Medical Hypotheses 6: 1157-1170, 1980

# MATERNAL PHYSICAL ACTIVITY, BIRTH WEIGHT AND PERINATAL MORTALITY

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## ABSTRACT

As a result of the acquisition of upright posture, adaptation to muscular exercise seems to be unique in man. It involves a redistribution of the cardiac output mediated by the sympathetic system towards priority organs which apparently do not include the pregnant uterus. This could explain the poor tolerance of the human fetus to maternal exercise. The hypothesis is supported by the independence of a detrimental effect of work from the effect of maternal nutrition and by an influence of maternal posture in late pregnancy on its outcome. Possible relations between maternal activity before and during late pregnancy and perinatal mortality are discussed in the context of this hypothesis.


## INTRODUCTION

Birth weight, stillbirth rate and neonatal mortality are influenced by the social class of the mother. This was apparent from the first statistics of the nineteenth century (1) and remained so after a high standard of perinatal care became available for the majority of the population (2). Historically, the first factor to have been incriminated to explain this was the high level of physical activity of women of low socio-economic status in the last weeks of pregnancy (3). Early this century, social measures were taken in all industrialized countries to allow pregnant women to stop their industrial work and this possible contribution to perinatal mortality is considered to have progressively disappeared although it is well known that domestic work is sometimes more physically demanding than occupational work, especially in low income groups (4).

Many decades later, when nutrition emerged as a science, it was suggested that this social distribution of perinatal mortality could be the consequence of a poor maternal nutrition in underprivileged groups, even though most obstetricians of the time used to give restrictive advice to their wealthy patients in the firm belief that

this would improve fetal wellbeing. If nutrition is taken in its widest context implying the growth, health and adult size of the mother, its influence on birth weight is indisputable (5). The effect of diet taken during pregnancy on the other hand is less well substantiated. Birth weight has been shown to be depressed by a reduced food intake only in very unusual circumstances such as wartime famines (6) or by radical alterations of the usual diet (7), and food supplementation of women of poor socio-economic level has had disappointing results.

Since it does not seem possible to explain all variations of birth weight associated with socio-economic status by differences of food intake, the first factor to have been incriminated at the turn of the century, namely the level of maternal activity during pregnancy should be reconsidered. That early hypothesis is now supported by some evolutionary considerations regarding fetal growth.

Evolutionary aspects of fetal nutrition

An inadequate utero-placental blood flow resulting from man's acquisition of upright posture has been proposed recently as a possible cause of the slight fetal growth faltering which occurs towards term (8). This view gives physiological backing to the empirical belief among obstetricians that the fetus benefits from the maternal rest at the end of pregnancy and supports early ideas about the social distribution of birth weights.

During exercise there is a massive reduction of vascular peripheral resistances (9) and a decrease of blood volume (10). In animals a drop of blood pressure is prevented by an increase in the cardiac output (11). In upright man however this reaction does not seem to be able to maintain blood pressure presumably as a result of an inefficient venous return limiting the cardiac output. At all events, it is associated with a visceral vasoconstriction mediated by the sympathetic system (9). Comparative evidence suggests that this reaction does not protect the pregnant uterus : in experimental animals utero-placental blood flow is depressed by sympatheticomimetic drugs (12-15). In evolutionary terms, the purpose of this reaction was presumably to keep blood pressure stable in rare emergency situations such as fight, aggression or acute blood loss since it is only then that it is activated in all other mammals (16). One may assume that maintenance of placental blood flow is not a priority in these circumstances. Although man relies heavily on the sympathetic system to regulate his blood pressure a depressing effect of this reaction on placental perfusion may well have persisted, since evolutionary changes are likely to be slow for functions of no immediate survival value (17).

Since fetal nutrition is largely dependent on placental blood flow (18), this peculiarity of human physiology makes it likely that maternal exercise at the end of pregnancy will result in fetal deprivation and that this effect is independent of maternal nutritional status. This suggests also that the standing position which by itself affects venous return, decreases plasma volume and activates the sympathetic system (9), has the same effect. That interpretation which assumes that muscles have priority over utero-placental circulation in the distribution of cardiac output also implies that physical performances are not altered during pregnancy.

In the context of this hypothesis with its various implications for the social distribution of birth weights and perinatal mortality some observations made before the introduction of modern legislation and some studies of the physiology of exercise during pregnancy deserve re-examination.

Need for rest in late pregnancy

The need for rest at the end of pregnancy was first suggested in 1895 by the French obstetrician A. Pinard (3). He noticed that there was a difference in mean birth weight of 280g between infants born to mothers who had spent at least ten days at rest in a Parisian Council refuge for the indigent and those whose mothers came directly to the maternity hospital for delivery. His samples consisted of 500 consecutive births in each group. He reported that the group of mothers who rested comprised 69% primigravidae which suggests that this group had an excess of first births compared to the general population, so that the difference between the two samples might be underestimated. This first observation was confirmed shortly afterwards by L. Letourneur (19) whose work is unique in that he published all his data and it is possible to test statistically his assertions on the effect of rest (Table 1). In another maternity home, in Vienna, a few years later a similar effect of maternal rest on birth weight was reported by Peller (20)(Table 2).

The effect of rest in a maternity home on birth weight was apparently associated with a dramatic reduction in perinatal mortality. Peller's data (21) are numerous enough to test this association (Table 3). The reported decrease in stillbirth rate can only be explained satisfactorily by an improvement of fetal wellbeing in the last weeks of pregnancy. This suggests that the differences of birth weight reported in these maternity homes were at least partly due to improved fetal growth.

| Factors influencing birth weight | Mean value of the effect | Standard error | Level of significance |
|---|---|---|---|
| Rest before delivery | + 202g if more than 8 days | 37g | p. less than 0.001 |
| Parity | + 193g if mother multipara | 37g | p. less than 0.001 |
| Sex of the newborn | + 100g for boys | 37g | p. less than 0.01 |
| Nature of maternal work | + 15g if not physically demanding | 38g | not significant |

TABLE 1. Factors influencing birth weight in Letourneur's material from 627 deliveries in Paris in 1896 using a multiple regression.

The mean birth weight of a girl born from a primigravida with a demanding profession was 2889g in the absence of rest.

Among women who had a physically demanding profession (cooks, housemaids .....) the effect of rest was to increase birth weight by 238g compared to 161g among mothers with less tiring work (needlewomen, florists .....). This difference between these two groups is not significant.

| Number of cases | Duration | Birth weight | |
|---|---|---|---|
| | | Boys | Girls |
| 1380 | Less than 2 days | 3216g | 3107g |
| 576 | At least 1 week | 3334g | 3234g |

TABLE 2. Effect of sojourn in a maternity home of unmarried primigravidae on birth weight (Vienna 1917).

Although the standard deviation of birth weight is not reported, this difference would appear to be significant if one assumes the usual value.

| Duration of stay | Number of cases | Stillbirth | Neonatal deaths |
|---|---|---|---|
| Less than 2 days | 1925 | 4.7% | 4.8% |
| Between 2 and 7 days | 223 | 5.8% | 4.0% |
| Between 8 and 28 days | 417 | 1.9% | 1.9% |
| More than 28 days | 203 | 2.3% | 0.5% |

$X^2 = 25$ p less than 0.01

TABLE 3. Effect of duration of stay in a maternity home on perinatal mortality (Vienna, 1931).

These early studies in maternity homes resulted in the introduction of social legislation restricting maternal work in industrialised countries at the beginning of the century. They have a special value as they compared women of low socio-economic status who were able to rest completely with similar women continuing physically demanding activity. This presumably explains why the differences in birth weights or perinatal mortality reported in these studies were larger than in later surveys which compared working women protected by social laws with housewives whose domestic chores prevent complete rest.

It may be argued that we do not know how this early material was collected and to what extent it is reliable. Some evidence suggests however, that it was of good quality. Analysis of Letourneur's data shows a distribution of birth weights highly consistent with present

experience and a relation between birth weight and sex of the newborn and parity very similar to what was to be described many decades later (22). Finally, differences in stillbirth rate comparable to those mentioned early this century in maternity homes have been recently reported from Zaire in a subsistance farming community in which a similar institution has persisted (23).

Selection of women coming to these maternity homes may be a more serious obstacle to interpreting the data from these early studies. It cannot be assumed *a priori* that women who came to rest were randomly selected. A cause and effect relation between rest in a maternity home and low perinatal mortality cannot be considered to be proved by data which could be biased by some unknown confounding factor. Some details suggest, however, that these institutions were effective : they were basically charities set up to help unsupported poor women and it is likely therefore that they recruited subjects mainly from the most deprived social groups which are known to have a higher risk of perinatal mortality. Moreover, they had a large proportion of unmarried women (22) and as previously mentioned an excess of primigravidae. Differences in birth weights and perinatal mortality can therefore reasonably be attributed to the improvement of living conditions that mothers-to-be enjoyed in these institutions.

Independence of the effect of rest from maternal nutrition

It could be argued that the observed effect of a sojourn in a maternity home on birth weight is the result of improved maternal nutrition due to a better diet and a reduction of energy expenditure. That maternal nutrition has some influence on fetal growth was shown during World War II in Holland when famine resulted in a depression of birth weights (5). Restrictive diets given a few years ago by some obstetricians to prevent pre-eclampsia had the same effect (6) and this allows the same conclusion, namely that reducing the usual diet of pregnant women depresses birth weight. It does not follow, however, that increasing their spontaneous food intake will have the reverse effect. Attempts to do so has had disappointing results so far and even in deprived communities, maternal dietary supplementation seems to have had much less effect on birth weight than had the admission to a maternity home early this century. A carefully controlled study in a poor rural community in Guatemala showed that maternal protein intake has no influence on birth weight (24). The design of this survey in which the groups of women receiving different levels of supplementation were self selected does not allow a precise assessment of the influence of energy intake. Its data, however, suggest that unlimited availability of food supplement during pregnancy resulted in a mean birth weight increase in the experimental villages of only 50g. This result is similar to another nutritional intervention in Colombia with randomized samples of supplemented and unsupplemented women (25). The full term newborn infants

of supplemented women weighed on average 50g more than the controls. This difference was not significant except in the male sub-sample. Women involved in these studies had a grossly deficient food intake compared to the F.A.O./W.H.O. recommendation (26). In industrialized countries no supplementation experiment with satisfactory methodology has ever resulted in a significant increase in the mean birth weight, even in poorer social groups.

This lack of spectacular effect of food supplementation during pregnancy on birth weight is not surprising considering that even in deprived communities of developing countries, most breast fed infants grow satisfactorily, at least during the first three months of life (27). This makes it unlikely that their growth *in utero* was limited by insufficient maternal food intake. Lactation, nutritionally is more demanding than pregnancy (28) and should be impossible if maternal reserves were exhausted by the demands of the fetus. This suggests that the slight increase of birth weights observed after supplementation in deprived communities is more likely to be due to an extra transfer of glucose to the fetus, perhaps with no other benefit than extra fat stores (29), rather than to the correction of the energy balance. This makes it likely that the apparent effect of rest at the end of pregnancy on fetal growth is not due to the correction of an energy deficit in supposedly malnourished women.

That conclusion is supported by Letourneur's comments in the nineteenth century. He noticed that women who did physically demanding work and had a robust constitution such as cooks or housemaids had infants of lower birth weight when they worked throughout their pregnancy than thinner women such as needlewomen or florists who rested before delivery (19) (Table 1). He concluded that the amount of work at the end of pregnancy has more influence on birth weight than maternal morphology which is contrary to a purely nutritional interpretation of birth weight variations. A recent survey in Ethiopia (30) has come to the same conclusion and reported differences in birth weights according to maternal activity very similar to those observed by Letourneur in Paris in 1896.

An influence of work by itself, independent of energy balance, on birth weight was also suggested by Balfour in the late 20's from observations in India (31). She noticed that textile workers who had on average a higher energy intake (2120 kcal./day) than the general population (1860 kcal./day) had newborn infants with a lower birth weight (Table 4). These women usually worked in standing positions but their work was not physically demanding and the effect of work on birth weight in this case also seems unlikely to be due to an excess energy expenditure. Maternal mortality was lower among workers and this suggests that they enjoyed better health than

their non-working counterparts. Finally, during a several month's strike which, one may assume, can only have had unfavourable effects on the ability of workers to buy food, their mean birth weight increased significantly (Table 4).

| | Number of cases | Mean birth weight | Standard deviation |
|---|---|---|---|
| Mill workers before strike (Group 1) | 134 | 2441g | 407g |
| Mill workers during and after strike (Group 2) | 89 | 2594g + | 414g |
| Wives of mill workers (Group 3) | 236 | 2639g ++ | 390g |
| Non-industrial families (Group 4) | 538 | 2767g ++ | 446g |

\+ p less than 0.05 compared to Group 1
++ p less than 0.01 compared to Group 1

TABLE 4. Effect of maternal work on birth weight in India (1930).

The dramatic effect of maternity homes on perinatal mortality is even more difficult to explain in nutritional terms than their effect on birth weight. That maternal diet during pregnancy has some influence on fetal survival is still largely speculative and has been, to some extent, contradicted by the Dutch famine during which there was a decrease in perinatal mortality (6). Since this trend was not statistically significant, and that a shift in the social distribution of pregnancies may have biased these observations, one cannot reject totally a possible link between diet and pregnancy outcome but it seems unlikely that it has major clinical importance. At all events, observations made throughout World War I in the maternity home of Vienna (32) do not support the hypothesis that the favourable effect of these institutions on perinatal mortality was due to the improved diet that the mothers received from them, but presumably to rest. Vienna at the end of World War I suffered a period of food shortage and women in the maternity home had their daily food intake cut from

2850 kcal./day in 1913 to 1800 kcal./day in 1918-1919 and the pre-war level was to be recovered only after 1925 (1). This reduction of food availability was associated with a depression of birth weights in women from the maternity home as well as those who came to the hospital only for delivery (Table 5). Perinatal death rates observed during these variations in birth weights remained remarkedly constant (Table 6). The reduction of perinatal mortality in the maternity homes is also unlikely to be of nutritional origin.

| Duration of sojourn in a maternity home | 1912-1913 | | 1920-1922 | |
|---|---|---|---|---|
| | Boys | Girls | Boys | Girls |
| Less than 2 days | 3200g | 3104g | 3084g | 3043g |
| At least one week | 3336g | 3186g | 3240g | 3154g |

TABLE 5. Effect of post-war food restriction on birth weights in Vienna.

The size of the samples is not mentioned in the original article. Other publications from the same author suggest that he reviewed on average 2000 deliveries a year.

| Duration of sojourn in a maternity home | 1912-1913 | | 1920-1922 | |
|---|---|---|---|---|
| | Stillbirth | Neonatal death | Stillbirth | Neonatal death |
| Less than 2 days | 2.9% | 3.5% | 3.2% | 3.2% |
| More than one week | 1.3% | 0.7% | 1.3% | 0.7% |

TABLE 6. Effect of post-war food restriction on perinatal mortality in Vienna.

Same sample as in Table 5.

Importance of posture during pregnancy

At the beginning of this century many obstetricians relying on empirical observations already believed that work in a standing position in the last weeks of pregnancy had unfavourable effects on the fetus. During World War I in France, women in ammunition factories were exempted from work in this position as soon as their pregnancy became apparent (33).

A few decades later in England, Balfour, who had already suspected the importance of this factor at the end of her survey in the textile industry in India, undertook another study also in the textile industry which gave her the opportunity to confirm the influence of posture in late pregnancy on birth weight (34). She compared infants whose mothers had worked either in a sitting or a standing position during pregnancy and she found that the former were significantly heavier (Table 7). Additional data on incidence of prematurity (presumably defined as a birth weight less than 5½ lb) suggest that this effect was greater when work was continued after the sixth month of pregnancy. According to this author, none of the occupations of these women could be looked upon as heavy and all were apparently of the same social background.

| | Number of cases | Mean birth weight | s.d. | Stillbirth rate |
|---|---|---|---|---|
| Sitting workers | 236 | 3468g | 537g | 6.4‰ |
| Standing workers | 1074 | 3386g* | 476g | 20.3‰ |

* p less than 0.05

TABLE 7. Effect of posture during work on birth weight and stillbirth rate.

These variations of birth weight in relation to posture, in contrast to those induced by the level of food intake seem to be associated with differences in perinatal mortality. This is strongly suggested by Balfour's study but, although she reports a trebling in stillbirth rate among standing workers (Table 7), her samples had not the required size to make this difference significant. Data from Hirsch in Berlin (35) also from the textile industry fulfil this criterion. He reported a still higher difference in stillbirth rate between standing and sitting workers which was statistically highly significant ( Table 8).

| | Stillbirth rate |
|---|---|
| Sitting workers (n = 414) | 1.1% |
| Standing workers (n = 2751) | 4.1% |

$X^2$ = 7.9 p less than 0.01

TABLE 8. Effect of posture during work on stillbirth rate.

Details given in the text suggest however, that standing workers tended to stop their work more often or earlier than their sitting colleagues.

### Low priority of uteroplacental circulation during exercise

Pregnant women feel subjectively less able to perform exercise especially towards term (5). This apparently results from their unusually high body weight and altered balance unrelated to an impaired or an insufficient cardiac function. Healthy women, even when they engage in strenuous physical activity towards term do not exhibit the association of clinical signs which are characteristic of circulatory failure. Furthermore, cardiovascular response to exercise such as cycling which eliminates the effect of the excess of body weight is not altered in late pregnancy (36) and the physical work capacity tends to be maximal in the third trimester (37).

The poor tolerance of the human fetus to maternal exercise at a time when apparently there is no major impairment of maternal cardiovascular functions supports the idea that uteroplacental blood flow has a low priority in the redistribution of cardiac output which occurs during muscular activity. Bearing in mind that this redistribution is mediated by the sympathetic system, this interpretation is consistent with measurements of blood flow to different organs in the ewe after perfusion of catecholamines (12). They show that uteroplacental perfusion is among the more severely depressed.

Physically trained subjects who have a high blood volume and need only a minor diversion of cardiac output from the viscera during mild exercise (38) should be theoretically in a better position to sustain fetal growth at the end of pregnancy. That this may be the case and may be clinically relevant is suggested by a prospective study by Erkkola showing that women with a high physical work capacity tend to have bigger infants (37). This possible effect of physical training on fetal growth added to the fact that fit women tend to have shorter labours (39,40) suggests that apart from late pregnancy, an active life could be an advantage in reducing the risk of perinatal incidents.

## CONCLUSION

### Relevance to the present situation

In the developing countries, most women need to continue physically demanding domestic chores or even agricultural work until delivery. This is a major public health problem inasmuch as in the tropics, heat is an additional stress for the cardiovascular system necessitating an increased level of sympathetic activity (9). Allowing women to rest in the last weeks of pregnancy seems to be a prerequisite to reduce perinatal mortality in these areas.

In industrialized countries hard physical work in late pregnancy has largely disappeared as a result of appropriate legislation. Patterns of physical activity however are still closely related to social class. Before pregnancy and during its early weeks, women in low income groups are likely to have a more sedentary life than the average since they engage in fewer sporting activities and their work is unlikely to provide an equivalent source of energy expediture (2). Industrial work in the low income groups tends no longer to be distinguished by intense muscular work but rather by prolonged standing or long commuting time which, however, subjectively fatiguing they may be, do not have the same physiological implications as outdoor leisure activities.

Although information on maternal activity at home is rather scanty, one can assume that this social effect tends to be altered in late pregnancy. Rest is really possible only for women with substantial help at home or having a high standard of living exempting them from the most demanding domestic chores.

These differences in the usual level of physical activity and variations in the opportunity to rest in late pregnancy are consistent with the observed social distribution of birth weights and perinatal mortality. Whether this factor does play a role in the present situation in industrialized countries is an open question. Epidemiological surveys, taking into account the opposed effects of long term and short term physiological adjustments to exercise and the influence of posture in late pregnancy are needed to solve this problem.

Acknowledgements

I thank Dr. F.E. Hytten and his colleagues from the Division of Perinatal Medicine (Clinical Research Centre, Harrow, Middlesex, UK) for their help and advice in the preparation of this article. I thank Dr. D.G. Altman for his statistical analysis of Letourneur's thesis.

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