

Acute maternal exercise during the third trimester of pregnancy, influence on foetal heart rate.

Ejercicio físico durante el tercer trimestre de embarazo, influencia en la frecuencia cardiaca fetal.

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Abstract

A substantial amount of research has investigated the influence of physical exercise during pregnancy on certain maternal and foetal parameters. Regarding the behaviour of the foetal heart rate (FHR) during the maternal exercise certain controversy exists; as several investigations have studied this parameter obtaining varied results.

To test the hypotheses that the foetal heart rate (FHR) increases during maternal exercise, performed on a static bicycle during the third trimester. To know if the magnitude of the increase is related to gestational age or parity. This research involved a collaboration with the Gynaecology and Obstetrics Service of "Severo Ochoa" Hospital (Madrid) and Universidad Politécnica de Madrid (UPM). The approval of the Committee of Investigation as well as of the Ethical Commission of the Hospital was obtained. Twenty healthy pregnant women have been studied, in the last trimester. No women showed any medical complications in their pregnancy or contraindications for the practice of physical exercise. Informed consent was obtained. The exercise protocol consisted in the first part (rest), followed by a session of 20 minutes of moderate work (static bicycle exercise) and then rest until the FHR returned to the pre-exercise levels. Data for the evaluation of the FHR was obtained using an Electronic Foetal Monitor, Philips FM 20; and an Accurex Plus, Polar Electro OY was used for the control of the maternal heart rate. The clinical history of the pregnant women provided data about medical and personal factors. For the statistical analysis, Pearson correlation and Student's t test for unpaired data were used.

Our results show increases (11 - 36 beats/min, mean= 24 beats/min) of the FHR in all the studied cases. The gestational age shows no correlation with increments of FHR (Pearson 0.06) and there are larger increments of FHR in secundigravid (mean=152 ± 6.0 beats/min) than in primigravid (mean=147 ± 4.6 beats/min). Maternal aerobic and moderate exercise developing during last trimester increments FHR without harmful effects. These increments do not depend on the maternal age. Parity has influence on the level of increments of the FHR.

Key words: foetal heart rate; exercise; pregnancy

Resumen

Una cantidad importante de investigaciones han valorado la influencia del ejercicio físico durante el embarazo en ciertos parámetros fetales. En relación al comportamiento de la frecuencia cardiaca fetal (FCF) durante la realización del ejercicio existe cierta controversia, muchas investigaciones han estudiado este parámetro con resultados variados.

El objetivo de este estudio fue comprobar la hipótesis de un aumento de la FCF durante la realización de ejercicio en bicicleta estática en el tercer trimestre de embarazo. También conocer si esos aumentos se relacionan con la edad gestacional o la paridad de la gestante. Este estudio se ha desarrollado mediante una colaboración entre el Servicio de Ginecología y Obstetricia del Hospital Severo Ochoa de Leganés y la Universidad Politécnica de Madrid. Se obtuvo la aprobación del Comité de Investigación así como de la Comisión Ética. Fueron estudiadas 20 gestantes en el último trimestre, sin complicaciones ni contraindicaciones médicas para el ejercicio, cada mujer firmó un consentimiento informado. El protocolo de ejercicio consistió en una primera parte de reposo, una sesión de 20 minutos de trabajo moderado en bicicleta estática y el reposo final con retorno a los niveles normales de FCF. Los datos correspondientes a la FCF se obtuvieron por medio de un Monitor Fetal Electrónico Philips FM 20, y un pulsómetro Accurex Plus, Polar Electro OY, fue usado para el control de la frecuencia cardiaca materna. La historia clínica de cada gestante aportó datos relativos a características médicas y personales. Para el análisis estadístico se utilizaron mecanismos descriptivos, el índice de correlación de Pearson y la t de Student para comparación de medias.

Nuestros resultados muestran aumentos de la FCF de 11-36 lat/min (media de 24 lat/min). Los días de gestación no presentaron una correlación positiva con el nivel de los incrementos (Pearson 0.06). Hubo mayores aumentos en gestantes secundigravidas (media=152 ± 6.0 lat/min) que en primigravidas (media=147 ± 4.6 lat/min). El ejercicio aeróbico y moderado materno desarrollado durante el tercer trimestre de embarazo incrementa la FCF sin efectos perjudiciales. Los aumentos no dependen de la edad gestacional de la madre. La paridad de la gestante tiene influencia en el nivel de los incrementos.

Palabras claves: frecuencia cardiaca fetal; ejercicio; embarazo

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Introduction

With physical exercise becoming an integral part of life for many women, the question whether exercise during pregnancy may have an adverse effect on the growing foetus is very important (Riemann & Kanstrup, 2000. Gouveia et al, 2007).

A substantial amount of research has been carried out regarding the way in which maternal physical exercise during gestation affects the pregnancy outcome (Barakat, 2006). Little information exists however on the adaptive responses of the foetus to maternal physical exercise. New knowledge in this area will help to establish and update guidelines regarding maternal occupational and recreational physical activity (Sternfeld, 1997).

The study of foetal heart rate (FHR) patterns during maternal exercise provides a safe, non-invasive method to evaluate foetal wellbeing.

Many scientific studies report no harmful effects of aerobic and moderate maternal physical exercise on the foetal growth and development (Wolfe & Mottola, 1993. Clapp et al, 2002. Barakat et al, 2006).

Nevertheless, regarding the behaviour of the foetal heart rate (FHR) during maternal exercise the results are controversial, different results have been reported by various authors (Dale, Mullimax & Bryan, 1982. Gorski, 1985). This controversy is caused by the use of different research designs, regarding the type, intensity and duration of the physical activity performed by the pregnant woman.

The development of simple and easy protocols for physical exercise for pregnant women which are independent of their physical habits before pregnancy is highly desirable. As a result, such protocols could be used by the large proportion of the population of pregnant women, according to recent studies women want to exercise during pregnancy.

OBJECTIVE: The aim of this study is to test the hypotheses that the foetal heart rate (FHR) increases during maternal exercise performed on a static bicycle during the third trimester. Also to investigate whether the magnitude of the increase is related to gestational age or parity.

MATERIALS AND METHODS: This research has been carried out via a collaboration between the Gynaecology and Obstetrics Service of the Severo Ochoa Hospital Leganés (SGOHSO) and the Faculty of Physical Activity and Sport Sciences-INEF. Technical University of Madrid (UPM).

The approval of the Research Committee as well as of the Ethical Commission of the SOH was obtained. Each woman signed an informed consent before carrying out the program of physical activity.

Sample: The participants in the study were 20 healthy pregnant women, age between 21 and 38 years (mean=29.6 ± 4.3). Inclusion criteria for women was uncomplicated pregnancies and no

contraindications for the practice of physical exercise (ACOG, 2002. Artal, O'Toole & White, 2003). Ten of them were primigravid and the other ten were secundigravid. All 20 women were in the third trimester of their pregnancy however they had different gestational ages.

Procedure and measurements

The main study variable was the FHR, the physical exercise in the static bicycle was the independent variable. Also we valued the influence of the parity and gestational age as variables of importance. Relative to gestational age, although all pregnant women were all in the third trimester, it was important to know if the length of gestation (days) could influence the results. To minimize other factors the women were evaluated for the confounding variables: maternal age, parity, smoking, occupational activities and physical habits before and during pregnancy.

The clinical history of the pregnant women provided data about medical and personal factors (age, parity, smoking, gestational age, maternal weight gain, evolution of the arterial blood pressure). The 20 women were also interviewed regarding their occupational data as well as past and current habits of physical activity.

Protocol of physical exercise: the session of physical exercise included 20 minutes of work on a static bicycle with an intensity of 50-60% of FC máx.

For the estimate of the intensity of exercise we have used the Karvonen formulation (Colberg S, 2003) and the Borg Scale for perceived exertion adapted to the pregnancy (O'Neill et al, 1992). This mechanism tells us the ranges of maternal heart frequency at which each woman should work. During the realization of the protocol the pregnant women didn't overcome the limit of 140 beat/min, this it is the main recommendation (about intensity) for physical work during the pregnancy (ACOG, 2002).

The pregnant women carried out one session of physical exercise, we have obtained data corresponding to rest, 5 minutes, 10 minutes, 15 minutes and 20 minutes of exercise.

The foetal heart rate (FHR) was recorded by Electronic Foetal Monitor every 30 seconds. The recording period included 5 minutes before the exercise (rest), the 20 minutes of exercise on the static bicycle, and the recovery, which continued until the FHR returned to the pre-exercise levels. A graph of the behavior of the FHR was obtained for each case.

The mean of FHR of exercise phase and the mean of the increment of the FHR were also obtained.

The mean FHR of exercise was calculate using each one of the values after 5,10, 15 and 20 minutes. The increment in the FHR for each time period (0-5, 0-10, 0-15 and 0-20 minutes) was calculated using the individual increases of each one of the fetuses from rest during the corresponding time period of the maternal exercise.

For the recordings of the experimental data we used Electronic Foetal Monitor, Philips FM 20, for the evaluation of the FHR and Accurex Plus, Polar Electro OY, for the control of the maternal heart rate.

For the statistical analysis the SPSS 14.0 program was used to calculate the main variables:

- ✓ Mean of different stage of protocol and increment of FHR (Descriptive).
- ✓ Influence of gestational age (Pearson correlation).
- ✓ Influence of parity on FHR (Student's *t* test for unpaired data).

Using the Pearson correlation we looked at whether the increases of the FHR has relationship with the gestational age of the pregnant women, in other words if a bigger quantity of days of pregnancy was correlated with bigger increases in the FHR.

Also it has analyzed the influence of the confounding variables using:

- ✓ Influence of occupational activity on FHR (Anova test).
- ✓ Influence of smoking on FHR and influence of leisure time habits (Student's *t* test for unpaired data).
- ✓ To know if relationship existed between the pregnant woman's age and the maternal weight gain Pearson correlation was used.

Results

Table 1: Characteristics of the women involved in this study.

Maternal characteristics
Data are presented as mean \pm standard deviation or N (%) as appropriate.

| VARIABLE | |
|------------------------------------|--|
| Maternal Age (mean) | 29.6 \pm 4.3 |
| Parity ¹ | 0= 10 (50 %) 1= 10 (50 %) |
| None Smoking NS | NS= 14 (70 %) |
| Occupational activity ² | 1= 11 (55 %) 2= 5 (25 %) 3= 4 (20 %) |
| Gestational age (days) | 239 \pm 14.3 |
| Leisure time ³ | 0= 2 (10 %) 1= 18 (90 %) |
| Maternal weight gain | 10.9 \pm 2.5 |

¹ 0= No gestation before 1= One or more than one gestation before

² 1= Housewives 2= Sedentary job 3= Active job

³ 0= Sedentary 1= Active

Table 2: Behaviour of the FHR, during the seven different sections: rest (5 minutes), exercise (5, 10, 15 and 20 minutes), mean of FHR during exercise and increment of FHR.

Means of foetal heart rate. Descriptive Statistics

| | N | Mean | Std. Deviation |
|-----------------------|----|------|----------------|
| rest | 20 | 125 | 4,898 |
| 5 minutes (exercise) | 20 | 145 | 7,766 |
| 10 minutes (exercise) | 20 | 147 | 7,539 |
| 15 minutes (exercise) | 20 | 152 | 6,467 |
| 20 minutes (exercise) | 20 | 152 | 7,046 |
| mean exercise fphase | 20 | 149 | 5,914 |
| increment fhr | 20 | 24 | 7,650 |
| Valid N (listwise) | 20 | | |

Table 3: Pearson Correlation between FHR and Gestational Age of pregnant.

Pearson Correlation between Mean of FHR (exercise phase) and Gestational Age ($p < 0.05$)

Descriptive Statistics

| | Mean | Std. Deviation | N |
|------------------------|------|----------------|----|
| mean exercise phase | 149 | 5,914 | 20 |
| gestational age (days) | 239 | 14,153 | 20 |

Correlations

| | | mean exercise phase | gestational age |
|---------------------|---------------------|---------------------|-----------------|
| mean exercise phase | Pearson Correlation | 1 | ,060 |
| | Sig. (2-tailed) | | ,803 |
| | N | 20 | 20 |
| gestational age | Pearson Correlation | ,060 | 1 |
| | Sig. (2-tailed) | ,803 | |
| | N | 20 | 20 |

Table 4: Independent sample test between two groups of parity (0=primigravid and 1=secundigravid).

Student t test for Equality of Means. Parity and FHR.
Group Statistics

| | parity | N | Mean | Std. Deviation |
|---------------------|--------|----|------|----------------|
| rest | 0 | 10 | 124 | 4,909 |
| | 1 | 10 | 126 | 4,858 |
| 5 minutes | 0 | 10 | 144 | 6,533 |
| | 1 | 10 | 146 | 8,994 |
| 10 minutes | 0 | 10 | 144 | 6,408 |
| | 1 | 10 | 150 | 7,495 |
| 15 minutes | 0 | 10 | 151 | 6,795 |
| | 1 | 10 | 155 | 6,005 |
| 20 minutes | 0 | 10 | 148 | 6,038 |
| | 1 | 10 | 157 | 4,832 |
| mean exercise phase | 0 | 10 | 147 | 4,612 |
| | 1 | 10 | 152 | 6,068 |
| increment fhr | 0 | 10 | 23 | 8,134 |
| | 1 | 10 | 26 | 7,232 |

Independent Sample Test

| | t-test for Equality of Means | | | | | | |
|-----------------------|------------------------------|--------|-----------------|-----------------|-----------------------|---|--------|
| | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | Lower | Upper |
| rest | -1,053 | 18 | ,306 | -2,300 | 2,184 | -6,888 | 2,288 |
| | -1,053 | 17,998 | ,306 | -2,300 | 2,184 | -6,889 | 2,289 |
| 5 minutes (exercise) | -,740 | 18 | ,469 | -2,600 | 3,515 | -9,986 | 4,786 |
| | -,740 | 16,428 | ,470 | -2,600 | 3,515 | -10,036 | 4,836 |
| 10 minutes (exercise) | -2,052 | 18 | ,055 | -6,400 | 3,118 | -12,952 | ,152 |
| | -2,052 | 17,576 | ,055 | -6,400 | 3,118 | -12,963 | ,163 |
| 15 minutes (exercise) | -1,151 | 18 | ,265 | -3,300 | 2,868 | -9,325 | 2,725 |
| | -1,151 | 17,731 | ,265 | -3,300 | 2,868 | -9,331 | 2,731 |
| 20 minutes (exercise) | -3,680 | 18 | ,002* | -9,000 | 2,445 | -14,138 | -3,862 |
| | -3,680 | 17,174 | ,002* | -9,000 | 2,445 | -14,155 | -3,845 |
| mean exercise phase | -2,209 | 18 | ,040* | -5,325 | 2,410 | -10,388 | -,262 |
| | -2,209 | 16,796 | ,041* | -5,325 | 2,410 | -10,415 | -,235 |
| increment fhr | -,879 | 18 | ,391 | -3,025 | 3,442 | -10,256 | 4,206 |
| | -,879 | 17,757 | ,391 | -3,025 | 3,442 | -10,263 | 4,213 |

*Significant difference between groups ($p < 0.05$)

Our results show, in general, an increase in the FHR, that remains during the realization of the physical exercise protocol, of between 11 and 36 beats/min (table 2). On the other hand the increases does not show any relationship with the gestational age of the pregnant women, as can be seen by the very low (0.06) Pearson correlation (table 3). Regarding the parity, we observed a tendency to larger increments in FHR in the secundigravidas that in primigravidas, especially during the last phase of exercise (20 minutes) (table 4).

Discussion

This study was designed to examine the FHR response to a protocol of 20 minutes of aerobic and moderate maternal exercise during the third trimester.

It is very important to observe that the maternal and foetal heart rate kinetics are related, thought the placenta, where gas exchange, nutrient transport, metabolic excretion and endocrine production occur. For example, blood in the umbilical arteries is oxygenated at the placenta and returns to the foetal in the umbilical vein, which enter the liver and divides into the portal vein, which traverses the hepatic parenchyma and the ductus venosus, which by-passes the liver. This explains why the appropriate flow of maternal blood is a fundamental element for the correct circulation and health of the foetal organs (Wolfe, Brenner & Mottola, 1994).

During maternal exercise, blood flow to the exercising muscles is increased and blood flow to the visceral region is decreased (Manders et al, 1997. Rafla & Cook, 1999. Wolfe & Weissgerberg, 2003). The elevated levels of maternal catecholamine concentration which occur in response to exercise are also a problem; although the placenta contains a high concentration of catecholamine-metabolizing enzymes, approximately 10-15 % of the maternal catecholamine may reach the foetus. This could, in theory, reduce both uterine and umbilical blood flow. However some studies have reported that umbilical blood flow remains constant during maternal exercise (McMurray et al, 1993. Wolfe, Brenner & Mottola, 1994).

The principal question that remains to be answered is does the selective redistribution of blood flow during regular or prolonged exercise in pregnancy interfere with the trans-placental transport of oxygen, carbon dioxide and nutrients, and, if it does, what are the long term effects, if any? (Artal, O'Toole & White, 2003).

From the scientific point of view, it is important to understand the changes caused by maternal exercise to the FHR and the time for which these changes remain in the maternal-foetal organism (Barakat, 2006).

As discussed above, the study of FHR during maternal exercise has several important clinical implications. Maternal aerobic exercise may induce changes in FHR that are indicative of an adaptive response. This may be useful to identify women with previously undetected utero-placental insufficiency (Wolfe, Brenner & Mottola, 1994).

In recent years the FHR response to maternal exercise has been studied with mixed results (Artal, O'Toole & White, 2003).

Most of the authors report an increase of between 5-25 beats/minutes as the most common foetal response, with the increase appearing to be independent of gestational age (Collings, Curet and Mullin, 1983. Carpenter et al, 1988. Rafla & Cook, 1999. Avery et al, 1999. Macphail & Wolfe, 2000. Riemann & Kanstrup, 2000. Wolfe & Weissgerber, 2003. Kagan & Kun, 2004. Morris & Johnson, 2005). In women performing mild to moderate exercise the foetal heart rate returns to a pre-exercise baseline value within 15 minutes (Van Doorn et al, 1992. Clapp, Little & Capeless, 1993).

Other studies report minimal increases or they also report an appearance of transitory foetal bradycardia as a normal adaptive response, without harmful foetal consequences (Jovanovic, Kressler & Petersen, 1985. Artal et al, 1984).

Apparently, a number of factors may contribute to the FHR elevation in response to maternal exercise. These include an augmented state of foetal activity, an increased foetal temperature, or a moderate reduction in foetal PO₂ related to reduced uterine blood flow produced by maternal exercise. All of these factors could trigger an increase in the foetal sympathoadrenal catecholamine output leading in turn to an elevation of the FHR (Artal, Wiswell & Drinkwater, 1991).

Regarding foetal bradycardia, studies report that it is much more likely to occur after rather than during moderate exercise. The most reasonable explanation is a reduction in both uterine blood flow and uteroplacental oxygen delivery, which occurs in the immediate post-exercise period. Several lines of experimental evidence however, suggest that sporadic occurrences of moderate exercise-induced bradycardia in the fetuses of women experiencing healthy pregnancies are usually unimportant from a clinical point of view (Wolfe, Brenner & Mottola, 1994).

It should be recognized that foetal bradycardia is a normal fetoprotective reflex, which is accompanied by hypertension and redistribution of foetal cardiac output to favour vital organs including the brain, heart, adrenal gland and placenta. The apparent purpose of these autonomic reactions is to minimize the amount of oxygen used by the foetus. It is important to remember that the oxygen disposed by the foetus is obtained through the uterine blood flow, if this diminishes during the physical exercise, then the readiness of the foetal oxygen also diminishes. In answer to the decrease caused by the exercise, the reaction of the foetus is to use only the quantity of oxygen necessary for the vital organs. Thus, in such cases it is likely that foetal bradycardia is a normal foetal reflex response to maternal hemodynamic changes secondary to exercise (McMurray et al, 1993. Wolfe, Brenner & Mottola, 1994).

Our results show that, in all the cases that were analyzed, the elevations of the FHR oscillated between the 11 and the 36 beats/min (mean= 24 beats/min), hence confirming the hypothesis of this study. The increments in the FHR were independent of the length of gestation (during the third trimester of pregnancy) and the time it took the FHR to return to pre-exercise levels was between 5-7 minutes.

There was not a relationship between the means of the increments of the FHR and the gestational age. The possible relationship was looked for amongst each one of the four measured phases of the exercise protocol and it was observed that the gestational age was a non influential factor on the increments of the FHR.

The variable parity showed an influence in the level of increase of the FHR, after 20 minutes of exercise. The means for the two populations are: secundigravid (157 ± 4.8) and primigravid (148 ± 6.0), ($p=0.02$). We also note that the mean for the total duration of the protocol of FHR was higher in secundigravid (152 ± 6.0) than in primigravid (147 ± 4.6) ($p=0.04$). These results allow us to speculate that the secundigravid pregnant women have bigger increases of the FHR.

In this case (parity), studies with protocols of more duration and intensity are necessary.

No case of foetal bradycardia were observed, no foetus presented values of FHR below the 100 beats/min. during and after protocol.

The analyses of the results show us that none of the other confounding variables has had influence on the increases of the FHR

Conclusion

The common foetal response to maternal exercise on a static bicycle was observed to be an increase between 11 to 36 beats/min in the FHR for all the cases studied. Our findings support the hypothesis that FHR is increased as a protective mechanism of the foetus in response to the redistribution of blood flow produced by the maternal exercise.

There was no correlation between the length of gestation and the magnitude of the increase of FHR. Seemingly, parity has an influence on increment of FHR during aerobic exercise.

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References

- ACOG. American College of Obstetricians and Gynecologists. (2002) Exercise during pregnancy and the postpartum period. Committee Opinion N° 267 . Washington, DC. January. *Obstet Gynecol*; 99:171-3.
- Artal, R. O´Toole, M. and White, S. (2003) Guidelines of the American College of Obstetrician and Gynecologists for exercise during pregnancy and the postpartum period. *Br J Sports Med*; 37: 6-12.
- Artal, R. Romen, Y. Paul, R. and Wiswell, R. (1984): Foetal bradycardia induced by maternal exercise. *Lancet*, 2:258-60.
- Artal, R. Wiswell, R & Drinkwater, R. (1991) *Exercise in pregnancy*. Baltimore: Ed. Williams and Wilkins.
- Avery, N. Stocking, K. Tranmer, J. Davies, G. and Wolfe, L. (1999). Foetal responses to maternal strength conditioning exercises in late gestation. *Can J Appl Physiol*; 24(4): 362-376.
- Barakat Carballo, R. (2006) *El ejercicio físico durante el embarazo*. Madrid. Ed. Pearson Alhambra.
- Barakat Carballo, R. Alonso Merino, G. Rodríguez Cabrero, M. y Rojo Gonzalez, J. (2006) El ejercicio físico y los resultados del embarazo. *Prog Obstet Ginecol*, 49(11):630-8.
- Carpenter, M. Sady, S. Hoergsberg, B. et al. (1988) Foetal heart rate response to maternal exertion. *JAMA*; 259: 3006-3009.
- Clapp, JF III. Kim, H. Burciu, B. Schmitd, S. Petry, K. and Lopez B. (2002): Continuing regular exercise during pregnancy: effect of exercise volume on fetoplacental growth. *Am J Obstet Gynecol*; 186 (1):142-7.
- Clapp, JF III. Little, K. and Capeless, E. (1993). Foetal heart rate response to sustained recreational exercise. *Am J Obstet Gynecol*;168:198-206.
- Colbert, S. (2003) *Diabetes y ejercicio*. Madrid. Ed. Tutor.
- Collins, C. Curet, L. and Mullin J. (1983) Maternal and foetal responses to a maternal aerobic exercise program. *Am J Obstet Gynecol*; 145:702-707
- Dale, E. Mullimax, K. and Bryan, D. (1982): Exercise during pregnancy: effects on the fetus. *Can J Appl Sport Sci*; 7:2, 98-103.
- Gorski J. (1985) Exercise during pregnancy: maternal and foetal responses. A brief review. *Med Sci Sports Exerc*;17(4): 407-16.
- Gouveia, R. Martins, S. Sandes, AR. Nascimento, C. Figueira, J. Valente, S. Correia, S. Rocha, E. and Silva, LJ. (2007) Pregnancy and physical exercise: myths, evidence and recommendations. *Acta Med Port*. May-Jun; 20(3):209-14.
- Jovanovic, L. Kessler, A. and Peterson, C. (1985): Human maternal and foetal response to graded exercise. *J Appl Physiol*; 58: 1719-22.

Barakat, R.; Stirling, J.; Zakyntinaki, M.; Alejandro, L. (2008). Acute maternal exercise during the third trimester of pregnancy, influence on foetal heart rate. *Revista Internacional de Ciencias del Deporte*. 13(4), 33-43. <http://www.cafyd.com/REVISTA/01303.pdf>

Kagan, KO. and Kuhn, U. (2004) *Herz*, Jun; 29(4): 426-34.

Macphail, A. and Wolfe L. (2000) Maximal exercise testing in late gestation: foetal responses. *Obstet Gynecol*; 96: 565-70.

Manders, M. Sonder, G. Mulder, E. and Visser, G. (1997) The effects of maternal exercise on foetal heart rate and movement patterns. *Early Hum Dev*, May 28; 48(3): 237-47.

McMurray, R. Mottola, M. Wolfe, L. Artal, R. Millar, L and Pivarnik, J. (1993) Recent advances in understanding maternal an foetal responses to exercise. *Med Sci Sports Exerc*; 25(12): 1305-21.

Morris, S and Johson, N. (2005) Exercise during pregnancy: a critical appraisal of the literature. *J Reprod Med*; Mar; 50(3): 181-8.

O'Neill, M. Cooper, B. Mills, C. Boyce, E. and Hunyor, S. (1992) Accuracy of Borg's rating of perceived exertion in the prediction of heart rates during pregnancy. *Br J Sports Med*; 26(2): 121-124.

Rafla, N. and Cook, J. (1999) The effect of maternal exercise on foetal heart rate. *J Obstet Gynaecol*, Jul; 19(4): 381-4.

Riemann, M. and Kanstrup Hansen, L. (2000) Effects on the foetus of exercise in pregnancy. *Scand J Med Sci Sports*; (10): 12-19.

Van Doorn, M. Lotgering, F. Struijk, P. Jan Pool, B. and Wallenburg, H. (1992) Maternal and foetal cardiovascular responses to strenuous bicycle exercise. *Am J Obstet Gynecol*; 166: 854-9.

Wolfe, L. and Mottola, M. (1993) Aerobic exercise in pregnancy: an update. *Can J Appl Physiol*; 18: 119-147.

Wolfe, L. and Weissgerberg, T. (2003) Clinical physiology of exercise in pregnancy: a literature review. *J Obstet Gynaecol Can*; 25(6): 451-3.

Wolfe, L. Brenner, I. and Mottola, M. (1994) Maternal exercise, foetal well-being and pregnancy outcome. *Exerc Sport Sci Rev*; 22: 145-94.