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Best practice guidelines

Fetal and maternal metabolic responses to exercise during pregnancy

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ABSTRACT

Pregnancy is characterized by physiological, endocrine and metabolic adaptations creating a pseudo-diabetogenic state of progressive insulin resistance. These adaptations occur to sustain continuous fetal requirements for nutrients and oxygen. Insulin resistance develops at the level of the skeletal muscle, and maternal exercise, especially activity involving large muscle groups improve glucose tolerance and insulin sensitivity. We discuss the maternal hormonal and metabolic changes associated with a normal pregnancy, the metabolic dysregulation that may occur leading to gestational diabetes mellitus (GDM), and the consequences to mother and fetus. We will then examine the acute and chronic (training) responses to exercise in the non-pregnant state and relate these alterations to maternal exercise in a low-risk pregnancy, how exercise can be used to regulate glucose tolerance in women at risk for or diagnosed with GDM. Lastly, we present key exercise guidelines to help maintain maternal glucose regulation and suggest future research directions.

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1. Introduction

Pregnancy is characterized by major physiological, endocrine and metabolic adaptations which create a pseudo-diabetogenic state of progressive insulin resistance. These adaptations occur in order to sustain the continuous requirements of the fetus for nutrients and oxygen. As pregnancy progresses there is sparing of maternal glucose utilization in the peripheral tissues, increased blood concentrations of glucose and amino acids, and diminished insulin responses to various levels of glycemia. Since insulin resistance develops at the level of the skeletal muscle, exercise, especially activity involving large muscle groups promoting insulin sensitivity, is a logical intervention. The steady concentration of glucose during exercise is maintained by interactions of the sympathoadrenal and neurohumoral systems reflected in a decline in plasma insulin paralleled by increased levels of norepinephrine, epinephrine, cortisol, glucagon and growth hormone [1]. The physiological adaptations of the maternal metabolic and endocrine systems to exercise are presented here.

This article will discuss the maternal hormonal and metabolic changes associated with a normal pregnancy, the metabolic dysregulation that may occur leading to gestational diabetes mellitus (GDM), and the consequences to mother and fetus. We will then examine the acute and chronic (training) responses to exercise in the non-pregnant state and relate these alterations to maternal exercise in a low-risk pregnancy, how exercise can be used to regulate glucose tolerance in women at risk for or diagnosed with GDM. Lastly, we present key exercise guidelines to help maintain maternal glucose regulation and suggest future research directions.

1.1. Maternal endocrine adaptations to pregnancy

The major control centre for much of the maternal endocrine system is through the hypothalamus by co-ordinating incoming signals from multiple endocrine organs through paracrine and autocrine signaling. The maternal endocrine adaptations are complex and involve networking with the pituitary, thyroid, parathyroid, adrenal glands and the ovary which then interact with and cross the fetal-placental-maternal interface.

1.1.1. Hypothalamic hormones

Hypothalamic stimulatory hormonal concentrations, such as gonadotropin-releasing hormone (GnRH), growth hormone-releasing hormone (GHRH), corticotropin-releasing hormone (CRH), and thyrotropin-releasing hormone (TRH) are all increased during [2] pregnancy. In addition, the inhibitory hypothalamic hormones such as prolactin-inhibiting factor and somatostatin are also increased to create an endocrine balance within the pregnant system.

1.1.2. Pituitary

As pregnancy progresses some of the hypothalamic and pituitary hormone production will decline, however circulating concentrations will increase because of placental production of variant or biochemical identical hormones [3]. Among the anterior pituitary hormones, growth hormone production (GH) is reduced, but placental-like growth hormone increases significantly and peaks towards the end of term. An increase is also observed in adrenocorticotropic hormone (ACTH) and thyrotropin (TSH) concentration through a similar mechanism. The mid lobe of the pituitary secretes melanocyte-stimulating hormone (MSH), which is thought to be linked to the skin hyper-pigmentation in pregnancy. The posterior pituitary is a reservoir for antidiuretic hormone (ADH) and oxytocin which are produced in the paraventricular and supra-optic hypothalamic nuclei. It is suggested that the gradual increase in maternal plasma volume is caused by pregnancy-induced hormones that reduce peripheral vascular resistance, which in turn activates the renin–angiotensin–aldosterone system, leading to increased release of ADH and fluid retention to maintain blood pressure [4].

1.1.3. Parathyroid and thyroid

The pregnant state is characterized by an elevated basal metabolic rate that results in tachycardia and intolerance to heat. Serum thyroxine-binding globulin (TBG) is increased almost two fold during pregnancy. Thyroid-stimulating hormone (TSH) decreases early in pregnancy because of weak stimulation of TSH receptors caused by high concentrations of human chorionic gonadotropin (HCG), however thyroxine (T4) and Triiodothyronine (T3) rise during the first 20 weeks of pregnancy and then plateau. In some women there is a transient subclinical hyperthyroidism (suppressed TSH, elevated T4) which is considered physiologic [5]. Theoretically, this transient physiological hyperthyroidism may cause transient intolerance to exercise, although there are no such reports in pregnancy.

1.1.4. Adrenal (catecholamines)

The early stages of pregnancy are associated with substantial adaptations in cardiac autonomic control, with decreases in parasympathetic tone and augmentation in sympathetic activity [6], leading to an increase in resting heart rate, up to 15 to 20 bpm above non-pregnant values by the end of pregnancy. An increase in basal sympathetic activity during early pregnancy may also have the advantage of adapting the pregnant woman to hemodynamic changes reducing the risk of hypotension upon changing positions from lying to standing [6]. However, the augmented sympathetic activity may increase the risk of hypertension and pre-eclampsia if normal cardiovascular adaptations become dysregulated. It is suggested that only 10–20% of the maternal circulating catecholamines cross the placenta as the remainder can be metabolized by the placental release of catecholamine-O-ethyl-transferase [7]. Significant concentrations of

catecholamines increase with advancing gestational age as reflected in metabolites recovered in amniotic fluid. Specifically metanephrine, although not detected prior to 30 weeks gestation can be retrieved in progressively higher concentrations in amniotic fluid after 30 weeks. Metanephrine is significantly higher when recovered from patients in labor, as a reflection of increased fetal sympathetic nervous system activity during this event [8]. The placenta plays an important role in blocking maternal catecholamines from crossing the placenta to the fetal side early in pregnancy however, metanephrine found in amniotic