

Physical activity levels during pregnancy and gestational weight gain among women who are overweight or obese

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Abstract

Issue addressed: There is contradictory research assessing physical activity patterns during pregnancy and postpartum among women who are overweight or obese. The aim of this study was to evaluate physical activity among overweight and obese women over the course of pregnancy and the initial postpartum period.

Methods: Three hundred and five overweight or obese pregnant women completed physical-activity questionnaires at three time points during pregnancy and at 4-months postpartum.

Results: Physical activity declined between early pregnancy and 28-weeks gestation ($P < 0.001$) and declined further at 36-weeks gestation ($P < 0.001$) before increasing significantly at 4-months postpartum ($P < 0.001$). However, reported activity at 4-months postpartum remained significantly lower than that reported in early pregnancy ($P < 0.001$). There was no significant difference either cross-sectionally or for changes over pregnancy and postpartum for total levels or categories of physical activity for women with different body mass index (BMI) or gestational weight gain (GWG). BMI was the only independent predictor of the change in total physical activity over the study and GWG, with women with higher BMI having larger decline of physical activity ($\beta = 0.114$, s.e. = 0.750, $P = 0.032$) and less GWG ($\beta = -0.253$, s.e. = 0.063, $P < 0.001$).

Conclusions: Physical activity declined significantly between early pregnancy and 28-weeks gestation, with a further decline to 36-weeks gestation. At 4-months postpartum, physical activity significantly increased but not to the level of that reported at early pregnancy.

So what? The promotion of appropriate physical activity should be implemented early in pregnancy and postpartum to prevent the decline in activity we have observed in overweight and obese women. Future research should also explore the barriers and enablers to women engaging in exercise during pregnancy and the postpartum period.

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Introduction

Being physically active is recognised as an essential part of a healthy pregnancy and is associated with improved cardiovascular function and physical fitness,¹ and reduced risk of adverse maternal outcomes including gestational diabetes, pre-eclampsia and preterm birth.² Current physical-activity guidelines recommend that women with an uncomplicated pregnancy be active with moderate to intensive exercise for 30 min or more on most days of the week.³ Systematic reviews of randomised trials in this field suggest that the benefits of exercise in pregnancy outweigh potential harms such as intrauterine growth restriction.⁴

It is estimated that between 34 and 50% of pregnant women in Australia are overweight or obese.⁵ Both increased maternal body mass index (BMI) on entering pregnancy and high gestational weight gain (GWG), defined by the US Institute of Medicine (IOM) guidelines as greater than 11.4 kg in women who are overweight and 9 kg in women who are obese,⁶ have been reported to be associated with an increased risk of adverse maternal and neonatal outcomes.⁷ Our systematic review indicates that exercise during pregnancy for overweight or obese women is effective in limiting GWG, although the effect on maternal and infant clinical outcomes remains unclear.⁸ In contrast, it is unclear whether exercise in the postpartum period for

overweight or obese women is effective in limiting weight retention.⁹ This has potential implications for maternal weight management with regards to both limiting obesity at subsequent pregnancies and reducing long-term obesity-associated morbidity and mortality.

The limited existing literature examining changes in total physical activity during pregnancy included women of all BMI categories^{10–14} and indicated a reduction in activity over the course of pregnancy.¹⁵ However, the research evaluating physical activity during pregnancy specifically among women who are overweight or obese is limited to only two papers with relatively small sample sizes and has produced contradictory findings.^{16,17} Some authors report an increase in activity from early to mid-pregnancy, followed by a decline in the third trimester,¹⁶ while others report a constant reduction in activity across gestation.¹⁷ In addition, there is limited information describing cross-sectional comparisons or changes in physical activity from pregnancy to postpartum in women of different GWG categories with an inverse correlation previously reported between GWG and physical activity.^{18,19} A comprehensive evaluation of physical activity patterns across pregnancy and the postpartum period is warranted to aid in identification of appropriate time points in which to target future interventions to prevent both excessive gestational weight gain and postpartum weight retention. This is particularly relevant in overweight and obese women given the additional adverse maternal, fetal and child outcomes associated with increased adiposity during and following pregnancy.

Previous research has also focussed on total physical activity. Examination of the specific subcomponents of physical activity (e.g. leisure time activity, commuting and work activity and household activity) is crucial to allow an understanding of the contribution of different types of physical activity to overall exercise patterns and to aid in identifying potential targets for interventions during pregnancy and postpartum. There is currently no research assessing levels of physical activity in women with different BMI or GWG either cross-sectionally or over the course of pregnancy and the postpartum period.

The aim of this study was to evaluate changes in physical activity among women who are overweight or obese during pregnancy and the initial postpartum period, and to evaluate the effect of both BMI and GWG on activity levels.

Methods and procedures

Study population

This prospective cohort study is nested within a randomised trial evaluating the effect of an antenatal intervention to limit weight gain among overweight and obese pregnant women on maternal and infant health outcomes (the LIMIT study).²⁰ The methodology of the randomised trial has been described in detail previously.²⁰ Women were eligible for inclusion in the current study if they were randomised to the control group of the LIMIT trial, received standard antenatal care with no specific encouragement of physical activity

during pregnancy, were recruited between September 2009 and August 2011 and who had complete data available for the physical activity questionnaires at all time points ($n = 305$). Specific inclusion criteria were women with a BMI ≥ 25 kg m⁻² and singleton pregnancy, with their first antenatal visit between 10⁺⁰- and 20⁺⁰-weeks gestation. Women with previously diagnosed type-1 or -2 diabetes before pregnancy were not eligible. Women were recruited from three public maternity hospitals across the Adelaide metropolitan area, and provided written informed consent to participate. The medical ethics committees of all the participating hospitals approved the study.

Clinical measurements

Baseline demographic information was collected at study entry, including age, parity, ethnicity and postcode of residence. An assessment of socioeconomic disadvantage was calculated using the Socioeconomic Indexes for Areas disadvantage score (SEIFA). Height, weight and BMI were measured at study entry and at 36-weeks gestation. Women were categorised as overweight or obese according to the World Health Organisation criteria (overweight 25–29.9 kg m⁻²; obese I 30.0–34.9 kg m⁻²; obese II 35.0–39.9 kg m⁻², and obese III ≥ 40 kg m⁻²).²¹ GWG was defined as weight at 36 weeks minus weight at trial entry and categorised based on BMI category, as below, within or above the IOM recommendations (if overweight GWG 6.8–11.4 kg; if obese GWG 5–9 kg).

Physical activity questionnaire

Women completed the Short Questionnaire to Assess Health-enhancing physical activity (SQUASH) at study entry (1–2 weeks after recruitment), 28-weeks-gestational age, 36-weeks-gestational age and at 4-months postpartum. The SQUASH questionnaire was developed by the Dutch National Institute of Public Health and Environment. It has been validated in different populations^{22,23} and is a widely used tool to examine physical activity behaviour. The questionnaire includes 11 questions relating to the time spent on different types of physical activity and takes ~3–5 min to complete.^{22,23} The categories of activity types listed in SQUASH were commuting activity (including walking to and from work and bicycling to and from work), leisure time activity (including walking, bicycling, gardening, odd jobs, sports specified by participants), household activity (including light household work and intense household work) and activity at work (including light work and intense work).

Data analysis

An activity-specific intensity code from the Compendium of Physical Activities was assigned to each reported activity.²⁴ The Compendium of Physical Activities is a comprehensive list of physical activities with corresponding estimates of intensity in Metabolic Equivalent Task units (MET), where 1 MET is equal to the energy expended during quiet sitting.²⁴ The number of minutes spent in each reported activity recorded in the SQUASH questionnaire was multiplied by its MET

intensity and summed to calculate total daily energy expenditure. Since MET is a measure of intensity and rate of physical activity, the concept of MET-minute was used to quantify the total amount of physical activity in a way comparable between individuals and across different types of activities. For example fast walking to and from work for half an hour (a moderate intensity activity of 3.3 MET) accounts for ~100 MET-min and is equivalent to fast bicycling for ten minutes (a vigorous intensive activity of 10 MET). As the SQUASH questionnaire asks women to report their physical activity of an average week in the past months, MET-minutes per week were calculated as duration (in minutes) × frequency (days per week) × MET intensity.

Statistical analyses

Data were analysed using the Statistical Package for the Social Sciences (SPSS, Chicago, IL) software (version 18). Data are presented as mean ± standard deviation (s.d.). Data were assessed for normality and non-parametric statistical tests were utilised where data were non-normally distributed. Physical activity patterns were analysed using repeated-measures analysis of variance (ANOVA) with BMI category and GWG category as between-subject factors in *post hoc* Bonferroni tests. Stepwise multiple logistic regression analysis (for continuous outcomes) was conducted to assess the independent determinants for the change of physical activity during pregnancy and postpartum and for GWG. A *P*-value of <0.05 was considered statistically significant.

Results

Participant characteristics

During the study period, 305 women randomised to the control group of the LIMIT trial were recruited who completed SQUASH questionnaires at all four time points. The baseline characteristics of women are presented in Table 1 and are similar to the reported demographic characteristics of pregnant women in South Australia.²⁵ Approximately 45.6% of the women were categorised as overweight, with 30.2% of women as obese I, 15.1% as obese II and 9.1% as obese III. The mean gestational age at trial entry was 14.0 ± 2.1 weeks, with 30.1% of women in trimester 1 and 69.9% in trimester 2. With regards to GWG according to the IOM recommendations, fewer obese women had GWG within the IOM recommendations compared with overweight women, with women with BMI 30.0–34.9 kg m⁻² most likely to have GWG above recommended levels (Table 2).

Physical activity across pregnancy and postpartum

The levels of total physical activity across pregnancy and postpartum are summarised in Table 3. There was a significant change over pregnancy and postpartum (*P*<0.001), where physical activity declined significantly between trial entry and 28-weeks gestation (*P*<0.001), followed by a further decline to 36-weeks gestation (*P*<0.001). Physical activity then increased significantly at 4-months postpartum (*P*<0.001); however, the activity level at 4-months

Table 1. Baseline characteristics

Data are presented as mean ± s.d. or proportions. BMI, Body mass index; SEIFA, socioeconomic indices for areas disadvantage score

| Category | <i>n</i> | % | Mean ± s.d. | General population % ^A |
|--------------------------|----------|------|-----------------------|-----------------------------------|
| Age | | | | |
| <20 | 3 | 0.9 | 30.4 ± 5.1 | 4.1 |
| 20–30 | 131 | 42.9 | | 44.3 |
| 30–40 | 160 | 52.5 | | 47.8 |
| 40+ | 11 | 3.8 | | 3.8 |
| Parity: Parity = 0 | 127 | 41.6 | 0.9 ± 0.9 | 41.5 |
| BMI | | | | |
| Overweight | 139 | 45.6 | Overall 31.7 ± 5.5 | 54.1 ^B |
| Obese I | 92 | 30.2 | Overweight 27.3 ± 1.3 | 25.8 |
| Obese II | 46 | 15.1 | Obesity 35.3 ± 4.8 | 12.1 |
| Obese III | 28 | 9.1 | | 8 |
| Smoker: Yes | 30 | 9.8 | | 15.9 |
| Race: Caucasian | 279 | 91.5 | | 85 |
| SEIFA | | | | |
| 1–2 deciles ^C | 71 | 23.3 | | 20 |
| 3–4 deciles | 64 | 21 | | 20 |
| 5–6 deciles | 57 | 18.8 | | 20 |
| 7–8 deciles | 61 | 20 | | 20 |
| 9–10 deciles | 52 | 17 | | 20 |

^ASource: Pregnancy Outcome in South Australia 2009, Government of South Australia.

^B% calculated excluded underweight women and women of normal weight

^CSEIFA. For example, decile 1 contains the bottom 10% of the collection districts and Decile 2 contains the next 10%.

Table 2. Prevalence of gestational weight gain within US Institute of Medicine (IOM) recommendation

BMI, body mass index; GWG, gestational weight gain

| BMI | Below | GWG | Above |
|------------|----------------|------|----------------|
| | recommendation | Meet | recommendation |
| | (%) | (%) | (%) |
| Overweight | 20.1 | 38.9 | 40.0 |
| Obese | 28.9 | 22.2 | 48.9 |
| Obese I | 17.4 | 21.7 | 60.9 |
| Obese II | 37.0 | 23.9 | 39.1 |
| Obese III | 53.6 | 21.4 | 25.0 |

postpartum was significantly lower than that reported at study entry (*P*<0.001).

There was a significant change in all different physical activity-categories over pregnancy and postpartum (*P*<0.001) except leisure activity (*P* = 0.063). At trial entry, 68.5% women reported still working, declining to 58% at 28 weeks, 40% at 36 weeks and 16% at 4-months postpartum (*P*<0.001). From trial entry to postpartum, commuting (*P*<0.001) and work activity (*P*<0.001) decreased and were significantly reduced at 4-months postpartum compared with trial entry. All women reported ever engaging in light household activities over pregnancy and postpartum and 85% in intense household work. Household activities decreased from trial entry to 28 weeks (*P*<0.001)

Table 3. Physical activity (metabolic equivalent task (MET) minutes per week) in different stages of pregnancy and 4-months postpartumData are presented as mean \pm s.d. GWG: gestational weight gain; MET-minutes per week: metabolic equivalent task units in minutes per week

| | Trial entry | 28 weeks | 36 weeks | Postpartum | P- value Overall effect on time |
|----------------------|-----------------------|----------------------|----------------------|-----------------------|---------------------------------|
| Activity category | | | | | |
| Total (n = 305) | 9744.6 \pm 6081.0 | 7026.6 \pm 5197.3* | 5165.1 \pm 4182.6* | 7190.2 \pm 5266.2*# | <0.001 |
| Commuting | 155.5 \pm 754.5 | 112.0 \pm 395.1* | 47.2 \pm 181.3* | 33.1 \pm 191.7*# | <0.001 |
| Leisure | 1194.8 \pm 1414.8 | 1037.5 \pm 1810.9* | 1043.4 \pm 2082.0 | 1187.8 \pm 2702.0* | =0.063 |
| Household | 4226.3 \pm 5034.7 | 2905.9 \pm 3067.1* | 2428.9 \pm 2391.3* | 5283.1 \pm 4083.4*# | <0.001 |
| Work | 4116.7 \pm 3416.4 | 2971.1 \pm 4225.2* | 1645.3 \pm 2566.3* | 686.1 \pm 2023.1*# | <0.001 |
| Weight category | | | | | |
| Overweight (n = 139) | 10 026.0 \pm 6610.6 | 6946.4 \pm 4822.5* | 5211.2 \pm 3765.7* | 7298.3 \pm 4969.6*# | <0.001 |
| All Obese (n = 166) | 9508.7 \pm 5608.6 | 7093.8 \pm 5503.2* | 5126.5 \pm 4512.8* | 7099.8 \pm 5515.6*# | <0.001 |
| Obese I (n = 92) | 10 219.1 \pm 6460.1 | 7489.3 \pm 6358.8* | 5697.6 \pm 4600.3* | 7316.8 \pm 5531.7*# | <0.001 |
| Obese II (n = 46) | 8773.9 \pm 4476.9 | 7430.2 \pm 4430.3* | 4883.0 \pm 4926.6* | 7285.2 \pm 6329.3*# | <0.001 |
| Obese III (n = 28) | 8381.4 \pm 3770.8 | 5241.8 \pm 3454.8* | 3649.6 \pm 3033.6* | 6246.1 \pm 3881.9*# | <0.001 |
| GWG category | | | | | |
| Below (n = 76) | 9849.5 \pm 7704.1 | 6939.4 \pm 4028.6* | 5205.6 \pm 4050.6* | 7314.5 \pm 5414.7*# | <0.001 |
| Within (n = 91) | 10 070.3 \pm 5909.6 | 7282.6 \pm 6333.3* | 5348.4 \pm 4092.9* | 7479.4 \pm 5726.9*# | <0.001 |
| Above (n = 138) | 9471.7 \pm 5144.6 | 6878.3 \pm 4058.0* | 5020.2 \pm 4451.9* | 6931.2 \pm 4879.7*# | <0.001 |

^ASignificantly different compared with the preceding time point $P < 0.05$.^BSignificantly different compared with Trial Entry.

and from 28 weeks to 36 weeks ($P < 0.001$), followed by an increase after birth ($P < 0.001$). There was an overall increase in household activities over the study duration ($P < 0.001$) and women were involved in significantly more household activity 4-months postpartum compared with trial entry ($P < 0.001$).

The most commonly identified structured activity was walking (either commuting (reported by 23% of all women) or leisure activity (76.4%)) with the most frequently reported leisure walking duration being 60 min per week (18%). There were 21.6% of women who reported being engaged in leisure activities other than those listed in the SQUASH questionnaire. The top three most frequently reported leisure activities other than walking (76.4%) and bicycling (4.6%) were gym aerobic classes (3.9%), netball (3.6%), and yoga (2.3%). While the time spent in leisure activities decreased from trial entry to 28 weeks ($P < 0.001$) and increased from 36 weeks to 4-months postpartum ($P = 0.022$), there was no significant change in leisure activities over the entire study duration ($P = 0.063$) and no difference in leisure activity at 4-months postpartum compared with trial entry ($P = 0.150$).

Physical activity across pregnancy and postpartum according to different BMI or GWG categories

With regards to comparing women of different BMI categories, there was no significant difference either cross-sectionally at each time point ($P = 0.070$) or for changes over pregnancy and postpartum ($P = 0.923$) for total levels of physical activity. With regards to different categories of physical activity in women of different BMI categories, there were also no significant difference at each time point ($P = 0.706$ for commuting, $P = 0.676$ for leisure, $P = 0.254$ for household, $P = 0.510$ for work related physical activity). Likewise, there were no significant differences for changes over pregnancy and postpartum for all four categories of physical activity ($P = 0.563$ for commuting,

$P = 0.491$ for leisure, $P = 0.882$ for household, $P = 0.577$ for work related physical activity). With regards to comparing women of different GWG categories, there was no significance difference either cross-sectionally at each time point ($P = 0.957$) or for changes over pregnancy and postpartum ($P = 0.845$) for total levels of physical activity. With regards to different categories of physical activity in women of different GWG categories, there was also no significant difference at each time point ($P = 0.644$ for commuting, $P = 0.393$ for leisure, $P = 0.534$ for household, $P = 0.475$ for work related physical activity). Similarly, there were no significant differences for changes over pregnancy and postpartum for all four categories of physical activity ($P = 0.736$ for commuting, $P = 0.760$ for leisure, $P = 0.854$ for household, $P = 0.618$ for work related physical activity). Fig. 1 demonstrates the MET-minutes per week distribution for different physical activity categories, at each time point and by maternal BMI and GWG category.

Determinants of the change of physical activity

A multiple linear regression model was constructed to assess independent predictors of the change in physical activity from trial entry to 4-months postpartum, including work status during pregnancy, age, BMI, ethnicity, smoking status, parity, trimester at study entry, breastfeeding status and SEIFA. The strongest determinant of the change of physical activity during pregnancy and postpartum was maternal BMI ($\beta = 0.114$, s.e. = 0.750, $P = 0.032$), with women of higher BMI having larger decline of physical activity. Work status during pregnancy, age, ethnicity, smoking status, parity, trimester at study entry, breastfeeding status and socioeconomic status as measured by SEIFA were not independent predictors of physical activity during pregnancy and postpartum. A one unit increase in BMI was associated with a 0.114 increase in the decline in physical activity between trial entry and 4-months postpartum.

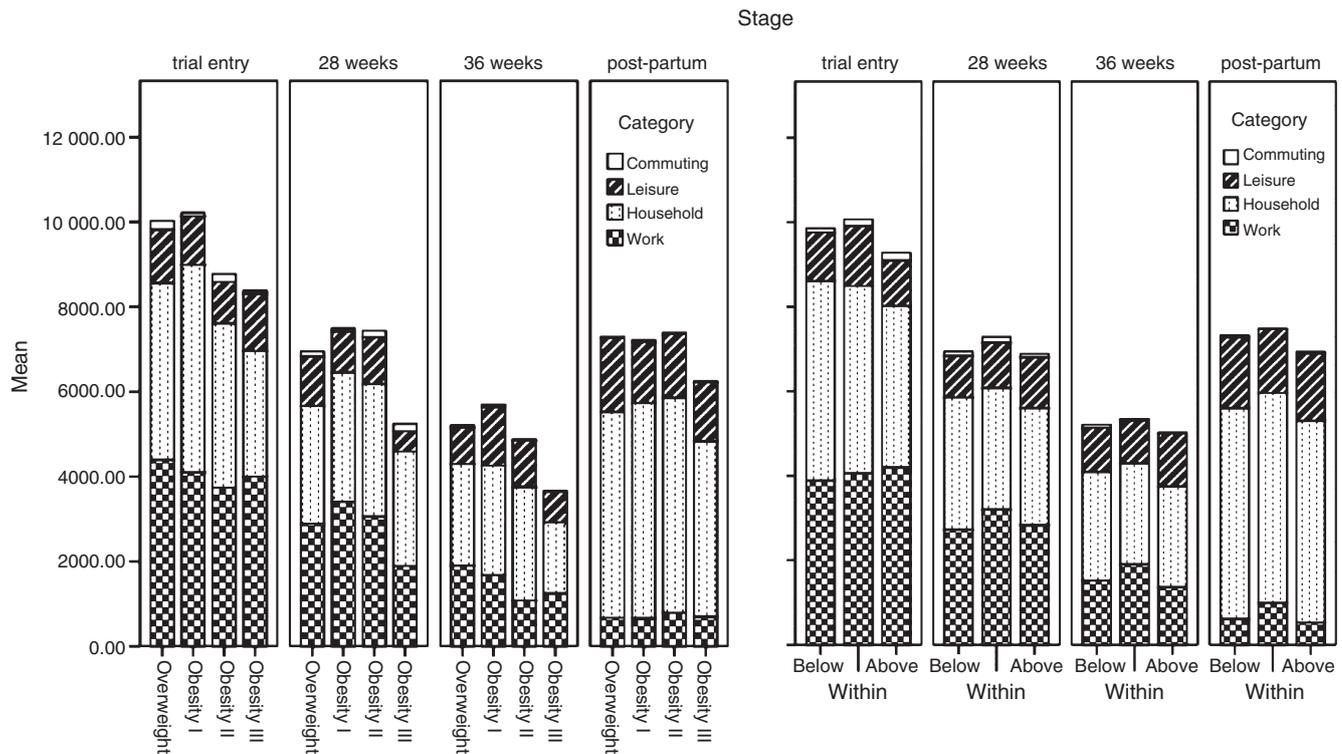


Fig. 1. Mean physical activity in metabolic equivalent task (MET) minutes per week throughout pregnancy and postpartum for women of different body mass index (BMI) and gestational weight gain categories. The bar graph demonstrates the MET-minutes per week distribution for different physical-activity categories, at each time point, and by maternal BMI (overweight, obese I, obese II and obese III) and gestational weight gain (below, within and above the recommendation) category.

Determinants of GWG

A multiple linear regression model was constructed to assess independent predictors of GWG including work status during pregnancy, different categories of physical activity, age, BMI, ethnicity, smoking status, parity, trimester at study entry, breastfeeding status and SEIFA. The strongest determinant of GWG was maternal BMI ($\beta = -0.253$, s.e. = 0.063, $P < 0.001$), with women of higher BMI having lower GWG. Work status during pregnancy, different categories of physical activity during pregnancy, age, ethnicity, smoking status, parity, trimester at study entry, breastfeeding status and SEIFA were not independent predictors of GWG.

Discussion

We report here for the first time an examination of physical activity during pregnancy and postpartum in overweight and obese women of different BMI and GWG categories. The aim of this study was to evaluate changes in physical activity among women who are overweight or obese during pregnancy and 4-months postpartum and to assess the effects of BMI and GWG on activity levels. Physical activity declined significantly between early pregnancy and 28-weeks gestation, with a further decline to 36-weeks gestation. At 4-months postpartum, physical activity significantly increased but

not to the level of that reported at early pregnancy. There was no significant difference between reported physical activity among women with different BMI or GWG categories either cross-sectionally at each time point or over time. Maternal BMI was a significant independent determinant of GWG and the change of physical activity during pregnancy and postpartum with women of higher BMI having less GWG and a larger decline in physical activity from early pregnancy to postpartum.

As previously reported for both overweight and obese women and women of all BMI categories,^{17,26} total physical activity decreased across pregnancy and increased in the postpartum period.²⁶ These changes were related to a gradual reduction in work activity throughout pregnancy and postpartum, consistent with a reduction in the number of women working across pregnancy and the early postpartum period. This may be partially explained by a reduction in commuting activities, which contributed a relatively small proportion of activity time later in pregnancy and postpartum. Despite the reductions in work and commuting activity across pregnancy and postpartum, we also observed that working status during pregnancy was not a significant determinant of the change of physical activity or GWG. This is consistent with the limiting existing literature reporting no relationship between employment and exercise.^{13,27} In contrast to the reduction in physical activity observed in this current study,

Renault and colleagues reported an increase in total physical activity between early and mid-gestation in 163 obese Danish women.¹⁶ Furthermore, McParlin and colleagues reported a constant reduction of physical activity during pregnancy in 55 overweight and obese women.¹⁷ This is consistent with our observation that physical activity declined from early pregnancy to 36-weeks gestation in both overweight and obese women. Although the methodology of these studies is strengthened by the use of objective measures of physical activity assessment (including accelerometers¹⁷ and pedometers²⁶), we note the small sample sizes for the studies specifically focussing on overweight and obese women ($n=55^{17}$) and the lack of an overweight subgroup for Renault *et al.*¹⁶ The findings of our study also indicate most physical activity during pregnancy consists of household- and work-related activities, with household activity increasing postpartum. This is consistent with previous research assessing physical activity during pregnancy in women of all BMI categories where household and caregiving activity constituted 24–40% of total energy expenditure as assessed by 24 h recall across each trimester.¹⁰ This highlights the importance of including these activities in an overall assessment of physical activity in women during pregnancy and postpartum.

Our findings also show that despite an increase in physical activity postpartum, at 4-months postpartum, total physical activity was significantly reduced compared with early pregnancy levels. This is consistent with previous research that physical activity remains at a low level at 3-months and 12-months postpartum in women of all weight ranges.²⁸ There is only one study examining postpartum physical activity specifically in overweight and obese women that reported a large amount of sedentary activity and a large proportion of women not meeting the physical activity guidelines.²⁹ The results suggest that poor engagement in physical activity postpartum may contribute to postpartum weight retention. This is consistent with the findings of Ostbye *et al.*, who reported that a high level of physical activity was a significant predictor of postpartum weight loss in overweight and obese women.³⁰ This is of particular relevance in overweight and obese women who are more likely to have larger weight gain or weight retention 1–2 year postpartum than women of a lower BMI.³¹ Previous studies have reported that although women thought it was appropriate to exercise at 3-months postpartum, the reasons for poor engagement with physical activity include a lack of time and issues with child caring.^{32,33} There are no data examining barriers to engaging in physical activity postpartum specifically in overweight and obese women and this warrants further research.

We found no significant difference in total physical activity or physical activity categories at each time point or over pregnancy and postpartum between overweight and obese women. There is limited research evaluating the determinants of physical activity during pregnancy and the effect of maternal BMI on physical activity are unclear, with some^{12,13} but not all^{11,14,27} studies reporting an association between increasing BMI and reduced physical exercise. The bulk of the literature focusses on women of all weight ranges,

with a lack of data investigating the relationship between BMI and total physical activity or physical activity patterns in overweight and obese women. Previous research also identified other determinants of physical activity during pregnancy in women of all weight ranges, including higher education and income, no other children at home, being white and high level of pre-pregnancy physical activity.¹⁵ Although we did not find any association between these factors and changes in physical activity, we note that there is no previous research specifically examining the determinants of physical activity in overweight and obese women. Although data about general population indicates that people of higher BMI are generally more likely to be sedentary,³⁴ our population may comprise a more sedentary population when the effect of BMI is greater than more subtle contributions from other determinants.

We found no significant difference in total physical activity or physical activity categories at each time point or over pregnancy and postpartum between women of different GWG categories. However, we found that BMI was inversely related with GWG in overweight and obese women, which is consistent with previous findings.^{18,19} We also report that there was no relationship between physical activity and GWG. Despite meta-analysis reporting that antenatal exercise interventions are effective in limiting GWG in the overweight and obese population,⁸ previous literature also suggests that only vigorous physical activity for leisure is associated with less GWG.¹⁹ This may explain our finding, as leisure activity was only a small component of the total amount of physical activity in our participants. A systematic review examining the effect of dietary and lifestyle interventions in pregnancy on maternal weight and obstetric outcomes also reports that although lifestyle interventions in pregnancy reduce GWG and improve health outcomes, dietary interventions are more effective for weight related and clinical outcomes than exercise interventions.³⁵ Thus, identification of other factors, including social demographic features, dietary intake and women's perceptions of diet and exercise during pregnancy, may aid in determining the contributing factors to GWG.

Physical activity declined significantly from early pregnancy to 28-weeks gestation, when it would be assumed that weight gain would not have been sufficient to impair the comfort level in exercise. This raises the issue as to additional interpersonal and psychological factors that may influence physical activity behaviour in early pregnancy. These may include pregnancy complications, fatigue and safety concerns relating to exercise during pregnancy,^{36,37} which have been previously reported to be determinants of low level of physical activity during pregnancy.

The strengths of our study include the relatively large sample size and prospective assessment of physical activity behaviour across pregnancy and the early postpartum period. Our results are limited by the recognised accuracy and reliability of self-reported questionnaires, which are only tools for ranking level of physical activity in a certain population.²² Although the use of objective

measures such as pedometers and accelerometers provide a more reliable estimate of physical activity, it was not practical to utilise these tools in this study due to the large sample size of the broader LIMIT study. Furthermore, even pedometers cannot provide precise estimates of physical activity.³⁸ The SQUASH questionnaire was utilised in this study as it has been validated in a variety of different populations including overweight and obese individuals,³⁹ is able to rank individuals on level of physical activity^{22,23} and has been previously utilised to detect associations between different types of chronic conditions and physical activity patterns.⁴⁰ This supports its utility in our current research context, which assesses behavioural patterns in physical activity rather than precise amounts of energy expenditure. We also note here the lack of data on postpartum weight and hence cannot provide analysis for weight retention. Another limitation of our study is the small sample size of women with certain demographic determinants (e.g. smoking status at trial entry and ethnicity), which may limit our ability to assess the effect of the determinants on physical activity and GWG.

Exercise in pregnancy is beneficial for reducing adverse maternal and fetal outcomes such as pre-eclampsia and preterm birth. Furthermore, exercise in overweight and obese women during pregnancy may be an efficient tool to limit GWG, and improve maternal- and infant-health outcomes. Future work promoting healthy lifestyles for overweight and obese women during pregnancy should focus on identifying effective approaches to facilitate an increase or maintenance of leisure activity during pregnancy. There is currently limited literature examining the complexity of psychosocial factors influencing physical activity during pregnancy. Given the decrease in activity during pregnancy reported in this and other studies, it is crucial to explore the effect of body-image perception and social support on physical activity behaviour and identify the barriers and enablers for engaging in exercise during pregnancy and the postpartum period. Furthermore, an understanding of physical activity patterns across pregnancy and postpartum could help identify which time point to target future interventions to increase physical activity. This has the potential to minimise excess GWG and postpartum weight retention, and hence reduce the risk of future obesity and obesity-related chronic conditions. Health-promotion strategies are warranted focussing on optimising physical activity from early pregnancy and in the postpartum period. Further research should explore barriers and enablers of being active during pregnancy and postpartum.

Conflicts of interest

The authors have no conflict of interests to declare.

Clinical trial registration

Australian and New Zealand Clinical Trials Registry
ACTRN12607000161426.

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