Do the changes in energy balance that occur during pregnancy predispose parous women to obesity?

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Abstract

The aim of this review was to re-assess whether the changes in energy balance that accompany pregnancy predispose parous women to obesity. A number of cross-sectional studies have sought to answer this question by examining the relationship between parity and maternal body weight. However, these studies were unable to control for the large number of sociobehavioural confounders that might be responsible for the apparent effect of parity on body weight. Longitudinal studies that examine changes in maternal body weight before and after pregnancy avoid these problems by using each mother as her own control. Nevertheless, these studies have to overcome three methodological constraints: They must obtain an accurate measure of prepregnant body weight, they must give each mother sufficient time to lose any weight retained following delivery, and they must take into account the effect of ageing on maternal weight gain during pregnancy and the follow-up period. More than 90% of the studies reviewed found body weight to be greater after pregnancy than it was before (by 0·2–10·6 kg), and previous researchers who have examined the evidence for pregnancy-related weight gains suggest that body weight increases by an average of 0·4–4·8 kg following pregnancy. However, only three of the 71 longitudinal studies examined in the present review complied with the three methodological criteria. These studies concluded that mothers gain, on average, 0·9–3·3 kg more weight following pregnancy than nonpregnant controls, and that mean body weight remained 0·4–3·0 kg higher, even after controlling for a number of sociobehavioural confounders. This apparently modest increase in mean maternal body weight for women having one or two children conceals the fact that some mothers experience a substantial increase in body weight and become obese following pregnancy. It remains unclear whether these increases are simply the result of changes in energy metabolism during pregnancy and lactation, or whether they are influenced by inherent changes in lifestyle that accompany pregnancy and motherhood. Understanding the relative importance of these alternatives might help to explain the aetiology of maternal obesity.

"Clover was a stout motherly mare approaching middle life, who had never quite got her figure back after her fourth foal"
George Orwell (1945) *Animal Farm*. London: Secker and Warburg.

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Introduction

In its simplest form, energy balance can be defined as the difference between energy intake and energy expenditure (James & Schofield, 1990). Energy intake is determined by the quantity and energy density of ingested food, and the efficiency with which this food can be digested and utilized. Energy expenditure is determined by the amount of energy used to support basal metabolism, thermoregulation, digestion and physical activity. When changes in energy intake and/or expenditure result in a net change in energy balance, any surplus or deficit is reflected by the amount of energy deposited in, or removed from, body stores (Garrow, 1987). Because changes in the size of the body's energy stores inevitably cause changes in body weight, changes in body weight can be used to evaluate overall energy balance (Milne *et al.* 1991).

In practice, using changes in body weight to evaluate changes in energy stores represents an oversimplification, because changes in body weight can also reflect changes in body composition and fluid balance that occur without any change in energy balance. This is particularly relevant during pregnancy, when substantial changes in extracellular volume and body composition occur which create changes in body weight (Sohlström & Forsum, 1995) that are usually interpreted as changes in fetal tissue and maternal energy reserves (Hytten, 1990*a*). Nevertheless, the pattern of maternal weight gain during pregnancy also reflects the changes in energy intake and/or energy expenditure that place a pregnant woman in positive energy balance (Hytten, 1990*b*).

It has been suggested that an increase in energy intake, mediated by enhanced appetite (Rosso, 1987) may be responsible for the weight gained during pregnancy. However, others (e.g. Durnin *et al.* 1985) suggest that increased energy intake is insufficient to account for the changes in energy balance that occur during pregnancy. Indeed, inadequate energy intake during pregnancy can result in the depletion of maternal energy stores (Winkvist *et al.* 1992) and net weight loss following delivery (Chowdhury, 1987). Nevertheless, several studies have shown that women are capable of supporting a successful pregnancy with a smaller increase in reported energy intake than that required to cover the estimated maintenance costs and costs of tissue accretion during pregnancy (Durnin *et al.* 1985; Hytten, 1990*c*). These studies indicate that a variety of physiological and behavioural adaptations may take place which help to improve energy efficiency during pregnancy and reduce the overall cost thereof (King *et al.* 1994). For example, Illingworth *et al.* (1987) found that pregnant women display a reduction in postprandial energy expenditure which might reflect more efficient digestion and/or absorption of food. Poppitt *et al.* (1993) described a reduction in basal metabolic rate and an improvement in the efficiency of exercise during pregnancy among rural Gambian women which they interpreted as energy-sparing adaptations. Similar women also display an apparent decline in core body temperature during the latter half of pregnancy (Whitehead *et al.* 1986) which would reduce the amount of energy required for thermoregulation.

The same changes in basal metabolism (Durnin *et al.* 1985; Prentice *et al.* 1989; Goldberg *et al.* 1993; King *et al.* 1994), thermoregulation (Clapp, 1991) and energy expenditure during exercise (Clapp, 1989) have been observed in well nourished pregnant women from developed countries who also tend to be less active during pregnancy (Dibblee & Graham, 1983; Durnin *et al.* 1985; Clissold *et al.* 1991). This might explain why they display an increase in maternal body weight over and above that required for the growth of the fetus, placenta and other products of conception. Indeed, women from Scandinavia, Western Europe and North America who experience healthy, uncomplicated pregnancies enter motherhood with 2–10 kg of additional fat stores (King *et al.* 1949; see Table 1). Even in the past, when weight gain during pregnancy was restricted (as in the studies reviewed by Chesley, 1944), women were 1·7–2·2 kg

Table 1. Mean (± SEM)[a] postpartum weight and fat retention among well nourished women from Scandinavia, Western Europe and North America

Country	Weight retention[d] (kg)	Maternal fat stores (kg)	1st date (ap/pp: ante-/post-partum)	Last date	n	Reference
Scotland	1·9 ± 0·3	1·8 ± 0·3[c]	≤12 wks	6–8 wks pp	91	Hytten *et al.* (1966)
Scotland	3·9 ± 0·1	1·4 ± 0·0[b]	10 wks	1 wks pp	84	Taggart *et al.* (1967)
United States	2·7 ± 0·1	0·8 ± 0·0[b]	≤14 wks	≤2 wks pp	34–61	Morse *et al.* (1975)
England	0·1 ± 0·4	−0·1 ± 0·5	10–14 wks	6–15 wks pp	26	Pipe *et al.* (1979)
Canada	1·9 ± 0·1	1·3 ± 0·1	8–12 wks	4 wks pp	16	Dibblee & Graham (1983)
Scotland		2·3 ± 0·3	10 wks	4–6 wks pp	88	Durnin (1987)
Holland		2·0 ± 0·3	10 wks	4–6 wks pp	57	Durnin (1987)
Sweden	9·0 ± 0·6	4·9 ± 0·6	0 wks	3 dys pp	56	Langhoff-Roos *et al.* (1987)
Holland	1·5 ± 0·0	1·2 ± 0·0	12 wks	5 wks pp	57	Van Raaij *et al.* (1987; 1988; 1989)
Sweden	6·5 ± 0·6	5·8 ± 0·5	0 wks	5–10 dys pp	27	Forsum *et al.* (1988; 1989), Sadurskis *et al.* (1988)
Scotland		3·9 ± 0·1	0 wks	2–3 wks pp	115	Lawrence *et al.* (1991)
United States	4·0 ± 0·5	3·5 ± 0·3	0 wks	4–8 wks pp	11	South-Paul *et al.* (1992)
England		2·8 ± 0·9	0 wks	36 wks ap	12	Goldberg *et al.* (1993)
United States		4·7 ± 0·7	0 wks	34 wks ap	15	King *et al.* (1994)
Mexico	3·0 ± 0·1	2·7 ± 0·1[b]	0 wks	0–13 wks pp	31	Martínez *et al.* (1994)
United States		7·2 ± 0·4[b]	0 wks	37 wks ap	79	Clapp & Little (1995)
Sweden	9·7 ± 2·5	5·0 ± 1·1	0 wks	5–10 dys pp	15	Sohlström & Forsum (1995)
United States	4·8 ± 0·2	4·5 ± 0·2[c]	0 wks	4–6 wks pp	10	Van Loan *et al.* (1995)

[a] Where necessary, standard errors of changes in body weight and body fat were calculated using the mean coefficient of variation for measurements of body weight and body fat before and after pregnancy.
[b] Analyses of changes in % body fat based on skinfold measurements and the allometric equations of Durnin & Womersley (1974).
[c] Calculated from estimates of total body water using the equation of Keys & Brozek (1953).
[d] Weight retention is defined as weight gained during pregnancy that is not lost at birth.

heavier at 6 weeks postpartum than they were prior to pregnancy. However, to a large extent, the weight gains experienced by these women are simply the result of an increased energy intake and a decline in the amount of energy expended on activity, because energy-sparing metabolic adaptations are comparatively modest, and occur more often in thin or malnourished women (Poppitt *et al.* 1994). In affluent societies, women who are underweight are less likely to gain weight during pregnancy (Harris *et al.* 1996) while in impoverished communities, women who are underweight are least likely to be capable of increasing their energy intake. It is therefore not surprising that energy-sparing adaptations are much more common among women from developing countries (Poppitt *et al.* 1994) who can be faced with a decline in energy intake and an increase in agricultural activity while they are pregnant (Prentice *et al.* 1981). Under these circumstances, energy sparing adaptations offset the cost of pregnancy and enable women to experience successful pregnancies with little or no weight gain (Prentice *et al.* 1987), although inadequate weight gains are also associated with suboptimal birth weights and a depletion of maternal energy reserves (Chowdhury, 1987; Winkvist *et al.* 1992).

In an evolutionary context, the accumulation of additional energy stores during pregnancy might have had distinct advantages when the availability of food to support fetal growth (Hytten, 1990*b*) and lactation (Whitehead *et al.* 1986) was unpredictable. Indeed, a similar argument has been proposed to explain why women have larger fat reserves than men (Garrow, 1987). However, well nourished women living in modern industrialized societies have little need for extensive fat reserves to guard against food shortages (Hytten, 1990*a*). Under these circumstances maternal fat deposits might be viewed simply as a "redundant evolutionary hangover" from less favourable times (Hytten, 1990*a*). As early as 1862, Gassner (cited by Stander & Pastore, 1940) recognized that pregnant women tend to gain more weight than that required for the products of conception. In 1942 Waters was able to demonstrate that a large proportion of this additional weight was not lost during the puerperium, and by 1949 it was suggested that it was "a matter of common observation that women may ... develop a severe obesity after having a baby" (Sheldon, 1949). Undoubtedly, the view that pregnancy can lead to excessive weight gain has been widely held for some time (Gurney, 1936; Greene, 1939), and in 1978 Bray included pregnancy as one of four potential endocrinological causes in his aetiological classification of obesity. Not surprisingly, overweight mothers often cite pregnancy as the root cause of their obesity (Gurney, 1936; Mullins, 1960; James & Bisdee, 1982; Bradley, 1985; Abraham, 1989; Lean *et al.* 1989; Öhlin & Rössner, 1990), and weight gain during pregnancy has become an increasing concern for women who want to avoid obesity and regain a fashionable, slim figure after they have had children (Baric & MacArthur, 1977; Feigenberg & Schiller, 1977; Orr & Simmons, 1979; Harrison & Hicks, 1983; Palmer *et al.* 1985; Dawes *et al.* 1992; Franko & Walton, 1993). These concerns are exacerbated by the recent guidelines of the United States Institute of Medicine (1990), which recommended higher weight gains during pregnancy than previously (Committee on Maternal Nutrition, 1970; AAP/ACOG, 1983; see Table 2), and may increase the risk of weight retention *post partum* (Abrams, 1993; Keppel & Taffel, 1993; Parker & Abrams, 1993). Although no such guidelines exist in the UK, authoritative bodies such as the British Nutrition Foundation (1994) and the National Dairy Council (1994) have reproduced the weight gain guidelines published by the US Institute of Medicine (1990), and it is likely that these recommendations have some influence on antenatal care within the UK. In view of the importance currently attached to the high prevalence of obesity amongst women in North America (National Institutes of Health, 1985) and Europe (Millar & Stephens, 1987; Department of Health, 1992) a clearer understanding of what effect, if any, pregnancy has on long-term maternal weight gain is urgently required

Table 2. Recommended ranges for gestational weight gain, by prepregnancy Body Mass Index

Recommendations	ACOG† (1985)	IoM‡ (1990)
Prepregnant BMI (kg.m^{-2})	*Weight gain in kg (lb)*	*Weight gain in kg (lb)*
Low (BMI < 19·8)	> 11·3 (25)*	12·5–18·0 (28–40)
Normal (BMI 19·8–26·0)	9·1–11·3 (20–25)	11·5–16·0 (25–35)
High (BMI > 26·0 to 29·0)	< 9·1 (20)*	7·0–11·5 (15–25)
Obese (BMI > 29·0)	< 9·1 (20)*	> 6·0 (15)

* Based on Taylor's (1971) recommendation that underweight women should be allowed to gain more weight than women of normal weight and that obese women should be allowed to diet and lose weight.
† American College of Obstetricians and Gynecologists.
‡ United States Institute of Medicine.

(Manson *et al.* 1994). The aim of this review will be to re-examine the evidence that pregnancy predisposes parous women to obesity.

Reviewing the literature

The studies examined in this review were obtained by a MEDLINE (US National Library of Medicine, Silver Platter International, NV) literature search extending back through 1995 to 1985 using the following paired key words: 'Pregnancy' and 'Obesity'; 'Pregnancy' and 'Body weight'; 'Pregnancy' and 'Weight gain'. Any publications that examined the relationship between maternal body weight and parity, or the pattern of maternal weight gain during and after pregnancy, were selected. These publications were subsequently reviewed and back-referenced until no further relevant papers could be found. This exhaustive survey should have identified any study containing suitable data for examining the effect of pregnancy on long-term changes in maternal body weight.

Methodological considerations

The changes in energy balance which accompany pregnancy are natural phenomena that are most appropriately investigated using case-control studies. These would examine the effect of pregnancy on maternal body weight by comparing the postpartum body weight of pregnant women with the body weight of matched, non-pregnant controls. Indeed, the first systematic studies were based on demographic and industrial surveys of women's body weight, such as those conducted by: the Industrial Fatigue Research Board (Cathcart *et al.* 1927), United States Department of Agriculture (1941), the Ministry of Food (Kemsley, 1950), Lowe & Gibson (1955), and the Joint Clothing Council (Karn, 1957). These surveys found that women with children had a higher body weight than those without, and that maternal body weight increased with increasing parity (Fig. 1*a*). A similar cross-sectional design was used by 21 of the studies identified in the present review (Table 3). All but four (Lee-Feldstein *et al.* 1980; Prentice *et al.* 1981; Chowdhury, 1987; Kumanyika, 1987) of these studies observed an increase in maternal body weight with parity, and two of these four took place among undernourished rural

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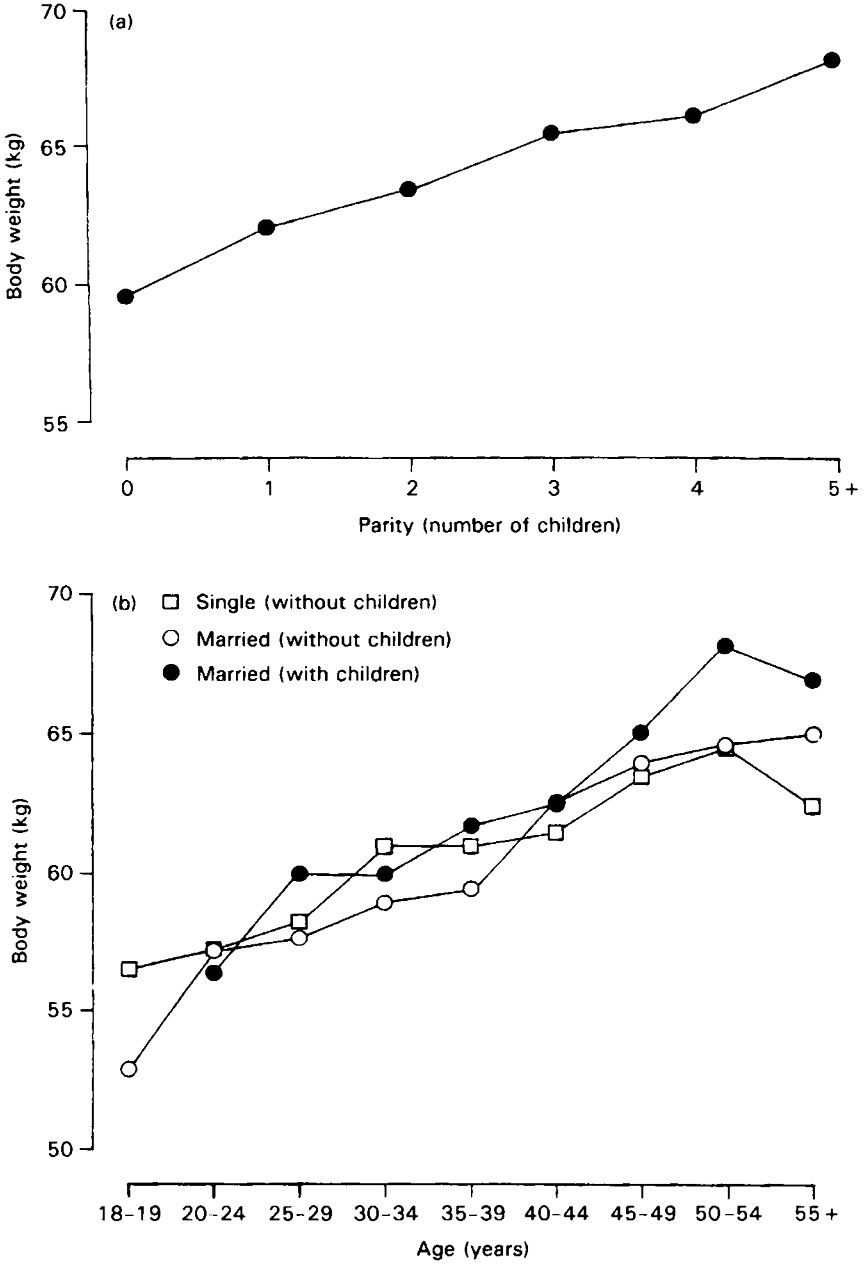

Fig 1. (a) The relationship between parity (number of children) and body weight among married women examined by the Joint Clothing Council in 1957. (b) The relationship between age, marital status and body weight among nulliparous and parous women examined by the Joint Clothing Council in 1957.

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Table 3. Cross-sectional studies that examined the relationship between parity and maternal body weight

Country	Date of data collection	Control for potential confounders	Sample size (n)	Reference
England	1945–55	1, 2	5081	Lowe & Gibson (1955)
Scotland	–	1, 3	–	Thomson & Billewicz (1965)
Sweden	1962–63	1, 2, 4	378	Cederlöf & Kaij (1970)
Netherlands	1980	1, 2, 3, 5, 6, 7, 8	2092	Baecke *et al.* (1983)
United States	1968–69	1, 3, 7, 9	755	Lee-Feldstein *et al.* (1980)
Sweden	1968–69	1, 2, 3, 5, 6, 10, 11, 12	1373	Noppa & Bengtsson (1980)
Finland	1966–72	1, 2, 3, 6, 7, 13, 14	17688	Heliövaara & Aromaa (1981)
Gambia	1978–79	15	139	Prentice *et al.* (1981)
Wales	1965–79	1, 2, 3, 6, 14, 30	35556	Newcombe (1982)
England and Scotland	1972	1, 2, 3, 6, 16	7013	Rona & Morris (1982)
United States	1977–78	1, 2, 3, 5, 6, 9, 12, 14	1133	Forster *et al.* (1986)
United States	1981	1, 3, 9, 14, 19, 20, 21, 31	514	Caan *et al.* (1987)
Bangladesh	1975–78	1	2446	Chowdhury (1987)
United States	1971–80	1, 3, 9	7414	Kumanyika (1987)
United States	1984–87	1, 3, 26	1186	Kritz-Silverstein *et al.* (1989)
Sweden	Mid 1980s	1	2295	Öhlin & Rössner (1990)
United States	–	1, 3, 29	87	Rodin *et al.* (1990)
United States	1985	1, 2, 3, 5, 14	41184	Brown *et al.* (1992)
United States	1976	3	113606	Manson *et al.* (1992)
United States	1971–84	1, 2, 3, 5, 6, 14, 24, 25, 26, 29	2547	Williamson *et al.* (1994)
United States	1991–92	1, 17	211	Hunt *et al.* (1995)

Potential confounders: 1, maternal age; 2, marital status; 3, maternal height; 4, heterozygosity (monozygotic twins); 5, education; 6, occupation, social class and employment status; 7, urbanization; 8, religion and church attendance; 9, ethnicity; 10, size and housing; 11, husband's age; 12, income; 13, capacity for work; 14, smoking status; 15, fertility; 16, husband's BMI; 17, obesity during adolescence and adult life; 18, age at menopause and/or menopausal problems; 19, birth weight of previous child; 20, body weight during first pregnancy; 21, household size; 22, age at menarche; 23, contraceptive and/or HRT use; 24, alcohol use; 25, physical activity; 26, medical history and health status; 27, family history of breast and/or endometrial cancer; 28, menstrual cycle rhythmicity; 29, dieting and weight cycling; 30, lactation; 31, interbirth interval.

communities in developing countries (The Gambia, Prentice *et al.* 1981; Bangladesh, Chowdhury, 1987). However, parity is associated with a number of sociodemographic characteristics, such as higher maternal age, lower social class and marriage, that are independently associated with an increased risk of weight gain (Karn, 1957; Knight, 1984; Millar & Stephens, 1987; Flegal *et al.* 1988; Kahn *et al.* 1991). Using the information on maternal age and marital status collected by the Joint Clothing Council (1957) to examine the independent effect of age, marriage and parity (see Fig. 1*b*), it is clear that the relationship between parity and maternal body weight (Fig. 1*a*) was largely the result of confounding (see Fig. 1*b*). Most of the studies listed in Table 3 (19; 90·5%) attempted to control for confounding by taking into account differences in maternal age between mothers of differing parity. Others controlled for marital status (10; 47·6%), social class (7; 30·4%) and a number of additional factors (such as smoking cessation, see Table 3) that are known to be associated with higher weight gain (Gordon *et al.* 1975; Williamson *et al.* 1991). Although this approach reduces the possibility that any remaining differences in body weight between women of differing parity are simply the result of confounding, it is probably not feasible to control for all of the factors that might be responsible for differences in energy balance. At the same time, there might be inherent, immeasurable, and therefore uncontrollable differences between women who choose to have one or more child and those who have none. Even the study by Cederlöf & Kaij (1970), which eliminated the effect of genetic characteristics (Sørensen & Stunkard, 1993) by comparing the body weight of parous and nulliparous monozygotic twins, could not control for differences in attitudes towards motherhood, body image and weight gain between different twin sisters which might have influenced body weight (Strang & Sullivan, 1985; Copper *et al.* 1995). Similar inherent differences might ultimately mask or create an apparent relationship between parity and body weight. For this reason, cross-sectional studies are inappropriate for investigating the role of pregnancy in the development of maternal obesity.

An alternative approach would be to conduct longitudinal studies and use pregnant women as their own controls by comparing their postpartum body weight with that recorded prior to pregnancy. Any differences in body weight could then be directly attributed to events that occurred during the intervening period. To assess whether persistent changes in maternal body weight occur, and whether pregnancy might be responsible for any of the changes observed, these longitudinal studies must satisfy three important criteria:

(i) they must obtain an accurate measure of prepregnant body weight;
(ii) they must give each mother enough time to lose any weight retained after the birth of their child;
(iii) they must take into account any increase in maternal body weight that would normally occur with age.

The accurate measurement of prepregnant body weight

In practice, prepregnant measures of maternal body weight are rarely available because most pregnancies are unplanned, and mothers are not routinely weighed before they conceive. Nevertheless, a few prospective studies have obtained accurate measurements of prepregnant body weight by recruiting women who were trying to become pregnant (e.g. Forsum *et al.* 1988, 1989; South-Paul *et al.* 1992; Goldberg *et al.* 1993; Van Loan *et al.* 1995). Unfortunately, these studies tend to have small sample sizes (n = 10–27) and include women who are likely to be unrepresentative of the population as a whole. A number of longitudinal studies (such as

NHANES I and the CARDIA study) have managed to avoid these problems by collecting body weight data from large, representative samples of non-pregnant women, some of whom become pregnant and give birth during the period of follow-up (Rookus *et al.* 1987; Kusin *et al.* 1992; Smith *et al.* 1994; Williamson *et al.* 1994). However, for retrospective studies there is no alternative but to use self-reports of prepregnant weight or measurements of maternal weight recorded early in pregnancy. Although self-reports of body weight tend to underestimate true body weight (Palta *et al.* 1982; Stewart, 1982; Rössner & Öhlin, 1995), those studies that used self-reported weights before and after pregnancy (e.g. Greene *et al.* 1988; Rössner, 1992; Keppel & Taffel, 1993; Parker & Abrams, 1993; Hunt *et al.* 1995) should provide a fairly accurate measure of maternal weight gain, because the effect of under-reporting should cancel out. But for those studies that used self-reports of prepregnant weight and measurements of maternal body weight *post partum*, under-reporting of prepregnant weights would tend to overestimate the amount of weight gained following pregnancy (see Fig. 2). These studies might also create the impression that overweight and obese women, who are particularly prone to under-reporting their body weight (Palta *et al.* 1982; Stewart, 1982; Stevens-Simon *et al.* 1992), gain more weight following pregnancy than normal and underweight women (Öhlin & Rössner, 1990; Parham *et al.* 1990; Boardley *et al.* 1995). The only remaining option for studies that lack a direct measure of prepregnant body weight is to use a measurement of maternal weight collected early in pregnancy. Since the 1940s mothers have been routinely weighed during pregnancy (Scott & Benjamin, 1948; Hytten, 1981, 1990*a*), yet most women only attend antenatal care after 8–12 weeks gestation (Kotelchuck, 1994; Sikorski *et al.* 1996), by which time they have usually gained some weight (Forsum *et al.* 1988; Van Raaij *et al.* 1989; Clapp, 1991). For this reason, any studies that use maternal weight measurements recorded early in pregnancy tend to overestimate prepregnant body weight, and underestimate the amount of weight gained as a result of pregnancy (see Fig. 2).

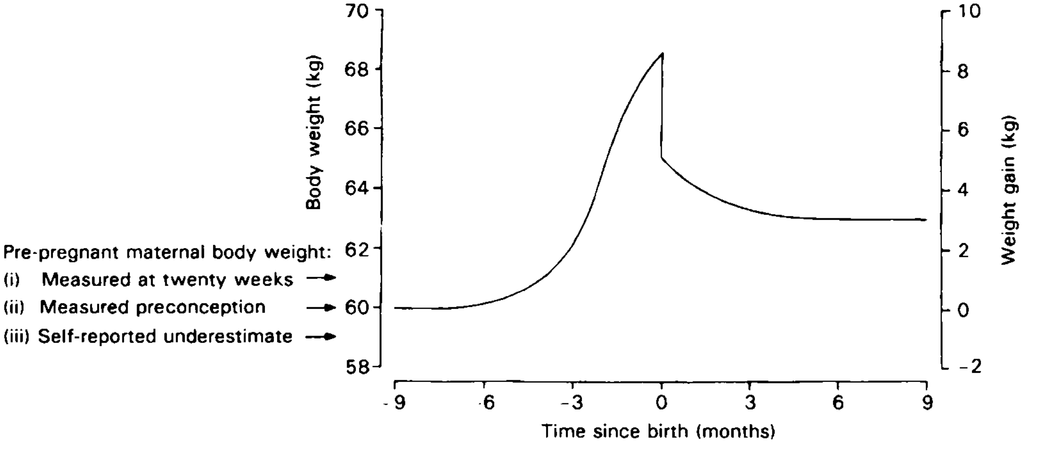

Fig 2. The effect of over- and under-estimating prepregnant body weight on calculations of long-term maternal weight gain. In this hypothetical example maternal weight measured at 20 weeks gestation (i) was 1 kg higher than that measured preconception (ii) and produced an underestimate of long-term weight gain at 2 kg. Self-reported underestimates of prepregnant body weight (iii) were 1 kg less than that measured preconception (ii) and produced an overestimate of long-term weight gain at 4 kg.

The amount of time required to lose any weight retained following pregnancy

In the short term, it appears that most well nourished women gain weight as a result of pregnancy because they enter motherhood with 2–10 kg of additional fat stores (Table 1). In the long term, however, there is no theoretical reason why mothers should not mobilize these fat stores and return to their prepregnant body weight, provided they are given enough time to do so. Any studies that weigh mothers before they have had time to lose the fat gained during pregnancy are likely to conclude that pregnancy causes a permanent increase in maternal body weight. These studies need to give each woman sufficient time to lose any weight retained following the birth of their child before assessing whether *permanent* changes in body weight have occurred. This methodological constraint applies as much to the cross-sectional studies examined in Table 3 as it does to longitudinal studies of maternal weight gain following pregnancy. Nevertheless, only 2 of the 21 studies examined in Table 3 excluded parous women who had recently given birth, and 10 even failed to assess whether the women were currently pregnant.

In theory, the amount of time required to lose any excess weight retained *post partum* can be estimated by calculating its energy content and the amount of time required to use up this energy. In this review, net maternal weight gain during pregnancy (the amount of weight gained during pregnancy minus the baby's birth weight) was used to provide an estimate of the amount of weight retained following pregnancy (after Parham *et al.* 1990). This measure of retained weight included the weight of the placenta and amniotic fluids, together with any increase in maternal blood volume and lean body tissue that occurred during pregnancy (Sohlström & Forsum, 1995). However, it was assumed that retained weight consisted entirely of maternal fat stores (Langhoff-Roos *et al.* 1987; Hytten, 1991) in order to provide an overestimate of the amount of energy contained therein and a conservative estimate of the amount of time required to use up this energy. Energy values were assigned to each mother's retained weight, taking the energy density of fat as 37 000 kJ/kg (8843 kcal/kg: James & Schofield, 1990). Assuming that each mother adhered to a modest weight reducing diet of 7113 kJ (1700 kcal) per day (which is consistent with a steady weight loss of approximately 0·4–0·5 kg per week; Perri *et al.* 1992), and that these mothers required 9205 kJ (2200 kcal; non-lactating) to 11297 kJ (2700 kcal; lactating) per day (in accordance with the recommended daily allowance for energy; Murphy & Abrams, 1993), they should have lost 2092–4184 kJ (500–1000 kcal) or 57–114 g of their retained weight per day. To illustrate this, Fig. 3 shows the hypothetical weight loss trajectories for women who retained different amounts of weight, when they were subject to different weight reducing diets. Theoretical weight retentions of 5 and 15 kg were selected since they approximate to the upper and lower limits of normal retained weight (Parham *et al.* 1990). A non-lactating woman who enters motherhood with a weight retention of 5 kg would take nearly 3 months to return to her prepregnant weight on a 7113 kJ (1700 kcal) diet (see Fig. 3), while non-lactating women who retain 15 kg would take nearly 9 months to do so on the same diet. Lactating women, with their higher energy requirements, would take just over 6 weeks to remove 5 kg of retained weight on a 7113 kJ (1700 kcal) diet, and nearly 4·5 months to mobilize 15 kg. Indeed, even if they stopped eating altogether, non-lactating women would still need around 9 weeks to mobilize 15 kg of retained weight while lactating women would do so in just 7 weeks!

The increase in body weight with age during the study period

There is a tendency for maternal body weight to increase with age even in the absence of pregnancy (Colditz *et al.* 1990; Williamson *et al.* 1994). For this reason, studies of long-term

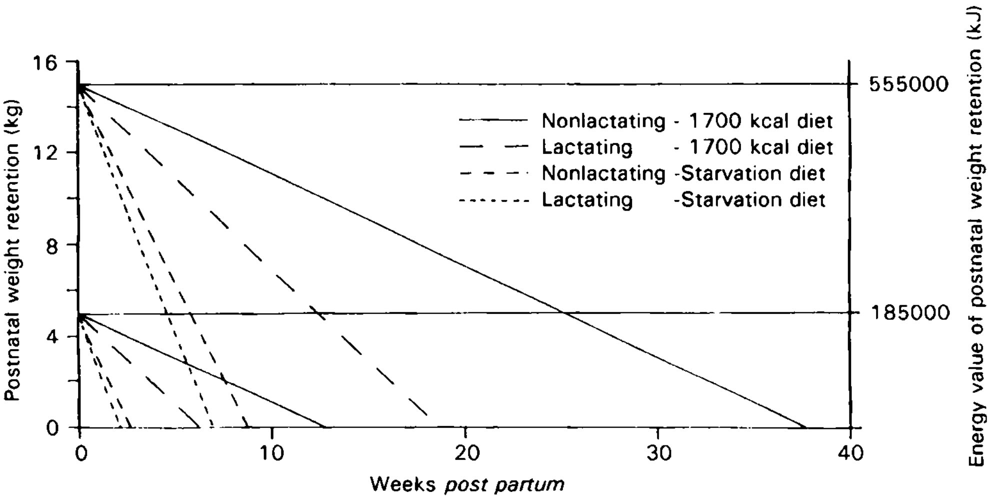

Fig 3. Hypothetical weight loss trajectories of mothers who retained 5 kg or 15 kg after the birth of their baby (Parham *et al.* 1990). Trajectories were calculated for women on both a 1700 kcal weight reducing and a zero kcal starvation diet, assuming that non-lactating women require 2200 kcal per day and lactating women require 2700 kcal per day (Murphy & Abrams, 1993).

changes in maternal body weight need to take into account the amount of weight mothers would normally gain had they not been pregnant. Contemporary estimates of ageing-related weight gain, for well nourished women of childbearing age, range from 0·29 kg to 0·96 kg per year (Colditz *et al.* 1990; Kuskowska-Wolk & Rössner, 1990; Parham *et al.* 1990; Kahn *et al.* 1991; Klesges *et al.* 1992; Sowers *et al.* 1996). It is therefore extremely important to obtain an appropriate estimate of ageing-related weight gain for each individual woman. McKeown & Record (1957) achieved this by recording maternal weight gain from 12 to 24 months *post partum* and subtracting this amount from the weight gained between conception and 12 months *post partum*. However, suitable data for calculating pre- or post-pregnant changes in maternal body weight are usually unavailable, and most studies are faced with two possibilities for controlling for the effect of ageing on maternal weight gain: they can either correct for differences in the duration of follow-up (e.g. Greene *et al.* 1988), or they can account for the amount of weight gained by similar, non-pregnant women during the same period of time (e.g. Öhlin & Rössner, 1990; Parham *et al.* 1990). The first approach tends to undercontrol for the effect of ageing, because it fails to account for the effect of ageing on maternal weight gain during the period of pregnancy. The second approach suffers from the same limitations as the cross-sectional studies reviewed in Table 3, because any differences in the amount of weight gained by pregnant and non-pregnant women might simply be the result of confounding. Indeed, non-pregnant, nulliparous women tend to gain more weight than non-pregnant parous women (Williamson *et al.* 1994) which suggests that their tendency to gain weight may be related to their ability or decision to bear children (Zaadstra *et al.* 1993). Nevertheless, in some respects a cross-sectional analysis provides the most sensitive approach, because it can control for a number of behavioural changes that commonly occur during pregnancy (Clissold *et al.* 1991), such as smoking cessation (Williamson *et al.* 1991) and inactivity (Klesges *et al.* 1992), which might increase the risk of weight gain among women who experience pregnancy (see Öhlin & Rössner, 1994).

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Table 4. Longitudinal studies that examined changes in maternal body weight before and after pregnancy

Country	Date of data collection	Type of prepregnant weight measurement	Net weight gain during pregnancy 95% CI (kg)[a]	Postpartum follow-up	Control for ageing (kg/year)	Long-term weight gain $x \pm$ SEM (kg)[b]	n	Reference
United States	–	measured 12 wks gestation	8·0[d]	3 wks[g]	–	5·0[d]	48	Plass & Yoakam (1929)
England	–	measured 24 wks gestation	1·9[d]	6 wks[h]	–	– 4·2[d]	710	McIlroy & Rodway (1937)
United States	–	self-report	7·3[c,d]	8 dys[g]	–	4·5[d]	64	Bray (1938)
United States	–	measured 6 wks gestation	10·5[c,d]	6 wks[g]	–	4·5[d]	2502	Stander & Pastore (1940)
United States	–	–	7·1 – 8·1[c]	3 mths[g]	0·45	0·9 ± 0·2	226	King (1949)
England	1949–50	measured ≤ 28 wks gestation	3·6 – 3·6[e]	24 mths[h]	0·27	0·8 ± 0·0	289	McKeown & Record (1957)
Scotland	–	measured ≤12 wks gestation	7·1 – 8·1	6–8 wks[g]	–	1·9 ± 0·3	91	Hytten *et al.* (1966)
Gambia[f]	1962–63	measured ≤10 wks gestation	0·4 – 4·4	36 wks[h]	0·0	2·0 ± 0·5	10	Thomson *et al.* (1966)
Scotland	–	measured 10 wks gestation	7·3 – 7·7	6–8 wks[g]	–	2·0 ± 0·3	84	Taggart *et al.* (1967)
Australia	1960–62	self-report	6·6 – 7·6	6 mths[h]	–	– 0·2 ± 0·0	26	English & Hitchcock (1968)
United States	–	self-report	6·2 – 6·8[c]	6 wks[g]	–	1·8 ± 0·1	700	Abitbol (1969)
United States	–	self-report	–	> 3 mths	–	1·5[d]	1206	Weiss *et al.* (1969)
Scotland	1949–64	measured 20 wks gestation	–	18–108 mths[h]	~ 0·4	1·8 ± 0·1	3583	Billewicz & Thomson (1970)
Malaysia	1968	measured 8 wks gestation	7·0[c,d]	6 wks[g]	–	3·7[d]	44	Sinnathuray & Wong (1972)
United States	1969	measured ≤14 wks gestation	4·1 – 4·5[c]	6–8 wks[g]	–	0·2 ± 0·0	61	Morse *et al.* (1975)
United States	1973–74	self-report	9·7 – 12·7[c]	8–12 wks[g]	–	3·1 ± 0·2	21	Blackburn & Calloway (1976)
Japan	1973–74	measured 10 wks gestation	5·9[d]	4 mths[h]	–	0·0[d]	2000	Kawakami *et al.* (1977)
United States	1972	self-report	7·1[d]	~ 15 mths[h]	–	1·6[d]	1601	Garn *et al.* (1978; 1983; 1984)
England	1965–75	measured 20 wks gestation	–	6 wks	–	– 0·2 ± 0·0	50	Beazley & Swinhoe (1979)
England	–	measured 10–14 wks gestation	6·3 – 7·6[c]	6–15 wks[g]	–	0·0[d]	26	Pipe *et al.* (1979)
United States	1962–75	measured ≤12 wks gestation	5·6 – 6·0	4–6 wks[g]	–	1·0 ± 0·1	602	Gormican *et al.* (1980)
United States	–	self-report	8·7 – 11·1	1 mth[g]	–	4·8 ± 0·2	23	Butte *et al.* (1981)
Taiwan	1967–73	measured before conception	3·9 – 4·4[c]	15 mths[h]	–	0·7 ± 0·0	125	Adair *et al.* (1983, 1984)
England	–	measured < 16 wks gestation	8·4 – 10·4	5–7 dys[g]	–	4·6 ± 0·7	29	Gillmer (1983)
Canada	–	measured 8–12 wks gestation	10·6 – 11·8	4 wks[g]	–	1·9 ± 0·1	12	Diblee & Graham (1983)
United States	–	self-report	10·1 – 12·5	12 wks[g]	–	4·0 ± 0·1	27	Manning-Dalton & Allen (1983)
India	1978	measured during gestation	–	6–8 wks	–	2·5[d]	56	Singh *et al.* (1983)
United States	1978–81	self-report	10·0 – 11·6	6 mths[g]	–	2·1 ± 0·6	46	Quandt (1983)
United States	–	self-report	13·0 – 13·7[c]	13–18 mths[h]	–	1·6 ± 0·0	26	Meserole *et al.* (1984)
Gambia	1982–84	measured ≤12 wks gestation	3·2 – 3·4[c]	~ 6 mths[h]	–	2·9 ± 0·0	31	Lawrence *et al.* (1985)

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United States	–	self-report	8·8–9·7	6 wks[g]	–	2·7 ± 0·1	182	Olsen & Mundt (1986)
Sweden	1985	self-report	10·2–12·0	8 wks[g]	–	4·5 ± 0·2	54	Langhoff-Roos *et al.* (1987)
Netherlands	1980–85	measured before conception	6·4–7·0	12 mths[h]	0·40	1·6 ± 0·4	40	Rookus *et al.* (1987)
Netherlands	–	measured before conception	7·3–9·5	9 wks[g]	–	2·7 ± 0·1	23	Van Raaij *et al.* (1987, 1988, 1989)
Netherlands	–	measured 6–12 wks gestation	6·4–7·0[c]	50–60 wks[h]	–	1·8 ± 0·0	21	Van Raaij *et al.* (1987, 1988, 1990)
Sweden	–	measured before conception	9·2–11·1	6 mths[h]	–	1·3 ± 0·7	27	Forsum *et al.* (1988, 1989), Sadurskis *et al.* (1988)
United States	1959–65	self-report	6·2–6·5	< 6 yrs[h]	0·45	1·5 ± 0·1	7116	Greene *et al.* (1988)
Australia	1981–85	self-report	10·2–11·3	12 mths[h]	–	1·6 ± 0·1	121	Ash *et al.* (1989)
Canada	?	?	?	4 mths	–	2·1	257	Walker (1989) In: Johnston (1991)
Sweden	mid-1980s	self-report	10·5–10·8	12 mths[h]	0·10	1·5 ± 0·1	1423	Öhlin & Rössner (1990, 1994)
United States	–	self-report	8·7–10·5	6–9 mths[h]	0·5	3·8 ± 0·9	37	Parham *et al.* (1990)
Japan	1988–89	measured 16 wks gestation	7·1–7·7	1 mth[g]	–	3·3 ± 0·0	245	Yamagishi *et al.* (1990)
Scotland	–	measured 7–13 wks gestation	8·1–8·7	2–3 wks[g]	–	3·9 ± 0·1	115	Lawrence *et al.* (1991)
United States	1970–80	self-report	13·7–14·9	12 mths[h]	–	2·7 ± 0·1	206	Potter *et al.* (1991)
Indonesia	1982–89	measured before conception	3·6–3·7	12 mths[h]	–	0·0[d]	452	Kusin *et al.* (1992)
Sweden	–	self-report	–	12 mths	–	9·0 ± 0·7	113	Rössner (1992)
Australia	1984–85	self-report	–	6 mths	–	1·6 ± 0·0	618	Rutishauser & Carlin (1992)
United States	1989–90	measured ~12 wks gestation	9·3–9·8	~6 mths[h]	–	1·4 ± 0·2	795	Schauberger *et al.* (1992)
United States	–	measured before conception	–	4–8 wks	–	4·0 ± 0·2	11	South-Paul *et al.* (1992)
United States	1986–89	self-report	8·6–13·1	2–11 wks[g]	–	4·0 ± 0·4	107	Stevens-Simon & McAnarney (1992)
United States	1986	self-report	11·3–13·4[c]	24 mths[h]	–	0·8 ± 0·0	53	Dewey *et al.* (1993)
United States	1988	self-report	–	10–18 mths	–	1·3[d]	1592	Keppel &Taffel (1993)
United States	–	self-report	12·7–14·1[c]	6 mths[g]	–	2·9 ± 0·1	24	Kramer *et al.* (1993)
United States	1987–92	self-report	9·3–11·8[c]	6 wks[g]	–	4·9 ± 0·5	668	Scholl *et al.* (1993)
Mexico	–	measured before conception	2·3–3·4	8 mths[h]	–	1·8 ± 0·2	31	Martínez *et al.* (1994)
United States	1987–92	measured ~17 wks gestation	10·2–11·7	4–6 wks[g]	–	4·9 ± 0·2	580	Scholl *et al.* (1994)
United States	1986–89	self-report	–	40 mths	–	10·6 ± 0·9	30	Segel & McAnarney (1994)
United States	1985–91	measured before conception	–	12–60 mths	0·76	5·3 ± 1·2	202	Smith *et al.* (1994)
United States	1971–84	measured before conception	–	24–156 mths	0·38	1·7 ± 0·6	215	Williamson *et al.* (1994)
United States	–	self-report	10·5–11·4	7–12 mths[h]	–	5·0 ± 0·1	345	Boardley *et al.* (1995)

(*continued*)

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Table 4. (*continued*)

Country	Date of data collection	Type of prepregnant weight measurement	Net weight gain during pregnancy 95% CI (kg)[a]	Postpartum follow-up	Control for ageing (kg/year)	Long-term weight gain $x \pm$ SEM (kg)[b]	n	Reference
United States	1991–92	self-report	8·6 – 9·4[c]	6 wks[g]	–	3·4 ± 0·1	115	Hunt *et al.* (1995)
India	–	measured 12 wks gestation	7·1 – 9·6	24 wks[h]	–	2·6 ± 0·2	13	Piers *et al.* (1995)
United States	1985–88	self-report	10·8 – 11·8	6 mths[g]	–	4·8 ± 0·5	274	Scholl *et al.* (1995)
Sweden	–	measured before conception	10·0 – 15·8	12 mths[h]	–	3·4 ± 1·2	10	Sohlström & Forsum (1995)
United States	–	measured before conception	7·2 – 8·4[c]	4–6 wks[g]	–	4·8 ± 0·2	10	Van Loan *et al.* (1995)

[a] Net weight gain during pregnancy = (mean gestational weight gain) – (mean birth weight). Where necessary, standard errors of net weight gain during pregnancy were calculated using the mean coefficients of variation for measurements of maternal body weight recorded before and after pregnancy.

[b] Long-term maternal weight gain = (mean maternal body weight at postpartum follow-up) – (mean prepregnant body weight), and was uncorrected for ageing. Where necessary, standard errors of long-term maternal weight gain were calculated using the mean coefficients of variation for measurements of maternal body weight recorded before and after pregnancy.

[c] Data on birth weight were not provided, and net weight gain during pregnancy was calculated assuming that mean birth weight was 3500 g.

[d] No comprehensive information on the extent of variation in weight gain was provided and only mean or median values are available.

[e] Estimated maternal weight gain from conception to 3 months *post partum*.

[f] Data from the dry season (February – August).

[g] Based on a weight loss of 57 g per day (see text for details) there would not have been enough time for these mothers to lose their net weight gain during the period of postpartum follow-up.

[h] Based on a weight loss of 57 g per day (see text for details) there would have been enough time for these mothers to lose their net weight gain during the period of postpartum follow-up.

Discussion

The literature search identified a total of 71 longitudinal studies that examined maternal weight gain following pregnancy, although 6 of these studies (Sheldon, 1949; Prentice *et al.* 1981; Caan *et al.* 1987; Samra *et al.* 1988; Brown *et al.* 1992; Parker & Abrams, 1993) gave no specific information regarding long-term weight gain following pregnancy. Salient methodological characteristics of the remaining 65 studies have been summarized in Table 4, and the distribution of long-term weight gains indicated by these studies is shown in Fig. 4.

Fig. 4 clearly shows that most of the studies (90·8%) found body weight to be greater after pregnancy than it was before. Only 6 of the studies (McIlroy & Rodway, 1937; English & Hitchcock, 1968; Kawakami *et al.* 1977; Beazley & Swinhoe, 1979; Pipe *et al.* 1979; Kusin *et al.* 1992) showed no overall increase in body weight following pregnancy (see Fig. 4). However, 3 of these (McIlroy & Rodway, 1937; English & Hitchcock, 1968; Beazley & Swinhoe 1979) were conducted at a time when clinicians routinely advocated weight restriction during pregnancy, which is notable since high gestational weight gain may be one of the most important risk factors for maternal obesity in developed countries (Greene *et al.* 1988; Keppel & Taffel, 1993; Parker & Abrams, 1993; Boardley *et al.* 1995; Rössner & Öhlin, 1995; Scholl *et al.* 1995). One of the three remaining studies used women from a developing country where maternal depletion, rather than maternal obesity, was the norm (Indonesia: Kusin *et al.* 1992), and another study may have been unreliable by virtue of its small sample size (n = 26: Pipe *et al.* 1979). At the other extreme, there were 2 studies that found pregnancy-related weight gains far in excess of 5·0 kg (9·0 kg: Rössner, 1992; 10·6 kg: Segel & McAnarney, 1994). These studied sampled women who were of low socioeconomic status (Segel & McAnarney, 1994) or who were obese (Rössner, 1992), both of which have been identified as risk factors for weight gain, irrespective of pregnancy (Schauberger *et al.* 1992; Stevens-Simon *et al.* 1992; Parker & Abrams, 1993; Boardley *et al.* 1995).

Overall, the results of the 65 studies suggest that pregnancy-related weight gains vary greatly. However, only 11 of these 65 studies obtained accurate measures of maternal body weight prior to conception, while 21 used weight measurements recorded early in pregnancy (6–20 weeks gestation) and 27 used self-reports of prepregnant body weight. Likewise, the duration of follow-up ranged from 5 days (Gillmer 1983) to 156 months (Williamson *et al.* 1994). By calculating the upper 95% confidence intervals of net weight gain during pregnancy, and assuming a conservative weight loss of 57 g per day (as described above), it was possible to establish that fewer than half (25) of the 53 studies, with appropriate data on gestational weight gain, gave their subjects sufficient time to lose the weight retained after delivery. Similarly, only 10 studies corrected for the potential effect of ageing on weight gain during pregnancy and the follow-up period. To assess the effect of methodological differences on estimates of long-term weight gain, the studies contained in Table 4 were grouped according to the type of prepregnant weight measurement used and their long-term weight gain was plotted against the duration of postpartum follow-up (see Fig. 5). As expected, studies that used self-reports of prepregnant weights had higher estimates of long-term weight gain, while those using weight measurements recorded early in pregnancy had lower estimates of long-term weight gain. Studies that gave mothers insufficient time to lose the weight retained following delivery displayed an apparent decrease in long-term weight gain as the duration of follow-up increased. In contrast, those studies that gave mothers enough time to lose any retained weight displayed a slight increase in long-term weight gain over time, which reflects the effect of ageing.

Applying the three methodological criteria (an accurate measure of prepregnant weight, sufficient time to lose retained weight and control for ageing) to each of the studies examined in

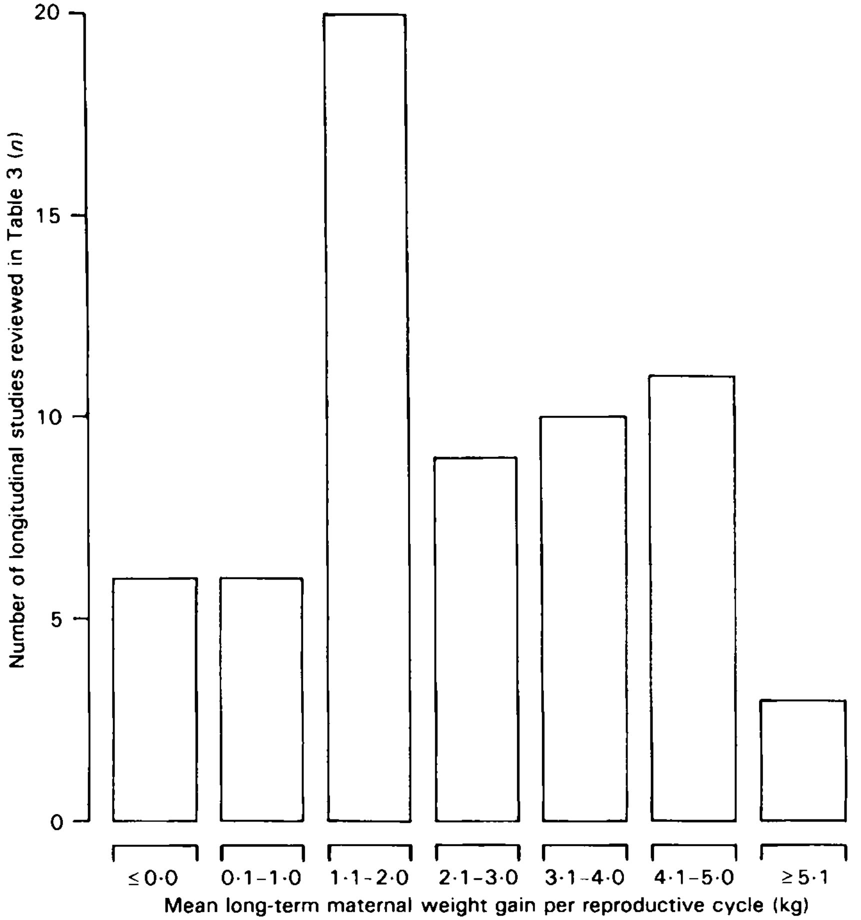

Fig 4. The distribution of mean long-term weight gains following pregnancy, as assessed by the longitudinal studies that examined changes in maternal body weight before and after pregnancy.

Table 4, just one (Rookus *et al.* 1987) appeared to comply with all three. Two additional studies (Smith *et al.* 1994; Williamson *et al.* 1994) failed to provide sufficient data to calculate net weight gain during pregnancy, although the duration of follow-up in both these studies (>12 months) would have been sufficient to lose the highest amount of net weight gain observed (15·8 kg; Sohlström & Forsum, 1995). These three methodologically sound studies suggest that average maternal weight gains range from 0·9 kg (Rookus *et al.* 1987) and 1·7 kg (Williamson *et al.* 1994) to 3·3 kg (Smith *et al.* 1994) over and above that gained by non-pregnant controls. However, these differences in weight gain were somewhat smaller (0·4 kg, Rookus *et al.* 1987; 0·6–3·0 kg, Smith *et al.* 1994; 1·4–1·6 kg, Williamson *et al.* 1994) after accounting for a range of potential confounders. These included age, height, education, parity, giving up work and smoking status (Rookus *et al.* 1987), together with prepregnant body weight and activity (Smith *et al.* 1994) as well as alcohol consumption, marital status, morbidity and dieting behaviour (Williamson *et al.* 1994).

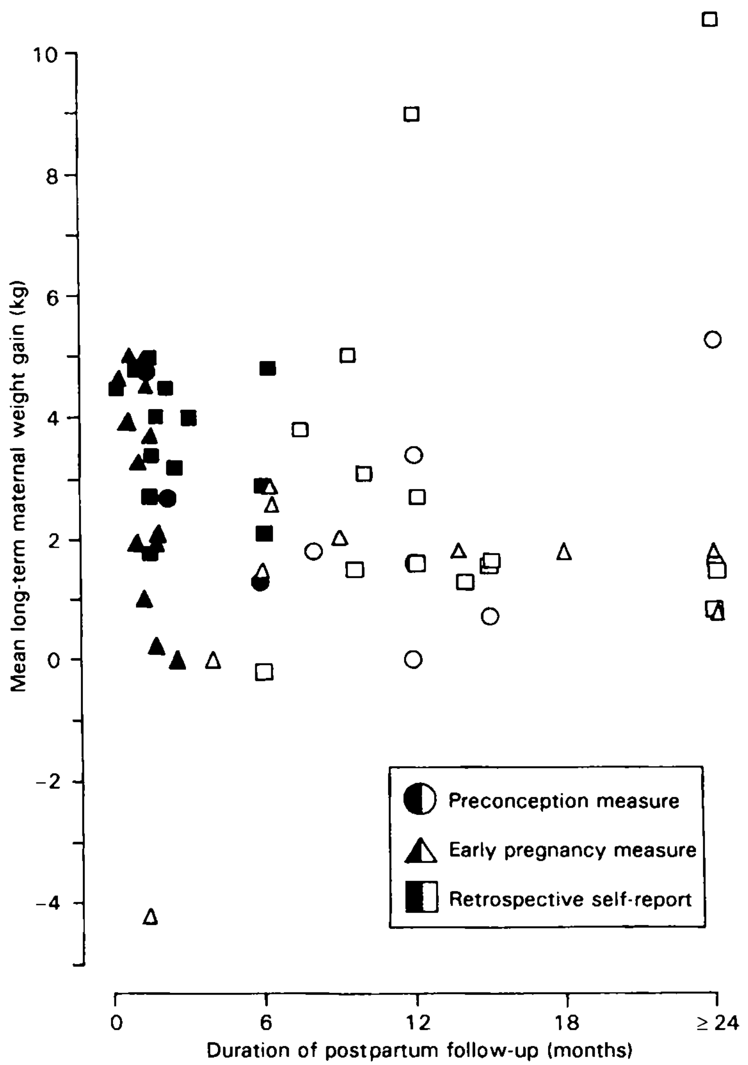

Fig 5. The relationship between mean long-term weight gain and the duration of post-partum follow-up for 65 longitudinal studies that examined changes in maternal body weight before and after pregnancy. Each study has been categorized according to the type of prepregnant weight measurement used (○, preconception measure; △, early pregnancy measure, and □, retrospective self-report) and whether the study gave their subjects sufficient time to lose any weight retained following delivery (○, □, △) or not (●, ■, ▲).

Compared to previous reviews of maternal obesity (Johnston, 1991; Lederman, 1993; Crowell, 1995; Rössner & Öhlin, 1995), our findings provide the most complete collection of studies and apply the most stringent methodological criteria. By comparison, Johnston (1991) asked whether pregnancy might lead to an increase in body weight over and above that expected as a result of ageing. She included a variety of studies dating from 1949 to 1990, but cited only 14 of the 42 studies listed in Table 4 that predate publication of her review, and

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Table 5. Methodological criteria of previous reviews which investigated the impact of pregnancy on long-term changes in maternal body weight

Methodological Criteria	Johnston 1991	Lederman 1993	Crowell 1995	Rössner and Öhlin, 1995
1. Accurate measure of prepregnant weight	*x*	√	*x*	√
2. Sufficient time to lose any retained weight	*x*	*x*	*x*	√
3. Correction for the weight gain with ageing	√	√	√	√
4. Risk factors for maternal obesity discussed	√	√	√	√
5. Number of studies cited	22	17	15	12
6. Mean long-term maternal weight gain per reproductive cycle (kg)	0·5–4·8	< 1·5	1·0	0·4–3·8

summarized only the mean long-term weight gains for nine of these (see Table 5). Although the significance of inaccurate measures of prepregnant weight and insufficient time to lose weight retained following delivery were not discussed, she concluded that most studies show pregnancy to be associated with a modest overall increase in body weight. She also emphasized that both high gestational weight gain and an already high prepregnant weight are important risk factors for maternal obesity. In a similar way, Crowell (1995) reviewed studies over a ten year period from 1983 to 1993, and cited 14 of the 59 studies listed in Table 4 (see Table 5). She concluded that, on average, women tend to be about 1·0 kg heavier after pregnancy than they were before, after accounting for the increase in weight with ageing. Like Johnston (1991), she suggested that there are approximately 1 in 10 women at risk of excessive (>6·6 kg) pregnancy-related weight gains. Crowell's (1995) review focused on risk factors for maternal obesity. In particular, she concluded that those women who gain more than 15·7–18·0 kg during pregnancy are at greatest risk of maternal obesity. Other important risk factors discussed include high prepregnant weight, low socioeconomic status, smoking cessation, high parity, and ethnicity. Both Crowell (1995) and Johnston (1991) concluded that lactation has, at best, an inconsistent effect on weight change after delivery.

In contrast, Lederman (1993) challenged the 'widely held view' that many women increase their body weight permanently as a result of pregnancy. She also explored the determinants of postpartum weight retention using studies from the decade preceding publication of her review (see Table 5). Lederman (1993) extracted and synthesized data on gestational weight gains and postpartum weight changes to identify alternative explanations for weight changes that have been credited to pregnancy in the past. By reassessing existing studies, Lederman (1993) identified a variety of inappropriate assumptions made by past studies of maternal obesity, and demonstrated that ageing was a major determinant of the weight increases associated with parity in cross-sectional studies. She concluded that average pregnancy-related weight gains are generally less than 1·5 kg during a single reproductive cycle (before pregnancy to 1 year *post partum*), but that obese women have larger weight changes (both lower and higher) than lower-weight women. In addition, this review (Lederman, 1993) emphasizes that under-reporting of prepregnancy weight, particularly by overweight women, would tend to overestimate weight gained in association with pregnancy. Like Crowell (1995) and Johnston (1991), Lederman (1993) acknowledged that a small number of women increase weight greatly during a

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reproductive cycle, although the studies she reviewed do not *prove* that this weight gain is a direct result of pregnancy. For this reason Lederman (1993) suggested that the changes in lifestyle associated with pregnancy and motherhood, such as cessation of smoking, delayed return to work, depression, attitude to weight gain, and changes in body image, may be a more likely cause of maternal obesity than pregnancy itself. This conclusion was echoed by Rössner & Öhlin (1995) who presented a summary of the findings and lessons learnt from the Stockholm Pregnancy and Weight Development Study (Öhlin & Rössner, 1990, 1994; Rössner, 1992). In this review, Rössner & Öhlin (1995) demonstrated that most cross-sectional studies showed an increase in body weight with parity that was independent of ageing, but suggested that, for the population generally, the effect of pregnancy on future weight development is often difficult to predict. Their own research showed that for women who develop obesity, pregnancy can be an important triggering life event, and their review of the literature provided an estimate of long-term maternal weight gain of 0·4–3·8 kg (see Table 5). Nevertheless, they identified a number of methodological criteria to be taken into account when evaluating the results of previous studies. (1) There are problems associated with uncertain measures of prepregnant weight. (2) They discuss the implications of when to determine postpregnancy body weight. (3) There is need to correct for the increase in body weight that would have occurred normally as a result of ageing. They also discuss the relevance of risk factors for maternal obesity, including gestational weight gain, cessation of smoking, and various other behavioural and sociodemographic factors (Öhlin & Rössner, 1990, 1994) which explain some of the considerable variation in pregnancy-related weight gains that are observed.

In the present review pregnancy-related weight gains appear modest in mothers who experience only one or two pregnancies, yet they mask the fact that some mothers experience a substantial increase in body weight following pregnancy and mothers who have 3 or more pregnancies may accumulate more than 10 kg in weight. Whether these increases are simply the result of changes in energy balance during pregnancy and lactation (e.g. Illingworth *et al.* 1986; Prentice *et al.* 1989) or whether they are influenced by inherent changes in lifestyle that accompany pregnancy and motherhood (e.g. Leifer, 1977; Clissold *et al.* 1991) remains unclear. Understanding the relative importance of these alternatives might help to explain why most mothers gain little weight following pregnancy while some become obese (Sheldon, 1949).

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