A Pneumatic, Adjustable-Buoyancy Wearable for Prenatal Water Activities

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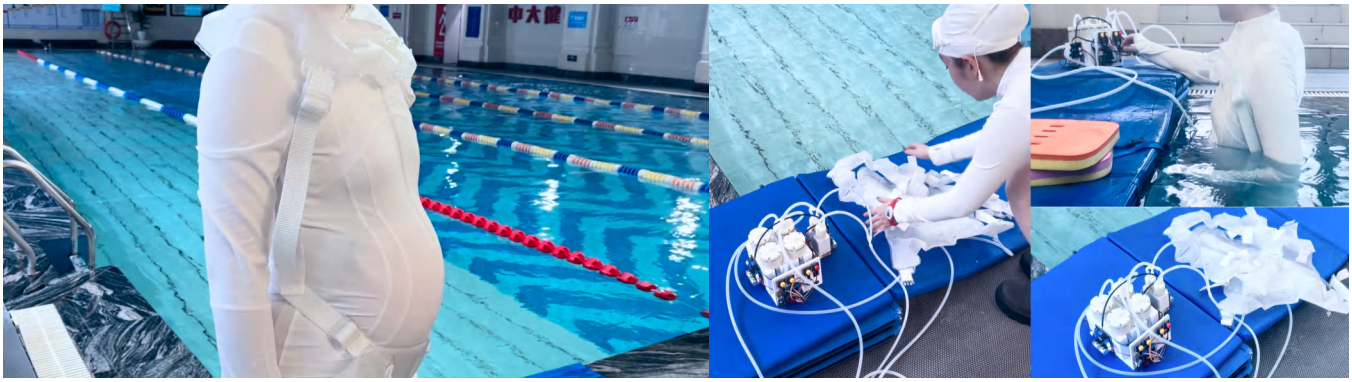


Figure 1: Overview of our pneumatic, adjustable-buoyancy wearable and its poolside deployment for prenatal water activities.

Abstract

Swimming during pregnancy is widely seen as health-promoting, but pregnancy-related bodily changes can increase imbalance risk and safety anxiety in public pools, limiting participation. To reduce these barriers and enable flexible "swim-or-rest" engagement, we propose an adjustable-buoyancy wearable using distributed air and water bladders across the torso to create localized lift and counter-weighting. This supports stable transitions among three postures: sitting-in-water, head-up breaststroke, and supine floating. Based on interviews and co-design workshops (N = 22), we defined design goals and built a prototype, then ran an in situ feasibility study in a public pool with three participants, assessing perceived effort, trunk support, subjective safety, and movement constraints. Results show that the prototype offers nonrestrictive support: it reduces abdominal sinking without compressing the torso, preserves limb mobility, lowers perceived risk, and improves overall experience. We contribute reusable mechanisms and design implications for inclusive aquatic wearables and soft interactive systems.

CCS Concepts

• **Human-centered computing** → **Accessibility design and evaluation methods**; **Interaction devices**; *Interaction techniques*; *Empirical studies in HCI*.

Keywords

Pregnancy, swimming, aquatic wearables, pneumatic actuation, buoyancy control, inclusive design, embodied interaction

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CHI EA '26, Barcelona, Spain
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ACM ISBN 979-8-4007-2281-3/26/04
https://doi.org/10.1145/3772363.3799369

ACM Reference Format:
Yuhe Qin, Zihe Ran, Xiyu Li, and Min Fan. 2026. A Pneumatic, Adjustable-Buoyancy Wearable for Prenatal Water Activities. In *Extended Abstracts of the 2026 CHI Conference on Human Factors in Computing Systems (CHI EA '26), April 13–17, 2026, Barcelona, Spain.* ACM, New York, NY, USA, 8 pages. https://doi.org/10.1145/3772363.3799369

1 Introduction

In recent years, wearable research has shifted from technology-driven approaches toward contextualized and accessibility-oriented perspectives [48], emphasizing how devices support people in entering and sustaining participation in real-world activities. Aquatic environments have therefore emerged as a key site for embodied interaction: buoyancy can afford lightness and relaxation, yet it also introduces safety risks and anxiety about loss of bodily control [8, 28, 35]. This tension is intensified during pregnancy [3, 29].

Although aquatic wearables, smart wearables for pregnancy, and terrestrial maternity support devices have each matured in their respective domains, systematic exploration of wearable support for participating in public pools during pregnancy remains limited. Existing aquatic devices primarily focus on monitoring [20, 27, 49] or training [4, 11, 16, 24, 31, 32, 47]. Work on safety and accessibility has largely targeted beginners, children, and disabled users [2, 5–7, 13, 17–19, 25, 33, 34, 45, 46], with little attention to pregnant users. By contrast, pregnancy wearables predominantly emphasize health monitoring and alerts [1, 26, 37, 41, 44]. Terrestrial abdominal or support belts can reduce physical load [12, 36, 40, 42] but do not readily transfer to aquatic contexts [42]. Commercial floating relaxation products are also fragmented and lack systematic design grounded in pregnancy-specific needs or validation in real pool settings.

Against this backdrop, we aim to provide pregnant women with a lower-barrier and more controllable way to engage in aquatic environments. Drawing on Assets-Based Design [22, 23] and Inclusive Design [21, 50], we conceptualize aquatic wearables as mechanisms for expanding pathways to participation rather than as tools for "correcting" the body. From an embodied interaction perspective [15], we further view the device as an embodied mediator in the human–water relationship, rendering experiences of entering the water and remaining/resting in water as designable. We propose and implement a pneumatic, adjustable-buoyancy wearable system for pregnancy-related aquatic activity, using buoyancy differentials as the core interaction material, and complete a prototype and feasibility study to inform future iterations.

We make three contributions: (1) We introduce "buoyancy differentials" as an interaction mechanism for aquatic wearables, conceptualized as a designable posture-guiding material; (2) We implement a pneumatic, adjustable-buoyancy wearable prototype for pregnancy-related aquatic participation; (3) Grounded in real pool contexts, we offer reusable design considerations for inclusive aquatic wearables and soft interactive systems in WaterHCI.

2 Formative Research

Between August 19 and September 4, 2025, we conducted online semi-structured interviews with 20 women (aged 25–39) who had experience swimming during pregnancy, one obstetrician with childbirth experience, and one swimming instructor with childbirth experience.

We analyzed the data using thematic analysis, which yielded three design goals guiding our system design:

DG1. Safety First: Ensure that the nose and mouth remain above water to reduce the risk of choking and loss of balance.

During pregnancy, women must attend not only to their own physical condition but also to the well-being of the fetus. As a result, they place greater emphasis on exercise safety compared with the pre-pregnancy period. This need was repeatedly highlighted by participants in our formative study (N = 18).

DG2. Low Physical Exertion: The design should reduce the burden caused by decreased physical strength and reduced mobility.

In the formative study, participants (N = 9) reported that physical changes during pregnancy increased swimming resistance to varying degrees, limiting them to short-duration swimming activities.

DG3. Reducing Anxiety Around Swimming During Pregnancy: Adjustable support should be provided to enhance stability, thereby increasing users' sense of autonomy and reassurance.

At present, both infrastructure (e.g., the lack of dedicated swimming lanes) and the broader social environment remain insufficiently supportive of pregnant swimmers. In addition, bodily changes before and after pregnancy can create differences in swimming experiences that lead to feelings of insecurity (N = 6). The design should therefore aim to restore a level of comfort comparable to that experienced before pregnancy.

From a thematic synthesis of participants' in-water practices, we identified three common posture states that also offer clear opportunities for design intervention:

(1) **Sitting-in-water (short rest / pausing):** With pregnancy-sensitive stamina, some participants (N = 4) wanted brief in-water pauses after swimming. Yet without treading-water skills, many must stand or keep moving; thus, "being able to sit and rest in the water" became a concrete need.

(2) **Head-up breaststroke (low-risk movement):** Breaststroke is common during pregnancy. The head-up variant keeps the head above water, easing breathing strain and choking anxiety, and is often recommended by instructors.

(3) **Supine floating (deep relaxation):** Several participants (N = 6) wanted to lie flat and relax in water. While supine rest on land can be uncomfortable during pregnancy, buoyancy enables comfortable supine stretching and floating.

Together, these three postures operationalize a practical participation loop. Rather than optimizing for swimming faster or "better," they support a "swim-or-rest" aquatic flow, enabling users to switch among exertion, pausing, and relaxation.

3 Concepts, Design, and Prototype

3.1 Trunk-First Zoning, Routing, and Accessible Donning

Guided by DG2 and DG3, and with safety as a prerequisite, our design aims to minimize constraints on the pregnant abdomen and limb movement, while distributing abdominal load and pressure. The overall silhouette and paneling are shaped to better fit the pregnant body. Considering that pregnancy-related body changes are dynamic (e.g., abdominal circumference, physical load, and activity intensity vary across gestational stages), the system adopts a detachable and adjustable design. Accessibility for pregnant bodies is reflected in:

(1) **Zoning:** we divide the trunk into three regions, namely abdomen/waist, back, and pelvis, corresponding to the needs for abdominal support, dorsal lift, and lower-trunk stability.

(2) **Routing:** straps and structures are routed along biomechanical and skin-tension related lines to improve fit and comfort,[9, 30, 38] and we also draw on discussions of soft-tissue/apparel modeling and body landmarks for structuring wearable layouts[14, 43]. The routing is mainly placed along the lateral torso and near the underarm area to avoid direct compression on the front abdomen, while minimizing interference with limb swing and the activity of muscle groups involved in in-water movement, and reducing local constriction and interference.

(3) **Buckles and adjustability:** detachable buckles are placed at the side waist/hip to avoid risky operations such as bending, reaching behind the back, or pulling the system over the head, enabling quick donning and doffing. A multi-point adjustable design (e.g., straps and buckles) accommodates different body shapes and comfort preferences across gestational stages, and achieves stability by distributing loads across a larger trunk area without overtightening (Fig. 2).



Figure 2: On-body overview of the wearable prototype from five viewpoints (front, front three-quarter, side, back three-quarter, and back), showing body coverage and strap layout.

3.2 Buoyancy Differentials for Posture Control

Air bladders alone cannot reliably stabilize the changing prenatal body in water. We therefore pair air bladders (localized lift) with water bladders (localized ballast), using their distribution to create that guide posture and make switching safer and easier (DG1–DG3).

We encode the three high-frequency postures as three use states and apply the same zoned logic:

(1) **Sitting-in-water.** Stable sitting needs lift at chest/back and ballast at hips; we add pelvic ballast and torso support to reduce continuous sculling (Eq. 1).

$$F_{\text{net}}^{\text{chest/back}} > 0 \qquad F_{\text{net}}^{\text{hips}} < 0 \tag{1}$$

(2) **Head-up breaststroke.** Keeping the head above water is aided by more lift on the back than the abdomen (Eq. 2).

$$F_{\text{net}}^{\text{back}} > F_{\text{net}}^{\text{abdomen}} \tag{2}$$

(3) **Supine floating.** Stable supine floating is aided by more lift on the abdomen than the back, supporting sustained relaxation (Eq. 3).

$$F_{\text{net}}^{\text{abdomen}} > F_{\text{net}}^{\text{back}} \tag{3}$$

3.3 Wearable Modules

Our prototype is a wearable system for in-water stable dwelling and posture switching (Fig. 3). It has five torso modules. Two fixed baseline layers include an abdominal air bladder (M1) that supports the abdomen by distributing loads across the trunk, and a chest–back air bladder (M2) that provides primary safety lift to keep the face oriented upward. Three adjustable modules enable posture switching: a small waist air bladder (M3), a large lower-back air bladder (M4), and a fillable water ballast bladder (M5). Across all modes, M1 and M2 remain constant, while switching is achieved mainly by tuning M3–M5. The goal is repeatable posture stability through region-specific lift and ballast, rather than uniformly lifting the whole body with a single large float.

3.4 Hardware & Control

An Arduino-based controller coordinates the air and water modules via valves and a motor driver (Fig. 4). With one posture button press, the system runs a preset, timed sequence for inflation/water intake and maintenance, allowing users to reach the target state without manual tuning in the pool.

3.5 Interaction and Safety-Oriented Switching

For interaction convenience, we set the three postures as three preset modes, and each mode corresponds to a fixed buoyancy combination (Table 1). The interface provides four buttons: one button for each posture mode and one reset button. We use preset levels to indicate the amount of inflation/filling: 0 (off), L1 (~30%), L2 (~60%), and L3 (~80–90%). Percentages are calibrated with 100% defined as full capacity of the corresponding module (air bladders fully inflated; the water bladder fully filled).

Table 1: Preset levels for three posture modes. M1 (abdominal air) and M2 (chest–back air) are fixed baseline support layers across all modes; only M3–M5 are adjusted between postures.

Posture mode	M3	M4	M5
Sitting-in-water (rest)	0	L2	L3
Head-up breaststroke (mobility)	L3	L1	0
Supine floating (relax)	0	L1	L2

To reduce rolling or unintended flips, posture switching follows a fixed sequence: remove destabilizing factors first, then build the new support. For instance (Table 2), when switching from sitting-in-water to head-up breaststroke, the system drains ballast (M5), softens back support (M4), and only then adds waist lift (M3).

Table 2: Actuation-level changes for two representative posture transitions. Steps are executed sequentially (Step 1–3).

Transition	Step 1	Step 2	Step 3
Sitting-in-water to Head-up breaststroke	M5: L3 to 0	M4: L2 to L1	M3: 0 to L2
Head-up breaststroke to Supine floating	M3: L3 to 0	M5: 0 to L2	M4: keep at L1



Figure 3: Wearable module layout shown with a technical overlay and on-body photo. (a) Front view highlighting fixed modules M1–M2. (b) Back view highlighting fixed module M2 and adjustable modules M3–M5.

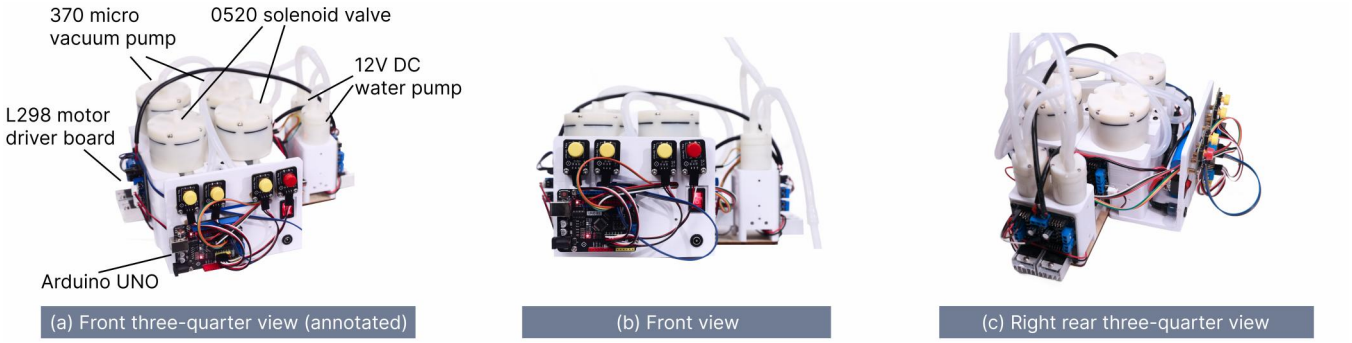


Figure 4: Hardware system shown from three viewpoints. (a) Front three-quarter view (annotated) highlighting key components. (b) Front view. (c) Right rear three-quarter view.

4 User Study

We conducted an exploratory in-situ pool study on 07/12/2025 (N = 3): a swim coach with prior childbirth experience, an intermediate swimmer, and a non-swimmer. Wearing a pregnancy-belly simulator, participants tried three postures (aquatic sitting, head-up breaststroke, supine floating) with and without the wearable, using one-button presets to enter and maintain each state. Through observation and brief interviews, we assessed effort reduction, trunk (abdominal/lumbar) support, perceived safety/relaxation, and movement constraints.

Three takeaways emerged. First, the multi-point adjustments accommodated different waist–abdomen sizes and tightening preferences, suggesting size inclusivity beyond pregnancy. Second, because support was localized to the torso rather than achieved by tight compression, limb mobility was largely preserved. Third, the system was most beneficial for slow, relaxation-oriented activity: distributed buoyancy across the waist–abdomen and back reduced abdominal sinking without constriction, improving stability during light sculling or static dwelling (Fig. 5).

5 Discussion, Conclusion, and Future Work

Compared to prior aquatic and liquid HCI work that often treats water as a medium that amplifies exertion, resistance, and performance-oriented training [4, 8, 31, 33, 39], our design shifts the goal toward dwelling: enabling pregnant users to safely enter, pause, and rest in water with lower anxiety. Guided by Assets-Based Design [23], we reframe prenatal swimming not as correcting deficits [9, 16, 42] but as supporting capabilities that emerges during pregnancy—seeking lightness, relaxation, and a sense of being held by buoyancy, rather than athletic performance. This stance also challenges the dominant medicalized framing in pregnancy-related technologies, which tends to prioritize monitoring over lived bodily experience [9, 42].

A key design move is to treat buoyancy differentials as an interaction material: instead of uniformly lifting the body, we distribute buoyant and ballast forces across torso regions to create localized tendencies to rise or sink, making stillness and posture switching valid forms of participation. This supports three representative postures (sitting-in-water, head-up breaststroke, and supine floating) while preserving limb mobility and avoiding torso compression, aligning with Soma Design's emphasis on bodily experience over external metrics [10, 15, 28]. We further leverage pool water as ballast, reducing reliance on extra materials and making the mechanism more context-situated.

Importantly, our formative interviews mainly involved women who were already skilled and comfortable in water before pregnancy, which likely underrepresents a large group of water-anxious pregnant beginners—those who may desire aquatic relaxation most yet are least likely to enter pools due to heightened risk perception. We therefore conceptualize participation as an "able/disabled"

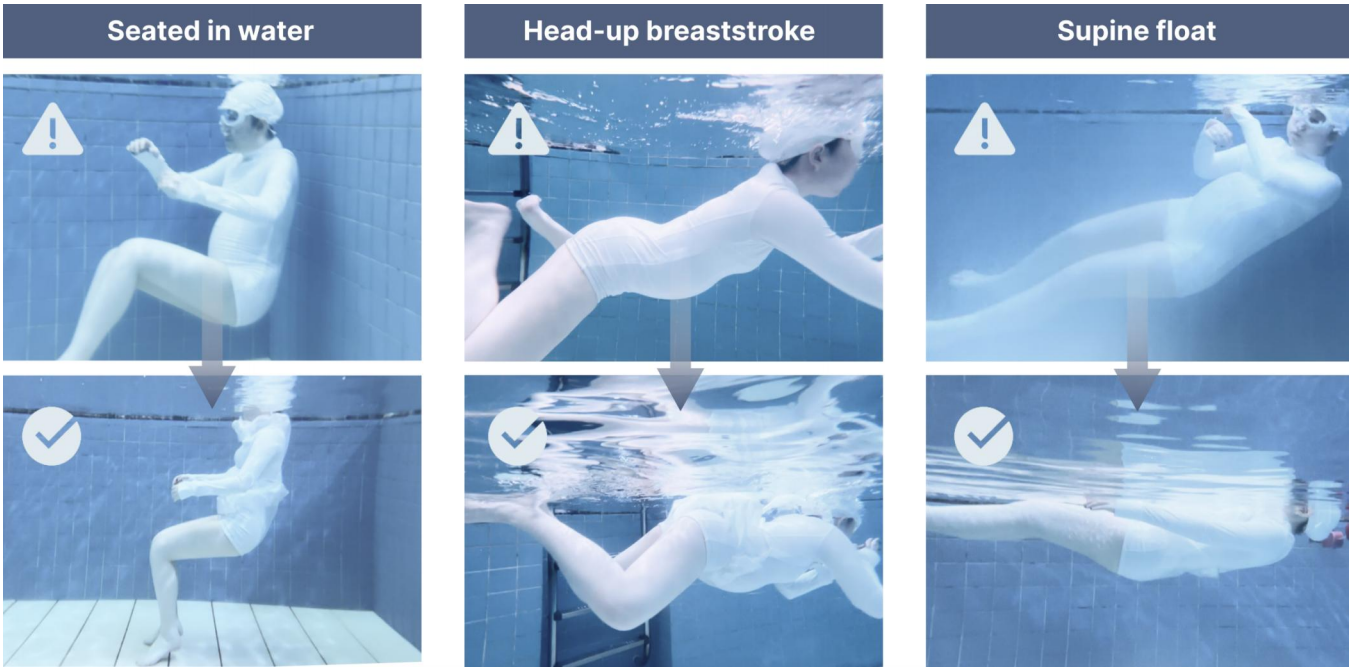


Figure 5: Before–after comparisons across three representative prenatal water postures. Top row shows typical instability without the wearable; bottom row shows improved stability and restability with the wearable. Left: seated in water; middle: head-up breaststroke; right: supine float.

spectrum jointly shaped by water familiarity and perceived safety (Fig. 6), where exclusion is driven not only by skill or strength but also by the interplay between bodily condition, environmental affordances, and subjective safety [46]. This lens expands our design space beyond prenatal swimmers to water-anxious beginners and other contextually constrained bodies (e.g., older adults and rehabilitation users), where being able to stop, rest, and reorient can be as critical as moving forward [6, 17, 39].

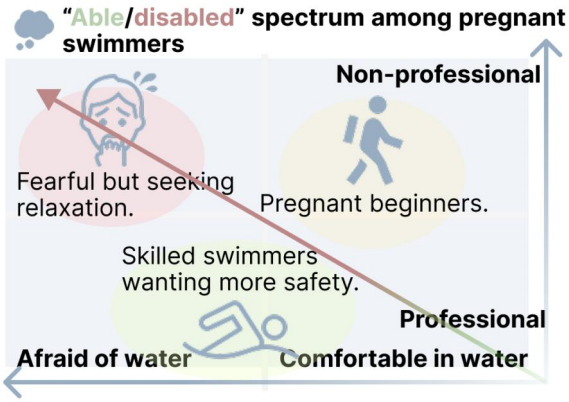


Figure 6: An ability spectrum among pregnant swimmers, mapped by water familiarity and perceived safety. The model highlights an underrepresented group in our interviews: water-anxious pregnant beginners who desire relaxation benefits but avoid pools during pregnancy.

Challenges and future work. Our research is in the preliminary design and pilot study phase. The current prototype prioritizes functional feasibility over aesthetic refinement; future iterations should improve social legibility and wearability in highly visible public pool settings. System integration (especially size reduction and waterproof sealing) remains a major challenge and calls for more compact bladders and pool-appropriate materials. While inflation and posture transitions are currently performed at the poolside, future versions could implement Bluetooth communication between the controller and the air pump to support more flexible operations. Furthermore, our pool study sample was small; future studies should include participants across gestational stages and levels of aquatic anxiety to further validate the quadrant model and evaluate effectiveness in real pool dynamics. Finally, reliance on electric pumps motivates exploring low-power or passive alternatives to improve safety and portability.

In summary, we address a fundamental prenatal tension in public pools, specifically the conflict between the desire to relax and the fear of losing control, by prioritizing safety and postural autonomy. Through a modular wearable based on buoyancy differentials, we demonstrate how entry barriers can be lowered while enabling richer "swim-or-rest" experiences, offering reusable implications for inclusive aquatic wearables and WaterHCI.

References

[1] Anika Alim and Masudul H Imtiaz. 2023. Wearable sensors for the monitoring of maternal health—a systematic review. *Sensors* 23, 5 (2023), 2411.

[2] Anna Atkins, Shenan Hoppe-Ludwig, Walter Guminiak Jr, Monica Hendricksen, and Laura Miller. 2025. Development and Usability of an Adjustable Prosthesis for Aquatic Therapy. *JPO: Journal of Prosthetics and Orthotics* 37, 3 (2025), 186–192.

[3] Mette G Backhausen, Ann Tabor, Hanne Albert, Susanne Rosthøj, Peter Damm, and Hanne K Hegaard. 2017. The effects of an unsupervised water exercise program on low back pain and sick leave among healthy pregnant women–A randomised controlled trial. *PloS one* 12, 9 (2017), e0182114.

[4] Bruce E Becker. 2009. Aquatic therapy: scientific foundations and clinical rehabilitation applications. *Pm&r* 1, 9 (2009), 859–872.

[5] Joshua Breighner, Sandra Saavedra, and Donna Snowdon. 2021. Efficacy and Safety of a Novel Aquatic Device for Children With Postural Dysfunction. *The Journal of Aquatic Physical Therapy* 29, 3 (2021), 65–72.

[6] Chung-Sing Chin and Yu-Lin Wang. 2013. A research on using adjustable buoyancy assistive device in hydrotherapy for cerebral palsy children. In *2013 1st International Conference on Orange Technologies (ICOT)*. IEEE, 185–188.

[7] Kyle Chuang et al. 2025. Safeswim: An Intelligent Wearable System for Drowning Detection and Prevention using Accelerometer-Based Motion Analysis and Underwater Acoustic Signaling. In *CS & IT Conference Proceedings*, Vol. 15. CS & IT Conference Proceedings.

[8] Christal Clashing, Maria Fernanda Montoya Vega, Ian Smith, Joe Marshall, Leif Oppermann, Paul H Dietz, Mark Blythe, Scott Bateman, Sarah Jane Pell, Swamy Ananthanarayan, et al. 2022. Splash! identifying the grand challenges for waterhci. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. 1–6.

[9] Rebecca Conder, Reza Zamani, and Mohammad Akrami. 2019. The biomechanics of pregnancy: A systematic review. *Journal of functional morphology and kinesiology* 4, 4 (2019), 72.

[10] Don Samitha Elvitigala, Armağan Karahanoğlu, Andrii Matviienko, Laia Turmo Vidal, Dees Postma, Michael D Jones, Maria F Montoya, Daniel Harrison, Lars Elbæk, Florian Daiber, et al. 2024. Grand Challenges in SportsHCI. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. 1–20.

[11] Zhenglong Feng, Aifeng Ren, Zhiyuan Chen, Adnan Zahid, Lei Ye, Muhammad Ali Imran, and Qammer H Abbasi. 2022. Portable and Feasible Device to Evaluate the Technique of Swimming Practitioners. *IEEE Access* 10 (2022), 88093–88104.

[12] Natasha AMS Flack, E Jean C Hay-Smith, Mark D Stringer, Andrew R Gray, and Stephanie J Woodley. 2015. Adherence, tolerance and effectiveness of two different pelvic support belts as a treatment for pregnancy-related symphyseal pain-a pilot randomized trial. *BMC pregnancy and childbirth* 15, 1 (2015), 36.

[13] Elena Gibelli, Diego Morra, Mirko Gelsomini, and Maristella Matera. 2023. Improving Swim Accessibility through Vibro-Tactile Sensory Substitution: A Preliminary Study. In *Proceedings of the 15th Biannual Conference of the Italian SIGCHI Chapter*. 1–8.

[14] Simeon Gill, Emma Scott, Carol McDonald, Anke Klepser, and Inga Dabolina. 2022. White Paper-IEEE 3D Body Processing Industry Connections–Landmarking for Product Development. *IEEE 3D Body Processing Industry Connections–Landmarking for Product Development* (2022), 1–48.

[15] Kristina Höök, Baptiste Caramiaux, Cumhur Erkut, Jodi Forlizzi, Nassrin Hajinejad, Michael Haller, Caroline CM Hummels, Katherine Isbister, Martin Jonsson, George Khut, et al. 2018. Embracing first-person perspectives in soma-based design. In *Informatics*, Vol. 5. MDPI, 8.

[16] Matevž Hribernik and Anton Kos. 2023. Exploring the applicability of haptic actuators in aquatic environments. *Internet of Things* 24 (2023), 100924.

[17] Mariana Ditboya Hukubun and Yelia Tomasoa. 2022. Development of Swimming Learning Aid Design toward Acceleration of Learning Swimming Techniques. *Development* 6, 2 (2022).

[18] Salman Jalalifar, Andrew Belford, Eila Erfani, Amir Razmjou, Rouzbeh Abbassi, Masoud Mohseni-Dargah, and Mohsen Asadnia. 2024. Enhancing water safety: exploring recent technological approaches for drowning detection. *Sensors* 24, 2 (2024), 331.

[19] Lawrence W Judge, Matt Moore, Aidan Biddle, Adam Smith, and Donald L Hoover. 2025. Enhancing Inclusivity in Sports: A Focus on Adaptive Synergy for Athletes with Physical Disabilities. *International Journal of Exercise Science* 18, 1 (2025), 470.

[20] Maliha Kabir, Teja Sree Mummadi, and Prabha Sundaravadivel. 2022. Poster: Towards Edge-Intelligent Wearable for early Drowning Detection. In *Proceedings of the 16th International Conference on Underwater Networks & Systems*. 1–2.

[21] Simeon Keates, P John Clarkson, and Peter Robinson. 2002. Developing a practical inclusive interface design approach. *Interacting with computers* 14, 4 (2002), 271–299.

[22] Scott R Klemmer, Björn Hartmann, and Leila Takayama. 2006. How bodies matter: five themes for interaction design. In *Proceedings of the 6th conference on Designing Interactive systems*. 140–149.

[23] John P Kretzmann and John McKnight. 1993. Building communities from the inside out. (1993).

[24] Jeroen Lecoutere and Robert Puers. 2016. Tracking elite swimmers in real time with wearable low-power wireless sensor networks. *Procedia Engineering* 147 (2016), 627–631.

[25] Nga-wun Li, Chu-po Ho, Kit-lun Yick, and Jin-yun Zhou. 2021. Design of novel buoyant swimming vest using inlay knitting technology. *Textile Research Journal* 91, 9-10 (2021), 1155–1166.

[26] Linkun Liu, Yujian Pu, Junzhe Fan, Yu Yan, Wenpeng Liu, Kailong Luo, Yiwen Wang, Guanlin Zhao, Tupei Chen, Poenar Daniel Puiu, et al. 2024. Wearable sensors, data processing, and artificial intelligence in pregnancy monitoring: a review. *Sensors* 24, 19 (2024), 6426.

[27] Xinyang Liu, Lei Wang, Jie Xiong, Chi Lin, Xinhua Gao, Jiale Li, and Yibo Wang. 2023. Uqrcom: Underwater wireless communication based on qr code. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 6, 4 (2023), 1–22.

[28] Steve Mann, Mark Mattson, Steve Hulford, Mark Fox, Kevin Mako, Ryan Janzen, Maya Burhanpurkar, Simone Browne, Craig Travers, Robert Thurmond, et al. 2021. Water-Human-Computer-Interface (WaterHCI): Crossing the borders of computation clothes skin and surface. *Proceedings of the 23rd annual Water-Human-Computer Interface Deconference (Ontario Place TeachBeach, Toronto, Ontario, Canada). Ontario Place TeachBeach, Toronto, Ontario, Canada (2021)* (2021), 6–35.

[29] JL McCrory, AJ Chambers, A Daftary, and MS Redfern. 2010. Dynamic postural stability during advancing pregnancy. *Journal of biomechanics* 43, 12 (2010), 2434–2439.

[30] Robert Michnik, Hanna Zadoń, Katarzyna Nowakowska-Lipiec, and Wanda Forczek-Karkosz. 2022. How Does the Lumbopelvic Complex Cope with the Obstetrical Load during Standing? Ergonomic Aspects of Body Posture in Pregnant Women. *Applied Sciences* 12, 9 (2022), 4330.

[31] Cecilia Monoli, Manuela Galli, and Jeffrey A Tuhtan. 2024. Improving the reliability of underwater gait analysis using wearable pressure and inertial sensors. *Plos one* 19, 3 (2024), e0300100.

[32] Jorge E Morais, João P Oliveira, Tatiana Sampaio, and Tiago M Barbosa. 2022. Wearables in swimming for real-time feedback: A systematic review. *Sensors* 22, 10 (2022), 3677.

[33] Ashton Margarete Moseley. [n. d.]. The development of an appropriate assistive device for water safety training in South African schools. ([n. d.]).

[34] Annika Muehlbradt, Varsha Koushik, and Shaun K Kane. 2017. Goby: A wearable swimming aid for blind athletes. In *Proceedings of the 19th international acm sigaccess conference on computers and accessibility*. 377–378.

[35] Florian 'Floyd' Mueller, Maria F Montoya, Sarah Jane Pell, Leif Oppermann, Mark Blythe, Paul H Dietz, Joe Marshall, Scott Bateman, Ian Smith, Swamy Ananthanarayan, et al. 2024. Grand challenges in WaterHCI. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. 1–18.

[36] Fitrah Ivana Paisal, Hidayanti Arifuddin, Risa Arieska, Rasumawati Rasumawati, Wiwit Vitania, and Adhar Arifuddin. 2025. Effectiveness of a Modified Pregnancy Support Belt in Reducing Back and Pelvic Pain in Pregnant Women: A Quasi-Experimental Study in South Jakarta. *Journal of Health and Nutrition Research* 4, 3 (2025), 1287–1292.

[37] Sohini Patel, Alexandra E Conway, Tricia Adjei, Isabella Abati, Saksham Dhawan, Zhenhua Yu, Ravi Vaidyanathan, and Christoph Lees. 2025. Is it possible to monitor fetal movements with a wearable device? A review of novel technologies. *European Journal of Obstetrics & Gynecology and Reproductive Biology* 305 (2025), 329–338.

[38] SP Paul. 2017. Biodynamic excisional skin tension (BEST) lines: revisiting Langer's lines, skin biomechanics, current concepts in cutaneous surgery, and the (lack of) science behind skin lines used for surgical excisions. *J Dermatol Res* 2, 1 (2017), 77–87.

[39] Sagrario Pérez-de la Cruz. 2020. Effect of an aquatic balance-training program in patients with chronic stroke: a single-group experimental pilot study. *Medicina* 56, 12 (2020), 656.

[40] Poppy Siska Putri, Sari Widya Ningsih, and Juanda Syafitasari. 2024. Innovation in the development of a maternity warm massage belt for reducing back pain intensity in working pregnant women. *Science Midwifery* 12, 4 (2024), 1478–1485.

[41] Manping Qin, Yong Xu, Yubao Liang, and Tie Sun. 2023. A wearable fetal movement detection system for pregnant women. *Frontiers in Medicine* 10 (2023), 1160373.

[42] Carolina Quintero Rodriguez and Olga Troynikov. 2019. The effect of maternity support garments on alleviation of pains and discomforts during pregnancy: a systematic review. *Journal of Pregnancy* 2019, 1 (2019), 2163790.

[43] Randy K Rannow, Carol McDonald, Alfredo Ballester Fernandez, Katy Schildmeyer, Emma Scott, and Simeon Gill. 2023. Skin and soft tissue modeling and its impact on apparel modeling. *Communications in Development and Assembling of Textile Products* 4, 2 (2023), 151–163.

[44] Kristina Stricker, Anda-Petronela Radan, and Daniel Surbek. 2025. Continuous remote home monitoring solutions for mother and fetus: A scoping review. *European Journal of Obstetrics & Gynecology and Reproductive Biology* 305 (2025), 170–177.

[45] Tina van Duijn, Jonathan Leo Ng, Carolina Burnay, Neil Anderson, Luiz Uehara, Kane Cocker, and Chris Button. 2021. The influence of equipment and environment on children and young adults learning aquatic skills. *Frontiers in psychology* 12 (2021), 733489.

[46] Wessel Wessels. 2022. *The human-centred design of an assistive swimming device to support water safety training*. University of Johannesburg (South Africa).

[47] Haisheng Xia, Muhammad Alamgeer Khan, Zhijun Li, and MengChu Zhou. 2022. Wearable robots for human underwater movement ability enhancement: A survey. *IEEE/CAA Journal of Automatica Sinica* 9, 6 (2022), 967–977.

[48] Luyao Yang, Osama Amin, and Basem Shihada. 2024. Intelligent wearable systems: Opportunities and challenges in health and sports. *Comput. Surveys* 56, 7 (2024), 1–42.

[49] Qiang Yang and Yuanqing Zheng. 2023. Aquahelper: Underwater sos transmission and detection in swimming pools. In *Proceedings of the 21st ACM Conference on Embedded Networked Sensor Systems*. 294–307.

[50] Emilene Zitkus, Patrick Langdon, and P John Clarkson. 2013. Inclusive design advisor: Understanding the design practice before developing inclusivity tools. *Journal of Usability Studies* 8, 4 (2013), 127–143.