
**International Journal of Innovative Technologies in Social Science**

e-ISSN: 2544-9435

**Operating Publisher**
**SciFormat Publishing Inc.**
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
editorial-office@sciformat.ca

| | |
|---|---|
| **ARTICLE TITLE** | DIFFERENT EXERCISE MODALITIES DURING PREGNANCY AND THEIR IMPACT ON MATERNAL AND FETAL HEART RATE VARIABILITY |
| **DOI** | https://doi.org/10.31435/ijitss.1(49).2026.4784 |
| **RECEIVED** | 08 January 2026 |
| **ACCEPTED** | 18 March 2026 |
| **PUBLISHED** | 30 March 2026 |
| **LICENSE** | The article is licensed under a **Creative Commons Attribution 4.0 International License.** |

# DIFFERENT EXERCISE MODALITIES DURING PREGNANCY AND THEIR IMPACT ON MATERNAL AND FETAL HEART RATE VARIABILITY

***Zofia Bogiel*** *(Corresponding Author, Email: zofiabogiel112@gmail.com)*
*National Medical Institute of the Ministry of Interior and Administration in Warsaw, Wołoska 137 Street, 02-507 Warszawa, Poland*
*ORCID ID: 0009-0002-5425-4906*

***Antonina Machała***
*Independent Public Complex of Health Care Facilities in Płońsk, Henryka Sienkiewicza 7, 09-100 Płońsk, Poland*
*ORCID ID: 0009-0004-3684-4579*

***Andrzej Domański***
*Independent Public Complex of Health Care Facilities in Płońsk, Henryka Sienkiewicza 7, 09-100 Płońsk, Poland*
*ORCID ID: 0009-0001-6041-8359*

***Małgorzata Dziekońska***
*Independent Public Complex of Health Care Facilities in Kozienice, Władysław Sikorski 10 Street, 26-900 Kozienice, Poland*
*ORCID ID: 0009-0009-9597-6017*

***Klaudia Kowalczyk***
*Independent Public Complex of Health Care Facilities in Płońsk, Henryka Sienkiewicza 7, 09-100 Płońsk, Poland*
*ORCID ID: 0009-0004-6442-0589*

***Martyna Wójcik***
*Scanmed Specialist Clinics – Rudolf Weigl Hospital in Blachownia, Sosnowa 16 Street, 42-290 Blachownia, Poland*
*ORCID ID: 0009-0005-6003-3474*

***Andrzej Wydrych***
*Independent Public Complex of Health Care Facilities in Płońsk, Henryka Sienkiewicza 7, 09-100 Płońsk, Poland*
*ORCID ID: 0009-0004-8466-2892*

**ABSTRACT**

**Introduction:** Heart rate variability (HRV), reflecting autonomic nervous system activity, emerges as a valuable, non-invasive marker for monitoring maternal and fetal health. It correlates with psychological resilience, inflammatory balance and overall cardiovascular fitness. Although physical activity in pregnancy is widely recommended for its broad health benefits, studies describing its effects on HRV remain limited.
**Methods:** We conducted a comprehensive literature search on Pubmed and Medline databases, with 20 articles selected as relevant to the subject of the study. We included studies where HRV was measured in healthy women in singleton pregnancy who performed various exercise modalities. We excluded the studies where pregnant women took medication which directly affected the cardiovascular system.
**Research objective:** This review aims to synthesize current findings on how different types, intensity and frequency of exercise impact HRV in pregnant women and their fetuses.
**Key findings:** Existing studies demonstrate that low-intensity activities, such as yoga, effectively improve maternal HRV by enhancing parasympathetic tone. Aerobic and Moderate-to-Vigorous Physical Activity (MVPA) also contributes positively when practiced consistently. Research additionally suggests that regular maternal exercise positively influences fetal HRV, indicating better autonomic development and emotional regulation extending into infancy.
**Conclusions:** In conclusion, structured physical activity during pregnancy has the potential to optimize autonomic control in both mothers and their offspring. HRV monitoring may serve as a useful tool for individualizing exercise prescriptions, enhancing maternal-fetal outcomes and help shape future public health guidelines. Further research is needed to clarify optimal exercise protocols in pregnant populations.

**KEYWORDS**

Heart Rate Variability, Pregnancy, Physical Activity, Autonomic Nervous System

**CITATION**

Zofia Bogiel, Antonina Machała, Andrzej Domański, Małgorzata Dziekońska, Klaudia Kowalczyk, Martyna Wójcik, Andrzej Wydrych. (2026) Different Exercise Modalities During Pregnancy and Their Impact on Maternal and Fetal Heart Rate Variability. *International Journal of Innovative Technologies in Social Science*. 1(49). doi: 10.31435/ijitss.1(49).2026.4784



## Introduction

Pregnancy is associated with several changes in the body's cardiophysiology such as increased heart-rate (HR) at rest by 15-20 beats-per-minute, circulating blood volume by 50% and decreased blood pressure by approximately 10 mmHg (Nakagaki et al. 2016; Brębborowicz 2024). Among cardiovascular adaptations during healthy pregnancy there is also altered autonomic function, which leans towards sympathetic activity dominance (Nakagaki et al. 2016; Purdy et al. 2019; Jaques et al. 2024; May et al. 2016; Dietz et al. 2016; Carpenter et al. 2015)

Heart rate variability (HRV) that is defined by the beat-to-beat variation in the duration of R-R interval (Shaffer et al. 2014), as an indicator of autonomic nervous system (ANS) tone (May, Scholtz, et al. 2014) proves itself a non-invasive marker in monitoring maternal and fetal health (Shaffer et al. 2014; Rowan et al. 2022) and correlates with psychological resilience and adaptability to ever-changing circumstances of the environment (Shaffer et al. 2014). Decreased HRV is frequently reported in depression and anxiety disorders in pregnancy (Shea et al. 2008) and correlate with lower parasympathetic activation which corresponds to increase in markers of inflammation and greater risk of all-cause mortality (Thayer et al. 2010). When considering fetal HRV, according to (May, Suminski, et al. 2014), increased fetal HRV improves motor development indices, influences body composition and allows for a better development of speech at 2 years of age.

Physical activity has a beneficial effect on both mother and fetus (Nakagaki et al. 2016; Jaques et al. 2024; Davenport et al. 2016) such as smaller maternal weight gain (Jaques et al. 2024; Stutzman et al. 2010), improvement in cardioautonomic control by facilitating sympathovagal balance (Jaques et al. 2024; Dietz et al. 2016; May, Suminski, et al. 2014; Stutzman et al. 2010), as well as better fetal prognoses (Jaques et al.

2024). Exercising also seems to reduce the incidence of gestational diabetes, hypertension and preeclampsia (May, Suminski, et al. 2014).

As many authors have stated (Jaques et al. 2024; Dietz et al. 2016; May, Suminski, et al. 2014; Carpenter, Emery, O. Uzun, et al. 2017; Carpenter, Emery, O Uzun, et al. 2017), there is still a shortage of studies examining changes in HRV in relation to different exercise protocols or optimal intensity of physical activity, especially in pregnant women. This research gap calls for evidence-based exercise recommendations for optimizing HRV outcomes in these groups.

The aim of this study is to examine different modalities and intensities of physical exercise and determine optimal exercise regime in pregnancy to improve autonomic control of pregnant women, as well as their children.

**Methods**

For the purpose of identification of suitable studies the following databases were searched: PubMed and Medline. Keywords used were “HRV”, “heart rate variability”, “physical activity”, “exercise”, “pregnancy”, “pregnant”, which were subsequently connected with the logic operators (AND, OR) to ensure a broad context of literature about the topic (detailed search query in the Appendix). Out of the searched 157 articles from PubMed and 1097 from Medline dating from 1979 to 2025, 20 articles were selected as relevant to the topic of this study. The majority of rejected articles didn’t meet the exact criteria of HRV measurement in pregnancy, involving physical activity. Selected 20 studies dated from 2001 to 2024, mainly from the last 10 years. All of the studies taken into account involved singleton healthy pregnancies, where women were not prescribed medication that would affect heart rate or blood pressure.

There are several methods to assess HRV, RMSSD being one of the most common indices in analysed studies. The RMSSD is the root mean square of successive differences between normal heartbeats calculated using R-R time intervals in milliseconds (Shaffer et al. 2014). Lower RMSSD values correlate with reduced vagal tone, implying stress or fatigue (Schmitt et al. 2015). Another frequently analyzed time-domain parameter is SDNN, which describes standard deviation of N-N intervals. SDNN is influenced both by parasympathetic and sympathetic nervous system, where higher SDNN values indicate better autonomic balance and lower signify poor cardiovascular health or stress. Most common frequency-domain parameters include low frequency-power (LF), high frequency power (HF) and LF/HF ratio. LF is strongly linked to the baroreflex function and describes both sympathetic and parasympathetic influence. HF reflects vagal activity and is directly linked to respiration. Higher LF and HF values indicate better autonomic control. LF/HF ratio is used as a marker of sympathetic vs parasympathetic dominance, higher LF/HF meaning decreased vagal tone. Among other HRV indices, very-low-frequency power (VLF) is associated with hormonal balance and inflammation, where increased VLF reflects sympathetic domination and decreased inflammatory response (Shaffer et al. 2014).

HRV measurement techniques varied across included studies. Most commonly, HRV was assessed via electrocardiography (ECG), though some studies utilized wearable monitors such as electronic watches or bands, as well as magnetocardiography (MCG) to measure fetal HRV specifically. The duration of HRV recording ranged from short-term recording sessions (5-10 min resting state recordings) to 24/7 at-home monitoring. Time-domain (e.g., RMSSD, SDNN) and frequency-domain (e.g., LF, HF, LF/HF ratio) were reported inconsistently across studies. Furthermore, data collection protocols differed with regard to participant posture (e.g., supine, seated), breathing control, and timing in relation to physical activity. These methodological differences were taken into account during data synthesis and interpretation.

**Analysis of the literature**

Available studies were analysed by type of exercise (aerobic/Moderate-to-Vigorous Physical Activity - MVPA, strength training, yoga, walking, mixed), intensity, duration and frequency of performed physical activity, as well as the impact on mother and fetus independently. Analyzed studies were briefly described in Table 1.

**Table 1.**

| No | Study | Type and intensity of exercise | Regularity |
|---|---|---|---|
| 1. | Effect of integrated yoga on stress and heart rate variability in pregnant women - Satyapriya et al. International Journal of Gynecology & Obstetrics 2009 | Yoga vs prenatal exercises combined with deep relaxation techniques (DRT) and supine rest respectively; low intensity | Once a week |
| 2. | The Effects of Exercise Conditioning in Normal and Overweight Pregnant Women on Blood Pressure and Heart Rate Variability - Stutzman et al. Biological Research For Nursing 2010 | Walking; low-intensity | 5 days a week up to 3 km |
| 3. | Influence of somatic state on cardiovascular measurements in pregnancy - D'Silva et al. Physiological Measurement 2014 | Stepping exercise; low-intensity | 4 sessions: at the end of each trimester and post-partum |
| 4. | Changes in heart rate variability and QT variability during the first trimester of pregnancy - Carpenter et al. Physiological Measurement 2015 | Stepping exercise; low intensity | 4 sessions: at the end of each trimester and post-partum |
| 5. | Effects of Stretching Exercise on Heart Rate Variability During Pregnancy - Logan et al. Journal of Cardiovascular Nursing 2017 | Stretching; low-intensity | Single session |
| 6. | Effect of Prenatal Yoga on Heart Rate Variability and Cardio-Respiratory Synchronization: A Prospective Cohort Study - Žebeljan et al. Journal of Clinical Medicine 2022 | Yoga; low-intensity VS walking; moderate-intensity | Yoga group: 90 min once a week; Walking group: 3 30-min-sessions |
| 7. | Effect of Prenatal Yoga versus Moderate-Intensity Walking on Cardiorespiratory Adaptation to Acute Psychological Stress: Insights from Non-Invasive Beat-to-Beat Monitoring - Lučovnik et al. Sensors 2024 | Yoga; low-intensity VS walking; moderate-intensity | Yoga group: 90 min once a week; Walking group: 3 30-min-sessions |
| 8. | Effects of Exercise During Pregnancy on Maternal Heart Rate and Heart Rate Variability - May et al. PM&R 2016 | Aerobic; Moderate intensity | 3x a week |
| 9. | Maternal cardioautonomic responses during and following exercise throughout pregnancy - Purdy et al. Applied Physiology, Nutrition, and Metabolism 2019 | MVPA - Moderate-to-vigorous Physical Activity | Single session |
| 10. | Monitoring one heart to help two: heart rate variability and resting heart rate using wearable technology in active women across the perinatal period - Rowan et al. BMC Pregnancy and Childbirth 2022 | MVPA | Recorded minutes of activity on a daily basis |
| 11. | Influence of antenatal physical exercise on heart rate variability and QT variability - Carpenter et al. The Journal of Maternal-Fetal & Neonatal Medicine 2017 | 18 minutes of recumbent cycling, 10 minutes of stretching and toning exercises and 15 minutes of pelvic floor exercises; moderate intensity | 4 sessions: at the end of each trimester and post-partum |
| 12. | Influence of physical exercise on baroreceptor sensitivity during pregnancy - Carpenter et al. The Journal of Maternal-Fetal & Neonatal Medicine 2017 | 18 minutes of recumbent cycling, 10 minutes of stretching and toning exercises and 15 minutes of pelvic floor exercises; moderate intensity | 4 sessions: at the end of each trimester and post-partum |

| No | Study | Type and intensity of exercise | Regularity |
|---|---|---|---|
| 13. | Effects of human pregnancy on cardiac autonomic function above and below the ventilatory threshold - Avery et al. Journal of Applied Physiology 2001 | Cycling on a cycloergometer; Moderate to high intensity | Single session |
| 14. | Differences in autonomic neural activity during exercise between the second and third trimesters of pregnancy - Nakagaki et al. Journal of Obstetrics and Gynaecology Research 2016 | Cycling; moderate intensity | Single session |
| 15. | Aerobic exercise during pregnancy influences fetal cardiac autonomic control of heart rate and heart rate variability - May et al. Early Human Development 2010 | Aerobic; moderate intensity | 30 min 3x/a week |
| 16. | Regular Maternal Exercise Dose and Fetal Heart Outcome - May et al. Medicine & Science in Sports & Exercise 2012 | Mixed, mostly aerobic | Recorded minutes of activity on a daily basis |
| 17. | Fetal cardiac autonomic control during breathing and non-breathing epochs: The effect of maternal exercise - Gustafson et al. Early Human Development 2012 | MVPA | 30 min 3x/a week |
| 18. | Maternal physical activity mode and fetal heart outcome - May et al. Early Human Development 2014 | Mixed; continuous and intermittent Leisure-Time Physical Activity (LTPA) | Recorded minutes of activity on a daily basis |
| 19. | Aerobic exercise during pregnancy influences infant heart rate variability at one month of age - May et al. Early Human Development 2014 | Aerobic; moderate intensity | 30 min for 3x/week |
| 20. | Preliminary findings of emotion regulation in 12-month-old infants of mothers enrolled in a randomized controlled trial assessing a nutrition + exercise intervention - Mortaji et al. Developmental Psychobiology 2023 | 10 000 steps/day + walking program; low intensity | walking program 25 min for 3-4x/week |

**Maternal HRV**

In terms of exercise type, the effects of yoga were the most consistent among studies in raising HRV in pregnant women (Satyapriya et al. 2009; Lučovnik et al. 2024; Žebeljan et al. 2022). Satyapriya et al. reported increased parasympathetic activity and stress reduction in women practicing integrated yoga approach on a regular basis. In the same study, stretching or prenatal exercises tested similarly to yoga, decreasing LF/HF ratio and increasing vagal tone in 20 weeks of gestation, with the effects enhanced in 36 weeks of gestation for the yoga group. Even a single session of stretching might bring benefits to balancing HRV, significantly increasing SDNN and RMSSD (Logan and Yeo 2017). Other studies examining low-intensity exercise modalities in the first trimester of pregnancy such as stepping exercise (Carpenter et al. 2015; D'Silva et al. 2014) performed for 6 minutes as a part of the measurement protocol, didn't agree as to whether short gentle forms of exercise impact HRV indices, shifting the autonomic tone towards sympathetic or parasympathetic domination, however it must be of note that in those studies only response to exercise performed during one-per-trimester session was measured. Stutzman et al. found that low-intensity walking helped mitigate HRV decline over gestation both in normal-weight and overweight women. Interestingly, it also showed sharper decline in HF power at rest (after low-intensity single-session cycloergometer exercise) in the control group than in the walking group, implying better autonomic regulation in women enrolled in the walking program.

Commonly recommended in pregnancy (Kwiatkowska et al., 2023; "Physical Activity and Exercise During Pregnancy and the Postpartum Period" ACOG Committee Opinion, 2020), also connected with improved HRV in non-pregnant populations (Manresa-Rocamora et al. 2021), aerobic exercise has been examined in several studies in terms of optimizing autonomic balance. According to Rowan et al. physical activity improved HRV, diminishing the HRV drop seen in pregnancy. Another study (Purdy et al. 2019) suggested better HRV recovery after MVPA in pregnant women than in non-pregnant controls. Moreover, measurements before and after PA showed higher sympathetic tone at rest in pregnancy, however during peak exercise pregnant women experienced less sympathetic activation than non-pregnant ones. These findings support exercise safety in pregnancy. The effect of improved

autonomic function in women who performed aerobic training regularly was even more pronounced in women with lower pre-pregnancy BMI (May et al. 2016).

Additionally, several authors considered an impact of mixed forms of exercise on HRV in pregnant women. However, in studies by Carpenter et al. 2017 where women performed mixed forms of exercise (cycling, toning, stretching and pelvic floor exercises) once a week, researchers showed a decline in parasympathetic tone reflected in RMSSD and HF in exercising pregnant women compared to those that didn't.

As aforementioned studies revealed, although short-term HRV might be blunted in the recovery period after exercise (Purdy et al. 2019), long-term maternal HRV response (May et al. 2016; Rowan et al. 2022) and the effect on the fetus (May, Scholtz, et al. 2014; Mortaji et al. 2023) were consistently positive across the studies examining regular moderate PA.

Studies on high-intensity training in pregnancy are limited in the context of HRV changes, although (Avery et al. 2001) showed that during a single session of high-intensity training sympathetic response was blunted in pregnant women as opposed to non-pregnant. Conversely, sympathetic activity during a single-session vigorous physical activity in the 3rd trimester was increased in comparison to the 2nd trimester, which raises concerns about strenuous exercise in otherwise sedentary women (Nakagaki et al. 2016). Although it is unclear whether higher exercise volume (>150 min/week) leads to better HRV outcomes, it seems that with increasing cumulative duration of exercise, the beneficial effects increased as well (May et al. 2012).

**Fetal HRV**

After analyzing maternal HRV changes, we next turn to the effects of physical activity on fetal autonomic control. (May, Suminski, et al. 2014) studied fetal HRV and divided activities performed by pregnant women in two groups - continuous and intermittent leisure-time physical activities (LTPA), where examples of continuous LTPA were jogging and walking; while for intermittent - strength training and yoga. Continuous LTPA showed positive correlation with fetal HRV observed in SDNN, VLF, LF and HF parameters, while impact of intermittent LTPA was significantly less prominent, although a positive correlation between intermittent LTPA and SDNN could be found. In this study by (May et al. 2012) HRV of the fetus was measured and fetal overall SDNN values significantly improved (increase of 0,5% for every hour of exercise and 4% increase for every unit of intensity), RMSSD values improved as well (0,5% for every additional hour of exercise). In a similar manner, (May et al. 2010) showed that aerobic training 3x/a week for 30 minutes had beneficial effects on fetal HRV at 36 week GA on all studied HRV indices. Regular maternal PA also had long-lasting positive effects on infant cardiac autonomic control (May, Scholtz, et al. 2014) and emotional regulation (Mortaji et al. 2023). Influence of aerobic exercise in pregnancy can also be seen during fetal *in utero* breathing movements, improving fetal vagal tone as well as reducing sympathetic withdrawal, possibly resulting in improved autonomic balance and ANS development (Gustafson et al. 2012).

**Discussion**

What is worth remembering is that pregnancy itself impacts HRV in women 32-34 (Mishra et al. 2024; Sarhaddi et al. 2022; Bossung et al. 2023) - HRV time-domain parameters decline slowly throughout pregnancy, reaching nadir 5-10 weeks before delivery, then recover. As to frequency-domain parameters, LF and HF decrease during the 2nd trimester, while in the 3rd trimester and post-partum HF increases. HRV parameters were observed to come back to pre-pregnancy levels 3 months after delivery, although optimal follow-up time of 6 months after giving birth is suggested (Heiskanen et al. 2008). Interestingly, higher level of education correlated with increased SDNN, RMSSD and HF indices (Sarhaddi et al. 2022), which may be due to lower levels of stress in highly educated women (Fiocco et al. 2007; Cardwell 2013). Age correlated negatively with all measured HRV parameters, except LF/HF (Shaffer and Ginsberg 2017). The link between BMI and HRV values was not clearly defined (Sarhaddi et al. 2022). Another factor to consider is twin pregnancies, where vagal influence is significantly decreased (lower RMSSD, SDNN and HF) (Meah et al. 2021).

There is also evidence that during acute exercise in the 3rd trimester, women experience increased sympathetic activation, in comparison to the 2nd trimester (Nakagaki et al. 2016). Regular exercise modifies these trends, slowing down the HRV decline in the 1st trimester and then reducing late HRV increase (Rowan et al. 2022). Low-intensity exercise and relaxation might also have statistically more pronounced effects in the 3rd trimester (Satyapriya et al. 2009).

**Conclusions**

Although HRV in healthy pregnancy declines in comparison to non-pregnant women, regular physical activity can improve HRV outcomes, restoring autonomic balance and improving parasympathetic tone. This effect was the most prominent in women performing low-intensity PA such as yoga, stretching or walking, especially connected with relaxation techniques. As to aerobic or MVPA, regularity of exercise is the key factor in achieving beneficial HRV changes. Conversely, if the activity wasn't regularly repeated, it had a detrimental impact on HRV indices, signifying increased sympathetic domination and stress. Additionally, there is evidence that short-term sympathetic response to exercise in the 3rd trimester is blunted, indicating that the organism might have a decreased ability to adapt to high-intensity training during this period. Although strength training might also bring benefits, evidence points mainly to exercise supporting cardiovascular health, such as aerobic, or low-intensity training. It is yet unclear whether HIT brings additional benefits regarding HRV, due to shortage of studies on this topic in the pregnant population. However, in terms of fetal HRV, physical activity performed in pregnancy seems to have a cumulative positive effect on fetal cardioautonomic control and autonomic system development, possibly through epigenetic factors, although more studies would be needed to determine this hypothesis. Moreover, the positive impact of physical activity persisted to infancy, improving emotional regulation in children. To summarize, HRV might be useful in monitoring exercise safety in pregnancy, helping to identify physical training overload, as well as following the changes and trends in HRV indices as the indicators of autonomic nervous system adaptation to ongoing pregnancy.

This review summarizes the available evidence on the influence of different exercise modalities and intensities, as well as timing of PA during pregnancy. Notable strengths of this review are the comprehensive search strategy and focus on both maternal and fetal outcomes. However, due to heterogeneity of study designs, small sample sizes and differences in HRV measuring tools and protocols might limit the ability to draw definitive conclusions.

The relationship between HRV and different exercise modalities across pregnancy still requires more research, especially regarding the impact of strength and high-intensity training on HRV indices, as well as studying larger groups of pregnant women (preferably in randomized controlled trials) across pregnancy stages. There are also some inconsistencies across HRV monitoring methods, which require standardization in future studies. The integration of HRV monitoring into clinical practice might help personalize physical activity intervention in the form of individual 'exercise prescription' and enable HRV-guided training approach to maximize positive HRV outcomes, both maternal and fetal. Additionally, acquired data might be of value in terms of creating future exercise recommendations in pregnancy or public health programs focused on optimizing cardiovascular health of the future generations.

**Appendix**

((("heart rate"[MeSH Terms] OR ("heart"[All Fields] AND "rate"[All Fields]) OR "heart rate"[All Fields]) AND ("variabilities"[All Fields] OR "variability"[All Fields] OR "variable"[All Fields] OR "variable s"[All Fields] OR "variables"[All Fields] OR "variably"[All Fields])) OR "hrv"[All Fields]) AND ("pregnancy"[MeSH Terms] OR "pregnancy"[All Fields] OR "pregnancies"[All Fields] OR "pregnancy s"[All Fields] OR ("pregnant"[All Fields] OR "pregnants"[All Fields])) AND ("exercise"[MeSH Terms] OR "exercise"[All Fields] OR ("physical"[All Fields] AND "activity"[All Fields]) OR "physical activity"[All Fields] OR ("exercise"[MeSH Terms] OR "exercise"[All Fields] OR "exercises"[All Fields] OR "exercise therapy"[MeSH Terms] OR ("exercise"[All Fields] AND "therapy"[All Fields]) OR "exercise therapy"[All Fields] OR "exercising"[All Fields] OR "exercise s"[All Fields] OR "exercised"[All Fields] OR "exerciser"[All Fields] OR "exercisers"[All Fields]))

## REFERENCES


1. Avery, N. D., Wolfe, L. A., Amara, C. E., Davies, G. A. L., & McGrath, M. J. (2001). Effects of human pregnancy on cardiac autonomic function above and below the ventilatory threshold. *Journal of Applied Physiology, 90*(1), 321–328. https://doi.org/10.1152/jappl.2001.90.1.321
2. Bossung, V., Singer, A., Ratz, T., Rothenbühler, M., Leeners, B., & Kimmich, N. (2023). Changes in heart rate, heart rate variability, breathing rate, and skin temperature throughout pregnancy and the impact of emotions—A longitudinal evaluation using a sensor bracelet. *Sensors, 23*(14), 6620. https://doi.org/10.3390/s23146620
3. Bręborowicz, G. H. (2024). *Położnictwo* (Vol. 1, 3rd ed.). PZWL Wydawnictwo Lekarskie.
4. Cardwell, M. S. (2013). Stress: Pregnancy considerations. *Obstetrical & Gynecological Survey, 68*(2), 119–129. https://doi.org/10.1097/OGX.0b013e31827f2481
5. Carpenter, R. E., D'Silva, L. A., Emery, S. J., Uzun, O., Rassi, D., & Lewis, M. J. (2015). Changes in heart rate variability and QT variability during the first trimester of pregnancy. *Physiological Measurement, 36*(3), 531–545. https://doi.org/10.1088/0967-3334/36/3/531
6. Carpenter, R. E., Emery, S. J., Uzun, O., Rassi, D., & Lewis, M. J. (2017). Influence of antenatal physical exercise on heart rate variability and QT variability. *The Journal of Maternal-Fetal & Neonatal Medicine, 30*(1), 79–84. https://doi.org/10.3109/14767058.2016.1163541
7. Carpenter, R. E., Emery, S. J., Uzun, O., Rassi, D., & Lewis, M. J. (2017). Influence of physical exercise on baroreceptor sensitivity during pregnancy. *The Journal of Maternal-Fetal & Neonatal Medicine, 30*(5), 514–519. https://doi.org/10.1080/14767058.2016.1179275
8. Davenport, M. H., Skow, R. J., & Steinback, C. D. (2016). Maternal responses to aerobic exercise in pregnancy. *Clinical Obstetrics & Gynecology, 59*(3), 541–551. https://doi.org/10.1097/GRF.0000000000000201
9. Dietz, P., Watson, E. D., Sattler, M. C., Ruf, W., Titze, S., & Van Poppel, M. (2016). The influence of physical activity during pregnancy on maternal, fetal or infant heart rate variability: A systematic review. *BMC Pregnancy and Childbirth, 16*(1), 326. https://doi.org/10.1186/s12884-016-1121-7
10. D'Silva, L. A., Davies, R. E., Emery, S. J., & Lewis, M. J. (2014). Influence of somatic state on cardiovascular measurements in pregnancy. *Physiological Measurement, 35*(1), 15–29. https://doi.org/10.1088/0967-3334/35/1/15
11. Fiocco, A. J., Joober, R., & Lupien, S. J. (2007). Education modulates cortisol reactivity to the Trier Social Stress Test in middle-aged adults. *Psychoneuroendocrinology, 32*(8–10), 1158–1163. https://doi.org/10.1016/j.psyneuen.2007.08.008
12. Gustafson, K. M., May, L. E., Yeh, H.-W., Million, S. K., & Allen, J. J. B. (2012). Fetal cardiac autonomic control during breathing and non-breathing epochs: The effect of maternal exercise. *Early Human Development, 88*(7), 539–546. https://doi.org/10.1016/j.earlhumdev.2011.12.017
13. Heiskanen, N., Saarelainen, H., Valtonen, P., et al. (2008). Blood pressure and heart rate variability analysis of orthostatic challenge in normal human pregnancies. *Clinical Physiology and Functional Imaging, 28*(6), 384–390. https://doi.org/10.1111/j.1475-097X.2008.00818.x
14. Jaques, L. A., Stermer, P. R. R., De Oliveira, A. K. B., et al. (2024). Autonomic modulation of heart rate during physical activity in pregnant women: A systematic review of literature. *Pacing and Clinical Electrophysiology, 47*(6), 802–814. https://doi.org/10.1111/pace.14976
15. Kwiatkowska, E., Kajdy, A., Sikora-Szubert, A., et al. (2023). Rekomendacje Polskiego Towarzystwa Ginekologów i Położników (PTGiP) oraz Polskiego Towarzystwa Medycyny Sportowej (PTMS) dotyczące aktywności fizycznej w ciąży i w czasie po porodzie. *Ginekologia i Perinatologia Praktyczna, 8*(2), 114–128. https://www.ptgin.pl/sites/scm/files/2024-08/Rekomendacje%20Polskiego%20Towarzystwa%20Ginekolog%C3%B3w%20i%20Po%C5%82o%C5%BCnik%C3%B3w%20%28PTGiP%29%20oraz%20Polskiego%20Towarzystwa%20Medycyny%20Sportowej%20%28PTMS%29%20dotycz%C4%85ce%20aktywno%C5%9Bci%20fizycznej%20w%20ci%C4%85%C5%BCy%20i%20w%20czasie%20po%20porodzie.pdf
16. Logan, J. G., & Yeo, S. (2017). Effects of stretching exercise on heart rate variability during pregnancy. *Journal of Cardiovascular Nursing, 32*(2), 107–111. https://doi.org/10.1097/JCN.0000000000000326
17. Lučovnik, M., Lackner, H. K., Žebeljan, I., et al. (2024). Effect of prenatal yoga versus moderate-intensity walking on cardiorespiratory adaptation to acute psychological stress: Insights from non-invasive beat-to-beat monitoring. *Sensors, 24*(5), 1596. https://doi.org/10.3390/s24051596
18. Manresa-Rocamora, A., Sarabia, J. M., Javaloyes, A., Flatt, A. A., & Moya-Ramón, M. (2021). Heart rate variability-guided training for enhancing cardiac-vagal modulation, aerobic fitness, and endurance performance: A methodological systematic review with meta-analysis. *International Journal of Environmental Research and Public Health, 18*(19), 10299. https://doi.org/10.3390/ijerph181910299
19. May, L. E., Glaros, A., Yeh, H.-W., Clapp, J. F., & Gustafson, K. M. (2010). Aerobic exercise during pregnancy influences fetal cardiac autonomic control of heart rate and heart rate variability. *Early Human Development, 86*(4), 213–217. https://doi.org/10.1016/j.earlhumdev.2010.03.002

20. May, L. E., Knowlton, J., Hanson, J., et al. (2016). Effects of exercise during pregnancy on maternal heart rate and heart rate variability. *PM&R, 8*(7), 611–617. https://doi.org/10.1016/j.pmrj.2015.11.006
21. May, L. E., Scholtz, S. A., Suminski, R., & Gustafson, K. M. (2014). Aerobic exercise during pregnancy influences infant heart rate variability at one month of age. *Early Human Development, 90*(1), 33–38. https://doi.org/10.1016/j.earlhumdev.2013.11.001
22. May, L. E., Suminski, R. R., Berry, A., Langaker, M. D., & Gustafson, K. M. (2014). Maternal physical activity mode and fetal heart outcome. *Early Human Development, 90*(7), 365–369. https://doi.org/10.1016/j.earlhumdev.2014.04.009
23. May, L. E., Suminski, R. R., Langaker, M. D., Yeh, H.-W., & Gustafson, K. M. (2012). Regular maternal exercise dose and fetal heart outcome. *Medicine & Science in Sports & Exercise, 44*(7), 1252–1258. https://doi.org/10.1249/MSS.0b013e318247b324
24. Meah, V. L., Kimber, M. L., Khurana, R., et al. (2021). Cardioautonomic control in healthy singleton and twin pregnancies. *Journal of Applied Physiology, 130*(4), 923–932. https://doi.org/10.1152/japplphysiol.00707.2020
25. Mishra, A., Park, J., Shapiro, I., et al. (2024). Trends in sensor-based health metrics during and after pregnancy: Descriptive data from the Apple Women's Health Study. *AJOG Global Reports, 4*(4), 100388. https://doi.org/10.1016/j.xagr.2024.100388
26. Mortaji, N., Krzeczkowski, J., Atkinson, S., Amani, B., Schmidt, L. A., & Van Lieshout, R. (2023). Preliminary findings of emotion regulation in 12-month-old infants of mothers enrolled in a randomized controlled trial assessing a nutrition + exercise intervention. *Developmental Psychobiology, 65*(2), e22376. https://doi.org/10.1002/dev.22376
27. Nakagaki, A., Inami, T., Minoura, T., Baba, R., Iwase, S., & Sato, M. (2016). Differences in autonomic neural activity during exercise between the second and third trimesters of pregnancy. *Journal of Obstetrics and Gynaecology Research, 42*(8), 951–959. https://doi.org/10.1111/jog.12990
28. American College of Obstetricians and Gynecologists. (2020). Physical activity and exercise during pregnancy and the postpartum period: ACOG Committee Opinion, Number 804. *Obstetrics & Gynecology, 135*(4), e178–e188. https://doi.org/10.1097/AOG.0000000000003772
29. Purdy, G. M., James, M. A., Wakefield, P. K., et al. (2019). Maternal cardioautonomic responses during and following exercise throughout pregnancy. *Applied Physiology, Nutrition, and Metabolism, 44*(3), 263–270. https://doi.org/10.1139/apnm-2018-0397
30. Rowan, S. P., Lilly, C. L., Claydon, E. A., Wallace, J., & Merryman, K. (2022). Monitoring one heart to help two: Heart rate variability and resting heart rate using wearable technology in active women across the perinatal period. *BMC Pregnancy and Childbirth, 22*(1), 887. https://doi.org/10.1186/s12884-022-05183-z
31. Sarhaddi, F., Azimi, I., Axelin, A., Niela-Vilen, H., Liljeberg, P., & Rahmani, A. M. (2022). Trends in heart rate and heart rate variability during pregnancy and the 3-month postpartum period: Continuous monitoring in a free-living context. *JMIR mHealth and uHealth, 10*(6), e33458. https://doi.org/10.2196/33458
32. Satyapriya, M., Nagendra, H. R., Nagarathna, R., & Padmalatha, V. (2009). Effect of integrated yoga on stress and heart rate variability in pregnant women. *International Journal of Gynecology & Obstetrics, 104*(3), 218–222. https://doi.org/10.1016/j.ijgo.2008.11.013
33. Schmitt, L., Regnard, J., & Millet, G. P. (2015). Monitoring fatigue status with HRV measures in elite athletes: An avenue beyond RMSSD? *Frontiers in Physiology, 6*, Article 343. https://doi.org/10.3389/fphys.2015.00343
34. Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. *Frontiers in Public Health, 5*, Article 258. https://doi.org/10.3389/fpubh.2017.00258
35. Shaffer, F., McCraty, R., & Zerr, C. L. (2014). A healthy heart is not a metronome: An integrative review of the heart's anatomy and heart rate variability. *Frontiers in Psychology, 5*, Article 1040. https://doi.org/10.3389/fpsyg.2014.01040
36. Shea, A. K., Kamath, M. V., Fleming, A., Streiner, D. L., Redmond, K., & Steiner, M. (2008). The effect of depression on heart rate variability during pregnancy: A naturalistic study. *Clinical Autonomic Research, 18*(4), 203–212. https://doi.org/10.1007/s10286-008-0480-1
37. Stutzman, S. S., Brown, C. A., Hains, S. M. J., et al. (2010). The effects of exercise conditioning in normal and overweight pregnant women on blood pressure and heart rate variability. *Biological Research for Nursing, 12*(2), 137–148. https://doi.org/10.1177/1099800410375979
38. Thayer, J. F., Yamamoto, S. S., & Brosschot, J. F. (2010). The relationship of autonomic imbalance, heart rate variability and cardiovascular disease risk factors. *International Journal of Cardiology, 141*(2), 122–131. https://doi.org/10.1016/j.ijcard.2009.09.543
39. Žebeljan, I., Lučovnik, M., Dinevski, D., et al. (2022). Effect of prenatal yoga on heart rate variability and cardio-respiratory synchronization: A prospective cohort study. *Journal of Clinical Medicine, 11*(19), 5777. https://doi.org/10.3390/jcm11195777