EXERCISE DURING PREGNANCY

A Clinical Update

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The goal of this article is to update the information provided in an article initially written for *Clinics in Sports Medicine* 5 years ago.[10] It begins with a brief summary of that information followed by a presentation of new data that continue to support its main conclusion—that beginning or continuing a regular program of recreational exercise during pregnancy is safe and beneficial for healthy women and their offspring. The reader is referred to the initial article for the older references. Additional new information includes sections addressing the effect of different training volumes, diet, and additional types of exercise on pregnancy outcome, the short- and long-term maternal cardiovascular benefits of continuing regular exercise during and after pregnancy, and other long-term benefits for mothers and their offspring.

SUMMARY OF EARLIER ARTICLE

Exercise programs involving strenuous, prolonged physical activity such as aerobics, circuit training, stair climbing, and running remain a way of life for almost one quarter of women planning a pregnancy. Most continue their exercise regimen during pregnancy and many of the

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regimens exceed the current sanctioned guidelines.[1] In addition, a recent national survey reports that 42% of women reported exercising during pregnancy and half of those exercised beyond the sixth month.[46] The unanswered question is: How much exercise can a woman do at various times in pregnancy without compromising the growth and development of her embryo or fetus? The underlying concern is that the exercise-induced increases in maternal body temperature, circulating stress hormones, caloric expenditure, and biomechanical stress coupled with the decreased visceral blood flow could have adverse effects on multiple aspects of the course and outcome of pregnancy. These potential adverse effects include infertility, abortion, congenital malformation, growth retardation, premature labor, brain damage, fetal trauma, premature rupture of the membranes, difficult labors, hemorrhage, and maternal musculoskeletal injury.

Fortunately, the literature dealing with human subjects does not support these concerns, but its value is limited because all exercise is not the same, and there are big differences among studies in the type, intensity, duration, and frequency of the exercise regimens and the time in pregnancy when the studies were carried out. In addition, abnormal pregnancy outcomes are infrequent in healthy women so a large number of women must be studied to be sure that a given exercise regimen does not have an adverse effect on pregnancy outcome.

There is still no information on the impact on early pregnancy outcome of beginning a program of regular exercise in the periconceptional period or early in the first trimester. On the other hand, all reports indicate that the incidence of infertility, spontaneous abortion, congenital malformation, and placental abnormalities is not increased in women who continue strenuous weight-bearing types of exercise (running, aerobics, cross-country skiing, stair-stepping, and so forth) throughout early pregnancy. Likewise, the concern that continuing a strenuous exercise regimen or beginning to exercise regularly in middle or late pregnancy causes preterm labor or premature rupture of the membranes is not supported by the data. In addition, it seems that women who continue weight-bearing exercise at or above a training level benefit by having their babies 5 to 7 days earlier than those who do not.

Most studies report that exercise during pregnancy has no effect on the course and outcome of labor.[5, 31, 34, 37, 38, 43] Only a few note positive effects. The difference seems to be related to the type and amount of exercise the women performed as much less medical intervention (e.g., Pitocin use, forceps delivery, cesarian section) is required in women who continue to run or perform aerobics regularly throughout pregnancy, who have shorter labors with uncomplicated vaginal deliveries more than 85% of the time.[12] Unfortunately, this is not the case for women who begin or continue low-intensity nonweight-bearing regimens or for those who decrease their exercise performance substantially during pregnancy.[5, 12, 31, 34, 37, 38, 43] The findings are similar for birth weight in that it is unchanged or slightly increased by low-intensity or nonweight-bearing regimens and in women who substantially decrease their exer-

cise performance. Conversely, women who perform sustained weight-bearing exercise at moderate to high intensity consistently deliver lean, healthy infants who weigh less because they have much less fat.[5, 12, 42] Currently, there is no evidence to suggest that regular maternal exercise is associated with fetal compromise or unexplained fetal death. Rather, the babies born of regularly exercising mothers tolerate labor well, show less behavioral or biochemical evidence of undue stress in late pregnancy and labor, are vigorous at birth, and do well in the immediate neonatal period.[12, 19, 30]

Despite the fact that ligamentous laxity increases in pregnancy,[27] there are still no specific reports of exercise-associated injuries during pregnancy and ongoing experience indicates that they are few and far between.[12] Likewise, regular exercise improves fitness, reduces the usual musculoskeletal complaints associated with pregnancy, enhances feelings of well-being, improves body image, and decreases maternal weight gain and fat deposition in late pregnancy.[12, 18, 31, 35, 43]

Thus, the data currently available indicate that healthy, fit women with normal pregnancies may begin or continue a program of regular exercise during pregnancy. Furthermore, certain exercise regimens (regular, weight-bearing, strenuous exercise) are associated with improved outcomes for mother and fetus. The reasons for this seem to be that regular exercise enhances placental growth and the normal physiologic changes of pregnancy, whereas the physiologic changes of pregnancy modify the potential adverse physiologic effects of exercise.[12, 32] Although sanctioned guidelines are available,[1] the factual data clearly support the development of a more flexible approach to exercise during pregnancy. The data suggest that beginning a regular exercise regimen before conception and continuing it during pregnancy may have several positive effects on maternal physiologic adaptations to pregnancy, which may lead to feto-protective effects later in the pregnancy. Beginning a regular exercise regimen at various points in pregnancy may prove to be of preventive or therapeutic value in certain disease states associated with anomalous fetal growth.[28] The level of exercise performance required to achieve these goals is currently unknown.

EFFECT OF EXERCISE TYPE, TRAINING VOLUME, AND DIET ON OUTCOME

Because the reported effects of maternal exercise on pregnancy outcome have been so variable, the author and others have begun a series of prospective protocols designed to assess the effects of specific exercise regimens on pregnancy outcome. For purposes of clarity, he has divided them into those that have studied a specific type of exercise, those that have examined training volume, and one study of the interaction between exercise and diet.

Type of Exercise

In recent years, several reports have examined the effects of stationary cycling, spinning, and brisk walking, and our laboratory has additional preliminary experience with several forms of weight training. Several studies have begun to examine the safety of exercise at high altitude and beneath the sea.

Stationary Cycling and Swimming

Current sanctioned guidelines recommend cycling and swimming as the safest forms of exercise during pregnancy. Occasional abnormalities of the fetal heart rate,[44] ultrasound evidence of fetal flow redistribution,[7] and similar evidence of behavioral stress[39] have been noted during training or testing on stationary cycle ergometers, and although common,[46] swimming has not been studied in detail.[13]

Preliminary analysis of a prospective controlled trial of the effects of stationary cycling three times a week for 25 minutes at 70% of maximum heart rate found evidence of improved maternal fitness, but the regimen had no effect on maternal weight gain, the duration of pregnancy, length of labor, birth weight, or the incidence of complications,[44] and more limited studies in the author's laboratory have also been unable to demonstrate a positive or negative effect. The author has also studied 18 Masters level swimmers who continued to train throughout pregnancy and has not identified any specific effect on maternal weight gain, pregnancy complications or term length, labor course, or birth weight.

Spinning

Spinning is a new, extremely popular variant of stationary cycle ergometry that is designed to mimic racing and is characterized by a high base intensity with frequent superimposed intense anaerobic intervals. The several women studied have elevated their pulse rates to the peak level seen during tests of maximal aerobic capacity and their venous lactate levels have exceeded 7 mmol/L. A study of 50 women in California who participate in spinning classes three to five times a week during pregnancy at heart rates of 150 to 160 bpm currently is being completed, and to date all pregnancy outcomes have been normal (Herman Falsetti, MD, personal communication, 1999).

Walking

Walking seems to be the most frequent (43%) form of exercise during pregnancy, and recent surveys have assessed the effects of regular walking on the course and outcome of pregnancy.[5, 31, 43, 46] Although regular walking improved maternal sense of well-being and reduced physical complaints, it had no discernible effect on maternal weight gain

or course of labor. In several of the reports, however, birth weight of the offspring was increased.[5, 31] The author's preliminary experience with women who begin a moderate walking program in early pregnancy (20 minutes at 55% of maximum aerobic capacity three to five times a week) is similar to other studies in that the only effect seen on this regimen is a significant increase in birth weight and placental weight. Supporting this, a recent well-designed trial found that walking during labor had no effect on labor length, need for analgesia, need for labor augmentation, or the incidence of operative delivery.[6]

Weight Training

There is no published literature on the effect of weight training on the course and outcome of pregnancy. The author currently is examining several of the many forms of weight training (free weights, weight machines, and the combination of free weights with stretching), and his preliminary experience indicates that strength and flexibility are improved, injury is not a problem, and there are no obvious positive or negative effects on weight gain, pregnancy complications, course of labor, or birth weight.

Scuba Diving

The effects of scuba diving during pregnancy recently were reviewed in detail.[8] Although there are no controlled trials, anecdotal evidence and surveys indicate that shallow diving not requiring decompression (in less than 30 ft, in which the risk of venous air embolism is low) is not associated with abnormal outcome unless it is frequent and occupationally related. In women who dive recreationally to levels requiring decompression on a regular basis, however, there is evidence of a three- to sixfold increase in the incidence of spontaneous abortion and congenital malformation and an increased incidence of fetal growth restriction and preterm labor. It seems appropriate to recommend that pregnant women at least limit their dives to 30 ft, and, if they go deeper than that level, it would be prudent for them to extend decompression times by a minimum of 50%.

Exercise at High Altitudes

The fact that the rates of pregnancy complications are clearly much higher and birth weights lower at altitudes above 10,000 ft suggests that exposure to the additional physiologic stress produced by exercising at high altitudes may not be wise.[2, 29, 33, 45] Two studies done at 6000 and 7300 ft above sea level in healthy but sedentary women in late pregnancy who resided at sea level indicate that short bouts of moderate- to high-intensity cycle ergometry are well tolerated by mother and fetus.[3, 4] The fact that no reports of injury, pregnancy complications, or losses associated with exercise at altitude (skiing, running, hiking, mountain biking,

and so forth) have been made is also reassuring. The studies to date have been conducted at moderate rather than high altitude, for short periods, and at low intensities (2 to 5 mets). There are no outcome data available in pregnant women who perform various types of recreational exercise at altitudes over 8000 ft and, given the increased reproductive risk present at altitudes above 10,000 ft, caution is advised until more information is available.

Training Volume and Diet

Most exercise programs for pregnant women intentionally limit weekly training volume, which is calculated in units as the product of the time spent exercising and the average exercise intensity (percentage of maximal aerobic capacity).[12, 13] To determine if between-study differences in weekly training volumes could explain the reported differences in the effect of exercise on pregnancy outcome, the author has begun to examine the impact of different weekly training volumes during pregnancy prospectively. In these studies, women are assigned randomly to begin one of five exercise regimens at 8 weeks' gestation with weekly training volumes ranging from 0 (control) to 16,500 units; the types of weight-bearing exercise and exercise intensity are standardized and controlled.

Preliminary results indicate that all regimens improve maternal feelings of well-being and various measures of fitness but that weekly training volumes have to exceed 11,000 training units to limit maternal weight gain and fat deposition or influence the course of labor.[13, 25, 26] In addition, a low to moderate training volume (3300–5500 units), throughout pregnancy or in late pregnancy alone, increases birth weight, whereas high training volumes (11,000–16,500 units) throughout pregnancy or in late pregnancy alone produce offspring who are lighter and leaner than those born of control women. For women who exercised regularly before pregnancy, the benefits are greatest in those who maintain or exceed their preconceptional training volume during pregnancy. Those who cut back significantly have outcomes similar to those found in women who begin a moderate program for the first time in pregnancy (i.e., maintain fitness and well-being, increased birth weight, and no effect on weight gain or labor). The earlier observational data presented in the author's initial article[10] and the current prospective randomized data indicate that differences in weekly training volume and the type of exercise help to explain the diverse results in the literature because training volume is an important determinant of the specific maternal benefits obtained and birth weight. Although mean values for maternal weight gain and birth weight differ substantially in the different training regimens, there is still a wide range of values in each training group. This suggested that, in addition to exercise, there was at least one other variable influencing these overall energy retention of these women during pregnancy (maternal weight gain plus birth weight). The most

obvious additional variable was diet, so the author reviewed the data and found that although there were no large differences in total caloric intake among the women, there were large differences in the amount and type of carbohydrates in their diets. It seemed that those who ate processed carbohydrates (most breads, baked goods, soda, and processed or instant rice), which produce an accentuated increase in blood glucose and insulin, gained more weight and had larger offspring when compared with those who ate unprocessed or natural carbohydrates (fruits, nuts, nontuberous vegetables), which cause minimal elevations in blood sugar and insulin.[14] The author undertook a prospective, randomized study of exercise combined with a diet rich in processed carbohydrates or one rich in natural carbohydrates.[11] As predicted, women who exercised and ate a diet high in natural carbohydrates gained much less weight (15 lb less) and had babies who were about 2 lb lighter than those who exercised and ate a diet rich in processed carbohydrate. Differences in dietary carbohydrate intake among women easily can obscure the effects of exercise on energy retention during pregnancy. Because diets have not been evaluated in most studies, this may provide an additional explanation for the differences among studies on the effects of exercise on birth weight.

SHORT- AND LONG-TERM MATERNAL CARDIOVASCULAR BENEFITS

Cardiovascular Adaptations to Pregnancy

Exercise and pregnancy increase plasma volume. When the two are combined, the effect is additive so that women who exercise have blood volumes which are about 20% greater than their sedentary controls.[41] Pregnancy and exercise increase cardiac output.[13] The fact that running throughout pregnancy increases maximal aerobic capacity by 8% postpartum suggests that exercise also may augment the pregnancy-associated increase in cardiac output and that the effect may persist postpartum.[17] The author has reviewed some earlier data to determine if the early pregnancy changes in cardiac output, as measured by M-mode echocardiography, were greater in women who exercised.[9, 22] Figures 1 through 3 detail the results. Note that the changes in end-diastolic volume and stroke volume at 8 and 16 weeks were 10% greater in the women who continued to exercise. As a result, the changes in cardiac output at rest were approximately 40% (400—500 mL/min) greater in the exercising women, and similar differences were seen in calculated total peripheral resistance.

Persistence of These Changes Postpartum

These findings led to a recently published study designed to determine if these changes persist postpartum in women who exercise.[16] The

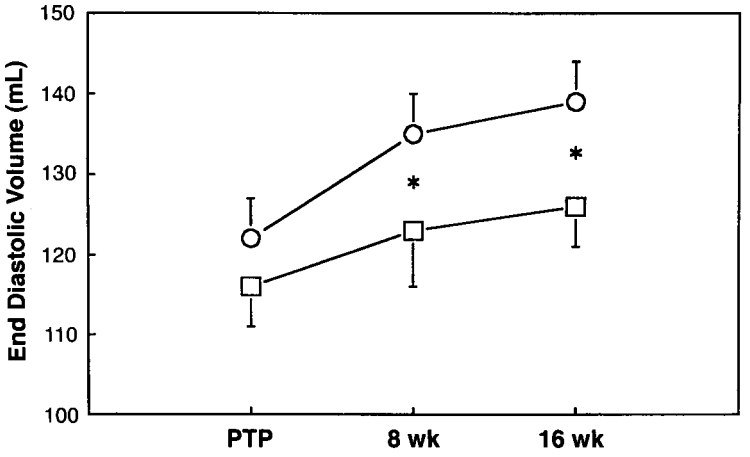

Figure 1. The effect of regular exercise on the changes in end-diastolic volume in early pregnancy. Circles = exercise subjects; square = control subjects. PTP = prior to pregnancy. *A significant difference between groups at the $P < 0.05$ level.

data indicate that these changes persist for up to 1 year postpartum and are accentuated by a subsequent pregnancy. In exercising women, cardiac output is still 11% higher and total peripheral resistance is 11% lower 1 year postpartum than the values obtained before pregnancy. This change probably underlies the increase seen in maximum aerobic capacity and performance in athletes following a pregnancy. It also

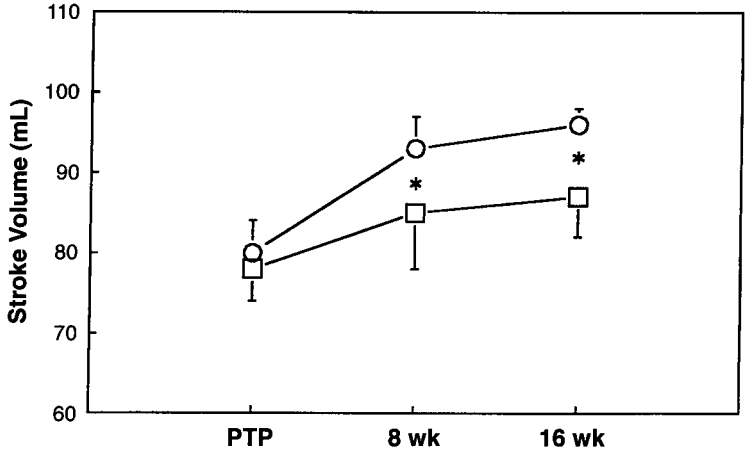

Figure 2. The effect of regular exercise on the changes in stroke volume in early pregnancy. Circles = exercise subjects; and squares = control subjects.* A significant difference between groups at the $P < 0.05$ level.

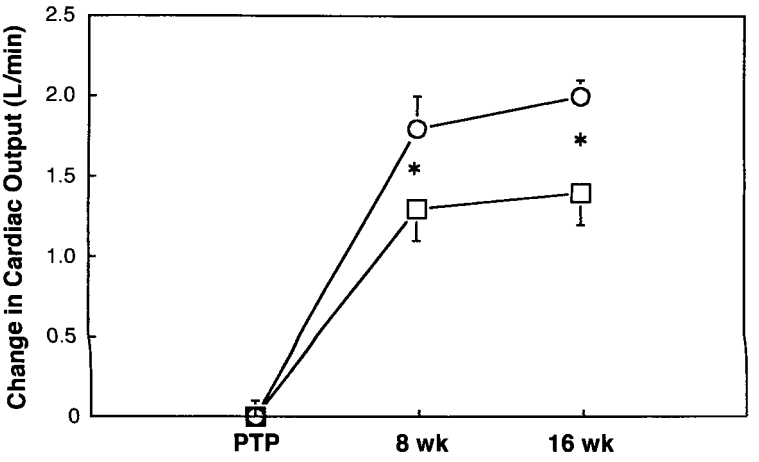

Figure 3. The effect of regular exercise on the changes in cardiac output in early pregnancy. Circle = exercise subjects; and square = control subjects.* A significant difference between groups at the $P < 0.05$ level.

suggests that the combination of exercise and pregnancy promotes vasodilation with a resultant decrease in barotrauma, which may protect against vascular disease later in life.

Physiologic Advantage during Hemodynamic Stress

The next question addressed was, is the increased blood volume and cardiac output seen in exercising women during pregnancy protective in times of unexpected hemodynamic stress? To answer this question, the author has begun to examine maternal vascular responses to mock hemorrhage (James F. Clapp III, MD, unpublished data) and to a standardized exercise load.[24]

In the mock hemorrhage experiments, central blood volume was depleted acutely by placing the women's legs in a negative pressure box and decreasing the pressure in it by 35 mm Hg. This trapped approximately 400 mL of blood in the leg veins in the nonpregnant state and a little more than twice as much during middle and late pregnancy. Figure 4 shows the changes seen to date in cardiac output produced by this hemorrhage before pregnancy and in middle and late pregnancy in regularly exercising women. Before pregnancy, the 400-mL mock hemorrhage reduced cardiac output more than 1 L, which caused most women to feel faint. During mid- and late pregnancy, however, although the volume of the mock hemorrhage was more than 800 mL, there was little decrease in cardiac output, the mothers felt well, and the babies were not perturbed. The expanded blood volume and cardiac reserve of pregnant women who exercise regularly are protective because they

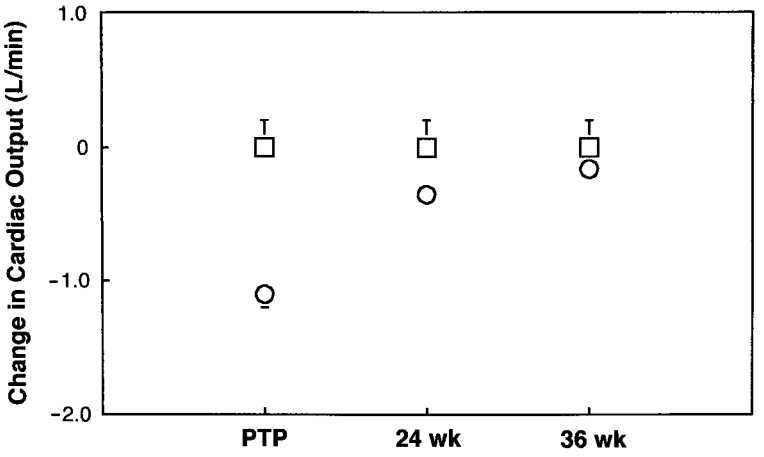

Figure 4. The combined effect of exercise and pregnancy on the changes in cardiac output following mock hemorrhage. Square = baseline measurements; circles = measurements obtained during the mock hemorrhage.

act to maintain excellent cardiovascular function under conditions that produce faintness in nonpregnant women.

Theoretically, the same mechanisms should maintain blood flow to the internal organs during exercise. To determine if this is the case, splanchnic blood flow has been measured with ultrasound in regularly exercising and fit control women just before and immediately after a 20-minute treadmill run at an intensity of 55% to 60% of maximum aerobic capacity. Before pregnancy, the exercise-induced decrease in splanchnic blood flow was similar in the two groups, but during middle and late pregnancy, the decrease in flow was 20% to 30% less in the women who continued to exercise during pregnancy. The expanded blood volume and increased cardiac output in the exercisers improve visceral blood flow during short-term hemodynamic stress.

OTHER LONG-TERM MATERNAL BENEFITS

The author currently is examining the affect on other parameters of continuing exercise throughout pregnancy and the first year postpartum, using examination and questionnaire approaches throughout the first year after the index pregnancy. To date, follow-up data have been obtained in approximately 150 women that address the areas of mental well-being, fitness, weight and fat retention, bone density, abdominal muscle tone, musculoskeletal injury, and bladder function.[13]

Women who continue to exercise throughout pregnancy and the postpartum period derive several mental benefits. In this author's opinion, the key to these benefits is that women find the time to continue to exercise. Their ability to do this indicates that they have developed a

support system and that they have a defined amount of personal time when their lifestyle is changing. The end result seems to be a marked decrease in reported perceived life stress; a more relaxed maternal–child relationship, as assessed by the parenting stress index; and a 60% decrease in symptoms of depression as assessed by psychiatric questionnaires.

More than 90% of women who maintain an exercise regimen during pregnancy continue to exercise after the birth and, of these, 70% reach or exceed their prepregnancy fitness level. The average time when these women begin exercise postpartum is at the end of the second week, with a range from 3 days to 8 weeks. Exercise intensity has returned to prepregnancy levels by the sixth month and at that time their maximal aerobic capacity exceeds their prepregnancy level by 6% to 15%. Nine out of 10 of these women had no pain; heavy bleeding; or musculoskeletal, reproductive, or breastfeeding problems associated with the early resumption of exercise postpartum.

In terms of weight loss, 30% more of the women who continue to exercise return to their prepregnancy weight within a year and even more return to their prepregnancy body fat level. Neither breastfeeding nor exercise hastens weight loss because the women spontaneously balance their increased energy needs by increasing their food intake. As a result, for most women, weight loss is a gradual but steady process. These women also regain their abdominal muscle tone rapidly. The average rating before pregnancy on a scale of 1 to 10 was 8, and a year after the birth it was 7 in those who continued to exercise and 4 in those who did not.

Most women develop some loss of bladder control during pregnancy, and in some, this becomes a chronic problem after the birth. One concern of many physicians and women alike has been that exercise during pregnancy and postpartum might accentuate this problem, but the data to date are reassuring. In the immediate postpartum period, the incidence is significantly less in the exercising women (40% versus 60%), and this falls progressively in both groups over time. At 1 year, the incidence of occasional loss of bladder control in the women who continued exercise is 20% versus 42% in the controls.

The author has been unable to demonstrate benefit in one area, bone density, hypothesizing that exercise during pregnancy and lactation would minimize the loss of bone mineral and improve skeletal integrity; however, with adequate calcium intake, women who exercise and those who do not maintain bone mineral during pregnancy but lose between 3% and 5% during lactation.[36] This striking loss is similar to that seen at menopause and seems to be caused by the hypoestrogenic state, which is present during the first 10 to 18 weeks of lactation.

BENEFITS FOR THE OFFSPRING BEFORE AND AFTER BIRTH

The fetal benefits of exercise seem to be caused by the stimulatory effects of an intermittent reduction in uterine blood flow on placental

growth, placental function, and fetal behavior coupled with a small but significant decrease in fetal nutrient availability.[11, 21, 30, 32] The physiologic result is that these fetuses are lean at birth and seem to have an increased tolerance for the physiologic stresses of late pregnancy, labor, and delivery.[12, 13, 19] In the first few days after birth, these infants are behaviorally different. They are more alert and less cranky, and the mothers believe that these differences persist.[20] Although unproved, these behavioral differences may be the result of the recurrent fetal behavioral stimulation associated with maternal exercise.

We hypothesize that these differences are the result of fetal imprinting (the effects of environmental factors experienced in utero [i.e., noise, high blood sugar, rhythmic motion, oxygen, etc.] on postnatal growth and development) and that they persist throughout childhood and perhaps into adult life.[40] To test this hypothesis, the author has examined offspring cohorts at 1 and 5 years of age.[15, 20] When compared with matched controls at 1 year, the exercise offspring exhibit slightly better motor skills but have identical mental skills and morphometry; however, at age 5 years they are much leaner than control offspring and perform much better on standardized tests of intelligence, particularly in the area of oral language skills. What the future holds for these children is uncertain, but it is anticipated that they will remain lean and intelligent and have improved cardiovascular and metabolic function, which should result in some degree of athletic prowess when they are young adults, improved insulin sensitivity, and diminished long-term cardiovascular risk. The studies to test that hypothesis will begin in the year 2000.

SUMMARY

Research dealing with exercise during pregnancy continues to demonstrate marked benefits for mother and fetus. The type, intensity, frequency, and duration of the exercise seem to be important determinants of its beneficial effects. Maternal benefits include improved cardiovascular function, limited weight gain and fat retention, improved attitude and mental state, easier and less complicated labor, quick recovery, and improved fitness. Fetal benefits may include decreased growth of the fat organ, improved stress tolerance, and advanced neurobehavioral maturation. Currently, the offspring are leaner at 5 years of age and have a slightly better neurodevelopmental outcome. Postpubertal effects are still unknown. In the absence of medical contraindications, women should be encouraged to maintain their prepregnancy activity level.

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