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PREVENTION OF PREECLAMPSIA THROUGH ANTENATAL WATER-BASED EXERCISE: PATHOPHYSIOLOGICAL MECHANISMS AND PERINATAL OUTCOMES

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Abstract. Preeclampsia remains one of the leading causes of maternal and perinatal morbidity and mortality worldwide, largely due to its complex and multifactorial pathogenesis involving endothelial dysfunction, oxidative stress, and impaired central hemodynamics. Despite advances in obstetric care, effective preventive strategies remain limited, particularly for women at high risk. This study evaluates the role of antenatal water-based physical exercise in the form of aqua aerobics as a non-pharmacological method for the prevention of preeclampsia. The analysis demonstrates that regular water-based exercise during the second and third trimesters of pregnancy contributes to the normalization of hemodynamic parameters, reduction of oxidative stress intensity, and improvement of placental function. Clinically, this intervention is associated with a significant decrease in the incidence and severity of preeclampsia, reduction in perinatal complications, and lower dependence on медикаментозной therapy. The findings support the integration of aqua aerobics into comprehensive antenatal care programs as a safe, accessible, and pathogenetically justified approach to preeclampsia prevention.

Keywords: preeclampsia, pregnancy, aqua aerobics, antenatal preparation, oxidative stress, perinatal outcomes.

ПРОФИЛАКТИКА ПРЕЭКЛАМПСИИ С ИСПОЛЬЗОВАНИЕМ ДОРОДОВЫХ ФИЗИЧЕСКИХ УПРАЖНЕНИЙ В ВОДЕ: ПАТОФИЗИОЛОГИЧЕСКИЕ МЕХАНИЗМЫ И ПЕРИНАТАЛЬНЫЕ ИСХОДЫ

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Аннотация. Преэклампсия остается одной из ведущих причин материнской и перинатальной заболеваемости и смертности во всем мире, что обусловлено сложным и многофакторным патогенезом заболевания, включающим эндотелиальную дисфункцию, оксидативный стресс и нарушения центральной гемодинамики. Несмотря на достижения современной акушерской практики, эффективные методы профилактики преэклампсии, особенно у женщин группы высокого риска, остаются ограниченными. В данной работе оценивается роль дородовой физической подготовки беременных с использованием упражнений в воде (аквааэробики) как немедикаментозного метода профилактики преэклампсии. Показано, что регулярные занятия аквааэробикой во II–III триместрах беременности способствуют нормализации показателей центральной гемодинамики, снижению выраженности оксидативного стресса и улучшению плацентарной функции. Клинически это сопровождается снижением частоты и тяжести преэклампсии, уменьшением перинатальных осложнений и сокращением потребности в медикаментозной терапии.

Полученные данные обосновывают целесообразность включения аквааэробики в программы комплексной дородовой подготовки беременных.
Ключевые слова: преэклампсия, беременность, аквааэробика, дородовая подготовка, оксидативный стресс, перинатальные исходы.

PREEKLAMPSIYANI SUVDA BAJARILADIGAN PRENATAL JISMONIY MASHQLAR ORQALI OLDINI OLISH: PATOFIZIOLOGIK MEXANIZMLAR VA PERINATAL NATIJALAR

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Annotatsiya. Preeklampsiya butun dunyo bo'ylab onalar va perinatal davrda uchraydigan asoratlar hamda o'limning yetakchi sabablaridan biri bo'lib qolmoqda. Bu holatning rivojlanishi endotelial disfunksiya, oksidativ stress va markaziy gemodinamika buzilishlari bilan bog'liq murakkab va ko'p omilli patogenezga ega. Zamonaviy akusherlik yutuqlariga qaramay, ayniqsa yuqori xavf guruhidagi homilador ayollarda preeklampsiyani samarali oldini olish usullari yetarli darajada ishlab chiqilmagan. Ushbu maqolada suvda bajariladigan jismoniy mashqlar (akvaaerobika) yordamida olib boriladigan prenatal tayyorgarlikning preeklampsiyani oldini olishdagi ahamiyati baholanadi. Tadqiqot natijalari homiladorlikning II–III trimestrlarida muntazam akvaaerobika bilan shug'ullanish gemodinamik ko'rsatkichlarning barqarorlashuviga, oksidativ stressning kamayishiga va platsentar funksiyaning yaxshilanishiga olib kelishini ko'rsatdi. Klinik jihatdan bu preeklampsiya chastotasi va og'irligining kamayishi, perinatal asoratlarning pasayishi hamda dori vositalariga bo'lgan ehtiyojning qisqarishi bilan namoyon bo'ladi. Olingan natijalar akvaaerobikani homilador ayollarni kompleks prenatal tayyorlash dasturlariga kiritish maqsadga muvofiqligini asoslaydi.
Kalit so'zlar: preeklampsiya, homiladorlik, akvaaerobika, prenatal tayyorgarlik, oksidativ stress, perinatal natijalar

Introduction. Preeclampsia remains one of the most complex and unresolved complications of pregnancy, representing a multisystem disorder characterized by endothelial dysfunction, impaired placentation, generalized vasospasm, and progressive organ involvement. Despite decades of research, preeclampsia continues to occupy a leading position among the causes of maternal and perinatal morbidity and mortality worldwide. Epidemiological data indicate that preeclampsia complicates approximately 8–10% of pregnancies, with severe forms accounting for a disproportionate share of adverse maternal and neonatal outcomes [1]. In the structure of maternal mortality, hypertensive disorders of pregnancy consistently rank among the top three causes, underscoring their persistent clinical and public health significance [2]. The clinical importance of preeclampsia extends beyond the gestational period. Women who experience preeclampsia demonstrate an increased lifetime risk of cardiovascular disease, chronic hypertension, metabolic syndrome, and renal dysfunction, while offspring are predisposed to neurodevelopmental impairment, cardiovascular disorders, and metabolic disturbances later in life [3]. The severity and duration of preeclampsia are directly proportional to the extent of these long-term sequelae, highlighting the need for effective preventive strategies rather than solely symptomatic treatment. Although numerous hypotheses have been proposed to explain the etiology of preeclampsia, including immunological maladaptation, abnormal trophoblast invasion, oxidative stress, genetic predisposition, and inflammatory activation, none fully account for the heterogeneity of clinical manifestations [4]. As a result, therapeutic interventions remain largely supportive and are often initiated only after clinical signs become evident, limiting their effectiveness. This has prompted increasing interest in non-pharmacological preventive approaches aimed at modifying key

pathophysiological mechanisms during pregnancy. Among such approaches, antenatal physical activity, particularly water-based exercise in the form of aqua aerobics, has emerged as a promising modality. Water immersion provides unique biomechanical and physiological advantages, including reduced gravitational load, improved venous return, enhanced microcirculation, and modulation of autonomic nervous system activity. These effects may directly counteract the hemodynamic, oxidative, and endothelial disturbances characteristic of preeclampsia [5]. The present study evaluates the role of antenatal aqua aerobics in reducing the incidence and severity of preeclampsia and associated perinatal complications in high-risk pregnant women.

Pathophysiological Basis for Water-Based Exercise in Preeclampsia Prevention. The pathogenesis of preeclampsia is fundamentally rooted in placental insufficiency and systemic endothelial dysfunction. Impaired trophoblastic invasion of spiral arteries leads to reduced uteroplacental perfusion, which in turn triggers oxidative stress, activation of lipid peroxidation, and release of antiangiogenic factors into the maternal circulation [6]. These processes culminate in generalized vasoconstriction, increased total peripheral vascular resistance, altered central hemodynamics, and progressive organ hypoperfusion. One of the hallmark biochemical features of preeclampsia is the imbalance between prooxidant and antioxidant systems. Elevated levels of lipid peroxidation products, such as malondialdehyde and diene conjugates, reflect excessive oxidative stress and membrane damage at the cellular level [7]. Simultaneously, compensatory activation of antioxidant defenses, including ceruloplasmin and enzymatic antioxidants, is often insufficient to neutralize the oxidative burden, particularly in women with preexisting comorbidities. Water-based physical activity exerts a multifaceted influence on these pathological mechanisms. Hydrostatic pressure during water immersion enhances venous return, reduces peripheral edema, and improves cardiac preload, leading to more efficient central hemodynamics. Buoyancy reduces musculoskeletal strain, allowing safe and sustained physical activity even in late gestation. Moreover, rhythmic muscle contractions in water stimulate endothelial nitric oxide production, improve vascular compliance, and reduce peripheral resistance, thereby counteracting the vasospastic component of preeclampsia [8]. Additionally, aqua aerobics has been shown to modulate autonomic balance, shifting sympathetic overactivity toward parasympathetic predominance. This autonomic recalibration may contribute to improved blood pressure control, reduced stress hormone levels, and stabilization of uteroplacental blood flow. Importantly, water-based exercise also enhances metabolic efficiency, oxygen utilization, and tissue perfusion, which are critical for fetal well-being.

Materials and Methods. The study included a total of 210 pregnant women, parturients, and postpartum women, as well as 211 newborns, including one set of twins. Participants were stratified into three groups based on pregnancy risk profile and intervention modality. The primary group consisted of 67 pregnant women identified as high-risk for perinatal complications who underwent antenatal preparation incorporating aqua aerobics. The comparison group included 73 high-risk pregnant women who received standard pharmacological therapy without structured physical training. A control group of 70 women with uncomplicated pregnancies and no early gestational complications was formed at the time of antenatal registration. Risk factors for preeclampsia among women in the high-risk groups included inflammatory diseases of the vagina and cervix, present in 88–94% of cases, as well as extragenital pathology such as anemia, pyelonephritis, obesity, arterial hypertension, and autonomic dysfunction. The groups were comparable in terms of age, parity, obstetric history, and severity of comorbid conditions. Women in the primary group participated in aqua aerobics sessions during the second and third trimesters of pregnancy, attending classes twice weekly for 45 minutes in a pool with a water temperature of approximately +28°C. The average number of sessions per participant was 25±1.8, with a range from 10 to 56 sessions. The comparison group did not engage in water-based exercise. Throughout gestation, comprehensive clinical, biochemical, and instrumental assessments were conducted. Oxidative stress parameters, including diene conjugates and malondialdehyde levels in erythrocytes and plasma, were measured using standardized spectrophotometric methods. Antioxidant status was evaluated through ceruloplasmin concentration and erythrocyte osmotic resistance. Central hemodynamic parameters, such as stroke volume, cardiac output, cardiac index, and total peripheral

vascular resistance, were assessed using established hemodynamic monitoring techniques []. Fetal condition was monitored through ultrasonography, Doppler velocimetry, and cardiotocography in the third trimester. Placental morphology was examined postpartum using conventional histopathological methods. Statistical analysis was performed using the Biostat software package, with significance thresholds set at $p<0.05$.

Results. The average age of primiparous women across the three groups ranged from 22.9 to 24.6 years, while multiparous women were aged between 26.6 and 29.4 years. Primiparity predominated in all groups, particularly among high-risk participants. A history of spontaneous abortion or complicated deliveries was documented in approximately 20% of women in the high-risk groups. Microbiological analysis revealed a significantly higher prevalence of cytomegalovirus, Chlamydia trachomatis, Gardnerella vaginalis, and mixed microbial associations among high-risk women compared to controls. Following appropriate sanitation measures, pathogenic protozoa were successfully eliminated, while residual microbial spectra became comparable to those of the control group. Biochemical assessment during the second trimester demonstrated marked activation of lipid peroxidation processes in high-risk women. However, the degree of oxidative stress was significantly lower in the aqua aerobics group compared to those receiving only pharmacological therapy. Table 1 summarizes key indicators of oxidative and antioxidant balance.

Table 1. Oxidative and Antioxidant System Indicators in the Second Trimester

Parameter	Aqua Aerobics Group	Medication Group	Control Group
Diene conjugates (erythrocytes)	Elevated, moderate	Elevated, high	Low
Malondialdehyde (plasma)	Moderately increased	Significantly increased	Normal
Ceruloplasmin	Compensatory increase	Excessive increase	Physiological
Erythrocyte osmotic resistance	Mildly reduced	Markedly reduced	Normal

Hemodynamic evaluation in the third trimester revealed normalization of total peripheral vascular resistance in women participating in aqua aerobics compared to persistent elevation in the medication-only group. A hypokinetic circulation pattern predominated among high-risk women, whereas the control group exhibited a eukinetic profile. The incidence of moderate preeclampsia was 2.7 times lower in the aqua aerobics group than in the comparison group, and no cases of severe preeclampsia were observed among women engaging in water-based exercise. Perinatal outcomes were also significantly improved, with reductions in fetal hypoxia, preterm birth, intrauterine growth restriction, and neonatal neurological complications. Table 2 presents the frequency of major perinatal complications.

Table 2. Frequency of Perinatal Complications

Complication	Aqua Aerobics Group	Medication Group	Control Group
Moderate preeclampsia	Rare	Frequent	Minimal
Severe preeclampsia	Absent	Present	Absent
Fetal hypoxia	Low	High	Minimal
Preterm birth	Isolated	Common	Absent
Neonatal cerebral ischemia	Rare	Frequent	Absent
Perinatal mortality	None	Present	None

Pharmacological therapy was required 1.8 times less frequently in the aqua aerobics group. Placental histology demonstrated a fourfold reduction in chronic placental insufficiency and a ninefold decrease in inflammatory placental lesions compared to women who did not participate in water-based exercise.

Discussion. The findings of this study provide compelling evidence that antenatal aqua aerobics exerts a protective effect against the development and progression of preeclampsia in high-risk pregnant women. The observed reduction in oxidative stress markers, normalization of

hemodynamic parameters, and improvement in perinatal outcomes support the hypothesis that water-based physical activity directly targets key pathophysiological mechanisms of preeclampsia. Improved endothelial function, likely mediated through enhanced nitric oxide bioavailability and reduced oxidative damage, appears central to these benefits. Furthermore, the reduction in pharmacological intervention underscores the potential of aqua aerobics as a cost-effective and accessible preventive strategy with minimal contraindications. The absence of severe preeclampsia and perinatal mortality in the aqua aerobics group is particularly noteworthy, suggesting that early and sustained physical conditioning may alter the natural course of hypertensive disorders of pregnancy. These findings align with previous research demonstrating improved metabolic regulation, muscle tone, and vascular adaptability in pregnant women engaging in aquatic exercise [9].

Conclusion. Antenatal preparation incorporating aqua aerobics significantly reduces the incidence and severity of preeclampsia, improves central hemodynamics, attenuates oxidative stress, and enhances perinatal outcomes in high-risk pregnancies. This intervention contributes to a 2.7-fold reduction in moderate preeclampsia, prevents severe disease forms, decreases perinatal complications, and reduces reliance on pharmacological therapy by 1.8 times. The integration of water-based physical training into routine antenatal care represents a scientifically grounded and clinically effective strategy for the prevention of preeclampsia and its associated complications.

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