 is the approximate proportion of fat in adipose tissue (26).

2.3.3 Grouping by social class, smoking habit and parity

The subjects were classified by social class according to the publication produced by the Office of Population Censuses and Surveys (27), but using a modified class grouping.

The occupation chosen to be coded was either the subject's occupation or the occupation of the subject's partner or husband, whichever corresponded to the highest value of social class. Students and persons out of employment were coded in two separate groups.

The following table compares the social classes grouping of OPCS and the one of this study.

Table 2. Social classes: OPCS versus this study

Social classes	
OPCS	this study
I- Professional occupations II- Intermediate occupations	I
III- Skilled occupations N: Non-manual	II
M: Manual IV- Partly-skilled occupations	III
V- Unskilled occupations	IV

In the analysis, a subject was considered to be a smoker if she smoked 10 cigarettes or more per day.

For the purpose of the analysis, the subjects were divided into groups of different parities, with women having their first baby (*primiparae*) in one group and women having their second or more baby (*multiparae*) in a second group.

2.3.4 Statistical analysis

All analysis were carried out using GENSTAT statistical language (28). A statistical significance level of $p<0.05$ was used for all tests.

An analysis of variance was carried out to determine whether or not the infant feeding method is a statistically significant factor that explains *post partum* changes in maternal body weight, skinfolds and circumferences. For the variables for which the infant feeding method was significant, the relationships were determined by a regression analysis.

Thereafter, an analysis of variance and a multiple regression analysis were used to choose and to fit some models for the prediction of *post partum* changes in maternal body weight in terms of the following factors: method of infant feeding, residual weight gain during pregnancy, smoking habit, parity and social class.

CHARACTERISTICS OF THE SAMPLE

When the sample of subjects is split into two with respect to the infant feeding method, both groups are quite comparable in terms of most of the maternal characteristics that were recorded in the course of this study. Table 3 presents a summary of some characteristics for which both groups are similar.

Table 3. Maternal characteristics related to age, height, parity and body weight changes during pregnancy by method of infant feeding

Characteristics	Breast-feeders (n=32)			Bottle-feeders (n=30)		
	Mean	SD	Range	Mean	SD	Range
Age (years)	30.4	2.7	23-34	26.6	4.0	20-34
Height (metres)	1.64	.05	1.47-1.73	1.62	.07	1.52-1.84
Parity	0.6	.8	0-4	0.5	.7	0-2
Pre-pregnant weight (kg)	55.4	5.2	45.9-67.4	55.7	7.0	43.7-75.9
Residual weight gain (kg)*	5.3	2.8	1.1-11.9	5.0	3.5	0-12.9
Fat gain (kg)	3.9	2.2	0.6-9.2	4.0	2.8	0-10.3
Birthweight (kg)	3.58	.37	2.78-4.58	3.42	.39	2.58-4.53

* Weight at 2 weeks *post partum* - pre-pregnant weight.

In addition, if we consider that about 8.9 kg is lost from parturition to two weeks *post partum* (29), the average total weight gain during pregnancy for both groups would be around 14 kg.

This value is slightly higher than what was reported for a sample of Glasgow mothers (13) but remains within the limits of what is usually reported for well-nourished European women (10).

The same conclusion applies to fat gain in this sample, with a value higher than the 2.3 kg reported in the Glasgow study (13). The differences found in fat and weight gains between this sample and the values calculated from the Glasgow study can probably be explained by the fact that in the present study, fat and weight gains are based on estimated and not measured previous body weights. It is possible that the pre-pregnant weights have been underestimated.

There are however two characteristics for which the two groups are not so similar. They are social class and smoking habit. Breast-feeders in this sample come from a higher social group than the bottle-feeders. This observation has been reported often in the past (see for example, 30,31). Even though the underlying reasons associating method of infant feeding and social class remain unclear, it seems that some other environmental factors such as education, nutrition, and facilities for child care might all be contributory (32).

Concerning smoking habits, 33% of bottle-feeders were smokers against only 6% of breast-feeders. It remains to be seen whether this is really a more common feature among bottle-feeders in general or if this sample is very peculiar in this respect.

Table 4 gives a classification of the subjects by social classes and smoking habits.

Table 4. Number of subjects classified by social class and smoking habit for each method of infant feeding

Characteristics	Breast-feeders (n=32)		Bottle-feeders (n=30)	
	n	%	n	%
Social class:				
I	24	75	11	37
II	1	3	6	20
III	5	16	9	30
IV	0	0	0	0
Student	2	6	0	0
OOE*	0	0	4	13
Total	32	100	30	100
Smoking habit:				
Smoker**	2	6	10	33
Non-smoker	30	94	20	67
Total	32	100	30	100

* OOE: out of employment

** 10 cigarettes or more per day

IV

EFFECT OF INFANT FEEDING METHOD ON POST PARTUM WEIGHT LOSS.

The first factor to be analysed for its possible effect on weight loss *post partum* is the method of infant feeding. As discussed earlier, some evidences, although contradictory, showed the importance of this factor on weight loss *post partum*.

4.1 Results.

A within subjects ANOVA was carried out using body weights of the subjects as the dependent variable and week of measurement (time) and method of infant feeding with possible interaction with week of measurement as the independent variables.

Table 5 is the analysis of variance table for the weight loss explained by the two infant feeding methods over a 26 week period.

TABLE 5. ANOVA FOR WEIGHT CHANGE AFTER DELIVERY

Source of variation	SS	DF	MS	F	P
Week	391.18	7	55.88	33.61	<.0005
Interaction week-infant feeding method	37.16	7	5.31	3.20	<.01
Residual	642.79	387	1.66		
Total	1071.13	401			

As shown by the F-ratio, weight loss after delivery is highly influenced by the week of measurement ($p<.0005$). So as the time goes on, the loss of weight tends to increase. This factor alone explains 37% of the total variance of the weight loss.

A very important finding emerged from this analysis. There is a significant difference ($p<.01$) between the two groups of infant feeding methods in their pattern of weight loss after delivery. A further 3.5% of the variance is explained by the presence of the interaction of infant feeding method with time.

A regression model was fitted and the coefficients of regression are presented in table 6.

TABLE 6. WEIGHT CHANGE AFTER DELIVERY

Week	Breast-feeders		Bottle-feeders	
	Estimate (kg)	S.E.	Estimate (kg)	S.E.
4	- .562	.233	- .260	.407
6	- .950	.238	- .307	.411
8	-1.359	.236	- .767	.415
12	-1.997	.233	-1.149	.415
17	-2.688	.246	-1.277	.424
22	-3.197	.249	-1.617	.419
26	-3.662	.249	-1.982	.411

From this table, one can see the cumulative weight loss for each group of infant feeding method. At any measurement time the weight loss of breast-feeders was greater than the weight loss of bottle-feeders.

Both groups started the study, at two weeks *post partum*, with exactly the same mean body weight, 60.7 kg. Breast-feeders were on average, 5.3 kg heavier than before pregnancy and bottle-feeders, 5.0 kg. At the end of the study, the total weight loss for the breast-feeders was 3.66 kg and for bottle-feeders, 1.98 kg.

By 26 weeks *post partum* neither of these two groups had reached their pre-pregnant weights. Breast-feeders were still 1.6 kg heavier (2.9%) than before pregnancy and bottle-feeders, 3.0 kg (5.4%). The pre-pregnant weight was considered to be reached when a woman was at most .5 kg over it.

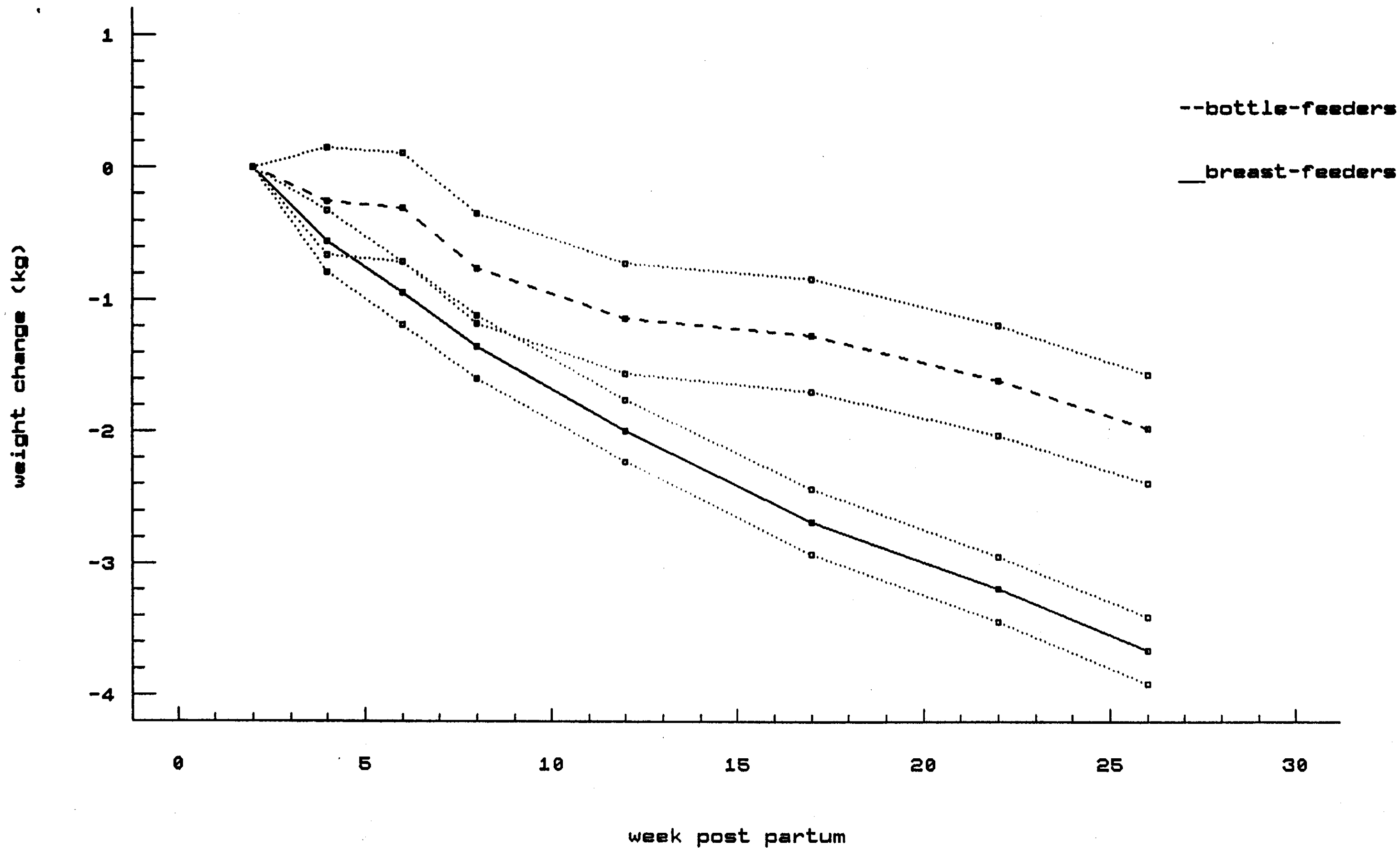
Within each group, we can identify different patterns of weight change. 92% (24 out of 26) of the breast-feeders had lost weight and 42% (11 out of 26) had reached or were below their pre-pregnant weight by 26 weeks *post partum*. The remaining 8% (2 out of 26) had gained weight but the weight gain was less than 1 kg in all cases.

As for bottle-feeders, 79% (23 out of 29) lost weight and 31% (9 out of 29) of them had reached or were below their pre-pregnant weight by 26 weeks *post partum*. 21% (6 out of 29) had gained weight, the range of weight gain being less than 1 kg for two of them and between 2.0 kg and 5.8 kg for the other four.

The average (and average ± SD) rate of weight loss for each group can be visualised on figure 1. The highest rate of weight loss occured between week 2 and 4 for breast-feeders, and between week 6 and 8 for bottle-feeders. As from week 8, there is a slowing down in the rate of weight loss for both groups.

The weight loss per week for breast-feeders averaged 153g and for bottle-feeders, 83g.

Figure 1. Weight change after delivery



4.2 Discussion.

These results show clearly that breast-feeding played an important part in promoting weight loss in this sample of healthy lactating women. Although this affirmation is not shared by many investigators (4-6, 20), it proves easily the theory assuming that maternal body fat will supply energy for lactation.

If we assume that the energy made available from one kilogram of body weight is 6500 kcal (33), breast-feeders had an average energy supply of 142 kcal per day from weight loss and bottle-feeders almost twice less, 77 kcal per day. For breast-feeders, this calculated energy supply is less than the theoretical 200 kcal per day (2), but since no attempt was made to measure energy intake or expenditure it is impossible to speculate about the exactness of this theoretical value.

It must be said that none of the breast-feeders has declared to be dieting at any moment during the study. They seemed well aware that a restriction in calories while lactating could easily make them tired and affect their milk supply. As for bottle-feeders, the majority of them were not dieting. One tried a restricted diet of 1000 kcal per day for two weeks and three others who did not admit dieting, said they were being careful about their nutrition.

Concerning their level of exercise, both groups appeared to be quite busy looking after their new baby and very few found the time to do some kind of regular exercise.

The amount of weight lost by breast-feeders at the end of three and six months *post partum* is in good agreement with previous reports (14,21,22).

By 26 weeks *post partum*, the pre-pregnant weight was not reached by either of both groups. Women were on average heavier, so presumably fatter than before pregnancy. This raises doubts about the assumption stating that a normal body composition should be re-established within six months (2). From these results, it seems that six months is not a sufficient period of time to allow the maternal body to get back to its pre-pregnant state.

An intriguing pattern of weight gain emerged for a minority of women. More bottle-feeders gained weight after delivery than breast-feeders. The range of weight gain was also greater for bottle-feeders. No previous studies reported that finding among well-nourished women, although Bradshaw and Pfeiffer (3) reported a weight gain from week 22 to week 28 among their bottle-feeders and none among the lactators. This pattern of weight gain is rather unexpected among well-nourished women, and the reasons explaining it are far from being clear. Some psychological and environmental factors are probably involved.

V

CHANGES IN MATERNAL SKINFOLDS AND CIRCUMFERENCES MEASUREMENTS

Both types of measurements reflect the distribution of fat on the human body, that is why results for these two variables are presented together in the same chapter.

There was no statistically significant difference in the pattern of change in skinfolds and circumferences measurements between the two groups of infant feeding method.

Consequently, both groups have been analysed together in regard to the pattern of change occuring after delivery for each of these two maternal variables.

5.1 Changes in circumferences measurements.

Post partum changes in four circumferences measurements are shown in table 7. Results are expressed in percentage of the first measurement made at week 2.

The patterns of change in buttocks and upper thigh circumferences were significantly different (respectively, $p<.0005$ and $p<.01$) over the six month period. They decreased respectively by 2.9% and 0.3% by the end of 26 weeks *post partum.* The buttocks circumference showed a regular decrease from 4 weeks up to 26 weeks *post partum.* The upper thigh circumference however, showed an increase up to week 8 and thereafter a gradual decrease until the end of the study.

Arm circumference changed significantly during the period of study ($p<.01$) and showed a net increase of 0.7% by 26 weeks *post partum*. Calf circumference did not change significantly over time and showed a net increase by 26 weeks *post partum* of 0.3%.

TABLE 7. POST PARTUM CHANGES IN 4 CIRCUMFERENCES

(BOTTLE-FEEDERS AND BREAST-FEEDERS COMBINED)

Week	Arm %	Calf %	Thigh %	Buttocks %
4	1.09	.10	.48	- .38
6	1.66	.48	1.00	- .73
8	1.74	.69	1.37	- .82
12	1.10	.32	.51	-1.43
17	1.55	.42	.21	-2.11
22	.62	.39	- .14	-2.68
26	.71	.30	- .27	-2.93

The pattern of change of four circumferences for the first six months *post partum* can be seen in figure 2.

5.2 Changes in skinfolds measurements.

Post partum changes in four skinfolds measurements are shown in table 8. Results are expressed in percentage of the first measurement made at week 2.

Figure 2. Post partum changes in 4 circumferences

(bottle-feeders and breast-feeders combined)

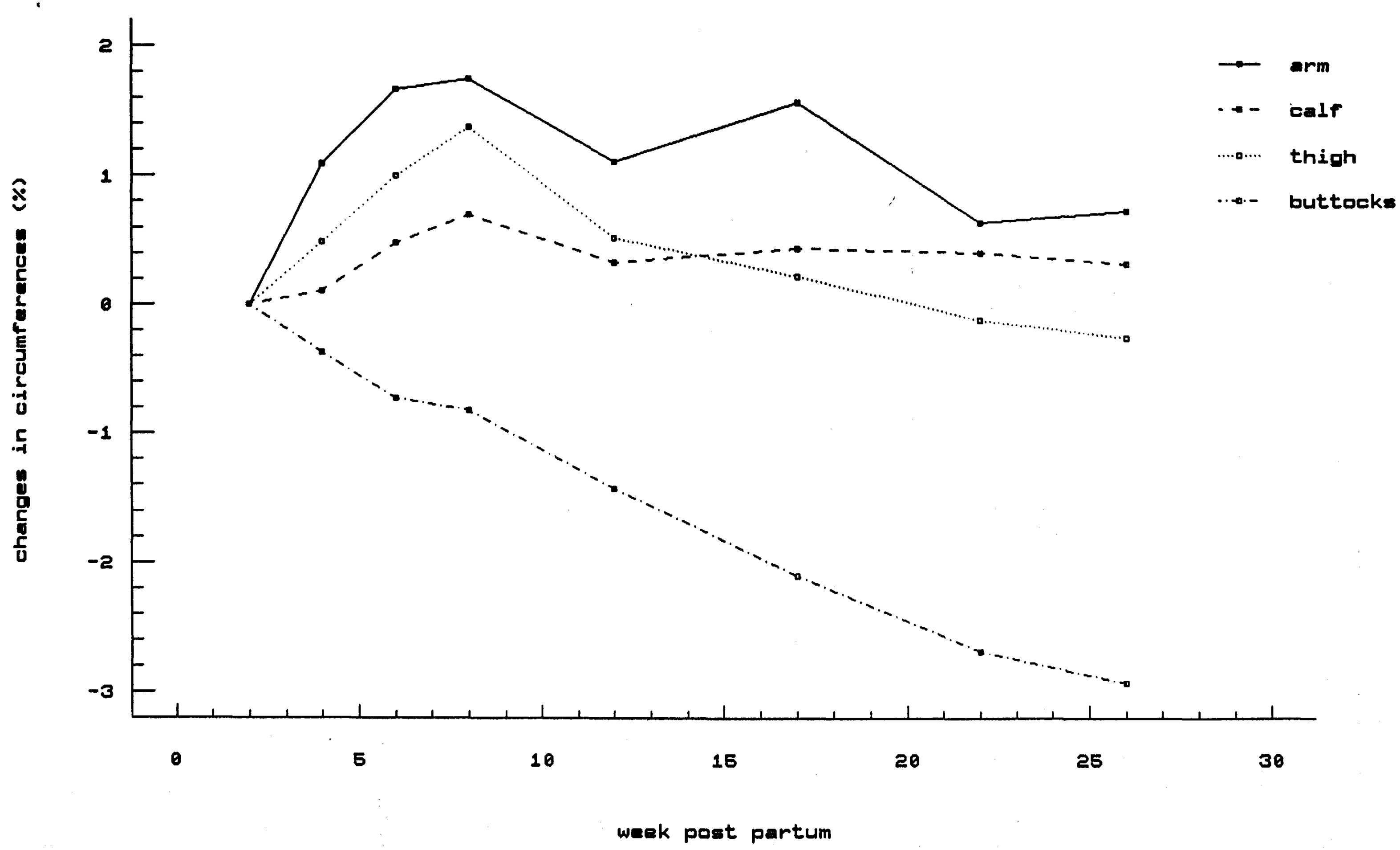


TABLE 8. POST PARTUM CHANGES IN 4 SKINFOLDS

(BOTTLE-FEEDERS AND BREAST-FEEDERS COMBINED)

Week	Triceps %	Biceps %	Subscapular %	Supra-iliac %
4	.46	-2.99	- 3.31	- 7.41
6	4.17	2.58	- 1.42	-10.45
8	5.58	- .32	- 1.98	-13.76
12	6.61	-1.47	- 6.27	-24.85
17	6.53	-1.80	-10.41	-29.78
22	2.12	-2.16	-12.56	-34.72
26	2.97	-2.88	-14.02	-36.05

There was a statistically significant decrease ($p<.0005$) in the sum of four skinfolds during the period of study. However, each individual skinfold behaved quite differently from one another. The biceps skinfold did not change significantly in time. The three other sites, triceps, subscapular and supra-iliac, showed a statistically significant (respectively, $p<.001$, $p<.0005$ and $p<.0005$) pattern of change during the six month study.

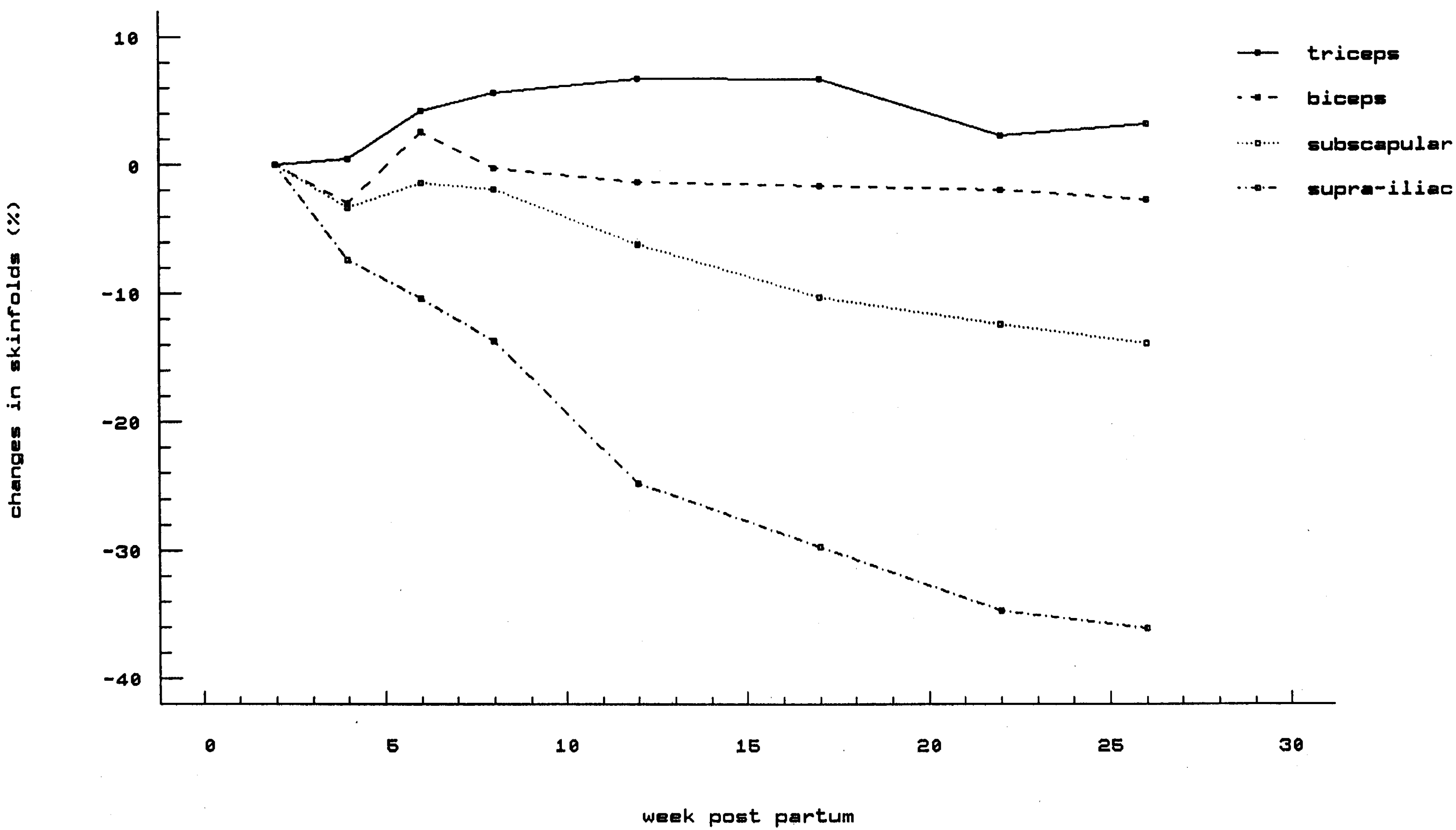
The patterns of change over 26 weeks *post partum* of four skinfolds are shown in figure 3.

The triceps site showed an increase from week 2 to week 17 and thereafter a gradual loss up to week 26.

The subscapular site showed, at first, a decrease up to week 4, after that an increase until week 8 and finally a decrease again until week 26. The only site for which a steady loss occured was the supra-iliac site.

Figure 3. Post partum changes in 4 skinfolds

(bottle-feeders and breast-feeders combined)



The net changes in triceps, subscapular and supra-iliac skinfolds were respectively 3.0%, -14.0% and -36.1% at week 26.

5.3 Changes in fat mass.

Changes in fat mass among breast-feeders did not differ significantly from those among bottle-feeders during the period of study. For each group, there was a significant decrease with time in fat mass calculated with the sum of four skinfolds.

The cumulative change in fat mass for both groups can be seen in table 9.

TABLE 9. CHANGES IN FAT MASS AFTER DELIVERY

Week	Breast-feeders (kg)	Bottle-feeders (kg)
4	- .488	- .303
6	- .402	- .266
8	- .508	- .316
12	-1.030	- .865
17	-1.364	-1.073
22	-1.769	-1.458
26	-1.940	-1.566

At every measurement time, the average fat loss of breast-feeders was greater than the one of bottle-feeders. A somewhat surprising finding is shown at week 4, where bottle-feeders had lost 303g of fat but only 260g of body weight (see section 4.1). At week 26, the total fat loss for breast-feeders averaged 1.94 kg, representing only 53% of the total weight loss. For bottle-feeders, the figure is quite different with a total fat loss of 1.57 kg, representing 79% of the total weight loss.

Figure 4 illustrates the changes in fat mass for both groups of subjects. The pattern of fat change is very similar for both groups. The rate of fat loss was greater for both groups between week 2 and week 4; between week 4 and 6 there is a sudden increase in fat mass, although very modest, and thereafter a gradual decrease until week 26.

5.4 Discussion.

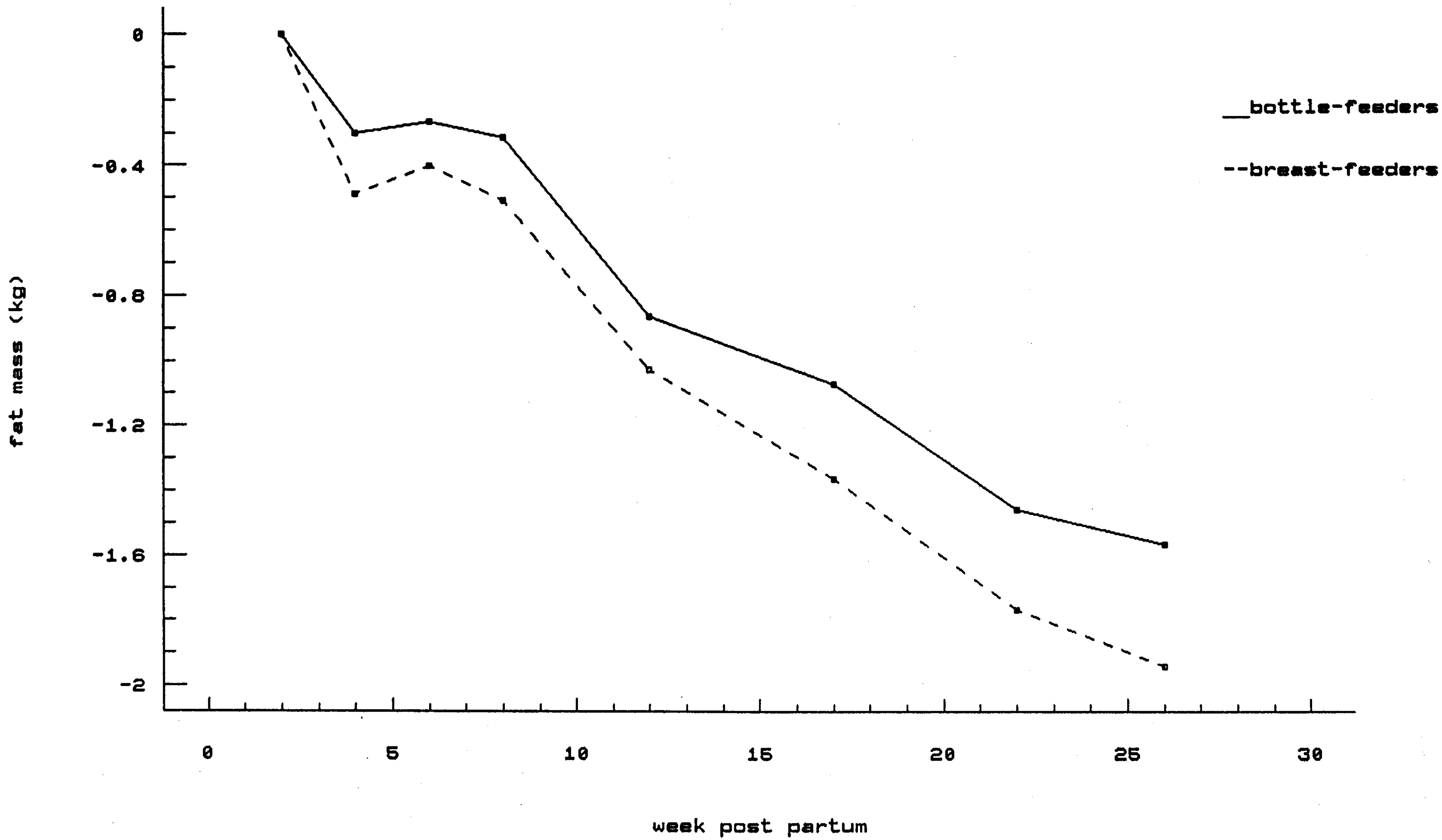
With regard to circumferences measurements, buttocks and upper thigh circumferences which represent the "trunk sites" showed the greatest changes over time. As for skinfolds measurements, once again the "trunk sites", subscapular and supra-iliac skinfolds, decreased the most during the period of study. These results suggest clearly that fat loss occured from the trunk rather than from the limbs. This observation has been made often in the past (see, for example, 20,21,34).

As in this study, other investigators (3,21,22,34) observed increases or maintenance of triceps measurements in lactating women, while a considerable amount of fat was lost from the supra-iliac site during the first weeks *post partum.*

It is certainly not clear why there is an increase in fat in the triceps site when the demand for fat mobilization should be very high. This should be especially true with well-nourished women who presumably have already enough fat reserve.

In marginally nourished women, Adair et al (35) reported increases in triceps and subscapular skinfolds in lactating women during the

Figure 4. Change in fat mass after delivery



first month *post partum.* They believe that a high metabolic efficiency, present during pregnancy, is still operating during the first *post partum* weeks, allowing fat deposition when the nutritional needs of the infant are lowest.

It is interesting to note that this pattern of fat redistribution is not exclusive to breast-feeders since the bottle-feeders in this study behaved in the same way.

The findings concerning the pattern in fat mass are very interesting. After the weight loss *post partum* was shown to be significantly different between the two groups of infant feeding methods one might have expected the fat loss to be significantly different as well. Since this is not what was obtained, explanations must be sought.

First, the easy way out is to say that estimation of fat mass by skinfold thicknesses measurements is not a reliable method in lactating women. Although these equations have been previously validated in a study made with 45 lactating women in 1985 (36), this is still a possibility.

Body density was assessed from underwater weighing and from linear regression equations derived from the logarithm of the sum of four skinfold thicknesses. Measurements were made once a month for four months *post partum.* The four regression equations were compared with the equation published by Durnin and Womersley (25) for non-pregnant, non-lactating females of the same age group. Body fat predicted from the published equation and for the tested equations was used to classify the 45 subjects into three arbitrary categories of body fat: <15%, 15-30% and >30%. The tested equations correctly categorized between 58% and 73% of the subjects for the four months, and the equation published by Durnin and Womersley (25) classified correctly between 56% and 68% of the cases over the same four months. There was no statistical difference in the proportion of individuals categorized correctly by both sets of equations.

The main concern about this study is the categories used to classify the subjects. Since non obese lactating women are more likely to fall within a range of 25-30% of body fatness, it would have been more appropriate to test the equations for that specific range of body fatness.

Skinfolds thicknesses may not be appropriate to measure accurately subcutaneous fat in women at least during the first month *post partum* as shown by the result found for bottle-feeders at week 4. According to this result, bottle-feeders lost 303g of fat but only 260g of body weight, which is a bit odd.

A possible explanation would be that the subcutaneous tissue is still engorged with some fluids producing a reading higher than normal. Even if the discrepancy seems to apply only for bottle-feeders, a closer look at the value found for breast-feeders, a loss of 488g of fat for 560g of body weight, shows that it is a very high value as well. Both groups have been possibly affected by this presumably higher than normal reading.

One can argue that skinfold thicknesses measurements are sensitive enough and that they really measure what they are supposed to and try to find another way to explain the similarities in fat loss between both groups.

If weight loss is different and not fat loss, this means that fat-free components change differently for breast-feeders and bottle-feeders. A possibility lies in the fact that both groups are very different in terms of one particular tissue, which is breast tissue.

The exact amount of breast tissue in excess during lactation is not known, but it is certainly not made up of fat (10). Bottle-feeders are likely to lose this excess breast tissue quite quickly after delivery, thus increasing their weight loss but not their fat loss. As for breast-feeders, with the milk flow coming in a few days after delivery, some weight can be expected to be gained by the breasts, and these will stay heavier for as long as lactation is on and that breast milk is the only food received by the infant.

An adjustment among breast-feeders, aiming at substracting this excess tissue from their body weight would have the effect of decreasing the fat mass calculated by skinfold thicknesses, therefore probably increasing the fat loss. The same kind of adjustment but the other way around could be made for bottle-feeders to account for the weight lost which did not contain any fat, implying that their fat loss might be lower than the one calculated by skinfold thicknesses.

VI

EFFECT OF OTHER FACTORS ON WEIGHT CHANGE AFTER DELIVERY

6.1 Residual weight gain.

As it can be seen from figure 5, the weight loss at week 26 depends on the residual weight gain. The correlation between these two variables is .508. Women who gained a lot of weight tended to lose a lot of weight and those who gained a small amount of weight tended to lose a small amount of weight. 92% of breast-feeders (24 out of 26) had a residual weight gain between 1 and 8 kg, whereas 76% of bottle-feeders (22 out of 29) fell within these limits. Bottle-feeders tended to have a wider range of residual weight gain. However both groups had the same average residual weight gain (see table 3). The unbroken line in figure 5 represents the state of regaining the pre-pregnant weight at week 26. Cases above it are those that are below their pre-pregnant weight at week 26. And those below it being the ones with an excess weight as compared with pre-pregnant weight.

6.2 Effect of smoking habit.

It was decided to analyse the remaining effect of the smoking habit on weight change after delivery when the effect of infant feeding method is already taken into account. First an ANOVA was carried out for the combined groups. The results that are presented in part a) of table 10 show that when entered after week and interaction week-infant feeding method, the interaction week-smoking habit is still a significant factor.

Figure 5. Weight loss at 26 weeks post partum according to residual weight gain (r=.508)

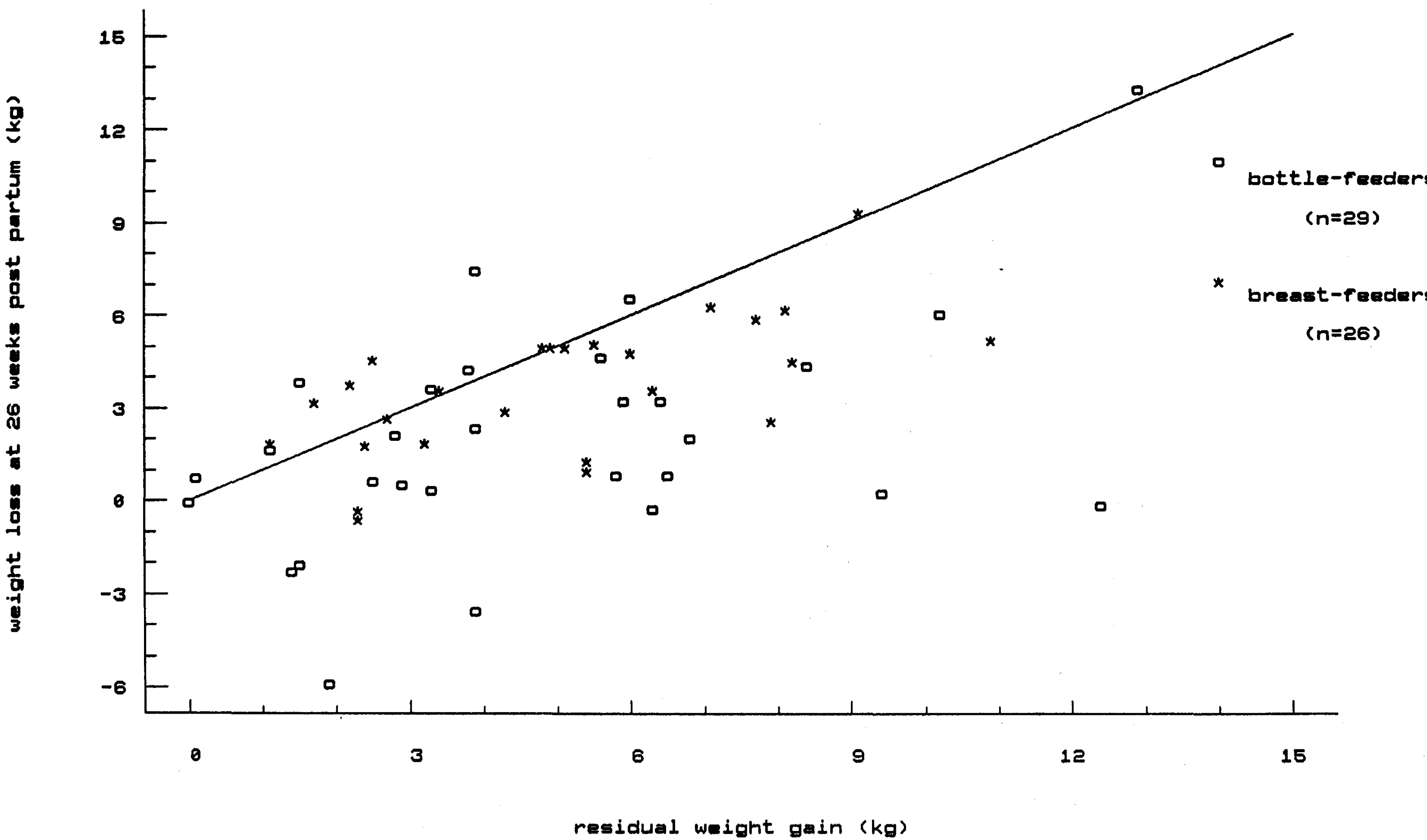


TABLE 10. ANOVA for weight change after delivery

(including the effect of smoking habit)

Source of variation	SS	DF	MS	F	P
a) combined:					
Week	391.18	7	55.88	35.00	<.0005
Interaction week-infant feeding method	37.16	7	5.31	3.32	<.01
Interaction week-smoking habit	36.07	7	5.15	3.23	<.01
Residual	606.72	380	1.60		
Total	1071.13	401			
b) breast-feeders:					
Week	328.47	7	46.92	53.87	<.0005
Interaction week-smoking habit	3.54	7	.51	.58	
Residual	168.06	190	.87		
Total	500.07	204			
c) bottle-feeders:					
Week	99.87	7	14.27	6.23	<.0005
Interaction week-smoking habit	52.31	7	7.46	3.26	<.01
Residual	418.98	183	2.29		
Total	571.06	197			

However, since only two breast-feeders were classified as smokers in the study, it seems justified to assume that most of the effect of smoking habit comes from the 10 bottle-feeders who were classified as smokers. To see whether this is the case, two ANOVA were carried out on each of the breast-feeders and the bottle-feeders group. The results are given in parts b) and c) of table 10. For breast-feeders, the smoking habit turned out to be not significant whereas for the bottle-feeders it was still significant. Consequently, it was decided to consider the smoking habit only for the bottle-feeders. Note that the number of smokers in this sample is so small that those results should be interpreted with caution.

Table 11 presents the regression coefficients for all the breast-feeders and for the bottle-feeders split into smokers and non-smokers. Note that the coefficients for the breast-feeders are the same as those presented in table 6.

TABLE 11. EFFECT OF SMOKING ON WEIGHT CHANGE AFTER DELIVERY

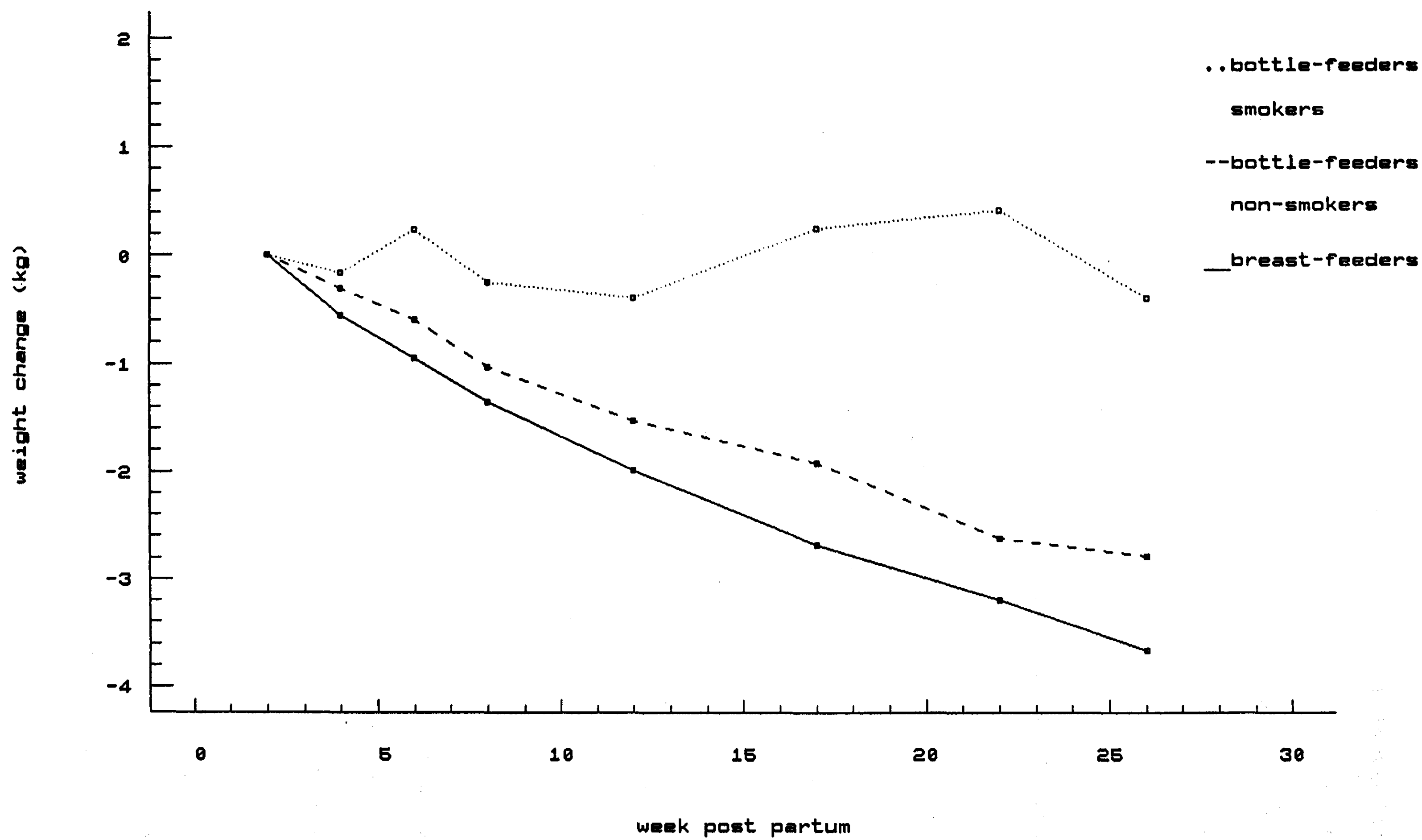
Week	Breast-feeders kg	Bottle-feeders Non-smokers kg	Bottle-feeders Smokers kg
4	- .562	- .310	- .160
6	- .950	- .600	.237
8	-1.359	-1.033	- .259
12	-1.997	-1.540	- .404
17	-2.688	-1.935	.230
22	-3.197	-2.631	.401
26	-3.662	-2.795	- .410

By 26 weeks *post partum* the three groups had lost weight. The total weight loss being 3.66 kg for breast-feeders, 2.80 kg for bottle-feeders non-smokers and only 0.41 kg for bottle-feeders smokers.

Figure 6 illustrates those weight changes for the three groups.

Only breast-feeders and bottle-feeders non-smokers showed a continuous weight loss whereas bottle-feeders smokers exhibited a very strange pattern of weight change.

Figure 6. Effect of smoking on weight change after delivery



Two periods of weight gain occured among bottle-feeders smokers. A short one between week 4 and 6 and a longer one between week 12 and 22.

The patterns of weight loss of breast-feeders and bottle-feeders non-smokers are very similar although the magnitude of the changes is different. One can see a net slowing down in weight loss between week 12 and 17, and from week 22 onwards for bottle-feeders non-smokers, whereas it is not present among breast-feeders.

For both groups of bottle-feeders, the highest rate of weight change, which corresponded to a weight loss in both groups, occured between week 6 and 8.

The overall rate of weight loss per week averaged 116g for bottle-feeders non-smokers and only 17g for bottle-feeders smokers.

6.3 Stepwise regression.

Finally, a stepwise regression was carried out with six possible factors, time, infant feeding method, residual weight gain, smoking habit, parity and social class.

The first factor to enter the regression model is obviously time, it explains 36.5% of the total variance in weight change.

The second factor to enter the model was the interaction week-residual weight gain. It is the factor that explains the most of the 63.5% of the variance that is unexplained by time. A further 8.8% of the total variance is explained.

The third factor, the one that explains the largest part of the 54.7% of the unexplained variance in weight change, was interaction week-infant feeding method. With this factor, an additional 3.5% of the total variance is explained.

As a fourth factor, smoking habit explains 2.1% of the total variance of weight change. It is the last significant factor to enter the model.

The other two factors, parity and social class, were not significant enough to enter into the model at this stage.

With the four factors in the model, 50.9% of the variance in weight change after delivery is explained.

The resulting ANOVA table is as follows:

TABLE 12 ANOVA for weight change after delivery

(including the effects of residual weight gain and smoking)

Source of variation	SS	DF	MS	F	P
Week	391.18	7	55.88	39.63	<.0005
Interaction week-residual weight gain	94.46	7	13.50	9.57	<.0005
Interaction week-infant feeding method	37.35	7	5.34	3.78	<.0005
Interaction week-smoking habit	22.15	7	3.16	2.24	<.05
Residual	525.99	373	1.41		
Total	1071.13	401			

Tables 13 and 14 present the coefficients to be used to estimate the weight change after delivery. It is split into breast-feeders, bottle-feeders non-smokers and bottle-feeders smokers. Again the split between smoking habit among breast-feeders was not justified.

TABLE 13. EFFECT OF RESIDUAL WEIGHT GAIN ON WEIGHT CHANGE AFTER DELIVERY AMONG BOTTLE-FEEDERS

Week	Bottle-feeders non-smokers kg	Bottle-feeders smokers kg	Residual weight gain
4	.000	- .005	-.0513
6	-.142	.102	-.0552
8	-.714	- .243	-.0481
12	-.791	- .237	-.1119
17	-.946	.526	-.1504
22	-.426	1.241	-.3527
26	-.253	.797	-.4280

The equation for the weight change after delivery is given by the appropriate constant plus the product of the appropriate coefficient for residual weight gain times the residual weight gain.

For example if we consider the average weight gain of bottle-feeders and breast-feeders, which was found to be around 5 kg for both groups, the weight change between week 2 and week 26 would be:

for a breast-feeder: -1.398 - .4504 (5) = -3.65 kg

for a bottle-feeder non-smoker: -.253 - .428 (5) = -2.39 kg

for a bottle-feeder smoker: .797 - .428 (5) = -1.34 kg

TABLE 14. EFFECT OF RESIDUAL WEIGHT GAIN

ON WEIGHT CHANGE AFTER DELIVERY AMONG BREAST-FEEDERS

Week	Breast-feeders kg	Residual weight gain
4	- .293	- .0512
6	- .616	- .0631
8	-1.058	- .0585
12	-1.335	- .1255
17	-1.777	- .1824
22	-1.309	- .3891
26	-1.398	- .4504

Residual weight gains of 2, 6 and 10 kg, which corresponded roughly to the areas of greatest density on the scatterplot showed in figure 5 (see section 6.1), have been used to illustrate the weight changes during the first 26 weeks *post partum*.

These weight changes are illustrated in figures 7, 8 and 9 for bottle-feeders smokers, bottle-feeders non-smokers and breast-feeders respectively.

Once again the patterns of weight changes, when residual weight gain is taken into account, of bottle-feeders non-smokers and breast-feeders is more similar than compared with the pattern of bottle-feeders smokers.

A closer look at the figures reveals that these three patterns have a common characteristic. There seems to be three distinct periods for which the rate of weight change differs. These changes occur around week 8 and week 17, making the three graphs looking kind of

Figure 7. Effect of a residual weight gain of 2,6 and 10 kg on weight change after delivery among bottle-feeders smokers

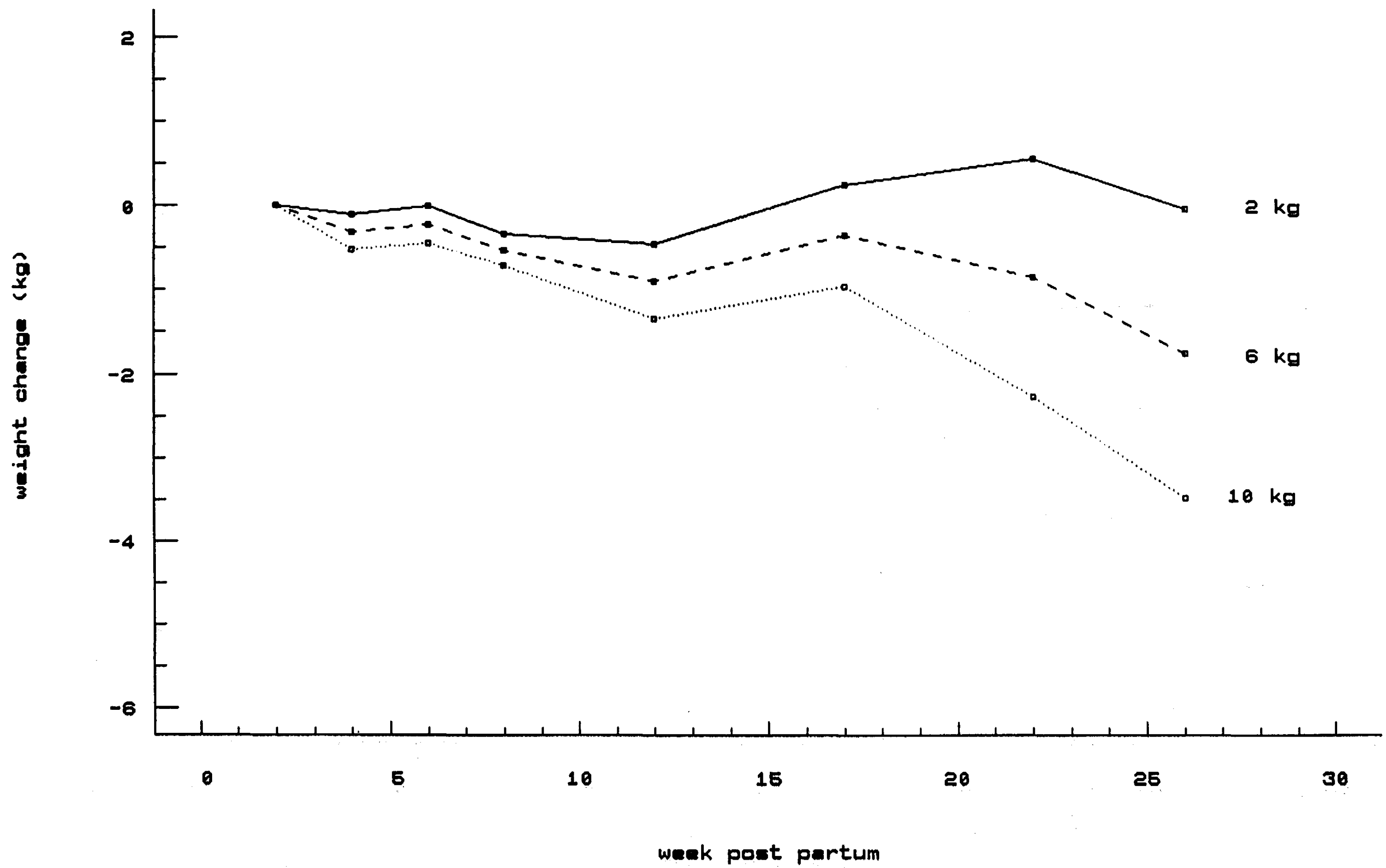


Figure 8. Effect of a residual weight gain of 2,6 and 10 kg on weight change after delivery among bottle-feeders non-smokers

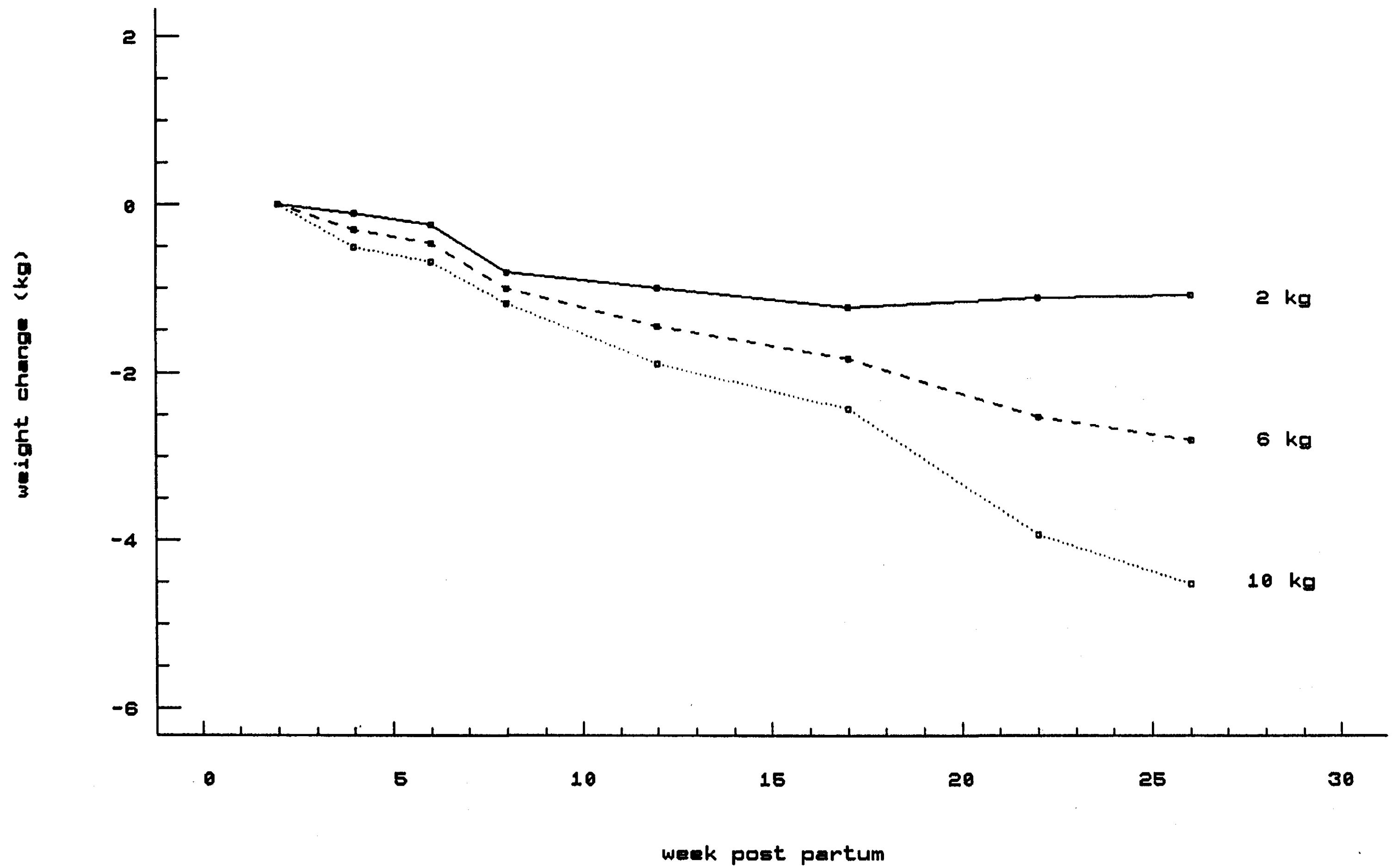
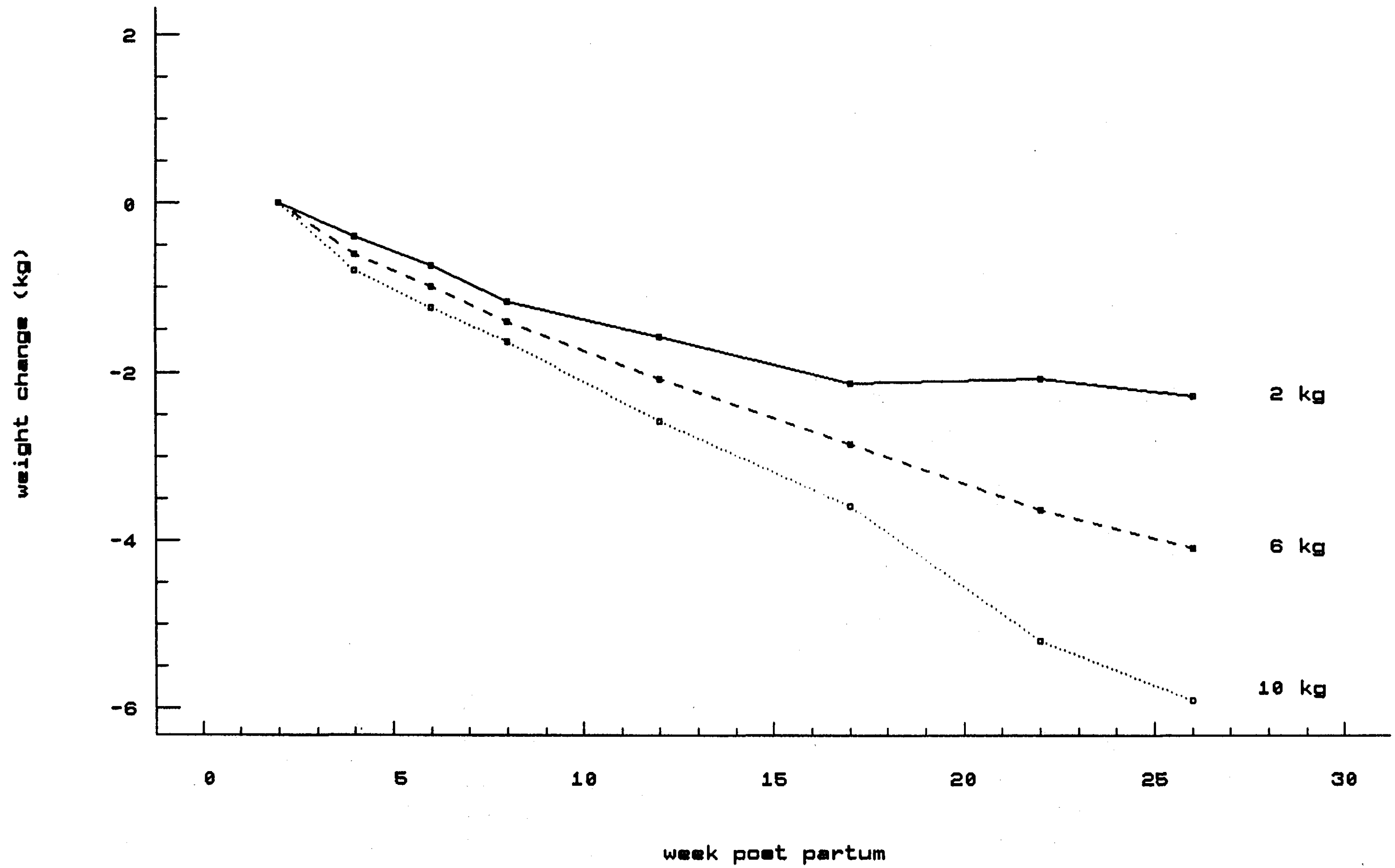


Figure 9. Effect of a residual weight gain of 2,6 and 10 kg on weight change after delivery among breast-feeders



"fork-shaped".

The rate of weight change is largely influenced by the magnitude of the residual weight gain. For example, one can see that from week 17, there is a net divergence of the three curves calculated for a residual weight gain of 2, 6 and 10 kg.

As the residual weight gain increases, the proportion of this residual weight gain lost by breast-feeders and bottle-feeders non-smokers decreases. This is true at any measurement time for breast-feeders, and from week 4 onwards for bottle-feeders non-smokers. For bottle-feeders smokers the relationship between residual weight gain and the proportion of this weight lost is not so straightforward since their pattern of weight change is so erratic, especially before week 17. From week 17 onwards, as the residual weight gain increases, the proportion of this residual weight gain lost increases as well.

A few numerical examples will help to clarify these points. For a small residual weight gain of 2 kg, a breast-feeder would have lost it entirely by six months *post partum* whereas a bottle-feeder non-smoker would have lost 1.1 kg or 55% of this weight gain. The predicted weight loss for a bottle-feeder smoker would be negligible, less than 0.1 kg or 5% of this 2 kg.

For a residual weight gain of 6 kg, which is near the average, the predicted weight loss at six months *post partum* would be 4.1 kg or 68% for a breast-feeder, 2.8 kg or 47% for a bottle-feeder non-smoker and 1.8 kg or 30% for a bottle-feeder smoker.

Finally, for a large residual weight gain of 10 kg, by six months *post partum* a breast-feeder would have lost 5.9 kg or 59% of it, a bottle-feeder non-smoker 4.5 kg or 45% of it, and a bottle-feeder smoker, 3.5 kg or 35% of it.

6.4 Discussion.

The results presented for the effect of smoking on weight change *post partum* show clearly that smokers, in this sample, lost less weight than non-smokers.

The possibility that smokers gained less weight during pregnancy than non-smokers and thus had less weight to lose after delivery was investigated, and after adjusting for the effect of residual weight gain, the effect of smoking remained the same.

In a study described earlier, Greene et al (23) found exactly the opposite, that is to say that smoking was negatively correlated with weight gain after delivery. We have to bear in mind though that the present study was made on a much shorter period of time than the one just mentioned.

The mechanisms by which smoking affects body weight are far from being clear. Data indicate that smokers weigh less than non-smokers and weight gain usually occurs after the cessation of smoking.

According to popular wisdom this would be related to energy intake, which would be less among smokers than non-smokers. But data are conflicting on this point since some studies suggested that smokers may in fact consume more calories per day than non-smokers (37).

Too many factors are unknown in the present study to interpret the results about smoking with accuracy. For instance, it is not known whether the smokers stopped smoking during pregnancy or how many calories smokers and non-smokers were consuming during the study.

Let us just say that globally, smokers are not certainly as health conscious as non-smokers and that some factors such as poor nutritional knowledge might have played a part in their unusual pattern of weight change *post partum.*

Results about the effect of weight gain during pregnancy (or in this study, the residual weight gain) on weight change *post partum* showed that this factor is a very important predictor of weight loss *post partum*. This finding is in agreement with previous reports (3,5,20,23).

In view of the importance of weight gain during pregnancy, it cannot be too much stressed to try and get an estimate as accurate as possible of the pre-pregnant weight when undertaking a study on weight loss *post partum*.

CONCLUSION

In this study, lactating and non-lactating mothers were followed for a period of six months after delivery. Both groups were very similar for several maternal characteristics such as pre-pregnant weight (55.4 kg for breast-feeders and 55.7 kg for bottle-feeders), estimated weight gain during pregnancy (14.2 kg for breast-feeders and 13.9 kg for bottle-feeders) and fat gain during pregnancy (3.9 kg for breast-feeders and 4.0 kg for bottle-feeders).

However breast-feeders came from a higher social group than bottle-feeders and smoking habit was more common among bottle-feeders.

At two weeks *post partum*, the mean body weight of each group was exactly the same, 60.7 kg. Breast-feeders started the study with a residual weight gain (as defined in 2.3.2) of 5.3 kg and bottle-feeders, 5.0 kg. In general, both groups of mothers showed a weight loss by the end of the study, with breast-feeders having lost 3.66 kg and bottle-feeders 1.98 kg. The difference in weight losses being statistically significant.

Neither group was back at its pre-pregnant weight by six months *post partum*. The proportion of breast-feeders who reached the pre-pregnant weight was however higher than for bottle-feeders.

Breast-feeding, in this sample of healthy well-nourished women, was shown to help losing weight quicker than bottle-feeding, presumably by using maternal fat reserve to meet the high energy cost of lactation.

Although the amount of weight lost *post partum* was significantly greater for breast-feeders than for bottle-feeders, the amount of fat lost was not statistically different for both groups. Fat mass was calculated by the method of skinfold thicknesses measurements as described by Durnin and Womersley (25).

The results found in the present study seem to indicate that skinfold thicknesses measurements might not be sensitive enough to give an accurate estimate of fat mass during the *puerperium*. Note that it is unlikely that any existing method would be precise enough. Moreover *post partum* changes in a fat-free component, the excess breast tissue deposited during pregnancy, might have played an important part in concealing the real changes in fat mass. Some adjustments should be made to take into consideration these changes in breast tissue when evaluating changes in fat mass among lactating and non-lactating mothers.

As in other studies, measurements of skinfolds and body circumferences gave a clear indication that fat loss occured over the trunk rather than over the limbs.

Four factors have been shown to be significantly related to weight change after delivery. These are, from the one having the greatest influence, time, residual weight gain, method of infant feeding and smoking habit.

The analysis of variance showed that a total of 50.9% of the variance in weight change after delivery was explained by these four factors. Two other factors, social class and parity were shown to be not significant.

The pattern of weight change among bottle-feeders smokers was erratic and therefore difficult to interpret. On the other hand, the effect of residual weight gain on breast-feeders, who were almost exclusively non-smokers, and bottle-feeders non-smokers led to interesting results.

As a rule, the smaller the residual weight gain, the greater the proportion of this weight that will be lost by six months *post partum*. For example, for a low residual weight gain, around 2 kg, a breast-feeder would lose it all, whereas a bottle-feeder non-smoker would lose only 55% of it. And for a large residual weight gain, around 10 kg, a breast-feeder would lose about 59% of it and a bottle-feeder non-smoker, 45%.

The type of woman standing the best chances to lose all the weight gained in pregnancy by 26 weeks *post partum* is a breast-feeder, non-smoker who gained less than 12 kg during pregnancy.

From the present study, it is clear that to obtain a complete and reliable set of results on *post partum* body composition changes, the minimum period of study should be six months. With regard to the small proportion of women who reached their pre-pregnant weight at the end of six months *post partum*, it might even be desirable to obtain some follow-up data until one year after delivery. It is doubtful that all the women who did not reached their pre-pregnant weight by the end of this study will remain with an excess of weight indefinitely.

As shown from the results of this study, weight gain during pregnancy is such an important factor for predicting weight change *post partum*, that it is impossible to separate the body weight changes occuring before and after delivery.

Thus ideally, the best studies that can be done on *post partum* maternal body weight changes are those studying women longitudinally from before conception to at least six months after delivery. Unfortunately, this implies that obtaining long-term co-operative subjects can pose a problem. Therefore in default of something better, it seems that an estimated pre-pregnant weight like the one that was used in this study provides a good enough baseline value.

More research is needed to clarify and understand fully all the changes occuring in the maternal body after delivery.

Future research could be directed more specifically towards the pattern of fat mobilization and the composition of the weight lost.

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