Doppler Examinations in AGA and IUGR Fetuses Before and After Maternal Physical Exercise

A. Kubilay ERTAN*, S. SCHANZ*, R. MEYBERG*, H. Alper TANRIVERDİ**, Werner SCHMIDT*
** Saarland University Medical School, Department of Obstetrics and Gynecology, 66421 Homburg- Germany*
*** Fellow from Karaelmas University Medical School, Department of Obstetrics and Gynecology, 67600 Kozlu-Zonguldak-TURKEY*

ABSTRACT

DOPPLER EXAMINATIONS OF FETAL AND UTEROPLACENTAL BLOOD FLOW IN AGA AND IUGR FETUSES BEFORE AND AFTER MATERNAL PHYSICAL EXERCISE WITH THE BICYCLE ERGOMETER

Objective: To study changes in uteroplacental and fetal circulation after maternal exercise in appropriate-for-gestational-age fetuses (AGA) and intrauterine-growth-retarded fetuses (IUGR).

Materials and Method: 33 women with an uncomplicated course of pregnancy and 10 women with IUGR were examined. Physical stress was caused through a bicycle ergometer with 1,25 W/kg maternal weight. Doppler flow measurements were performed in the umbilical artery, fetal aorta, arteria cerebri media and in the uterine artery. Fetal heart rate was documented by monitoring. Maternal lactate and glucose levels as well as maternal heart pressure were recorded.

Results: No significant changes after cycling could be observed in umbilical and uterine vessels neither in the normal pregnancies nor in pregnancies with IUGR. In contrast, in the fetal aorta an increase of the S/D-ratio was recorded in both groups (an increase of 16% [$p<0.01$] and 18%[$p<0.05$], respectively for AGA and IUGR cases). In cerebral arteries a decrease of the S/D-ratio was observed after cycling in both groups (a decrease of 24% [$p<0.01$] and 13%[$p<0.05$], respectively for AGA and IUGR cases). In AGA fetuses the S/D ratio of the aorta and a.cerebri media returned to pre-test level by the 18th minute of examination. In IUGR fetuses the S/D ratio of the aorta and a.cerebri media did not return to pre-test levels at the end of the test. Fetal heart rate remained unchanged in both groups.

Maternal blood pressure and heart rate increased during the exertion phase but returned to the initial values at the end of the test. A 21% and 24% (respectively for AGA and IUGR groups) reduction of maternal glucose values after exercise was observed ($p<0.001$). Lactate values doubled in both groups after exercise ($p<0.001$).

Conclusion: From the results obtained we conclude that maternal exercise does not significantly alter uterine and umbilical perfusion in AGA and IUGR pregnancies suggesting absence of change in the uterine vascular bed resistance. However, submaximal maternal exercise was followed by a fetal cerebral vasodilatation and an increase of resistance in the fetal aorta which was more evident in IUGR fetuses. This might be due to a circulatory deterioration in those cases.

Keywords: Bicycle ergometer, Doppler ultrasound, exercise, IUGR, pregnancy

As physical stress is relatively easy to standardize, several groups have studied changes in pregnant women as a result of sporting exertion, particularly the measurable physiological changes in the organisms of the mother and child. Although using different types of exercise - produced by ergometer, treadmill and running tests - all authors came to the conclusion that light and medium physical exercise has no significant adverse effect on the mother or the fetus [13, 15, 19].

Doppler flow measurements of the fetoplacental unit after physical exercise of the mother have been performed with varying results by several investigators [1-5, 8-10, 12, 14-16, 18, 20, 21]. Only one study compared Doppler flow in uncomplicated and complicated pregnancies after physical exercise of the mother [7].

Corresponding Author: *OA Dr. med. A. Kubilay Ertan*
University of Saarland, Dept. OB&GYN Kirrbergerstr. 9
66421 Homburg/Saar – Germany
(It was presented at the 2nd World Congress of Perinatal Medicine for Developing Countries, Antalya-TURKEY, 2002)

The effect of physical exertion on the fetoplacental unit in pregnancies complicated by intrauterine growth retardation or hypertensive disorders is of special clinical interest, because these fetuses are known to be at risk for long-term neurologic morbidity.

Therefore we conducted a study to investigate changes of the feto-uteroplacental unit after defined maternal exercise including measurements in the third trimester of pregnancy in appropriate-for-gestational-age fetuses (AGA) and intrauterine growth retarded fetuses (IUGR).

MATERIALS AND METHODS

Gestational age was calculated by last menstrual data and a sonographic measurement of the crown-rump length within the first 12 weeks' gestation. IUGR was defined as a fetal abdominal circumference <5th percentile for gestational age of our reference ranges [17].

A total of 33 pregnant women with AGA fetuses and ten patients with IUGR fetuses in the third trimester were examined. Multiple pregnancies, cases with maternal renal disease, maternal diabetes, maternal cardiovascular pathology other than hypertension and fetuses with chromosomal or structural anomalies were excluded from evaluation.

Informed consent was obtained from the patients after detailed explanations of the risks (possibility of uterine contractions, reduced placental perfusion with subsequent hypoxia, circulatory strain for mother and fetus, etc.).

The exercise period began with an acclimatization period of three minutes (30 W), followed by ten minutes of moderate exertion (1.25 W/kg body weight for each women). A bicycle ergometer from Mijnhardt (Mijnhardt-Jäger b.v., Bunnik, The Netherlands) was used.

Immediately after the exercise period Doppler flow measurements were performed by two experienced investigators at the department for prenatal diagnosis and ultrasound at the University Hospital, Department of Obstetrics and Gynecology, Homburg/Saar, University of the Saarland. The test period was 35 minutes. In the IUGR group fetal heart rate monitoring (FHR) was performed for additional 15 minutes before and after the exercise.

The Doppler examinations were performed with an Acuson 128 XP/10 (Mountain View, California, USA) and an ADR 5000 (Kranzbühler, Solingen, Germany) ultrasound equipment with a 3.5 MHz convex scanner. Doppler flow recordings of the umbilical arteries, fetal aorta, arteria cerebri media and the uterine arteries were performed. During all Doppler examinations the patients were positioned semi-recumbent to avoid "vena cava syndrome".

Doppler flow velocity waveforms were obtained from a free-floating central part of the umbilical artery in the absence of body movements, fetal breathing or cardiac arrhythmia with the sample volume covering the whole vessel. Care was taken to keep the insonation angle in the umbilical artery at the lowest possible angle. The fetal aorta was localized in its abdominal part at the origin of the renal arteries. The angle between ultrasound beam and fetal aorta was kept below 55°. The middle cerebral artery was visualized at about 1cm of its origin in the circle of Willis in an axial view. The insonation angle in the middle cerebral artery was always below 15°. Care was taken to minimize fetal head compression, because this is known to influence the flow velocity waveforms of the middle cerebral arteries.

For uterine artery Doppler the transducer was placed in the right or left lower part of the abdomen. Color Doppler imaging was used to localize the main uterine artery cranial to the crossing of the external iliac artery. The examination was repeated on the opposite side. The insonation angle was kept below 55° at the uterine arteries.

For every vessel examined five consecutive waveforms of similar quality were accepted for analysis. The ratio of peak systolic (S) over diastolic (D) velocity (S/D ratio) was determined. Abnormal umbilical, uterine and fetal aorta Doppler results were those >2 SD above the mean for gestational age of our local reference ranges [6]. Fetal brain sparing was supposed when the S/D ratio was <2 SD below the mean of our local reference ranges for the middle cerebral artery [6].

Glucose and lactate levels were measured in capillary blood samples taken from the finger pad before and after exercise ("Monotest-Lactat in Halbmicro-Technik", Boehringer Mannheim). The pulse and blood pressure of the mother was automatically registered at three-minute intervals during the test (Dinamap, Critikon).

The Wilcoxon pair difference test for associated random samples was used for statistical evaluation.

RESULTS

NORMAL PREGNANCIES:

The mean performance on the bicycle ergometer was 79 W (±11 W). Gestational age at delivery was 40.0 weeks (±8 days). The mean birth weight

Table 1: Changes of S/D ratio during exercise in AGA pregnancies (n = 33)

	S/D ratio (Mean ± SD)			
	Before exertion (baseline)	After exertion		
		1.-6. min	7.-12. min	13.-18. min
A.umbilicalis	2.6 ±0.5	2.5 ±0.5	2.6 ±0.5	2.6 ±0.4
p value		ns	ns	ns
Fetal Aorta	4.9 ±1.3	5.7 ±2	5.2 ±1.4	5.7 ±1.8
p value		p<0.01	ns	p<0.05
A.cerebri media	5.6 ±3.3.	4.3 ±1.8	6.1 ±3.9	5.9 ±2.9
p value		p<0.01	ns	ns
A.uterinae	1.8 ±0.6	1.7 ±0.4	1.8 ±0.5	1.8 ±0.4
p value		ns	ns	ns

S/D ratio: Systolic/diastolic ratio
ns: difference not significant
SD: Standart deviation

was 3270 g (±383 g).

Mode of delivery: Twenty four (73%) women delivered vaginal spontaneously, 1 (3%) vaginal operative and 8 (24%) by cesarean section.

Doppler flow results of normal pregnancies (Table 1)

Umbilical artery: The observed S/D ratios were within the normal range before and after exertion. However, in 4 (12%) fetuses the measurements reached the threshold range after exercise.

Fetal aorta: The mean S/D ratio before exercise was 4.9 (±1.3). In 8 (24%) fetuses the S/D ratio was at the threshold range (S/D ratio 6-7) and in 1 (3%) fetus at the pathological range (S/D ratio>7). A significant increase in the S/D ratio was determined following exertion (p<0.01). However, the mean value did not reach the pathological level. An increase in the S/D ratio of the aorta shortly after exertion was observed in 21 (63%) fetuses [(In 5 (24%/ within the threshold range, in 16 (76%) in the pathological range].

A.cerebri media: Before exercise, the S/D ratio was in the normal range in all cases. A significant reduction in the S/D ratio was determined shortly after the exertion phase (p<0.01). Twenty minutes after exertion, the results were almost the same as the baseline records.

Uterine artery: The observed S/D ratios were within the normal range before and after exertion.

FHR: The fetal heart rate remained nearly unchanged before and after exertion (Figure 1). In one case fetal bradycardia (lasting approximately two minutes at the end of the exertion phase) was ob-

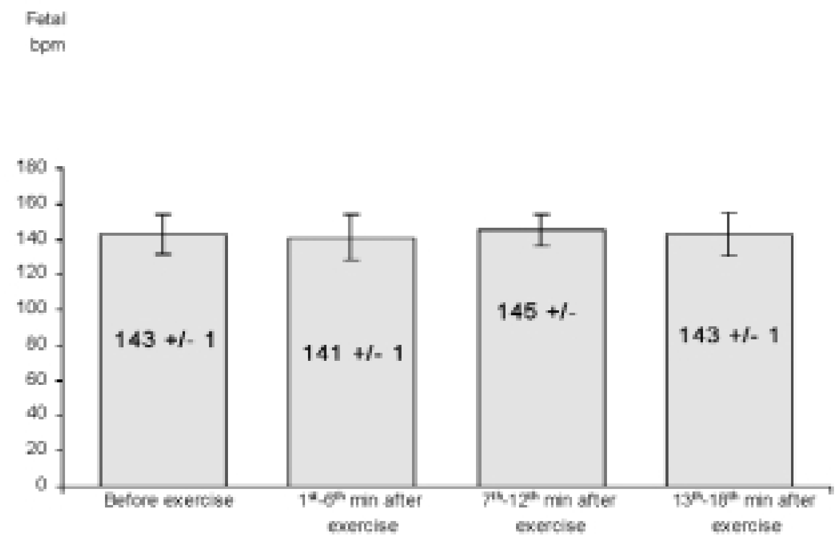

Figure 1. Fetal heart rate during the test period (mean ± SD) in AGA pregnancies (n=33).

served. This patient developed preeclampsia in the last two weeks of pregnancy.

Maternal parameters: The maternal blood pressure and the maternal heart rate increased during the exertion phase but returned to the initial values at the end of the test.

The maternal glucose levels decreased by 21% (p<0.001) after exercise, while the lactate values increased almost two-fold from 14.6 mg% to 27.6 mg% (p<0.001).

IUGR PREGNANCIES:

The mean performance on the bicycle ergometer was 68 W (±10 W). Gestational age at delivery was 37.6 weeks (±19 days). The mean birth weight was 2065 g (±526 g).

Mode of delivery: Five (50%) women delivered vaginal spontaneously and 5 (50%) by cesarean section.

Doppler flow results of IUGR pregnancies (Table 2)

Umbilical artery: In 3 (30%) fetuses the baseline value were in the threshold and in another 3 (30%) fetuses it was pathological. The remaining 4 (40%) fetuses had normal Doppler values. After exercise the S/D ratio was in the threshold range in one (10%) fetus and pathological in 4 (40%) fetuses.

The S/D ratio in the umbilical artery was pathologic in 3 fetuses already before exercise. This had a marked influence on the mean S/D ratio value, because of the very small sample size. Thus, the calculated mean values of all measurements were in the pathological range from the beginning. After exclusion of these 3 cases, S/D ratios became normal and no significant changes in S/D ratios of umbilical arteries occured during the test.

Fetal aorta: S/D ratios before exercise were within the pathological range in 3 (30%) fetuses and in 2 (20%) fetuses within the threshold range. The S/D ratio following exertion rose significantly (p<0.05).

Doppler flow measurements after exertion between minutes 1-6, minutes 7-12 and minutes 13-18 showed pathological values in 4 (40%), 5 (50%) and 6 (60%) fetuses, respectively.

The mean values of fetal aortic S/D ratios in IUGR fetuses were higher than in AGA fetuses (p<0.05). In contrast to the AGA group, in the IUGR group all S/D ratios after exercise were within the threshold or the pathologic range and did not return to normal values after exercise.

A.cerebri media: The S/D ratio revealed a stepwise reduction until 7 to 12 minutes after exertion (p<0.05) and made a "plateau" until 13 to 18 minutes after exertion. In 6 (60%) fetuses the S/D ratio following exertion was lower than the baseline values.

In growth retarded fetuses, the S/D ratios returned to normal levels more slowly than in AGA fetuses. In contrast to AGA fetuses, in IUGR fetuses the S/D ratios at the end remained well below the values registered at baseline (p<0.05).

Uterine artery: There were no significant changes in S/D ratios of the uterine vessels during the test.

FHR: The FHRs before and after exercise remained unchanged (Figure 2).

Maternal parameters: Maternal blood pressure

Table 2: Changes of S/D ratio during exercise in IUGR pregnancies (n = 10)

	S/D ratio (Mean ± SD)			
	Before exertion (baseline)	After exertion 1.-6. min	7.-12. min	13.-18. min
A.umbilicalis (all)	5.6 ±5.6	5.8 ±5.7	6.2 ±5.3	4.4 ±2.2
p value		ns	ns	ns
A.umbilicalis (without extremes)	2.8 ±0.5	2.9 ±0.8	2.8 ±0.4	3.2 ±0.8
p value		ns	ns	ns
Fetal Aorta 6.5 ±2.8	7.7 ±3.7	8.9 ±5.1	9.3 ±5.3	
p value		p<0.05	p<0.05	p<0.05
A.cerebri media	4.9 ±2.3.	4.3 ±1.6	3.9 ±0.6	4.1 ±1.8
p value		p<0.05	p<0.05	p<0.05
A.uterinae 1.7 ±0.8	2.1 ±0.8	1.9 ±0.5	1.9 ±0.3	
p value		ns	ns	ns

S/D ratio: Systolic/diastolic ratio
ns: difference not significant
SD: Standart deviation

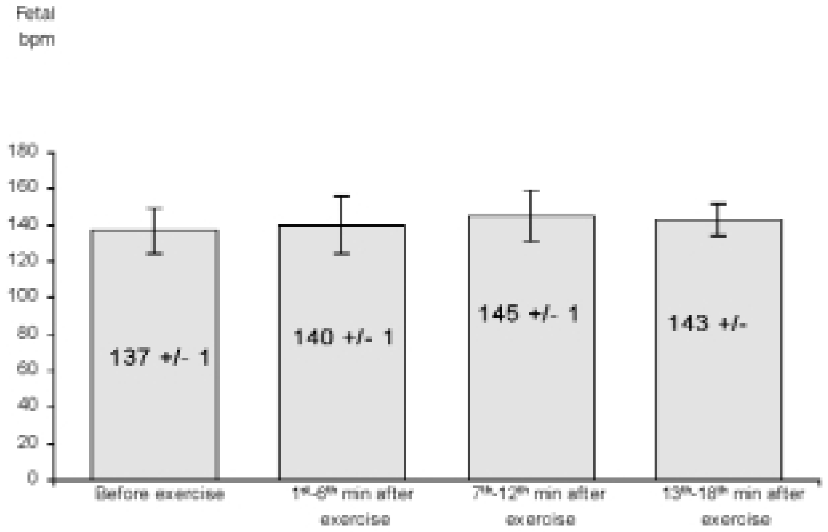

Figure 2. *: Fetal heart rate during the test period (mean ± SD) in IUGR pregnancies (n=10).*

and heart rate increased during exercise but regained normal values rapidly after exercise. The maternal glucose levels decreased about 24% ($p<0.001$), while the lactate concentrations doubled from 11.6 mg% to 24.2 mg% ($p<0.001$).

DISCUSSION

The objective of the study presented was to investigate the relationship between maternal exercise in the third trimester and Doppler flow results of the fetoplacental unit in uncomplicated pregnancies and those complicated by intrauterine growth retardation.

This study reports Doppler flow measurements of the placental vascular bed, the fetal aorta, umbilical artery together with the fetal cerebral arteries in the human AGA and IUGR fetuses after physical exercise of the mother.

There is concflicting data regarding the question of uteroplacental supply during and after physical exercise of the mother in uneventful pregnancies and pregnancies at risk.

In 1956 Morris et al. [11] already studied changes in uterine circulation following physical exertion by the mothers. The authors found a statistically significant lengthening of the uterine clearance half-time of NaCl and hence a reduction in circulation during exertion [11]. At rest, by contrast, the clearance half-time was shorter and uterine circulation improved. The main critic point to the results of this study was that during examination procedure the patient rested in supine position, thus inducing possible vena cava occlusion syndrome.

Several investigators reported of unchanged uteroplacental blood flow and umbilical perfusion after bicycle stress test in the third trimester [3, 10, 16, 18, 20]. Morrow et al. found higher S/D ratios in the uterine arteries and elevated fetal heart rates after exercise of the mother in the third trimester. S/D ratio in the umbilical artery however, was unaltered [12]. Erkkola et al. demonstrated in a series of uncomplicated pregnancies an increase in S/D ratio of the uterine arteries and the maternal blood pressure after exercise, whereas no change in S/D ratio occured in the umbilical artery. Of note, the fetal heart rate increased significantly after exercise [5].

The predictive value of maternal aerobic exercise for pregnancy-induced hypertension was studied by Hume et al. in a small series [8]. Preeclampsia developed in four patients with S/D ratios being elevated in the umbilical artery after recovery in these four patients. It was concluded, that aerobic exercise of the mother might be a valuable tool in predicting hypertensive pregnancy complications [8]. On the other hand decreased umbilical artery S/D ratios were reported after maternal exercise in the third trimester, thus indicating an improved placental circulation following exercise in healthy women [14].

Hackett et al. [7] performed a bicycle exercise test in thirty-four woman in the third trimester. Twelve pregnancies were uncomplicated, whereas 22 of the cases were complicated by small-for-gestational-age fetuses or maternal hypertension. Increase in pulsatility indices was more prominent in complicated pregnancies than in uncomplicated gestations, thus indicating an important reduction of uteroplacental blood flow by maternal exercise in complicated pregnancies [7]. In a more recent study a fetal cerebral vasodilatation with decrease in umbilical resistance induced by submaximal maternal dynamic exercise was reported. Fetal heart rate remained unchanged in this study [2].

The present Doppler flow results of the fetal aorta and fetal cerebral vessels in normal pregnancies showed significant differences before and after exertion. The S/D ratio in the aorta increased following exertion and remained higher for a considerable time (approx. 20 minutes), although the readings did not become pathological. In IUGR fetuses the increase of S/D ratio in the fetal aorta was more important with resistance indices being in the pathological range during the time period of the test.

The S/D ratio in the cerebral artery reduced significantly following exercise and returned very quickly approximately to its initial value in AGA fetuses. In IUGR cases reduction of S/D ratio could be observed until the end of the test without return to pre-test values, thus indicating an initially decreased fetal cerebral circulation in IUGR cases after maternal exercise. Subsequently, fetal centralization (brain sparing phenomenon) occured to maintain fetal cerebral circulation.

In the present study S/D ratios of the placental vascular bed and the umbilical arteries remained unchanged throughout the test period. In three cases of IUGR we found elevated S/D ratios in the umbilical artery prior to maternal exercise. After exclusion of those cases S/D ratios in the umbilical artery was in the physiolgical range during the test in AGA and IUGR fetuses. These findings are in good accordance to results reported in the literature [3, 5, 10, 12, 16, 18, 21].

Furthermore, in the present study fetal heart rate remained unchanged after maternal exercise in AGA and IUGR fetuses. This is partly in accordance with previous studies [3, 5, 10, 12, 16, 18, 21]. Differences in study protocols might account for these differences.

In conclusion, the presented results support evidence of fetal cerebral vasodilatation leading to redistribution of fetal blood volume to the cerebrum as a physiologic answer after moderate maternal exercise during the third trimester of pregnancy. In IUGR fetuses cerebral vasodilation (brain sparing phenomenon) lasted longer than in AGA fetuses and did not return to initial levels during the test period, pointing towards an altered fetal oxygenation under these circumstances. Furthermore, our results suggest that maternal exercise does not significantly alter uterine and umbilical perfusion in AGA and IUGR pregnancies suggesting absence of change in the uterine vascular bed resistance.

These findings underline the need of close antepartal surveillance of IUGR fetuses by Doppler flow measurements in order to detect circulatory deterioration in those fetuses and to reduce long-term morbidity. This is an important and relevant task of modern perinatal medicine.

REFERENCES

1. Baumann H, Huch A, Huch R. Doppler sonographic evaluation of exercise-induced blood flow velocity and waveform changes in fetal, uteroplacental and large maternal vessels in pregnant women. J.Perinat.Med. 1989;17(4):279-87.
2. Bonnin P, Bazzi-Grossin C, Ciraru-Vigneron N, et al. Evidence of fetal cerebral vasodilatation induced by submaximal maternal dynamic exercise in human pregnancy. J.Perinat.Med. 1997;25(1):63-70.
3. Drack G, Kirkinen P, Baumann H, Müller R, Huch R. Doppler ultrasound studies before and following short-term maternal stress in late pregnancy. Z Geburtshilfe Perinatol 1988;192:173-7.
4. Durak E, Jovanovic-Peterson L, Peterson C. Comparative evaluation of uterine response to exercise on five aeorobic machines. Am.J.Obstet.Gynecol. 1990;162:279-84.
5. Erkkola RU, Pirhonen JP, Kivijarvi AK. Flow velocity waveforms in uterine and umbilical arteries during submaximal bicycle exercise in normal pregnancy. Obstet.Gynecol. 1992;79(4):611-5.
6. Ertan A, Hendrik H, Tanriverdi H, Bechtold M, Schmidt W. Fetomaternal Doppler sonography nomograms. Perinatoloji 2001;9(3):174-80.
7. Hackett GA, Cohen-Overbeek T, Campbell S. The effect of exercise on uteroplacental Doppler waveforms in normal and complicated pregnancies. Obstet.Gynecol. 1992;79(6): 919-23.
8. Hume RF, Jr., Bowie JD, McCoy C, et al. Fetal umbilical artery Doppler response to graded maternal aerobic exercise and subsequent maternal mean arterial blood pressure: predictive value for pregnancy-induced hypertension. Am.J. Obstet. Gynecol. 1990;163(3):826-9.
9. Manders MA, Sonder GJ, Mulder EJ, Visser GH. The effects of maternal exercise on fetal heart rate and movement patterns. Early Hum.Dev. 1997;48(3):237-47.
10. Moore DH, Jarrett JC, Bendick PJ. Exercise-induced changes in uterine artery blood flow, as measured by Doppler ultrasound, in pregnant subjects. Am.J.Perinatol. 1988; 5(2): 94-7.
11. Morris N, Osborn S, Wright H, Hart A. Effective uterine blood flow during exercise in normal and preeclpamtic pregnancies. Lancet 1956;361:481-3.
12. Morrow RJ, Ritchie JW, Bull SB. Fetal and maternal hemodynamic responses to exercise in pregnancy assessed by Doppler ultrasonography. Am.J.Obstet.Gynecol. 1989; 160(1): 138-40.
13. Pijpers L, Wladimiroff JW, McGhie J. Effect of short-term maternal exercise on maternal and fetal cardiovascular dynamics. Br.J.Obstet.Gynaecol. 1984;91(11):1081-6.
14. Rafla N, Beazely J. The effects of maternal exercise on fetal umbilical artery waveforms. Eur.J.Obstet.Gynecol.Reprod. Biol. 1991;1:119-23.

15. Revelli A, Durando A, Massobrio M. Exercise in pregnancy: a review of maternal and fetal effects. Obstet Gynecol Survey 1992;47:355-63.
16. Ruissen C, Jager W, von Drongelen M, Hoogland H. The influence of maternal exercise on the pulsatility index of the umbilical artery blood velocity waveform. Eur.J.Obstet.Gynecol.Reprod.Biol. 1990;37(1):1-6.
17. Schmidt W, Hendrik H, Gauwerky J, Junkermann H, Leucht W, Kubli F. Diagnosis of intrauterine growth retardation by intensive ultrasound biometry. Geburtsh Frauenheilk 1982;42: 543-8.
18. Steegers EA, Buunk G, Binkhorst RA, Jongsma HW, Wijn PF, Hein PR. The influence of maternal exercise on the uteroplacental vascular bed resistance and the fetal heart rate during normal pregnancy. Eur.J.Obstet.Gynecol.Reprod.Biol. 1988;27(1):21-6.
19. Van Hook JW, Gill P, Easterling TR, Schmucker B, Carlson K, Benedetti TJ. The hemodynamic effects of isometric exercise during late normal pregnancy. Am.J.Obstet.Gynecol. 1993;169(4):870-3.
20. Veille JC. Maternal and fetal cardiovascular response to exercise during pregnancy. Semin. Perinatol. 1996;20(4): 250-62.
21. Veille JC, Bacevice AE, Wilson B, Janos J, Hellerstein HK. Umbilical artery waveform during bicycle exercise in normal pregnancy. Obstet. Gynecol. 1989;73(6):957-60.