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ACUTE EFFECTS OF STATIC WATER IMMERSION AND WATER AEROBICS ON LOWER LIMB EDEMA AND HEMODYNAMIC RESPONSES IN THIRD-TRIMESTER PREGNANT WOMEN

EFEITOS AGUDOS DA IMERSÃO ESTÁTICA EM ÁGUA E AERÓBICA AQUÁTICA SOBRE O EDEMA DE MEMBROS INFERIORES E AS RESPOSTAS HEMODINÂMICAS EM MULHERES GRÁVIDAS NO TERCEIRO TRIMESTRE

EFECTOS AGUDOS DE LA INMERSIÓN ESTÁTICA EN AGUA Y AERÓBICA ACUÁTICA SOBRE EL EDEMA DE MIEMBROS INFERIORES Y LAS RESPUESTAS HEMODINÁMICAS EN MUJERES EMBARAZADAS EN EL TERCER TRIMESTRE

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ABSTRACT

Background: Lower-limb edema is a common physiological manifestation during late pregnancy that may impair maternal comfort and daily functioning. Aquatic interventions have been proposed as safe non-pharmacological strategies, although the relative contributions of static water immersion and aquatic exercise remain incompletely understood.

Objective: To compare the acute effects of static water immersion and water aerobics on lower-limb edema and maternal hemodynamic responses in healthy women during the third trimester of pregnancy.

Methods: Twenty-four healthy pregnant women in the third trimester participated in a repeated-measures within-subject experimental study. Each participant completed three conditions in a predefined sequence over one week: standing outside the pool (control), static water immersion, and supervised water aerobics. Foot and ankle circumferences, heart rate, and blood pressure were assessed immediately before and after each intervention. Within-condition comparisons were performed using the Wilcoxon signed-rank test, and between-condition comparisons were analyzed using the Friedman test.

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Results: Both static water immersion and water aerobics significantly reduced foot and ankle circumferences (all $p < 0.001$), whereas standing on land did not reduce lower-limb edema. Heart rate decreased significantly after both aquatic interventions, while water aerobics additionally reduced systolic ($p < 0.001$) and diastolic ($p = 0.021$) blood pressure. Between-condition analyses demonstrated significant post-intervention differences for heart rate, blood pressure, and lower-limb circumferences.

Conclusions: The hydrostatic properties of water alone are sufficient to promote acute reductions in pregnancy-related lower-limb edema. Water aerobics provides additional cardiovascular benefits by reducing blood pressure while preserving the anti-edema effects of immersion. These findings support both static water immersion and water aerobics as safe, effective, non-pharmacological strategies for managing lower-limb edema during late pregnancy, with aquatic exercise offering broader cardiovascular benefits when feasible.

Keywords: Pregnancy. Edema. Hydrotherapy. Water Exercise. Aquatic Exercise. Hemodynamics.

RESUMO

Contexto: O edema de membros inferiores é uma manifestação fisiológica comum durante a gravidez tardia que pode prejudicar o conforto materno e o funcionamento diário. As intervenções aquáticas foram propostas como estratégias seguras não farmacológicas, embora as contribuições relativas da imersão estática em água e do exercício aquático permaneçam incompletas.

Objetivo: Comparar os efeitos agudos da imersão estática em água e da aeróbica aquática no edema de membros inferiores e nas respostas hemodinâmicas maternas em mulheres saudáveis durante o terceiro trimestre da gravidez.

Métodos: Vinte e quatro mulheres grávidas saudáveis no terceiro trimestre participaram de um estudo experimental com medidas repetidas e desenho intra-sujeito. Cada participante completou três condições em sequência predefinida ao longo de uma semana: ficar em pé fora da piscina (controle), imersão estática em água e aeróbica aquática supervisionada. As circunferências do pé e tornozelo, frequência cardíaca e pressão arterial foram avaliadas imediatamente antes e depois de cada intervenção. As comparações dentro de cada condição foram realizadas usando o teste de Wilcoxon, e as comparações entre condições foram analisadas usando o teste de Friedman.

Resultados: Tanto a imersão estática em água quanto a aeróbica aquática reduziram significativamente as circunferências do pé e tornozelo (todos $p < 0,001$), enquanto ficar em pé no solo não reduziu o edema de membros inferiores. A frequência cardíaca diminuiu significativamente após ambas as intervenções aquáticas, enquanto a aeróbica aquática reduziu ainda mais a pressão arterial sistólica ($p < 0,001$) e diastólica ($p = 0,021$). As análises entre condições demonstraram diferenças significativas pós-intervenção para frequência cardíaca, pressão arterial e circunferências de membros inferiores.

Conclusões: As propriedades hidrostáticas da água por si só são suficientes para promover reduções agudas do edema de membros inferiores relacionado à gravidez. A aeróbica aquática oferece benefícios cardiovasculares adicionais ao reduzir a pressão arterial enquanto preserva os efeitos anti-edema da imersão. Esses achados apoiam tanto a imersão estática em água quanto a aeróbica aquática como estratégias seguras e eficazes não farmacológicas para o manejo do edema de membros inferiores durante a gravidez tardia,

com o exercício aquático oferecendo benefícios cardiovasculares mais amplos quando viável.

Palavras-chave: Gravidez. Edema. Hidroterapia. Exercício Aquático. Exercício Aquático. Hemodinâmica.

RESUMEN
Antecedentes: El edema de miembros inferiores es una manifestación fisiológica común durante el embarazo tardío que puede afectar el confort materno y el funcionamiento diario. Las intervenciones acuáticas se han propuesto como estrategias seguras no farmacológicas, aunque las contribuciones relativas de la inmersión estática en agua y el ejercicio acuático siguen siendo incompletamente comprendidas.

Objetivo: Comparar los efectos agudos de la inmersión estática en agua y la aeróbica acuática en el edema de miembros inferiores y las respuestas hemodinámicas maternas en mujeres sanas durante el tercer trimestre del embarazo.

Métodos: Veinticuatro mujeres embarazadas sanas en el tercer trimestre participaron en un estudio experimental de medidas repetidas con diseño intra-sujeto. Cada participante completó tres condiciones en una secuencia predefinida durante una semana: de pie fuera de la piscina (control), inmersión estática en agua y aeróbica acuática supervisada. Las circunferencias del pie y tobillo, la frecuencia cardíaca y la presión arterial se evaluaron inmediatamente antes y después de cada intervención. Las comparaciones dentro de cada condición se realizaron utilizando la prueba de Wilcoxon, y las comparaciones entre condiciones se analizaron utilizando la prueba de Friedman.

Resultados: Tanto la inmersión estática en agua como la aeróbica acuática redujeron significativamente las circunferencias del pie y tobillo (todos $p < 0,001$), mientras que estar de pie en tierra no redujo el edema de miembros inferiores. La frecuencia cardíaca disminuyó significativamente después de ambas intervenciones acuáticas, mientras que la aeróbica acuática redujo además la presión arterial sistólica ($p < 0,001$) y diastólica ($p = 0,021$). Los análisis entre condiciones demostraron diferencias significativas post-intervención para la frecuencia cardíaca, la presión arterial y las circunferencias de miembros inferiores.

Conclusiones: Las propiedades hidrostáticas del agua por sí solas son suficientes para promover reducciones agudas del edema de miembros inferiores relacionado con el embarazo. La aeróbica acuática proporciona beneficios cardiovasculares adicionales al reducir la presión arterial mientras preserva los efectos anti-edema de la inmersión. Estos hallazgos apoyan tanto la inmersión estática en agua como la aeróbica acuática como estrategias seguras y efectivas no farmacológicas para el manejo del edema de miembros inferiores durante el embarazo tardío, con el ejercicio acuático ofreciendo beneficios cardiovasculares más amplios cuando es factible.

Palabras clave: Embarazo. Edema. Hidroterapia. Ejercicio Acuático. Ejercicio Acuático. Hemodinámica.

1 INTRODUCTION

Pregnancy is a physiological condition that requires extensive maternal adaptations to ensure adequate fetal growth and development while maintaining maternal homeostasis. Throughout gestation, the maternal cardiovascular system undergoes progressive adjustments, including expansion of plasma volume, increased cardiac output, reduced systemic vascular resistance, and enhanced vascular compliance. These changes are essential to meet the increasing metabolic and circulatory demands of the maternal-fetal unit and occur in parallel with hormonal and metabolic adaptations that support a healthy pregnancy (Collins *et al.*, 2024; Kuate Kuate Defo & Daskalopoulou, 2023). Although physiological, these adaptations are accompanied by several clinical manifestations that become more evident as pregnancy progresses, particularly during the third trimester.

One of the most common consequences of these physiological adaptations is the development of lower-limb edema, particularly during the third trimester of pregnancy. The progressive enlargement of the uterus, increased venous pressure in the lower extremities, reduced venous return, hormonal changes that promote fluid retention, and alterations in lymphatic drainage favor the accumulation of interstitial fluid. Although lower-limb edema is usually considered a physiological manifestation of pregnancy, it may cause pain, a feeling of heaviness, fatigue, reduced mobility, and limitations in daily activities, substantially affecting maternal well-being and quality of life (Black *et al.*, 2023; Mollaelahi & Shahali, 2022).

Because pregnancy represents a unique physiological condition, the management of common gestational symptoms should prioritize interventions that are both effective and safe for the mother and fetus. Although lower-limb edema is generally physiological, it can significantly impair maternal comfort and daily functioning. Pharmacological management during pregnancy is often limited because many medications require careful evaluation of maternal and fetal risks. Consequently, effective non-pharmacological approaches have become an important component of prenatal care, particularly when they are capable of relieving symptoms without increasing maternal or fetal exposure to unnecessary therapeutic interventions (Mollaelahi & Shahali, 2022).

Among the non-pharmacological strategies currently recommended to improve maternal comfort during pregnancy, aquatic therapy has attracted considerable interest because immersion in water promotes physiological responses that cannot be reproduced under terrestrial conditions. Hydrostatic pressure exerts uniform compression on the immersed body, facilitating venous return and lymphatic drainage while promoting central

redistribution of body fluids. These effects increase renal perfusion and diuresis, favoring the reduction of peripheral edema. In addition, buoyancy decreases gravitational loading on the musculoskeletal system, reducing joint stress and improving comfort during movement, particularly in the advanced stages of pregnancy (Kuate Defo & Daskalopoulou, 2023; Mollaelahi & Shahali, 2022).

The potential therapeutic effects of aquatic interventions during pregnancy have been recognized for more than two decades. In a pioneering study, Kent *et al.* (1999) demonstrated that both static water immersion and water aerobics increased diuresis and reduced lower-limb edema compared with standing on land, suggesting that the aquatic environment may offer clinically relevant benefits for pregnant women. However, although these findings established an important physiological basis for the use of aquatic interventions during pregnancy, important gaps remain regarding, particularly concerning the acute hemodynamic responses associated with different types of aquatic exposure and their potential clinical implications.

Therefore, the aim of this study was to compare the acute effects of static water immersion and water aerobics on lower-limb edema and maternal hemodynamic responses in healthy women during the third trimester of pregnancy.

2 METODOLOGY

2.1 STUDY DESIGN

This experimental study employed a repeated-measures, within-subject design to compare the acute effects of three different conditions on lower-limb edema and maternal hemodynamic responses in healthy women during the third trimester of pregnancy. Each participant completed all experimental conditions, thereby serving as her own control.

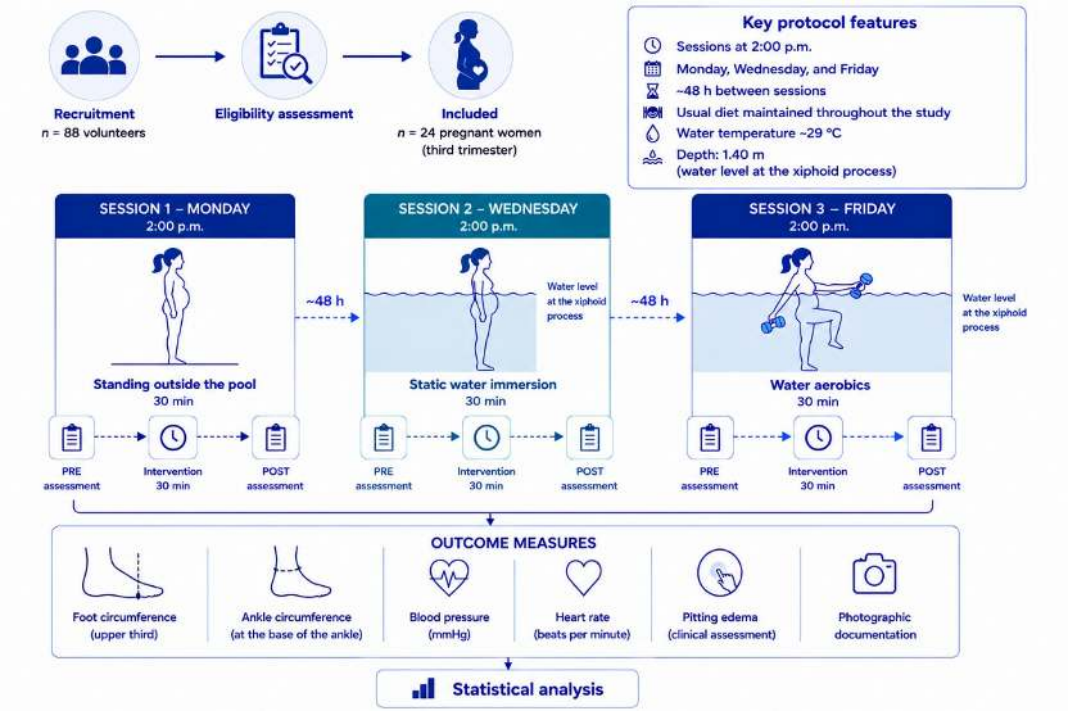
The three experimental sessions consisted of: (1) standing outside the pool (control condition), (2) static water immersion, and (3) a supervised water aerobics session. To ensure procedural consistency, all participants underwent the interventions in the same predefined sequence over a single week. The control condition was performed on Monday, followed by static water immersion on Wednesday and water aerobics on Friday. All experimental sessions were conducted at 2:00 p.m., with approximately 48-hour intervals between consecutive sessions.

Before and immediately after each intervention, participants underwent standardized assessments of lower-limb edema and maternal hemodynamic variables. Throughout the

experimental period, participants were instructed to maintain their habitual dietary pattern and avoid substantial changes in food intake between assessment days.

Figure 1

Schematic representation of experimental design and study protocol



Source: The Authors.

2.2 PARTICIPANTS

Twenty-four healthy women in the third trimester of pregnancy participated in this study. Participants were recruited from a public primary healthcare center in Goiânia, Brazil, which provided prenatal care through an obstetric service.

Prior to participant recruitment, the research team met with the attending obstetrician to present the study objectives, experimental procedures, and safety considerations. Following approval of the study protocol, participant recruitment was conducted within the prenatal care service through informational posters displayed outside the obstetric consultation room and by referral of potentially eligible women during routine prenatal visits.

Women who expressed interest in participating underwent clinical evaluation by the attending obstetrician. Only those who received written medical clearance confirming the absence of contraindications to physical exercise and water immersion during pregnancy were considered eligible for enrollment. All participants continued to receive routine prenatal

care throughout the study, and participation in the research did not interfere with their regular obstetric follow-up.

The inclusion criteria were: (1) singleton pregnancy in the third trimester (≥25 weeks of gestation); (2) written medical clearance from the attending obstetrician; (3) absence of restrictions to physical exercise; and (4) absence of medical or obstetric complications, including diabetes mellitus, hypertension, and cardiovascular disease. Exclusion criteria included multiple pregnancy, smoking, alcohol consumption, corticosteroid use, medical contraindications identified during follow-up, gestational age below 25 weeks, and inability to attend all scheduled experimental sessions.

A total of 88 pregnant women initially expressed interest in participating. Participant attrition was primarily related to loss of contact, health issues, scheduling conflicts, lack of motivation, and early delivery. Ultimately, 24 women completed all experimental sessions and were included in the final analyses.

2.3 ETHICAL APPROVAL

The study protocol was approved by the Research Ethics Committee under approval number 3.405.704. All participants received detailed information regarding the study objectives and procedures and provided written informed consent before enrollment.

2.4 EXPERIMENTAL INTERVENTIONS

All experimental sessions were conducted in the afternoon (2:00 p.m.), with approximately 48-hour intervals between consecutive sessions. Participants attended all three sessions wearing the same swimsuit and swim cap and remained barefoot throughout the experimental protocol. To minimize potential confounding factors, participants were instructed to maintain their habitual dietary pattern, avoid additional structured physical exercise during the experimental week, and attend all sessions at the scheduled time.

The aquatic interventions were performed in two covered heated swimming pools with comparable environmental characteristics. Both pools had a water depth of 1.40 m and a water temperature maintained at approximately 29°C, ensuring standardized environmental conditions throughout the study. The three experimental conditions were then conducted under these standardized conditions.

The land-based control condition consisted of standing quietly at the poolside for 30 minutes while wearing only a swimsuit and swim cap. Participants were instructed to remain

as still as possible, avoiding unnecessary movements and conversation. To minimize discomfort associated with prolonged standing during late pregnancy, they were allowed to alternate the supporting leg whenever necessary while maintaining an upright posture. Throughout the session, the evaluator provided standardized time reminders to facilitate adherence to the protocol.

During the static water immersion session, participants remained standing quietly in the swimming pool for 30 minutes with the water level maintained at the xiphoid process. The upper limbs remained immersed throughout the intervention. Participants were instructed to avoid unnecessary movements and conversation, while alternating the supporting leg whenever necessary to maintain comfort.

The water aerobics intervention consisted of a standardized 30-minute class conducted by the same instructor for all participants. The session comprised a 5-minute warm-up, a 20-minute main conditioning phase, and a 5-minute cool-down. The warm-up included slow walking in multiple directions (forward, backward, lateral, and circular) combined with progressive upper-limb movements. The main conditioning phase consisted of a standardized sequence of typical water aerobics exercises, including jumping jacks, stationary jogging (skip), pendulum movements, cross-country skiing movements, lateral kicks, coordinated arm and leg movements during walking, and low-impact jumps. The session concluded with low-intensity movements followed by gentle stretching exercises involving the major muscle groups. Exercise intensity was continuously monitored using the modified Borg Rating of Perceived Exertion scale, with participants encouraged to maintain a perceived exertion between 5 and 6 (moderate) throughout the main conditioning phase.

2.5 OUTCOME MEASURES

Outcome measures were obtained immediately before and after each experimental session by the same trained evaluator using standardized procedures. The primary outcome measures were foot and ankle circumferences, while blood pressure and heart rate were assessed as secondary physiological outcomes. In addition, pitting edema and standardized photographic records were used as complementary clinical assessments to document changes in lower-limb edema.

Primary outcome measures

Lower-limb edema was quantitatively assessed by measuring foot and ankle circumferences using a flexible, non-elastic measuring tape. All measurements were

performed before and immediately after each intervention by the same evaluator according to predefined anatomical landmarks.

Foot circumference was measured with the measuring tape positioned around the forefoot at the distal end of the first metatarsal. Ankle circumference was measured with the tape positioned 5 cm above the inferior border of the medial malleolus. The same anatomical landmarks and measurement procedures were adopted throughout the study to ensure consistency across all experimental sessions.

Secondary outcome measures

Systolic and diastolic blood pressure were measured after participants had remained seated quietly for 5 minutes, without talking, with an empty bladder, both feet resting parallel on the floor, and the right arm supported at heart level. Blood pressure was measured using an aneroid sphygmomanometer and a Littmann® stethoscope, following standardized procedures.

Heart rate was measured immediately after blood pressure assessment using a finger pulse oximeter, while participants remained in the same standardized seated position.

Complementary clinical assessments

Pitting edema was assessed using a standardized digital pressure test performed over the pretibial region immediately before and after each intervention. This assessment was used as a qualitative clinical indicator of lower-limb edema and served as a complementary measure to the quantitative circumference assessments.

Standardized photographic records of the lower limbs were also obtained immediately before and after each intervention using a Canon EOS 2000D digital camera. All photographs were taken at the poolside under the same environmental conditions, with participants seated, knees flexed, and feet supported on the floor, thereby ensuring consistent positioning for visual comparison of edema throughout the study.

2.6 STATISTICAL ANALYSIS

Descriptive statistics were calculated for all study variables and included measures of central tendency and dispersion (mean, median, and standard deviation).

Comparisons between pre- and post-intervention measurements within each experimental condition were performed using the Wilcoxon signed-rank test. Differences among the three experimental conditions (land-based control, static water immersion, and water aerobics) were assessed using the Friedman test for related samples.

A two-sided p value ≤ 0.05 was considered statistically significant.

3 RESULTS

Twenty-four healthy pregnant women completed all three experimental conditions and were included in the final analysis. Their baseline demographic and anthropometric characteristics are summarized in Table 1. No adverse events or intervention-related complications were observed during the study.

Table 1

Baseline demographic and anthropometric characteristics of the participants (n = 24)

Characteristic	Mean ± SD
Age (years)	28.5 ± 4.0
Gestational age (weeks)	33.2 ± 2.8
Height (cm)	162.4 ± 4.5
Body mass (kg)	75.8 ± 7.4

Source: The Authors.

Table 2

Pre- and post-intervention foot and ankle circumferences under the three experimental conditions

Outcome	Intervention	Pre (mean ± SD)	Post (mean ± SD)	*p* value
Right ankle circumference (cm)	Standing	22.3 ± 0.3	22.5 ± 0.3	0.190
	Static immersion	22.3 ± 0.2	21.8 ± 0.2	<0.001
	Water aerobics	22.4 ± 0.3	21.7 ± 0.3	<0.001
Left ankle circumference (cm)	Standing	22.3 ± 0.1	22.5 ± 0.2	<0.001
	Static immersion	22.3 ± 0.3	21.8 ± 0.3	<0.001
	Water aerobics	22.4 ± 0.3	22.1 ± 0.3	<0.001
Right foot circumference (cm)	Standing	23.1 ± 0.3	23.2 ± 0.3	0.066
	Static immersion	23.2 ± 0.2	22.7 ± 0.3	<0.001
	Water aerobics	23.2 ± 0.6	22.6 ± 0.5	<0.001
Left foot circumference (cm)	Standing	23.2 ± 0.3	23.2 ± 0.4	0.843
	Static immersion	23.2 ± 0.4	22.6 ± 0.4	<0.001
	Water aerobics	23.2 ± 0.5	22.7 ± 0.4	<0.001

Data are presented as mean ± standard deviation (SD). SD values will be added after retrieval of the original database. P values were obtained using the Wilcoxon signed-rank test.
Source: The Authors.

Pre- and post-intervention foot and ankle circumferences under the three experimental conditions are presented in Table 2. Changes in lower-limb circumferences were observed following each experimental condition, with statistically significant reductions in foot and ankle circumferences after both static immersion and water aerobics.

Note. Data are presented as mean ± standard deviation (SD). SD values will be added after retrieval of the original database. *P* values were obtained using the Wilcoxon signed-rank test. Source: The authors

After standing on land, no significant changes were observed in right ankle, right foot, or left foot circumferences (p = 0.190, 0.066, and 0.843, respectively). In contrast, statistically significant reductions were observed in both ankle and foot circumferences after static immersion and water aerobics (all p < 0.001). A statistically significant increase in left ankle circumference was also observed after standing (p < 0.001).

Pre- and post-intervention heart rate and blood pressure values under the three experimental conditions are presented in Table 3.

Table 3

Pre- and post-intervention heart rate and blood pressure values under the three experimental conditions

Outcome	Condition	Pre (mean ± SD)	Post (mean ± SD)	*p* value
Heart rate (beats·min⁻¹)	Standing	86 ± 15	92 ± 12	0.024
	Static immersion	86 ± 9.0	76 ± 0.7	<0.001
	Water aerobics	86 ± 10	79 ± 9.0	0.002
Systolic blood pressure (mmHg)	Standing	100 ± 7.0	103 ± 7,3	0.050
	Static immersion	100 ± 4.8	98 ± 5.0	0.406
	Water aerobics	107 ± 6.9	100 ± 6.0	<0.001
Diastolic blood pressure (mmHg)	Standing	61 ± 1.0	62 ± 1.0	0.050
	Static immersion	62 ±0.8	62 ± 0.7	0.233
	Water aerobics	66 ± 1.0	64 ± 0.9	0.021

After standing on land, heart rate, systolic blood pressure, and diastolic blood pressure increased significantly. Static immersion significantly reduced heart rate but did not significantly affect blood pressure. Water aerobics significantly reduced heart rate as well as systolic and diastolic blood pressure. Detailed values are presented in Table 3.

Between-condition comparisons using the Friedman test showed no significant differences in baseline heart rate (p = 0.437), systolic blood pressure (p = 0.064), ankle circumference (right: p = 0.852; left: p = 0.280), or foot circumference (right: p = 0.988; left: p = 0.856). Baseline diastolic blood pressure showed a statistically significant difference among conditions (p = 0.004). Following the interventions, significant differences among conditions

were observed for heart rate ($p < 0.001$), systolic blood pressure ($p < 0.001$), diastolic blood pressure ($p = 0.005$), ankle circumference (right and left, both $p < 0.001$), and foot circumference (right and left, both $p < 0.001$).

4 DISCUSSION

This study compared the acute effects of standing on land, static water immersion, and water aerobics on lower-limb edema and hemodynamic responses in healthy women during the third trimester of pregnancy. The main findings were that both static immersion and water aerobics significantly reduced foot and ankle circumferences, whereas standing on land did not reduce lower-limb edema. In addition, both aquatic interventions elicited favorable cardiovascular responses, characterized by reductions in heart rate, while water aerobics also significantly decreased systolic and diastolic blood pressure. Collectively, these findings suggest that aquatic interventions may represent effective non-pharmacological strategies for minimizing lower-limb edema and promoting cardiovascular adaptation during late pregnancy.

The significant reductions in foot and ankle circumferences observed after both static immersion and water aerobics are physiologically consistent with the adaptations elicited by water immersion. During late pregnancy, plasma volume expansion and the mechanical compression of the inferior vena cava and pelvic veins by the enlarging uterus increase venous pressure in the lower limbs and favor dependent fluid accumulation (Ochałek *et al.*, 2016; Kuate Defo & Daskalopoulou, 2023; Collins *et al.*, 2024). Immersion modifies this condition through the shared physical environment to which participants in both aquatic conditions were exposed. In particular, buoyancy counteracts gravity and reduces the gravity-driven intravascular pressure gradient in the dependent lower limbs, thereby limiting fluid extravasation and increasing the volume retained within the circulation (Weenink and Wingelaar, 2021). Because the participants underwent comparable levels of immersion in both aquatic conditions, these fundamental physical effects were likely present during both static immersion and water aerobics, regardless of the additional muscular activity performed during exercise.

The central redistribution of blood produced by immersion increases venous filling and atrial distension, stimulating atrial natriuretic peptide release, which contributes to the natriuretic response as part of a broader interaction among hormonal, neural, renal, and hemodynamic mechanisms (Epstein *et al.*, 1989). Water immersion also suppresses

vasopressin, renin, aldosterone, and angiotensin II, favoring renal water and sodium excretion (Stadeager *et al.*, 1992; Hammerum *et al.*, 1998). These coordinated cardiovascular and renal responses provide a physiologically plausible explanation for the consistent reductions in foot and ankle circumferences observed after both aquatic conditions in the present study.

Both aquatic interventions promoted significant reductions in heart rate, indicating that water immersion alone is sufficient to elicit favorable acute cardiovascular adaptations. The reduction in heart rate is consistent with the central redistribution of blood volume induced by immersion, which increases venous return and stroke volume, allowing cardiac output to be maintained with a lower heart rate (Weenink and Wingelaar, 2021; Pendergast *et al.*, 2015). In addition, immersion-induced atrial distension and the associated neurohormonal responses contribute to cardiovascular stabilization during immersion (Epstein *et al.*, 1989; Stadeager *et al.*, 1992; Hammerum *et al.*, 1998).

In contrast, significant reductions in systolic and diastolic blood pressure were observed only after water aerobics. This finding suggests that, although immersion alone is sufficient to improve central hemodynamics, the addition of dynamic exercise provides an extra cardiovascular stimulus capable of producing a measurable hypotensive response. Similar reductions in blood pressure during aquatic exercise have been reported in healthy pregnant women by Finkelstein *et al.* (2011), who demonstrated lower systolic, diastolic, and mean arterial pressures during water-based exercise than during equivalent exercise performed on land. Likewise, Kwee *et al.* (2000) reported transient reductions in maternal blood pressure together with increased urine production following 35 minutes of water immersion in healthy pregnant women, without adverse effects on fetal heart rate patterns, whereas Vázquez-Lara *et al.* (2018) demonstrated that a six-week aquatic exercise program improved blood pressure control and hydrosaline balance during pregnancy.Together, these findings support the concept that the cardiovascular benefits of aquatic exercise extend beyond those achieved by immersion alone, while reinforcing that the physical properties of water remain the fundamental physiological stimulus underlying both interventions.

Although Kwee *et al.* (2000) reported reductions in maternal blood pressure following static water immersion in healthy pregnant women, static immersion did not significantly modify blood pressure in the present study. Differences in participant characteristics, intervention protocols, and the timing of hemodynamic measurements may have contributed to these divergent findings, although direct comparisons between the studies remain limited.

In contrast, significant reductions in systolic and diastolic blood pressure were observed only after water aerobics. This finding suggests that, although immersion alone is sufficient to improve central hemodynamics, the addition of dynamic exercise may provide an additional acute cardiovascular stimulus capable of producing a measurable hypotensive response. Similar observations have been reported during aquatic exercise in pregnant women, with lower blood pressure responses during exercise performed in water than during equivalent exercise on land (Finkelstein *et al.*, 2011). In addition, a six-week aquatic exercise program was associated with improved blood pressure control during pregnancy (Vázquez-Lara *et al.*, 2018).

The present findings have important clinical implications for the non-pharmacological management of lower-limb edema during late pregnancy. Both static water immersion and water aerobics produced significant reductions in foot and ankle circumferences, indicating that the hydrostatic properties of water alone are sufficient to promote meaningful reductions in peripheral edema. This finding is particularly relevant because many women in late pregnancy experience pregnancy-related musculoskeletal symptoms, particularly low back pain, and may require modifications to their exercise programs because of the normal anatomic and physiologic changes associated with pregnancy (American College of Obstetricians and Gynecologists [ACOG], 2020). In these situations, static water immersion may represent a practical, accessible, and well-tolerated therapeutic option for reducing lower-limb edema. However, when exercise is feasible and no contraindications exist, water aerobics may offer additional cardiovascular benefits, as evidenced by the significant reductions in both systolic and diastolic blood pressure observed only after this intervention.

This study has important methodological strengths. Because all participants underwent each experimental condition, interindividual variability was minimized, allowing direct within-subject comparisons. In addition, the inclusion of both static water immersion and water aerobics as separate intervention conditions made it possible to distinguish the physiological effects of water immersion from those associated with dynamic exercise, providing a clearer understanding of the relative contribution of each intervention to reductions in lower-limb edema and hemodynamic responses. The simultaneous assessment of peripheral edema and hemodynamic responses also provided a comprehensive evaluation of the acute physiological effects of aquatic interventions during late pregnancy. However, some limitations should be acknowledged. The relatively small sample size and the inclusion of only healthy pregnant women limit the generalizability of the findings to women with

pregnancy-related complications, such as hypertensive disorders or severe edema. In addition, only the acute effects of single intervention sessions were evaluated, precluding conclusions regarding the long-term benefits of repeated aquatic therapy or exercise programs.

5 CONCLUSION

In conclusion, both static water immersion and water aerobics effectively reduced lower-limb edema in healthy women during the third trimester of pregnancy, demonstrating that the hydrostatic properties of water alone are sufficient to promote meaningful acute reductions in peripheral edema. Water aerobics, however, provided additional cardiovascular benefits by significantly reducing systolic and diastolic blood pressure, while both aquatic interventions decreased heart rate.

These findings provide new insight into the relative contributions of water immersion and dynamic exercise to the physiological responses elicited by aquatic interventions during pregnancy. From a clinical perspective, static water immersion may represent a practical non-pharmacological option for pregnant women who are unable to participate in structured exercise programs, whereas water aerobics may offer broader cardiovascular benefits when exercise is feasible. Together, these findings support the incorporation of aquatic interventions as safe and potentially valuable strategies for the management of lower-limb edema during late pregnancy.

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