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REVIEW OPEN ACCESS

Integrated Cardiovascular and Endocrine Remodeling of Maternal Physiology in Pregnancy

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Abstract

Introduction: Throughout pregnancy, there are dramatic cardiovascular and endocrine changes and adjustments that maintain maternal stability and support fetal growth. Hormonal signals minimize vascular resistance, expand blood volume, and increase cardiac output to maximize placental perfusion. When these adaptations fail, conditions such as preeclampsia arise and contribute to the future risk of cardiovascular disease. Understanding how endocrine pathways regulate cardiovascular change is necessary to understand both normal pregnancy physiology and pregnancy-related complications.

Methods: This review of the published literature investigates peer-reviewed research on cardiovascular and endocrine adaptations during pregnancy. Articles published between 2013 and 2025 were found through PubMed, Scopus, Web of Science, and Google Scholar. Studies were included if they described physiological changes in cardiac output, vascular adaptation, or hormone regulation during pregnancy, or discussed complications such as hypertensive disorders of pregnancy. Eligible primary and review studies were examined, organized, and categorized under themes outlining normal adaptations and dysfunctional processes.

Results: This review shows that endocrine signaling, particularly through estrogen, progesterone, and relaxin, influences important cardiovascular adaptations in pregnancy by increasing vasodilation, decreasing vascular resistance, and supporting increases in blood volume and cardiac output. These systems support effective uteroplacental perfusion. The reviewed evidence also demonstrates that disruption of these adaptations themselves, as seen in preeclampsia, results in impaired vascular function and hypertension. Long-term studies suggest that such complications can increase the likelihood of developing future risks for chronic hypertension, cardiovascular disease, and adverse outcomes in future pregnancies.

Discussion: By exploring how the cardiovascular and endocrine systems work together during pregnancy, this review helps to distinguish normal adaptations from those that may become harmful.

Conclusion: These findings support earlier detection and management of pregnancy-related hypertension disorders, the development of prevention strategies for at-risk individuals, and better guidance for long-term monitoring of maternal cardiovascular health.

Keywords: pregnancy adaptation; cardiovascular; endocrine; maternal physiology

Introduction

Pregnancy requires considerable maternal physiological adaptations to support fetal growth and development; the cardiovascular and endocrine systems orchestrate these changes to maintain a successful, healthy pregnancy [1, 2]. Cardiovascular and endocrine systems ensure proper blood flow to the placenta and support maternal homeostasis. The cardiovascular system adapts by increasing cardiac output (the amount of blood pumped by the heart each minute) by about 30–50% as both heart rate (HR) and stroke volume (SV) rise [1]. Blood volume also expands, increasing the amount of blood returning to the heart. At the same time, widespread vasodilation reduces the resistance the heart must pump against. These combined adjustments allow the heart to function more productively and support higher blood flow required for maternal tissues and the placenta [3]. The endocrine system guides these cardiovascular changes through hormone signaling. Estrogen promotes vasodilation, progesterone relaxes vascular smooth muscle, and prolactin supports metabolic and cardiac adjustments [4]. The influence of these hormones shifts over the course of pregnancy, and their interactions highlight the importance of hormonal balance for maintaining stable cardiovascular function. When adaptations are maladaptive, complications such as hypertensive disorders of pregnancy (HDP) can develop. HDP, including preeclampsia and gestational hypertension, remains an important cause of illness and death in pregnancy [5]. These disorders not only affect the current pregnancy but also increase the mother's long-term risk of hypertension and cardiovascular disease. Although many cardiovascular and hormonal changes in pregnancy are well

described, a better understanding of how these systems interact is critical. Clarifying their relationship and how disruptions lead to disease can help explain long-term maternal cardiovascular outcomes. Current evidence acknowledges the importance of these endocrine–cardiovascular interactions, showing their impact on maternal health and outcomes in future pregnancies.

Methods

This study used a narrative literature review design to examine current evidence on cardiovascular and endocrine adaptations during pregnancy. Peer-reviewed articles were identified through searches conducted in PubMed, Scopus, Web of Science, and Google Scholar. Search terms included "pregnancy", "cardiovascular physiology", "endocrine regulation", "hemodynamic adaptation", "estrogen", "progesterone", "relaxin", and "pre-eclampsia". Studies published between 2013 and 2025 were selected for relevance to maternal cardiovascular changes, hormonal influences on vascular function, and pregnancy-related complications. Earlier foundational papers were included when necessary to describe key physiological mechanisms and provide context for recent findings. The literature included in this review consists of both primary research studies and secondary review articles. A total of approximately 20–25 studies were identified through database searches. After screening titles and abstracts for relevance, 11 articles were selected for full-text review and inclusion. Studies were included if they focused on maternal cardiovascular and hemodynamic changes, hormonal regulation, or pregnancy complications including hypertensive disorders. Studies were excluded if they focused primarily on fetal physiology or lacked detail on maternal physiological mechanisms and complications. Both primary research studies and review articles were included to provide a representative overview of current evidence. The selection of studies was based on their relevance to the topic and research objectives. Primary sources informing cardiovascular and endocrine mechanisms include Kazma et al. (2020), Bisson et al. (2023), Clapp and Capeless (1997), Conrad et al. (2022), and Long and Fiset (2020). These studies provide original physiological data, hormonal analyses, or direct experimental findings relevant to maternal cardiovascular adaptation. Secondary sources used to contextualize and support these findings include review papers by Kodogo et al. (2019), Morton (2021), Fraser (2018), Tan and Tan (2013), Sanghavi and Rutherford (2014), and Chung and Leinwand (2014). These articles outline existing literature and provide broader summaries of cardiovascular physiology, endocrine regulation, pregnancy complications, and postpartum outcomes. After a thorough review of all included studies, the data were categorized into thematic groups that described: (1) normal cardiovascular adaptation, (2) endocrine regulation of hemodynamics, (3) interactions between hormonal and vascular pathways, and (4) maladaptive processes such as hypertensive disorders of pregnancy. Trends, points of agreement, and areas of uncertainty across studies were examined to identify consistent mechanisms.

Results

Cardiovascular Adaptations

Cardiovascular adaptations during pregnancy represent a highly demanding physiological process. To sustain adequate uteroplacental perfusion (the delivery of oxygenated, nutrient-rich blood from the mother to the placenta) and to ensure maternal homeostasis, the cardiovascular system undergoes through immense adaptations beginning as early as the first trimester. These changes include structural, hemodynamic, and functional changes to support the increased metabolic requirements of both the mother and the fetus, simultaneously preparing the body for the stress of labor and delivery [3, 6].

Structural and Anatomical

The maternal heart experiences specific anatomical and physiological transformations as gestation progresses. The enlarging uterus elevates the diaphragm, shifting the heart upward and laterally within the thoracic cavity, which often produces a mild left axis deviation on electrocardiogram [2, 7]. Imaging studies using echocardiography and cardiac magnetic resonance have shown evidence of modest left ventricular (LV) hypertrophy, characterized by proportional increases in chamber volume and wall thickness, features consistent with physiologic eccentric hypertrophy [8]. This change displays an adaptive response to the increased circulatory demands of pregnancy rather than a pathological process. Unlike the abnormal thickening that occurs in hypertension, the heart's enlargement during pregnancy preserves its normal structure, diastolic filling, and pumping performance [3, 8]. These adjustments improve stroke volume and cardiac output, allowing the heart to accommodate increased preload and maintain high blood flow without compromising ejection fraction or ventricular compliance.

Hemodynamic Alterations

Hemodynamic changes happen early and are among the most important physiological changes of pregnancy. Across multiple studies, cardiac output (CO) consistently increases by approximately 30–45% above pre-pregnancy levels, with longitudinal data indicating that over 70% of this increase occurs by mid-gestation. The magnitude and timing of these changes vary depending on study design and population characteristics, with some suggesting earlier hemodynamic adaptation in the first trimester [2, 6]. In early pregnancy, this rise is primarily caused by increased stroke volume, a direct result of blood volume expansion and augmented venous return (increased preload). Maternal HR gradually increases by 10–25 beats per minute as pregnancy progresses. This increase becomes the primary

contributor to maintaining high cardiac output in later trimesters when inferior vena cava compression begins to reduce venous return [7]. Twin and multifetal gestations further increase these demands, with CO increasing up to 60% above preconception levels [6]. These adjustments are necessary for maintaining uteroplacental perfusion, as uterine blood flow increases nearly tenfold near term to support fetal oxygenation and nutrient exchange [2].

Vascular Resistance, Blood Pressure, and Vasoregulation

During early pregnancy, profound systemic vasodilation occurs, resulting in a 30–40% reduction in systemic vascular resistance (SVR) by mid-gestation [6, 7]. The resulting decrease in afterload helps maintain forward cardiac output while keeping arterial pressures within normal ranges even as circulating volume increases. Mean and diastolic blood pressures typically decrease during the first trimester, reaching their lowest levels around 24–26 weeks of gestation before gradually returning to pre-pregnancy values by term [2]. Most studies report a decrease in blood pressure during early to mid-pregnancy; some findings show a progressive increase or minimal change. This reflects differences in measurement techniques (e.g., ambulatory versus clinic-based blood pressure monitoring), population health status, or gestational timing [2, 6, 7].

Blood Volume, Hematologic Changes, and Oxygen Transport

Plasma volume begins to rise as early as 6–8 weeks of pregnancy and peaks at 32 weeks, approximately 40–50% above normal [2]. Red cell mass also increases but to a lesser extent (about 30%), which causes physiologic hemodilution or "dilutional anemia." This adaptation improves placental perfusion and reduces blood viscosity, making it easier for nutrient and oxygen transport to the fetus. The total blood volume expansion increases venous return and preload, increasing SV and supporting elevated CO.

Pulmonary and Venous Circulation

Pregnancy decreases in pulmonary vascular resistance while continuing normal pulmonary capillary wedge pressure, allowing the right heart to accommodate increased flow [2]. However, in women with underlying pulmonary hypertension, this physiological adaptation fails, predisposing them to right-sided heart failure [2, 7].

Cardiac Hypertrophy, Function, and Reversibility

At the myocardial level, pregnancy triggers a reversible form of physiologic hypertrophy, different from pathological remodeling. The volume overload of pregnancy stimulates cardiac myocytes to increase in both length and width, while maintaining sarcomere organization and normal contractility [8]. LV function, as measured by ejection fraction and fractional shortening, generally remains stable throughout pregnancy; however, a small, temporary reduction may occur in late gestation due to increased load demands [8]. Importantly, these changes return to normal within weeks to months postpartum. These findings align with experimental and imaging studies reflecting that pregnancy-induced cardiac hypertrophy is predominantly physiological and reversible. However, the degree of reversibility and persistence postpartum varies across studies, with some reporting prolonged cardiovascular changes up to one year postpartum, suggesting a limited understanding of long-term remodeling [3, 8].

Clinical and Pathophysiological Implications

Preeclampsia is a condition affecting up to 8% of pregnancies and responsible for significant maternal and fetal morbidity [5]. Impaired vascular adaptation, endothelial dysfunction, and insufficient hormonal signaling have been associated with preeclampsia and gestational hypertension [9]. Although endothelial dysfunction is consistently identified as a central mechanism in preeclampsia, the initiating factors remain debated. Some studies state that placental ischemia is the primary driver, while others highlight systemic hormonal and angiogenic imbalance. This lack of consensus indicates a gap in identifying the primary casual pathway [5, 9].

Endocrine Adaptations

Pregnancy produces intense and coordinated endocrine changes that adapt maternal metabolism and vascular function to support fetal development, protect maternal homeostasis, and prepare for lactation [2, 4]. These adaptations involve the hypothalamic–pituitary–placental axis, maternal pancreas, thyroid, adrenals, and pituitary lactotrophs. Maternal endocrine adaptations interact closely with the cardiovascular system to modulate blood volume, vascular tone, and nutrient delivery [2, 4].

Endocrine Regulation of Vascular Tone and Volume Expansion

Endocrine-mediated mechanisms establish the low-resistance circulation required during pregnancy. Rising levels of estrogen and progesterone relaxes blood vessels and improve arterial compliance [2]. These hormonal effects support better blood flow to maternal tissues and the placenta. Hormonal pathways regulate blood volume expansion. Relaxin, produced by the corpus luteum and later the placenta, increases plasma flow and overall blood volume. Activation of the renin–angiotensin–aldosterone system (RAAS), a hormonal system that regulates blood pressure and fluid balance by increasing sodium and water retention, expanding plasma volume to maintain effective perfusion [6]. These mechanisms maintain circulatory capacity, and when these endocrine mechanisms are disrupted, cardiovascular adaptation becomes impaired. As a result, uteroplacental perfusion is compromised, and blood pressure rises [5].

Metabolic Reprogramming: Insulin, Glucose, and Lipids

Gestational diabetes mellitus (GDM) reflects a breakdown in the normal metabolic adaptations of pregnancy, where rising insulin resistance is not matched by adequate β-cell compensation [2, 4]. This dysregulation has important cardiovascular consequences; women with GDM demonstrate endothelial dysfunction, increased vascular inflammation, and a higher lifetime risk of developing hypertension, type 2 diabetes, and cardiovascular disease [4]. The cardiovascular risk profile associated with GDM parallels that of type 2 diabetes in the non-pregnant population, where metabolic disruption contributes to coronary artery disease and myocardial infarction. Because pregnancy reveals these risk patterns earlier in life, examining metabolic changes in GDM provides a unique opportunity to identify biomarkers and mechanisms that predict long-term cardiometabolic risk [4].

Pituitary and Prolactin Changes

The anterior pituitary enlarges during pregnancy due to lactotroph hyperplasia within the pituitary gland, a process initiated by increased estrogen levels and resulting in markedly elevated circulating prolactin [2]. Prolactin has many effects, promoting mammary gland development and lactation, as well as modulating cardiovascular function through pro-angiogenic and cardiomyocyte-protective pathways [4]. Under pathological conditions, such as increased oxidative stress in late gestation, proteolytic cleavage of prolactin produces smaller fragments known as vasoinhibins. These fragments are anti-angiogenic and have been implicated in peripartum cardiomyopathy (PPCM) through endothelial dysfunction and impaired cardiomyocyte performance [4]. This duality shows how endocrine adaptations that are normally protective and supportive of pregnancy can, in susceptible individuals, impair myocardial perfusion and contractility, contributing to severe cardiovascular pathology such as PPCM.

Placental Hormones and Growth Factors

The placenta is a transient endocrine organ that produces hormones that help regulate maternal metabolic adaptation. Key placental hormones include human placental lactogen (hPL), placental growth hormone, corticotropin-releasing hormone (CRH), progesterone, estrogens, and several peptide factors [2]. Placental growth hormone progressively replaces pituitary growth hormone (GH) in mid-pregnancy and stimulates maternal insulin-like growth factor (IGF) production, increasing hepatic glucose output and lipolysis to ensure nutrient availability for the fetus [2]. Placental CRH elevates maternal adrenocorticotropic hormone (ACTH) and cortisol levels, contributing to physiologic hypercortisolism that supports metabolic demands and prepares the maternal system for parturition [2]. When placental hormone signals become too strong or poorly regulated, they can worsen insulin resistance, increase fat breakdown, and make blood vessels more sensitive to stress hormones such as catecholamines [2, 4]. Changes like this strain the maternal cardiovascular system by damaging the endothelium, stiffening the arteries, and raising blood pressure. As a result, abnormal placental endocrine activity directly contributes to a higher risk of maternal cardiometabolic complications.

Hormonal Crosstalk and the Balance Between Adaptation and Pathology

Pregnancy-specific hormones work together to guide cardiovascular and metabolic adaptations that support the fetus, acting through synergistic, permissive, and sometimes antagonistic pathways [4]. When endocrine–angiogenic balance is disturbed, especially when levels of soluble fms-like tyrosine kinase-1 (sFlt-1), an anti-angiogenic factor that reduces blood vessel growth signaling, are too high, the availability of vascular endothelial growth factor (VEGF) and placental growth factor (PlGF) decreases, which damages endothelial function [5, 9]. Low angiogenic signaling also limits small-vessel growth and repair, increasing SVR, reducing placental blood flow, and raising cardiac workload. Growing evidence shows that hormones from the corpus luteum, particularly relaxin, are important for establishing early cardiovascular adaptation. Emerging evidence from assisted reproduction models suggests that the absence of the corpus luteum is associated with impaired early cardiovascular adaptation and increased risk of hypertensive disorders. These findings remain limited and require further validation in larger and more diverse populations [9]. Differences in early luteal support, such as those seen in assisted reproduction cycles, may affect HDP risk by altering early vasodilation and renal blood-flow responses [9].

Clinical Implications: GDM, PPCM, HDP, and Long-term Risk

Endocrine adaptations can create periods during which maternal cardiovascular and metabolic systems carry an increased physiologic load. When metabolic compensation is insufficient, GDM may develop, and persistent postpartum insulin resistance and endothelial dysfunction contribute to a higher long-term risk of type 2 diabetes and cardiovascular disease. Reduced VEGF/PlGF signaling and heightened vasoconstrictor sensitivity increase SVR. In this condition, oxidative stress promotes prolactin cleavage and vasoinhibin production, creating a damaging environment for the heart that contributes to LV systolic dysfunction and heart failure [4]. These findings highlight the importance of integrated endocrine–cardiovascular connections for early detection, risk stratification, and postpartum follow-up of women affected by pregnancy complications.

Cardiovascular–Endocrine Interactions During Pregnancy

The cardiovascular and endocrine systems throughout pregnancy coordinate vascular tone, plasma volume, CO,

and uteroplacental perfusion. Cardiovascular and endocrine systems do not function independently; hormonal mediators shape the timing and magnitude of cardiovascular adaptation [2, 4–6, 9]. Endocrine signals contribute to normal hemodynamic remodeling, and disruption of these pathways contributes to pregnancy complications.

Temporal Progression of Cardiovascular–Endocrine Adaptation

Profound cardiovascular changes begin within weeks of conception. Early gestation is marked by peripheral vasodilation and an initial 20% rise in CO, occurring before placental perfusion is fully established, indicating dependence on the corpus luteum and early placental endocrine factors [6, 9]. Between 12 and 28 weeks, plasma volume expansion intensifies, SV and CO increase by approximately 30–45%, and SVR decreases [2]. During late pregnancy, mechanical venous compression and sustained tachycardia preserve cardiac output, which rises transiently by up to 80% during labor due to catecholamine and oxytocin surges [7].

Estrogen and Progesterone: Vascular and Cardiac Effects

Estrogen enhances endothelial nitric oxide (NO) production, stimulates angiogenesis, and activates antioxidant pathways. It also influences cardiomyocyte signaling in ways that limit pathological hypertrophy and promote healthy, adaptive remodeling [4]. Progesterone supports vasodilation through both genomic and rapid non-genomic mechanisms (e.g., activation of PI3K/Akt → eNOS phosphorylation). It also contributes to plasma volume expansion and protects cardiomyocytes by reducing apoptosis (heart muscle cell death) [4]. Steroid hormones lower systemic vascular resistance, increase arterial compliance, and help protect maternal tissues against ischemic and oxidative stress. However, the final physiological effect depends on hormone concentrations, receptor expression levels, and the degree of crosstalk between signaling pathways, which can shift the balance toward either normal adaptation or pathology [4].

Principal Endocrine Mediators and Mechanisms

Estrogen increases maternal HR by influencing the sinoatrial node, the heart's natural pacemaker, contributing to physiologic tachycardia, a normal increase in heart rate during pregnancy [10]. Progesterone works with estrogen to maintain low vascular tone by promoting nitric oxide–mediated and prostacyclin-mediated (a vasodilatory molecule produced by blood vessels) pathways, to direct smooth muscle relaxation. It also increases venous capacitance to hold more blood and partially counteracts the effect of aldosterone, allowing plasma volume expansion without excessive sodium retention [7]. Relaxin promotes arterial compliance and renal vasodilation through nitric oxide–dependent mechanisms and extracellular matrix remodeling [9]. RAAS activation during pregnancy increases plasma volume through estrogen-driven increases in angiotensinogen, and when reduced, SVR stimulates renin and aldosterone release. At the same time, vasodilatory hormones help to preserve normal blood pressure [6]. Rising prolactin concentrations support endothelial stability and cardiomyocyte survival, although oxidative stress can generate the anti-angiogenic 16-kDa vasoinhibin fragment, which has been implicated in endothelial dysfunction and PPCM [4]. Cortisol and placental CRH further regulate vascular function by increasing responsiveness to catecholamines and stress hormones such as adrenaline, and by promoting sodium and water retention through mineralocorticoid receptor pathways. Estrogen also increases corticosteroid-binding globulin, elevating circulating cortisol and supporting circulatory stability [2, 7].

Discussion

Endocrine–Cardiovascular Dysregulation and Pathophysiological Outcomes

Pregnancy-related disorders can develop when normal coordination between endocrine and cardiovascular adaptations becomes maladaptive. Preeclampsia is one of the disorders, that occurs when early vascular remodeling and placental development do not proceed properly. Deficient placental blood flow leads to relative ischemia and the releases of anti-angiogenic factors, such as sFlt-1 and soluble endoglin (sEng) [5, 7]. These factors interfere with VEGF and PlGF signaling, weakening the endothelial repair mechanism and resulting in endothelial dysfunction. As vascular permeability increases and systemic vascular resistance rises, the maternal heart experiences increased cardiac afterload and reduced uteroplacental perfusion [5,7]. If the corpus luteum is abnormal and relaxin levels are low, the normal early vasodilation of pregnancy is limited. This leads to less than ideal cardiovascular adaptation that sets the stage for HDP. In this situation, the maternal heart must maintain a high cardiac output while pumping against a vascular system that is not adequately dilated. This makes hypertensive responses more likely, and in women with pre-existing heart disease, may trigger decompensation [9]. PPCM is another form of endocrine-vascular maladaptation. In late pregnancy, elevated oxidative stress interrupts angiogenic balance and creates a cardiotoxic endothelial environment that increases susceptibility to myocardial dysfunction. Oxidative cleavage of prolactin into vasoinhibins reduces myocardial capillary density and promotes cardiomyocyte apoptosis, directly weakening left-ventricular systolic function [4]. Endocrine-driven metabolic disturbances further strain the cardiovascular system. Insulin resistance in pregnancy, driven by placental GH, human placental lactogen, and progesterone, increases the risk of GDM [2]. The resulting endothelial dysfunction, oxidative stress, and chronic inflammatory signaling reduce nitric oxide production, increase arterial stiffness, and accelerate atherosclerotic

processes, thereby raising long-term cardiovascular risk. After pregnancy, persistent factors such as weight retention, dyslipidemia, and ongoing metabolic stress continue to contribute to the long-term trajectory of these diseases [4].

Long-Term Cardiovascular Effects and Endocrine Vascular Imprinting

Cardiovascular adaptations developed during pregnancy do not immediately return to normal (pre-conception) in the postpartum period. Invasive and echocardiographic studies show that cardiac output remains elevated for several months after delivery, while SVR may take up to a year to normalize, suggesting persistent vascular change beyond gestation [3]. Longitudinal studies indicate that repeated pregnancies can produce cumulative endocrine–vascular effects, referred to as "vascular imprinting", in which prior exposure to high estrogen, progesterone, relaxin, and prolactin enhances endothelial nitric oxide production, improves arterial compliance, and helps more rapid hemodynamic adaptation in subsequent pregnancies [3, 4]. In healthy pregnancies, these imprinted adaptations appear beneficial by promoting efficient vasodilation and rapid adjustment to the demands of gestation. However, in pregnancies complicated by hypertensive disorders, the imprinting process may instead reinforce maladaptive pathways. A second or third pregnancy has been shown to be associated with greater increases in ventricular volume and cardiac output, along with larger reductions in systemic vascular resistance, compared with women during their first pregnancy [3]. Because some cardiovascular and endocrine adaptations may persist beyond delivery, repeated exposure to pregnancy-related hormonal and hemodynamic stress may contribute to long-term vascular remodeling and increased cardiovascular strain over time. Inadequate postpartum recovery may influence maternal adaptation in future pregnancies. Both short and prolonged time intervals between pregnancies have been associated with increased risk of hypertensive pregnancy complications, suggesting that maternal vascular recovery and prior endocrine–vascular remodeling may affect subsequent pregnancy outcomes [3, 5]. Women with preeclampsia or gestational hypertension experience persistent postpartum endothelial dysfunction, sustained anti-angiogenic signaling, and incomplete reversal of LV hypertrophy. These alterations contribute to chronic arterial stiffness, elevated resting blood pressure, and increased myocardial workload, which have been proposed as mechanistic contributors to the two-fold increased lifetime risk of chronic hypertension, ischemic heart disease, stroke, and heart failure observed after HDP [5, 11]. Current evidence also suggests that certain maternal characteristics may increase vulnerability to endocrine–cardiovascular maladaptation and future pregnancy complications. Major risk factors associated with preeclampsia include chronic hypertension, pregestational diabetes, kidney disease, autoimmune disorders, multifetal gestation, and prior preeclampsia, whereas moderate risk factors include obesity, nulliparity, advanced maternal age, prolonged intervals between pregnancies, and in vitro fertilization [5]. Many of these conditions are independently associated with endothelial dysfunction, vascular stiffness, chronic inflammation, or impaired metabolic regulation before pregnancy begins. This suggests that pregnancy complications may develop more readily in women with pre-existing cardiovascular or metabolic vulnerability, supporting the concept that pregnancy functions as a physiologic cardiovascular stress test [5, 11]. Recurrent exposure to endocrine and hemodynamic stress across multiple pregnancies may add further to cumulative vascular disorders and increased long-term cardiovascular risk in susceptible individuals [3, 5].

Current Evidence and Limitations

The evidence suggests that cardiovascular and endocrine adaptations are integrated systems that evolve dynamically across pregnancy. However, the relative contribution of specific hormonal pathways remains inconsistent across studies and limits definitive conclusions [2, 4, 6, 9]. Based on the studies included in this review, many findings are derived from relatively small sample sizes or specific populations, which may limit generalizability. In addition, a portion of the mechanistic evidence originates comes from animal and in vitro models, which may not fully reflect human physiological complexity. Narrative review articles' conclusions rely partly on previously synthesized evidence. Furthermore, variability in study design, measurement techniques, and population characteristics contributes to differences across reported findings. These limitations revel the need for larger, longitudinal, and more diverse human studies to better define endocrine–cardiovascular interactions as well as improve clinical translation.

Conclusions

Pregnancy necessitates coordinated cardiovascular and endocrine adaptations to support fetal development whilst maintaining maternal hemodynamic stability. Hormonal signals, including estrogen, progesterone, relaxin, prolactin, and placental hormones, drive systemic vasodilation, plasma volume expansion, cardiac remodeling, and metabolic adjustments that generate the high-output, low-resistance circulation characteristic of healthy gestation [2, 4, 6, 10]. When these responses are strong and well-regulated, the maternal cardiovascular system adapts productively and returns toward pre-pregnancy function after delivery [3, 7]. Failures in early vascular remodeling, inadequate corpus luteum–derived vasoactive factors, and maladaptive neurohormonal activation contribute to conditions such as preeclampsia, peripartum cardiomyopathy, and gestational diabetes, each of which increases long-term cardiovascular diseases [5, 9, 11]. The literature positions pregnancy as both a powerful

physiological stress model and an important opportunity to protect women from heightened lifetime cardiometabolic risk. Understanding these interactions can inform improved screening, early intervention, and long-term cardiovascular care.

List of Abbreviations
ACTH: adrenocorticotropic hormone
CO: cardiac output
CRH: corticotropin-releasing hormone
eNOS: endothelial nitric oxide synthase
GDM: gestational diabetes mellitus
GH: growth hormone
HDP: hypertensive disorders of pregnancy
hPL: human placental lactogen
HR: heart rate
IGF: insulin-like growth factor
LV: left ventricle / left ventricular
NO: nitric oxide
PI3K: phosphoinositide 3-kinase
PlGF: placental growth factor
PPCM: peripartum cardiomyopathy
RAAS: renin–angiotensin–aldosterone system
sEng: soluble endoglin
sFlt-1: soluble fms-like tyrosine kinase-1
SV: stroke volume
SVR: systemic vascular resistance
VEGF: vascular endothelial growth factor

Conflicts of Interest
The author declares that they have no conflicts of interest.

Ethics Approval and/or Participant Consent
This study is a literature-based review and did not involve human participants, human data, or animal subjects; therefore, ethics approval and participant consent were not required.

Authors' Contributions
RF: conducted the literature search, extracted and synthesized data, and drafted all manuscript sections.

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