Lifestyle interventions for obese women before and during pregnancy: The effect on pregnancy outcomes
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The relationship of objectively measured physical activity and sedentary behaviour with gestational weight gain and birth weight.
The relationship of objectively measured physical activity and sedentary behaviour with gestational weight gain and birth weight

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Submitted
Abstract

Objective
To evaluate the relationship of objectively measured physical activity (PA) and sedentary behaviour with gestational weight gain (GWG) and birth weight.

Design
Combined analysis, data from two prospective studies: Cohort 1) Nulliparous pregnant women without body mass index (BMI) restrictions included between 2005 and 2006 and Cohort 2) Overweight and obese pregnant women at risk for gestational diabetes included between 2007 and 2011.

Methods
Daily PA and sedentary behaviour were measured objectively with an accelerometer around 15 weeks gestation and in the third trimester (32-35 wks). Linear regression analyses were performed to determine the association between the time spent in total PA, at least moderate PA and time spent sedentary with gestational weight gain and birth weight, adjusted for age, parity, BMI and gestational age. Main outcome measures were objectively measured gestational weight gain between 15 and 32 weeks of gestation and birth weight.

Results
We studied 113 women. Early in pregnancy, 32% of women spent ≥30 minutes/day in at least moderate PA versus 12% in late pregnancy. We did not find significant associations between time spent in total or moderate PA or sedentary behaviour with gestational weight gain or birth weight.

Conclusion
We found no relation between PA and sedentary behaviour with gestational weight gain or birth weight. The small percentage of women meeting the recommended levels of PA indicates the need to inform and support pregnant women to maintain regular PA, as there seems to be no adverse effect on birth weight and maintaining physical activity increases overall health.
Introduction

Excessive weight gain during pregnancy is associated with an increased risk of obstetrical, maternal and foetal complications, and postpartum weight retention. It increases the risk of obesity in children. This contributes to the prevalence of women who are overweight or obese and increases the long-term risk of body weight-associated diseases, which impose a great pressure on health care.

The American Institute of Medicine (IOM) updated their evidence-based guidelines for weight development during pregnancy in 2009. However, 53% of all women, gain more weight than advised by the IOM, with 68.9% and 59.8% of overweight and obese women respectively. Many trials have been conducted evaluating the effect of different lifestyle interventions on GWG and adverse pregnancy outcomes, which were recently reviewed and combined in a meta-analysis. Combining results of 15 interventions consisting of PA alone did not result in a statistically significant effect on GWG, and showed a very small but statistically significant reduction in mean birth weight.

However, it must be noted that the compliance with the interventions was either not assessed or insufficient in some trials. Furthermore, the total amount of PA of participants was often not measured. Therefore, a possible compensation of PA levels outside of the intervention sessions could not be taken into account. In most studies that did measure total PA, this was done with questionnaires, which might often not give a valid estimate of PA levels. All in all, although the design of intervention studies in general allows conclusions with regards to causality, the mentioned methodological shortcomings hamper causal inference of PA leading to lower GWG and birth weight.

The relationship between sedentary behaviour and weight (gain) has been found in women and adolescent girls outside of pregnancy. In pregnancy, US women spent more than half of the monitored day in sedentary behaviour. However, whether the amount of time spent sedentary influences weight gain or birth weight is currently unknown.

The primary aim of this study was therefore to examine the relationship of objectively measured physical activity and sedentary behaviour at two time points in pregnancy with gestational weight gain and birth weight in a population with a wide range of BMI.

Methods

We performed a secondary analysis of data of the randomised controlled trials performed by Althuizen et al. (ISRCTN85313483) and Oostdam et al. (NTR1139). The interventions evaluated in the two trials were not effective in reducing gestational weight gain in the total study population. Data from both trials were combined and analysed as a cohort, as the study design and procedures were similar for both trials. All participants were healthy pregnant women, only the BMIs were different (no BMI restrictions (Althuizen) and overweight or obese (Oostdam)). In
both trials, the participants were followed from 15 weeks of gestation until
delivery, with objective measurements of physical activity and sedentary
behaviour and body weight at baseline (around 15 weeks of gestation) and
at 32-35 weeks of gestation. Birth weight was reported in questionnaires.
The Medical Ethics committee of the VU University Medical Center had
approved design, protocols and informed consent procedures of both
studies.

The first cohort consisted of nulliparous pregnant women without BMI
restrictions. A complete description of the inclusion and exclusion criteria
have been published in Althuizen et al.\textsuperscript{21} The second cohort consisted
of pregnant women with a BMI of \textgreater 25 kg/m\textsuperscript{2} and at increased risk for
gestational diabetes mellitus (GDM). Women were considered to be at an
increased risk for GDM if they were obese (BMI \textgreater 30 kg/m\textsuperscript{2}) or overweight
(BMI \textgreater 25 kg/m\textsuperscript{2}) and had at least one of the three following characteristics:
(1) history of macrosomia (offspring with a birth weight above the 97\textsuperscript{th}
percentile of gestational age); (2) history of GDM; or (3) first-grade
relative with DM2. Exclusion criteria included: recruitment after 20 weeks
of gestation; age under 18 years; inadequate knowledge of the Dutch
language; having been diagnosed with (gestational) diabetes mellitus
before randomisation; severe chronic disease. A complete description of
the inclusion and exclusion criteria have been published in Oostdam et
al.\textsuperscript{22} For this paper, we excluded women with a twin pregnancy from the
analyses.

The relationship of objectively measured PA and sedentary behaviour
with gestational weight gain and birth weight was evaluated. The first
measurements were at baseline (around 15 weeks of gestation), and the
last measurements at 35 weeks of gestation in cohort 1 and at 32 weeks
of gestation in cohort 2.

Maternal body weight was measured using calibrated electronic
scales, with participants wearing only indoor clothing and no shoes. Pre-
pregnancy weight was self-reported. On the first measurement, maternal
body height was measured with bare feet and a (wall mounted) height
scale. The measured height and weight were used to calculate BMI (kg/
m\textsuperscript{2}). For the purpose of this paper, GWG was defined as the weight gained
between the first and the last measurement (kg). The neonatal outcome
was birth weight, reported by the women in a questionnaire six weeks
postpartum.

Daily PA was measured objectively using an accelerometer (ActiTrainee
accelerometer; ActiGraph\textsuperscript{TM}, Pensacola, FL, USA). This accelerometer is a
compact, lightweight, uniaxial device that measures and records time-
varying acceleration. Days with at least 8 hours registration time were
used. Total counts per minute were converted into light, moderate and
vigorous PA (100 to 2019 counts/min for light PA, 2020 to 5998 counts/
min for moderate PA and \textgreater 5999 counts/min for vigorous PA).\textsuperscript{25} Sedentary
behaviour was defined as \textless 100 counts/min. The time participants spent
sedentary, in light-to-vigorous (total PA), and moderate-to-vigorous PA
(MVPA) was calculated as a percentage of total registration time.
Ethnicity was derived from the country of birth of the participant’s parents. An individual was considered to be white European if both parents were born in Europe (with the exception of Turkey and Morocco; two groups with a higher risk for GDM) or North America. Furthermore, level of education was assessed as the highest level an individual reported to have achieved, which was then divided into lower, middle, or higher educational levels. Moreover, participants were asked to report on their status of employment (yes or no). Gestational age at delivery was self-reported.

The maternal characteristics of the study are presented as means and standard deviations for continuous variables, and as percentages for ordinal variables. For the outcomes gestational weight gain and birth weight, standard linear regression analysis was used to test the association between the percentage of time spent sedentary or in physical activity at baseline and at 32-35 weeks of gestation and the outcome. Regression models were controlled for the difference in gestational age between the two measurements (weight gain) or gestational age at birth (birth weight), BMI at first measurement during pregnancy, parity and age.

The analyses were checked for effect modification by age and BMI. It was concluded that effect modification was present in case the p-value of the interaction term was significant (p < 0.10). All analyses were performed using SPSS 20.0 (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA) for windows, and the level of significance was set to <0.05.

**Results**

A total of 390 women were included in the two trials; 269 in cohort 1 and 121 women in cohort 2. Of these women, 139 completed both baseline and late pregnancy data collection. Due to lack of compliance of the participants, data on objectively measured PA and sedentary behaviour were available for 111 (80%) women with a singleton pregnancy. They comprised the study sample for the analyses. The baseline characteristics of the study population and the outcome measures are presented in Table 1. The mean GWG was 10.3 (SD 4.3) kg and mean birth weight was 3545 (SD 441) g.

Total daily PA measured with accelerometers at baseline showed an average of 286 (SD 103) minutes per day (range 45 to 512 minutes per day). At 32-35 weeks of gestation the mean total PA was 273 (SD 103) minutes/day. At both times this accounted for 35% of registration time. Overall, the minutes spent per day performing moderate and vigorous PA (MVPA) reduced during the pregnancy. At baseline, the mean number of minutes of moderate and vigorous PA spent per week was 24 (SD 16) minutes/day. At 32-35 weeks of gestation the mean number of minutes of moderate and vigorous PA performed per week had decreased to 18 (SD 22) minutes/day. This was a drop from 3% to 2% of the total registration time. At baseline, 31% of the women spent ≥30 minutes/day in MVPA, and
therefore met the guidelines of the ACOG for sufficient PA.26 At 32 weeks, this proportion dropped to 12% of the women.

Sedentary behaviour remained relatively stable during pregnancy, with women spending more than 500 minutes/day (65% of the registration time) sedentary at both time points.

### Table 1. Characteristics of the study sample

<table>
<thead>
<tr>
<th></th>
<th>Total population (n=111)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years, mean (SD)</strong></td>
<td>29.6 (3.8)</td>
</tr>
<tr>
<td><strong>Ethnicity, N (%)</strong></td>
<td></td>
</tr>
<tr>
<td>White European</td>
<td>95 (86%)</td>
</tr>
<tr>
<td>Non-white</td>
<td>16 (14%)</td>
</tr>
<tr>
<td><strong>Nulliparous, N (%)</strong></td>
<td>81 (73%)</td>
</tr>
<tr>
<td><strong>BMI at 15 weeks (kg/m^2), mean (SD)</strong></td>
<td>27.0 (5.5)</td>
</tr>
<tr>
<td><strong>BMI category at 15 weeks, N (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>54 (49%)</td>
</tr>
<tr>
<td>Overweight</td>
<td>25 (22%)</td>
</tr>
<tr>
<td>Obese</td>
<td>32 (29%)</td>
</tr>
<tr>
<td><strong>Gestational age at birth, weeks, mean (SD)</strong></td>
<td>40.2 (1.2)</td>
</tr>
<tr>
<td><strong>Gestational weight gain, kg, mean (SD)</strong></td>
<td>10.3 (4.2)</td>
</tr>
<tr>
<td><strong>Birth weight, g, mean (SD)</strong></td>
<td>3541 (429)</td>
</tr>
<tr>
<td><strong>Total PA at 15 weeks, mins/day, mean (SD)</strong></td>
<td>286 (103)</td>
</tr>
<tr>
<td>% of registration time</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Total PA at 32 weeks, mins/day, mean (SD)</strong></td>
<td>273 (103)</td>
</tr>
<tr>
<td>% of registration time</td>
<td>35%</td>
</tr>
<tr>
<td><strong>MVPA at 15 weeks, mins/day, mean (SD)</strong></td>
<td>24 (16)</td>
</tr>
<tr>
<td>% of registration time</td>
<td>3%</td>
</tr>
<tr>
<td><strong>MVPA at 32 weeks, mins/day, mean (SD)</strong></td>
<td>18 (22)</td>
</tr>
<tr>
<td>% of registration time</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Sedentary behaviour at 15 weeks, mins/day, mean (SD)</strong></td>
<td>530 (170)</td>
</tr>
<tr>
<td>% of registration time</td>
<td>65%</td>
</tr>
<tr>
<td><strong>Sedentary behaviour at 32 weeks, mins/day, mean (SD)</strong></td>
<td>505 (173)</td>
</tr>
<tr>
<td>% of registration time</td>
<td>65%</td>
</tr>
</tbody>
</table>

Abbreviation: MVPA= moderate to vigorous physical activity; PA= physical activity; SD= standard deviation.
Table 2. Association between PA, sedentary behaviour and gestational weight gain and birth weight

<table>
<thead>
<tr>
<th>Model 1*</th>
<th>Gestational weight gain (kg)</th>
<th>Birth weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Total PA at 15 weeks</td>
<td>0.03</td>
<td>-0.7</td>
</tr>
<tr>
<td>% MVPA at 15 weeks</td>
<td>0.05</td>
<td>22.5</td>
</tr>
<tr>
<td>% Sedentary behaviour at 15 weeks</td>
<td>-0.03</td>
<td>0.7</td>
</tr>
<tr>
<td>% Total PA at 32 weeks</td>
<td>0.01</td>
<td>-3.8</td>
</tr>
<tr>
<td>% MVPA at 32 weeks</td>
<td>-0.32</td>
<td>-17.8</td>
</tr>
<tr>
<td>% Sedentary behaviour at 32 weeks</td>
<td>-0.01</td>
<td>3.8</td>
</tr>
</tbody>
</table>

| Model 2*                                      |                             |                  |
| % MVPA at 15 weeks                            | -0.02                        | 27.7             |
| % Sedentary behaviour at 15 weeks             | -0.04                        | 2.6              |
| % MVPA at 32 weeks                            | -0.41                        | -11.5            |
| % Sedentary behaviour at 32 weeks             | -0.04                        | 2.8              |

Abbreviation: CI= Confidence interval; MVPA= moderate to vigorous physical activity; PA= physical activity.

* model 1: total PA (light to vigorous), moderate to vigorous PA (MVPA) and sedentary behaviour were not entered into the same models. All models were controlled for age, parity, BMI and (change in) gestational age. Models for PA and sedentary behaviour at 32 weeks of gestation were also controlled for baseline values.

** moderate to vigorous PA (MVPA) and sedentary behaviour were entered into the same model, controlled for age, parity, BMI and (change in) gestational age. The model with MVPA and sedentary behaviour at 32 weeks of gestation was also controlled for baseline values.

No statistically significant association was found between total PA, MVPA, or sedentary behaviour at 15 weeks with GWG (Table 2). Also no significant associations were found between PA and sedentary behaviour at 32 weeks of gestation, controlled for baseline values. With birth weight as outcome, also no significant associations were found between the time in total PA, MVPA, or sedentary behaviour at either time point (Table 2). Gestational age was not related to any PA or sedentary behaviour parameter (data not shown). No effect modifications of age or BMI were found.

**Discussion**

In this study, the association between objectively measured moderate to vigorous PA and/or sedentary behaviour with GWG and birth weight was examined. We found that neither PA nor sedentary behaviour had an association with GWG or birth weight.

This is in line with the findings of a meta-analysis of 15 trials, showing no significant reduction in GWG in trials evaluating PA interventions.\textsuperscript{15,16} In this
same meta-analysis, the pooled result of 14 PA trials showed a small (-90 g) but significant reduction in birth weight.\textsuperscript{15,16} Our sample size was very likely insufficient to detect such a small reduction in birth weight. It was certainly insufficient to study the effect of PA on the number of babies born small or large for gestational age.

The relationship between objectively measured sedentary behaviour and GWG or birth weight has not been studied so far, to our knowledge. Although outside pregnancy, sedentary behaviour is related to weight status in girls and women,\textsuperscript{18,19} we could not establish an association with GWG or birth weight. This would indicate that trying to reduce sedentary behaviour in pregnant women would not likely lead to reduced GWG or changes in birth weight.

The data used for this study were collected in two separate trials,\textsuperscript{21,22} and the results presented here are from secondary analysis of the data. However, since the interventions neither had an effect on GWG nor on birth weight, the design and procedures were similar for both trials, and all participants were healthy pregnant women,\textsuperscript{21,23} we felt justified in analysing the data as a cohort. By combining the two datasets, there was a wider variation in PA levels in the data, which is needed for assessing an association with outcomes. However, the participants did not include women who participated in regular vigorous exercise. Our results can thus not be extrapolated to women who continue to participate in competitive exercise or elite sports during pregnancy.

The data on birth weight were self-reported by the mothers about six weeks after birth. This might have led to some inaccuracy in our outcome measure. Other studies showed, however, that self-reports of birth weight are accurate,\textsuperscript{27,28} with small, clinically non-relevant differences between birth weight in medical records and self-reports.\textsuperscript{28}

The data on physical activity and sedentary behaviour were objectively measured, reducing the reporting bias and increasing the accuracy of the results. The accelerometer, used for monitoring the amount of PA and sedentary behaviour, is an uniaxial device that measures and records vertical acceleration. In the Netherlands, many women cycle, and continue to do so during pregnancy. The accelerometer does not record such activity well due to its uniaxial nature. Therefore the amount of PA measured might be underestimated. Furthermore, it has been shown that accelerometers might be less valid in pregnancy, mostly because of slower walking speeds of the women.\textsuperscript{29} However, objective measurement of PA is to be preferred over using self-reported PA since most questionnaires show poor validity in pregnancy.\textsuperscript{30} In this study, nutritional intake was not taken into account, which might have confounded the results presented in this paper. And although we did not find an interaction with BMI, it might be useful to study the relationship between PA and sedentary behaviour in different BMI categories separately.
Conclusion

This study showed that PA is not associated with GWG or birth weight, and also sedentary behaviour did not seem to contribute to GWG or birth weight of the infant. The findings regarding sedentary behaviour are new, and need to be confirmed with studies using a design better suitable for studying causal relationships, such as randomised trials. The findings with regards to PA are not in line with the results of recent meta-analyses, and also here more research is needed assessing the relationship of objectively measured PA with GWG and birth weight. Another important finding is that only a small proportion of our pregnant women met the ACOG guidelines for sufficient MVPA\textsuperscript{26} in early pregnancy (31%) and even fewer at the end of pregnancy (13%). This is much lower than the 58% of women 20-40 years of age meeting similar guidelines in the general Dutch population in 2010 according to the Dutch Bureau of Statistics (www.statline.cbs.nl). This indicates that pregnant women need to be better informed and advised about maintaining PA levels throughout pregnancy.

In summary, we have conducted analyses estimating the relationship between PA and sedentary behaviour and GWG and birth weight. Key finding of this study was that neither behaviour, physical or sedentary, at any time during pregnancy was associated with gestational weight gain or birth weight of the new-born.
References

19. Costigan SA, Barnett L, Plotnikoff RC et al. The Health Indicators Associated With Screen-Based Sedentary Behavior Among Adolescent Girls: A Systematic


23. Oostdam N, van Poppel MN, Wouters MG et al. No effect of the FitFor2 exercise programme on blood glucose, insulin sensitivity, and birthweight in pregnant women who were overweight and at risk for gestational diabetes: results of a randomised controlled trial. BJOG 2012; 119(9):1098-1107.


