



Does exercise training during pregnancy affect gestational age? A randomised controlled trial

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ABSTRACT

Background: Some controversy exists over the possibility that exercise during pregnancy might increase the risk of preterm delivery.

Objective: This study aimed to determine the possible *cause-effect* relationship between regular exercise performed during the second and third trimesters of pregnancy by previously sedentary, healthy gravidae and gestational age at the moment of delivery.

Methods: Caucasian (Spanish) women with singleton gestation were assigned to either a training ($n = 72$) or a control ($n = 70$) group. The supervised training programme focused mainly on *very* light resistance and toning exercises and included ~ 80 sessions (three times/week, 35 min/session from weeks 12–13 to weeks 38–39 of pregnancy).

Results: No significant differences were found ($p > 0.05$) between the groups in those maternal characteristics (age, smoking habits, number of hours standing or prior parity history) that could potentially influence gestational age. The mean gestational age did not differ ($p = 0.745$) between the training (39 weeks, 3 days (SD 1 day)) and the control group (39 weeks, 4 days (SD 1 day)).

Conclusions: Previously sedentary, healthy gravidae with singleton gestation can safely engage in moderate, supervised exercise programmes until the end of gestation as this would not affect gestational age.

Historically, and largely based on socio-cultural reasons more than on scientific evidence, pregnant women have been encouraged to reduce physical activity (PA) and stop working during pregnancy because of perceived increased risk of problems, e.g., such as early pregnancy loss or reduced placental circulation.¹ In 1985 the American College of Obstetricians and Gynecologists (ACOG) provided conservative recommendations for exercise during pregnancy; women were told to avoid intense activities (such as jogging or cycling) for more than 15 minutes per session, and limit their heart rate to ≤ 140 beats/min.² In recent years, however, an increasing number of women are engaging in regular exercise during pregnancy.³ This tendency is overall supported by the results of several publications over the last decade, reporting few negative effects of PA on the pregnancy of a healthy gravida.^{4–7} More recent ACOG guidelines are in fact more proactive regarding exercise recommendations during pregnancy.⁸

Obstetricians, family practitioners and nurse midwives are, however, not always prepared to provide constructive guidance for their physically active patients. One question frequently addressed and still to be clearly answered relates to the possibility that high PA levels, especially during the

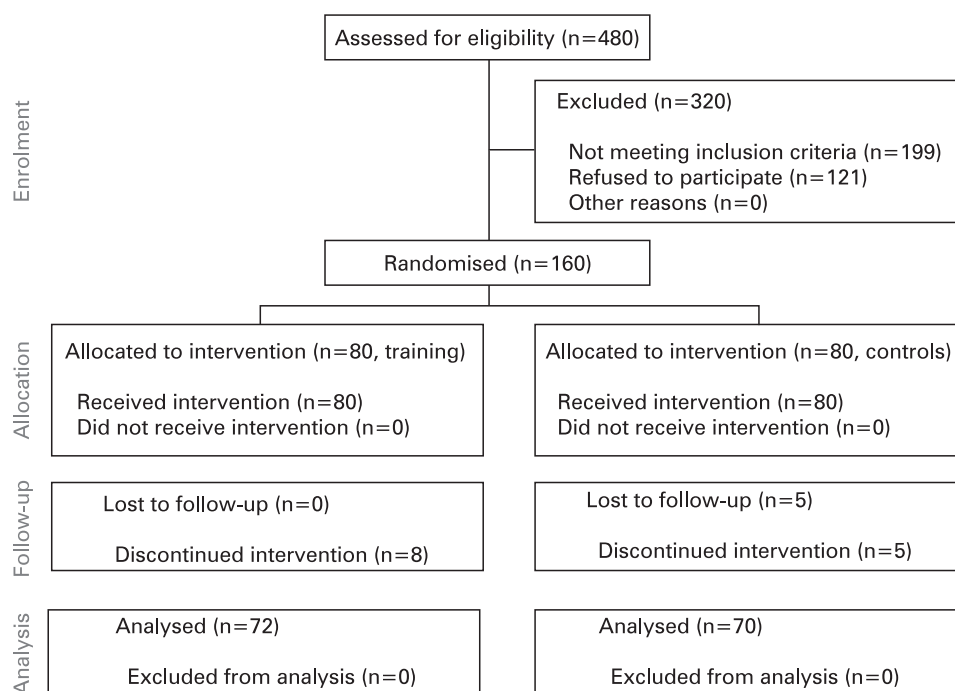
second part of pregnancy, might increase the risk for preterm delivery. A potential source of controversy on this issue arises from the fact that more “active” or energy-consuming occupational professional activities that require prolonged standing (> 3 h/day) and/or carrying loads > 10 kg, such as in industrial work or as cleaning staff and shopkeepers, might increase the risk of preterm births and low birth weight in comparison with a more sedentary type of activity, for example in executive staff, teachers or office staff.⁹ Indeed, while the results of most studies show PA during pregnancy to be beneficial overall to the maternal–fetal unit and to prevent the occurrence of maternal disorders such as hypertension,¹⁰ there is no definitive, complete answer regarding the effect of exercise during the total duration of pregnancy on the pregnancy outcome. Relevant data from non-controlled¹¹ and controlled pilot training studies¹² (sample size ≤ 15 women) and prospective reports on large population samples suggest no *association* between PA during pregnancy and pregnancy outcome (gestational age, risk of preterm delivery, intrauterine growth) in previously physically active (and thus fit) and usually middle–high-socioeconomic class women.^{4 13–19} If anything, vigorous exercise (eg ~ 2000 kcal/week) could be associated with decreased risk of preterm delivery.^{17 19} Controlled, randomised trials in large population samples are, however, lacking to objectively and specifically assess the possible *cause-effect* relationship between exercise interventions during the second half of pregnancy and pregnancy outcome. Accordingly, it was the purpose of our study to investigate the effects of a supervised maternal exercise training programme (performed during the second and third trimesters of pregnancy) on gestational age in a group of previously sedentary healthy women. A matched control group was assessed over the same time period. Given the fact that most studies in the field have used aerobic exercises, here we largely focused on very light resistance, toning exercises. To discard the possibility that exercise training during the last two trimesters of pregnancy might have a deleterious effect on the health status of the newborn, the latter variable was assessed in the two study groups using the classic Apgar test.

METHODS

Participants

Written informed consent was obtained from each subject prior to the start of the study, which was approved by the local institutional ethics committee (Hospital Severo Ochoa, Madrid, Spain) and

Figure 1 Flow diagram of the study participants' following the CONSORT guidelines (<http://www.consort-statement.org>).



was in accordance with the standards set by the Declaration of Helsinki (last modified in 2004).

A total of 480 pregnant women of the same ethnic origin (ie, Spanish (Caucasian) descent for three or more generations) and socioeconomic class (medium-to-low) were originally screened from the medical database of a primary care medical centre (Centro de Salud María Montessori, Leganés) in the southern metropolitan area of Madrid (Spain). Participants were originally deemed eligible for this investigation if they met all the following criteria in the first trimester of pregnancy: i) gravida with singleton and uncomplicated gestation; ii) not at high risk for preterm delivery (no history of recurrent spontaneous preterm birth, i.e., number of previous preterm deliveries ≤ 1); iii) 25–35 years of age; iv) being sedentary before gestation (exercising <20 min on <3 days/week); v) being under medical follow-up throughout the entire pregnancy period (and planning to give birth) in the same obstetrics hospital department (Hospital Severo Ochoa, Madrid, Spain); and vi) having no absolute or relative contraindication to exercise participation during pregnancy (such as, among others, haemodynamically significant heart disease, restrictive lung disease, pregnancy-induced hypertension, severe anaemia, maternal cardiac arrhythmia, chronic bronchitis, type I diabetes or extreme morbid obesity (body mass index >40 kg/m²)).⁸

Out of the total of 480 women originally contacted, 160 women who met all the abovementioned eligibility criteria at the start of the study (that is, at the start of their pregnancy) agreed to participate in this investigation. They were randomly assigned to either a training (n = 80) or a control group (n = 80). Eight subjects from the training group were finally excluded from the study because they did not complete the training programme due to i) exercise contraindications that appeared over the course of pregnancy (diagnosed multiple gestation at risk for premature labour, n = 1; pregnancy-induced hypertension, n = 1; persistent bleeding, n = 1); or ii) personal, not medically related reasons (n = 5). Ten subjects from the control group were finally excluded from the study because i) they finally decided to give birth in a different hospital (n = 5); or ii)

of health-threatening events occurring during pregnancy that could affect the main study outcome (pregnancy-induced hypertension, n = 2; molar pregnancy, n = 1; and threat of premature delivery, n = 2). Thus, the final number of subjects who were included as study subjects was n = 72 in the training group and n = 70 in the control group.

A flow diagram of the study participants' following the CONSORT guidelines to improve the reporting of a randomised controlled trial (RCT) (<http://www.consort-statement.org>) is shown in fig 1.

Study design and measurements

We used a randomised, controlled single-blind design. The treatment allocation system was set up so that the researcher who was in charge of randomly assigning participants to each group did not know in advance which treatment the next person would receive, a process termed "allocation concealment".^{20–21} Allocation concealment prevents researchers from (unconsciously or otherwise) influencing which participants are assigned to a given intervention group. Research assistants with no knowledge of group assignment were designated to determine the following variables in all the participants from the prenatal interview (in the aforementioned primary care centre) or from the clinical history (in the aforementioned hospital obstetrics department): maternal age and body mass index (BMI) at the start of the study; prior parity and eventual preterm deliveries (before 37 completed weeks of gestation); smoking habits; occupational activities and other daily activities (that is, number of hours standing), using the Minnesota Leisure-Time PA questionnaire.²² The gestational age at the time of delivery (in weeks, days) was recorded from hospital perinatal records. The results of the classic Apgar (acronym for Appearance (skin colour), Pulse (heart rate), Grimace (reflex irritability), Activity (muscle tone), and Respiration) test²³ were obtained from the reports of delivery room personnel (nurses) at 1 and 5 minutes after the complete birth of the baby.²⁴ This test is based on the aforementioned five signs (heart rate, respiratory

Table 1 Maternal characteristics: comparison between training and control groups

| | Training group (n = 72) | Control group (n = 70) | p Value |
|---|---------------------------|---------------------------|--|
| Maternal age (yrs) at the start of the study (mean (SEM) (95%CI)) | 30.4 (0.3) (29 to 31) | 29.5 (0.4) (28 to 30) | 0.108 |
| BMI (m/kg ²) at the start of the study (mean (SEM) (95%CI)) | 24.3 (0.5) (23.3 to 25.3) | 23.4 (0.4) (22.5 to 24.2) | 0.138 |
| <i>Parity: percentage of women with:</i> | | | |
| no previous gestation | 72.2% | 57.1% | p = 0.163** ($\chi^2_{(2)} = 3.624$) |
| one previous gestation | 22.2% | 35.7% | |
| two previous gestations | 5.6% | 7.1% | |
| Prior preterm delivery (n = 1)* | 2.8% | 4.3% | p = 0.316 (Z = -0.48) |
| Smoking habits (% of smokers) | 22.9% | 28.6% | p = 0.218 (Z = -0.78) |
| <i>Occupational activity (%)</i> | | | |
| Sedentary job | 36.1% | 30.0% | p = 0.609** ($\chi^2_{(2)} = 0.991$) |
| Housewives | 43.1% | 42.9% | |
| Active job | 20.8% | 27.1% | |
| Percentage of women spending >3 h/day standing | 52.8% | 65.7% | p = 0.0571 (Z = -1.58) |

*There were no women with more than one previous preterm delivery; **analysis of corrected typified residuals was not performed for the χ^2 test since p value was >0.05. 95%CI, 95% confidence intervals; BMI, body mass index.

effort, reflex irritability, muscle tone and colour) that are easy to evaluate. A score of one or two is given to each sign, depending on whether it is absent or present. Thus, the total score can range from 0 to 10. The prognosis of an infant is excellent if he or she receives one of the upper three scores (≥ 8), and poor if one of the lowest three.^{23 24}

Women in the intervention group performed a supervised exercise training programme during the second and third trimesters of pregnancy (see below), whereas the control subjects did not perform any type of programmed PA, except those activities necessary for daily living.

Training programme

The programme included a total of three (Monday, Wednesday, Friday) 35 minute weekly sessions from the start of the second trimester (weeks 12–13) to the end of the third trimester (weeks 38–39). Thus, an average of ~80 training sessions was originally planned for each participant in the event of no preterm delivery. All subjects wore a heart rate (HR) monitor (Accurex Plus, Polar Electro OY, Finland) during the training sessions to ensure that exercise intensity was light-to-moderate, that is, HR consistently $\leq 80\%$ of age-predicted maximum HR value (220 minus age). Each session included a 20 min core portion which was preceded and followed by a gradual warm-up and cool-down period, respectively (both of 7–8 min duration and consisting of walking and light, static stretching (avoiding muscle pain) of most muscle groups (upper and lower limbs, neck and trunk muscles). (The cool-down period also included relaxation exercises.) The core portion included the following *toning* and very light resistance exercises. Toning and joint mobilisation exercises included shoulder shrugs and rotations, arm elevations, leg lateral elevations, pelvic tilts and rocks. Resistance exercises were performed through the full range of motion normally associated with correct technique for each exercise and

engaged the major muscle groups (pectoral, dorsal, shoulder, upper and lower limb muscles). They included one set of ≤ 10 –12 repetitions of each of i) abdominal curls and ii) the following exercises using barbells (≤ 3 kg/exercise) or low-to-medium resistance bands (Therabands): biceps curls, arm extensions, arm side lifts, shoulder elevations, bench press, seated lateral row, lateral leg elevations, leg circles, knee extensions, knee (hamstring) curls, ankle flexion and extensions. We specifically avoided those exercises involving extreme stretching and joint overextension, ballistic movements, jumps and those types of exercises performed on the back.^{3 25} In order to maximise adherence to the training programme and its efficacy, all sessions were: i) supervised by a qualified fitness specialist (working with groups of 10–12 subjects); ii) accompanied by music; and iii) performed in a spacious, well-lighted room under favourable environmental conditions (altitude~600 m; temperature = 19–21°C; humidity = 50–60%).

Data analysis

We used a Student t test for unpaired data to compare between the two groups the mean value of the main outcome variable of the study, gestational age at the time of delivery. In order to assess the potential confounding effects of several maternal variables (maternal age and BMI, prior parity history and eventual preterm deliveries, smoking habits, main occupational activity and number of daily hours standing), we compared the two groups using either: i) a Student t test for unpaired data (maternal age and BMI), ii) a χ^2 test where appropriate, such as to compare between the two groups the percentage of women with no, one, two or more (if applicable) previous gestations and the percentage of participants who had an active job, a sedentary job or who worked as housewives; and iii) a Z-test for comparing two proportions where appropriate, such as to compare between the two groups the percentage of women who have had previous preterm delivery, the percentage of

Table 2 Gestational age and Apgar scores: comparison between training and control groups

| | Training group (n = 72) | Control group (n = 70) | p Value |
|--|--|---|-----------------------|
| Gestational age at the moment of delivery (weeks, days) (mean (SEM) (95%CI)) | 39 weeks 4 days (1 week 1 day) (39 weeks 1 day to 39 weeks 5 days) | 39 weeks 5 days (1 week 3 days) (39 weeks 1 day to 39 weeks 6 days) | 0.745 |
| % of preterm deliveries (<37 complete weeks) by the end of the study period | 2.8% (n = 2) | 4.3% (n = 3) | p = 0.316 (Z = -0.48) |
| Apgar score at 1 min (mean (SEM) (95%CI)) | 8.9 (0.1) (8.7 to 9.2) | 8.8 (0.1) (8.5 to 9.1) | 0.137 |
| Apgar score at 5 min (mean (SEM) (95%CI)) | 10.0 (0.0) (9.9 to 10.0) | 9.9 (0.0) (9.9 to 10.0) | 0.479 |

95%CI, 95% confidence intervals.

participants spending ≥ 3 h/day standing and the percentage of participants who were smokers. Finally, Apgar scores (maximum possible value of 10) were compared between the two groups using the *non-parametric* Mann–Whitney U test.

Data were expressed as mean (SEM) (maternal age, BMI) or % of total group where appropriate (parity history and eventual preterm deliveries, smoking habits, main occupational activity and number of daily hours standing). The level of significance was set at $p \leq 0.05$ for all statistical analyses.

RESULTS

Adherence to training and possible adverse effects

Adherence to training in the experimental group was $>90\%$. No major adverse effect and no major health problem were noted in the 72 subjects from the training group and the 70 subjects from the control group, except for two preterm deliveries in the training group and three preterm deliveries in controls (see below). Although no follow-up was systematically conducted in study participants after the study, women in the training group were satisfied with the intervention and reported their intention to follow a similar type of exercise on their own in future/eventual pregnancies.

Maternal characteristics

We found no significant differences ($p > 0.05$ for all between-group comparisons, table 1) in those maternal characteristics that could potentially influence the main study outcome, gestational age.

Gestational age and Apgar score

We observed no significant difference ($p = 0.745$) between the two groups in mean gestational age (table 2). Similarly, the percentage of preterm deliveries did not differ between the two groups ($p = 0.316$). Of the two women of the training group showing preterm delivery, one (gestational age: 36 weeks 2 days) had previous history of preterm delivery ($n = 1$) and the other one was a primigravida (gestational age: 35 weeks 6 days). Both participants finished the training programme at the end of week 35 and the health status of the newborn was normal (see below). Of the three controls with preterm delivery (gestational age of 36 weeks 2 days, 36 weeks 4 days and 36 weeks 5 days, respectively), none had previous history of preterm delivery and two were primigravidae.

Apgar scores at 1 and 5 min did not differ between the two groups ($p > 0.05$) and ranged within the upper scores indicative of an excellent prognosis for the newborn.²⁴ All individual values at 5 min were ≥ 9 .

DISCUSSION

The main finding of our study was that supervised, moderate exercise training performed over the second and third trimesters of pregnancy (~ 80 training sessions in total) does not negatively affect one of the main pregnancy outcomes, gestational age at the moment of delivery. Further, the overall health status of the baby is unaffected, as reflected by the results of the worldwide-used Apgar score. To reinforce our findings showing that regular exercise during the second part of pregnancy does not alter the risk for preterm delivery, several maternal, potentially confounding variables that might affect pregnancy outcome (for example age, previous parity history, smoking habits and number of hours standing) were controlled for, as we found no significant differences between the intervention and the control group. Ours is the first controlled, randomised trial that

objectively and specifically shows *no cause–effect relationship* between supervised, regular exercise, performed by a large sample of *previously sedentary* gravidae over the last two-thirds of pregnancy, and gestational age. An additional novelty of our study was that exercise training consisted mainly of very light resistance and toning exercises whereas most previous studies have solely analysed the effect of aerobic exercise. Even at low intensity (as here), resistance exercise should be an integral component of any exercise training programme. Indeed, increased muscle strength induced by resistance training results in an attenuated cardiovascular stress response to any given load during physical activities of daily living because the load now represents a lower percentage of the maximal voluntary contraction.²⁶

The issue addressed here is an important one and has strong clinical relevance due to i) the growing number of pregnant women who exercise during pregnancy¹⁰ and ii) the fact that preterm birth remains the leading cause of neonatal morbimortality in the world today (accounting for 75% of neonatal deaths) and a cause of long-term handicap in surviving infants.²⁷ On the other hand, the aetiology of preterm delivery is far from being clearly elucidated and strategies for prevention of prematurity have not proved very successful to date.²⁷ Despite lack of supportive scientific evidence, “strenuous activities” (for example endurance exercise such as brisk walking, cycling or jogging, and carrying loads) are still currently considered to be a potential cause of preterm birth by reference institutions²⁸ and are frequently discouraged by obstetricians. The results of most studies, however, show PA during pregnancy to be beneficial overall to the maternal–fetal unit¹⁰ and data from pilot non-controlled¹¹ or controlled¹² reports and prospective studies suggest no significant *association* between PA during pregnancy and pregnancy outcome (gestational age, risk of preterm delivery, intrauterine growth) in usually previously physically active (and thus fit) women.^{4 13–19} If anything, vigorous exercise (such as ~ 2000 kcal/week) could be associated with decreased risk of preterm delivery.^{17 19} The mechanisms that could explain the latter, somewhat striking findings are yet to be determined.¹⁹

Pregnancy is a physiological, naturally occurring process, though it is also somewhat unique in that most control systems of the body are transiently modified in an attempt to maintain both maternal and fetal homeostasis.⁷ In this regard, regular sustained exercise during pregnancy has traditionally been a cause of concern as it could potentially challenge the homeostasis of the maternal–fetal unit and thus it might adversely affect the course and outcome of pregnancy, by inducing changes in visceral blood flow, body temperature, carbohydrate

What is already known on this topic

Some controversy exists over the possibility that exercise during pregnancy might increase the risk of preterm delivery.

What this study adds

Previously sedentary, healthy gravidae with singleton gestation can safely engage in moderate, supervised exercise programmes (involving toning and very light resistance exercises) during the last two trimesters of gestation as this would not affect gestational age.

utilisation or shear stress.^{3, 29–32} Although regular exercise and the resulting high fitness level can in fact facilitate efficient and timely labour,³³ there has been concern that increases in norepinephrine and prostaglandin levels following each exercise bout during pregnancy could stimulate uterine motility and lead to premature labour and delivery.³⁴ Particular caution should theoretically be placed on exercise performed during the last trimester of pregnancy, which is necessary for the maturation of the fetal lungs and other organs in preparation for extra-uterine life. Another source of controversy arises from the fact that standing for long periods (>3 h/day), as during occupational activities, has been associated with increased risk of preterm birth.^{9, 35} In this regard, we could speculate that a source of controversy comes from the fact that some clinicians might erroneously associate number of daily hours standing (such as in industrial workers, cleaning staff or shopkeepers) with levels of actual daily PA, such as in structured exercise training programmes. The bulk of knowledge supports no significant changes in gestational outcome in women who engage in regular PA during pregnancy.^{4, 11–19, 30–32} Further, birth weight, a variable associated with gestational age, is unaffected in offspring of women who engage in aerobic training (stationary cycling, swimming, light weight exercises)³⁶ or yoga.³⁷ Our findings do further strengthen the notion that moderate, carefully supervised exercise can be safely performed by pregnant women until the end of pregnancy even if they were previously sedentary.

In summary, previously sedentary women with singleton gestation can safely engage in moderate, supervised exercise programmes until the end of gestation as this would not affect gestational age. Based on previous and present findings, exercise mode could include both aerobic and very light weight training/toning-oriented types of activities. Further research should be performed in women at high risk for preterm delivery. It would also be interesting to assess the maximum recommendable exercise intensity and the maximum tolerable resistance loads, based, for example, on hormonal (particularly catecholamines) determination.

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REFERENCES

- Schramm W, Stockbauer J, Hoffman H. Exercise, employment, other daily activities, and adverse pregnancy outcome. *Am J Epidemiol* 1996;**143**:211–18.
- Artal R, O'Toole M. Guidelines of the American College of Obstetricians and Gynecologists for exercise during pregnancy and the postpartum period. *Br J Sports Med* 2003;**37**:6–12.
- Clapp JF III. Exercise in pregnancy: a clinical update. *Clin Sports Med* 2000;**19**:273–86.
- Sternfeld B, Quesenberry C, Eskenazi B, et al. Exercise during pregnancy and pregnancy outcome. *Med Sci Sports Exerc* 1995;**5**:634–40.
- Horns P, Ratcliffe L, Leggett J, et al. Pregnancy outcomes among active and sedentary primiparous women. *J Obstet Gynecol Neonatal Nurs* 1996;**25**:49–54.

- McMurray RG, Mottola MF, Wolfe LA, et al. Recent advances in understanding maternal and fetal responses to exercise. *Med Sci Sports Exerc* 1993;**25**:1305–21.
- Wolfe L, Brenner I, Mottola M. Maternal exercise, fetal well-being and pregnancy outcome. *Exerc Sport Sci Rev* 1994;**22**:145–94.
- American College of Obstetricians and Gynecologists (ACOG). Exercise during pregnancy and the postpartum period. Committee Opinion 267. *Obstet Gynecol* 2002;**99**:171–3.
- Simpson J. Are physical activity and employment related to preterm birth and low birth weight? *Am J Obstet Gynecol* 1993;**168**:1231–8.
- Pivarnik JM, Chambliss HO, Clapp JF, et al. Impact of physical activity during pregnancy and postpartum on chronic disease risk. *Med Sci Sports Exerc* 2006;989–1006.
- Giroux I, Inglis SD, Lander S, et al. Dietary intake, weight gain, and birth outcomes of physically active pregnant women: a pilot study. *Appl Physiol Nutr Metab* 2006;**31**:483–9.
- Marquez-Sterling S, Perry AC, Kaplan TA, et al. Physical and psychological changes with vigorous exercise in sedentary primigravidae. *Med Sci Sports Exerc* 2000;**32**:58–62.
- Clapp JF III, Dickstein S. Endurance exercise and pregnancy outcome. *Med Sci Sports Exerc* 1984;**16**:556–62.
- Clapp JF III, Kim H, Burciu B, et al. Beginning regular exercise in early pregnancy: Effect on fetoplacental growth. *Am J Obstet Gynecol* 2000;**183**:1484–8.
- Hatoum N, Clapp JF, Neuman MR, et al. Effects of maternal exercise on fetal activity late in gestation. *J Matern-Fetal Med* 1997;**6**:134–9.
- Duncombe D, Skouteris H, Wertheim EH, et al. Vigorous exercise and birth outcomes in a sample of recreational exercisers: a prospective study across pregnancy. *Aust N Z J Obstet Gynaecol* 2006;**46**:288–92.
- Hatch M, Levin B, Shu X, et al. Maternal leisure-time exercise and timely delivery. *Am J Public Health* 1998;**88**:1528–33.
- Klebanoff M, Shiono P, Carey J. The effects of physical activity during pregnancy on preterm delivery and birth weight. *Am J Obstet Gynecol* 1990;**163**:1450–6.
- Berkowitz GS, Kelsey JL, Holford TR, et al. Physical activity and the risk of spontaneous preterm delivery. *J Reprod Med* 1983;**28**:581–8.
- Schulz KF, Chalmers I, Grimes DA, et al. Assessing the quality of randomization from reports of controlled trials published in obstetrics and gynecology journals. *JAMA* 1994;**272**:125–8.
- Schulz KF, Chalmers I, Hayes RJ, et al. Empirical evidence of bias. Dimensions of methodological quality associated with estimates of treatment effects in controlled trials. *JAMA* 1995;**273**:408–12.
- Taylor H, Jacobs D, Schucker B, et al. A questionnaire for the assessment of leisure time physical activities. *J Chron Dis* 1978;**31**:741–55.
- Apgar V. A proposal for a new method of evaluation of the newborn infant. *Curr Res Anesth Analg* 1953;**32**:260–7.
- Finster M, Wood M. The Apgar score has survived the test of time. *Anesthesiology* 2005;**102**:855–7.
- Artal R, Wiswell R, Drinkwater B. *Exercise in pregnancy*. 2nd edn. Baltimore: Williams and Wilkins, 1991.
- McCartney N, McKelvie RS, Martin J, et al. Weight-training-induced attenuation of the circulatory response of older males to weight lifting. *J Appl Physiol* 1993;**74**:1056–60.
- López Bernal A. Overview. Preterm labour: mechanisms and management. *BMC Pregnancy Childbirth* 2007;**7**(Suppl 1):S2.
- Spong CY. Prediction and prevention of recurrent spontaneous preterm birth. *Obstet Gynecol* 2007;**110**(2 Pt 1):405–15.
- Bergmann A, Zygmunt M, Clapp JF. Running throughout pregnancy: effect on placental villous vascular volume and cell proliferation. *Placenta* 2004;**25**:694–8.
- Clapp JF III. The effects of maternal exercise on early pregnancy outcome. *Am J Obstet Gynecol* 1989;**161**:1453–7.
- Clapp JF III. The course of labor after endurance exercise during pregnancy. *Am J Obstet Gynecol* 1990;**163**:1799–805.
- Clapp JF. Exercise during pregnancy—a clinical update. *Clin Sports Med* 2000;**19**:273–86.
- Wolfe LA, Hall P, Webb KA, et al. Prescription of aerobic exercise during pregnancy. *Sports Med* 1989;**8**:273–301.
- Lotgering FK, Gilbert RD, Longo LD. Maternal and fetal responses to exercise during pregnancy. *Physiol Rev* 1985;**65**:1–36.
- Teitelman AM, Welch LS, Heilenbrand KG, et al. Effect of maternal work activity on preterm birth and low birthweight. *Am J Epidemiol* 1990;**131**:104–13.
- Clapp JF. *Exercise through your pregnancy*. Omaha, NE: Addicus Books, 2002.
- Narendran S, Nagarathna R, Narendran V, et al. Efficacy of yoga on pregnancy outcome. *J Alt Comp Med* 2005;**11**:237–44.