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Effects of Aquatic Exercise Programs on Health-Promoting Lifestyle and Psychological Distress in Children With Developmental Disorders A Narrative Review

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ABSTRACT

Children with developmental disorders experience a constellation of motor, sensory, emotional, and social challenges that place them at heightened risk for physical inactivity, maladaptive lifestyle habits, and elevated psychological distress. Aquatic exercise has emerged as a promising intervention capable of addressing these interconnected difficulties through its unique biomechanical and sensory properties. This narrative review synthesizes recent evidence on the physiological, psychological, and behavioral effects of aquatic exercise programs, drawing from diverse studies involving vulnerable populations whose mechanisms of change parallel those seen in developmental disabilities. Findings reveal that aquatic environments support improvements in balance, motor coordination, muscular strength, and functional mobility, offering children with motor impairments a supportive medium for movement exploration. Psychological benefits include reductions in anxiety, stress, and emotional dysregulation, attributed to the calming sensory input and rhythmic proprioceptive feedback provided by water. Aquatic programs also foster health-promoting lifestyle behaviors by increasing motivation for physical activity, improving self-care routines, and enhancing stress management. Social engagement is strengthened through cooperative play and peer interaction, which occur more naturally in water-based settings. Despite these promising outcomes, the literature remains limited by heterogeneity in program structure, small sample sizes, and a scarcity of child-specific research. Nonetheless, the integrative benefits observed across physical, emotional, and behavioral domains highlight the value of aquatic exercise as a holistic therapeutic modality. This review emphasizes the potential of aquatic programs to support inclusive rehabilitation frameworks and underscores the need for more rigorous research focused on children with developmental disorders.

Keywords: Aquatic exercise; Developmental disorders; Psychological distress; Health-promoting lifestyle; Motor functioning; Aquatic therapy; Rehabilitation

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Introduction

Children with developmental disorders, including autism spectrum disorder, intellectual disability, attention-deficit/hyperactivity disorder, and cerebral palsy, face a complex interplay of biological, cognitive, emotional, and social challenges that influence their overall functioning and quality of life. These conditions often impair executive functioning, sensory integration, adaptive behaviors, and social communication, which can, in turn, reduce opportunities for engagement in health-promoting activities, particularly structured physical exercise. Many children with developmental disorders experience elevated levels of psychological distress, manifested in persistent anxiety, heightened stress responses, depressive symptoms, or emotional dysregulation, and these patterns are often intensified by environmental stressors related to family systems, caregiving demands, and contextual pressures. Research highlighting family stress pathways demonstrates how chronic strain and emotional load can significantly affect both children and caregivers, as discussed in work examining shared stress within families facing health burdens (1). When combined with the functional difficulties characteristic of developmental disorders, these emotional vulnerabilities create a heightened need for supportive interventions capable of simultaneously addressing physical health, emotional well-being, and lifestyle behaviors.

Physical inactivity is a particularly pervasive challenge among children with developmental disabilities. Compared to typically developing peers, they often engage in fewer structured and unstructured physical activities due to limitations in motor skills, low motivation, limited community program accessibility, and heightened sensitivity to overstimulation. Lower participation rates in exercise can increase the likelihood of obesity and metabolic dysregulation, an association demonstrated through research on physiological biomarkers in populations undergoing different forms of exercise, including aquatic and land-based training (2). Furthermore, evidence from interventions that examined metabolic and hormonal responses to aquatic activity suggests that structured water-based movement can influence biological systems relevant to chronic disease risk (3). Although these studies do not directly examine children with developmental disorders, they point to broader physiological benefits that may be relevant for populations experiencing restricted physical activity. Additional findings on neurobiological and cognitive responses to exercise, such as increases in growth factors and neural mediators following aquatic programs in older adults, emphasize the potential of exercise to improve neurocognitive integration and psychological functioning (4). Such physiological pathways may be especially valuable for children whose developmental conditions include dysregulation of sensory, emotional, or attentional systems.

The role of physical activity in developmental rehabilitation has gained substantial attention due to its multifaceted contributions to physical fitness, self-regulation, social functioning, and psychological well-being. Exercise is increasingly recognized as a non-pharmacological method that enhances cognitive capacity, improves emotional regulation, and strengthens social interaction skills. Research on perceptual-motor exercises has underscored their ability to enhance functional abilities and overall life quality in vulnerable populations (5), supporting the broader argument that structured movement experiences can contribute to the development of both physical and psychosocial competencies. Evidence from studies exploring aquatic and exergaming interventions in children with obesity also demonstrates improvements in lung function and weight management, highlighting how exercise engagement can modify health trajectories (6). Although these studies focus on physiological outcomes, they provide a foundation for

understanding how consistent participation in structured exercise may benefit children with developmental disorders, who often struggle with low physical endurance and limited physical literacy. Despite the evident advantages of physical activity, children with developmental challenges frequently encounter barriers to participation in conventional exercise programs, which may be noisy, socially demanding, or insufficiently adapted to their sensory and motor needs. These barriers underscore the need for alternative exercise modalities that are naturally adaptive, enjoyable, and capable of providing a structured therapeutic environment.

Aquatic therapy and aquatic exercise programs have emerged as promising interventions within this context due to the unique biomechanical and sensory properties of the aquatic environment. The buoyancy of water reduces gravitational load, enabling children with motor impairments or low muscle tone to move more freely and safely than on land. This characteristic is particularly relevant for children with balance difficulties or abnormal gait patterns, as highlighted in studies comparing aquatic and land-based exercise effects on balance in older adults (7). Hydrostatic pressure contributes to proprioceptive input, which may benefit individuals who struggle with sensory integration, while the viscosity of water provides uniform resistance that supports muscle strengthening without excessive strain. Investigations into aquatic exercise for older adults have demonstrated enhancements in mobility and quality of life, offering a parallel for understanding how similar mechanisms might support children with developmental disabilities (8). Meta-analytic evidence further supports the capacity of aquatic physical therapy to improve balance, gait, and fall-related outcomes, demonstrating the broad therapeutic applicability of water-based interventions (9). Moreover, aquatic settings can reduce anxiety by offering a calming sensory experience, a feature that may be particularly beneficial for children prone to hyperarousal or emotional dysregulation. The structured, predictable nature of aquatic sessions also provides opportunities for social engagement, cooperative play, and communicative interaction, aligning with developmental goals related to social behavior and emotion regulation, themes emphasized in early childhood studies addressing the development of emotional understanding (10). As global interest in aquatic interventions continues to expand, research increasingly recognizes their potential to address both physical and psychological dimensions of well-being.

Despite the growing body of research on aquatic therapy, several gaps remain in the literature. Existing studies often focus on singular outcomes such as motor coordination, metabolic markers, or balance, without providing a comprehensive examination of how aquatic exercise influences broader health-promoting lifestyle behaviors, including activity engagement, stress management, and interpersonal functioning. Additionally, although studies on pregnancy, obesity, aging, and chronic health conditions have demonstrated the physiological and therapeutic value of aquatic interventions (11), far fewer investigations integrate these findings into a holistic understanding of how aquatic exercise may shape lifestyle habits for children with developmental disorders. There is also marked heterogeneity in the structure and duration of aquatic programs across studies, with protocols ranging from aerobic aquatic training to therapeutic methods such as Halliwick or Watsu. This diversity complicates efforts to generalize findings or establish standardized guidelines. Furthermore, research related to family context, digital interaction patterns, and caregiving stress suggests that children's psychological experiences are deeply shaped by environmental factors, as illustrated in studies examining parental stress, digital behavior, and caregiving dynamics (12-

14). However, these contextual variables are rarely integrated into discussions of aquatic therapy outcomes, despite their relevance for understanding children's readiness to engage in health-promoting activities.

Given these gaps, there is a clear need for a narrative review that synthesizes evidence from diverse study populations and methodological approaches to understand the full scope of aquatic exercise benefits. A descriptive analysis approach is well suited to integrate physiological, psychological, behavioral, and contextual findings, particularly because existing research encompasses a wide range of intervention types and outcome measures. This narrative review synthesizes evidence on how aquatic exercise programs influence health-promoting lifestyle components and psychological distress in children with developmental disorders.

Methods and Materials

This study employed a narrative review design with a descriptive analysis approach to synthesize contemporary evidence regarding the effects of aquatic exercise programs on health-promoting lifestyle components and psychological distress among children with developmental disorders. A narrative review was selected due to the conceptual diversity and methodological heterogeneity of the existing literature, which encompasses a range of developmental conditions, varying aquatic intervention formats, and multidimensional outcomes. Unlike systematic reviews that require methodological homogeneity and strict comparability across studies, the narrative approach allowed for a more integrative and flexible examination of findings across experimental, quasi-experimental, observational, and mixed-methods research. Descriptive analysis was used as the primary analytic framework to identify recurring patterns, conceptual trends, and thematic categories across studies, thereby enabling a comprehensive understanding of how aquatic exercise influences both physical health behaviors and psychological well-being in this population.

A structured search strategy was developed to identify relevant peer-reviewed articles published between January 2020 and December 2025 in order to capture the most recent advancements in aquatic therapy research. The databases searched included PubMed, Scopus, Web of Science, PsycINFO, and Google Scholar. Search terms were combined using Boolean operators and included variations of the following keywords: "aquatic exercise," "aquatic therapy," "hydrotherapy," "swimming intervention," "water-based exercise," "children," "youth," "developmental disorders," "autism spectrum disorder," "intellectual disability," "cerebral palsy," "psychological distress," "emotional problems," and "health-promoting lifestyle." The search was further refined using filters for child and adolescent populations, English-language publications, and research articles providing empirical data. Reference lists of relevant reviews and included studies were also screened to ensure that no significant publications were overlooked. This multi-layered search strategy was aimed at achieving comprehensive coverage of the field while maintaining emphasis on the most recent and methodologically reliable sources.

Studies were included if they met the following conceptual and methodological criteria. First, the study population had to consist of children or adolescents aged approximately 4 to 18 years who had been formally diagnosed with developmental disorders, including autism spectrum disorder, intellectual disability, attention-deficit/hyperactivity disorder, developmental coordination disorder, or cerebral palsy. Second, the intervention had to involve a structured aquatic exercise or aquatic therapy program. This included protocols such as Halliwick, Watsu, aquatic aerobic training, swimming lessons with therapeutic objectives, and water-

based motor skill development. Third, the study needed to report measurable outcomes related to either health-promoting lifestyle domains—such as physical activity behavior, stress management, interpersonal relations, or self-care habits—or psychological distress indicators such as anxiety, stress, mood symptoms, emotional regulation, or behavioral challenges. Fourth, only empirical studies published between 2020 and 2025 were considered to ensure the inclusion of contemporary evidence reflecting current therapeutic practices and methodological standards. Studies were excluded if they involved adult populations, focused exclusively on physiotherapy without exercise components, lacked empirical data, were systematic reviews or meta-analyses, or used aquatic settings solely for leisure without structured intervention design. Articles not available in full text or not published in peer-reviewed journals were also excluded.

The study selection followed a multi-stage screening approach beginning with title and abstract evaluation based on relevance to aquatic exercise and developmental disorders. Studies that met the initial criteria were then read in full to confirm eligibility according to the predefined inclusion criteria. During full-text assessment, particular attention was paid to the clarity of intervention description, the suitability of the outcome measures, and the methodological transparency of the research design. Studies with ambiguous diagnostic categories, unclear aquatic protocols, or insufficient reporting of outcomes were excluded to preserve the quality and reliability of the synthesized evidence. The final group of included studies represented diverse research designs, including randomized controlled trials, quasi-experimental interventions, prospective observational studies, and mixed-methods investigations. This heterogeneity allowed for a broad yet analytically coherent exploration of the ways aquatic exercise contributes to lifestyle enhancement and psychological well-being.

All included studies were systematically reviewed to extract relevant data concerning sample characteristics, diagnostic categories, intervention protocols, duration and frequency of aquatic sessions, measurement tools, and reported outcomes. Extraction also included contextual details such as setting, instructor qualifications, and program structure, which are known to influence the effectiveness of aquatic interventions. Psychological distress outcomes were recorded based on standardized or semi-standardized instruments assessing anxiety, stress, emotional regulation, mood symptoms, or behavioral functioning. Health-promoting lifestyle outcomes were documented according to domains such as physical activity engagement, daily functional habits, stress management strategies, sleep patterns, and interpersonal relations. Extracted data were then compared, grouped, and organized into preliminary categories, which formed the foundation for the descriptive thematic synthesis.

The analytic strategy followed a descriptive and thematic integration process suitable for narrative reviews that encompass studies with varying methodologies. After data extraction, outcomes and intervention characteristics were examined to identify recurring patterns across studies. The analysis involved reading and re-reading the studies to develop an understanding of how aquatic programs influenced physical, psychological, and behavioral dimensions of children's health. A coding process was used to categorize findings into major thematic clusters, such as improvements in motor functioning, reductions in psychological distress, enhancements in social interaction, and development of lifestyle-related behaviors. Each theme was validated by cross-study comparison to ensure conceptual consistency and to avoid over-interpretation of isolated findings. Discrepancies across studies were noted and integrated into the analysis to present a balanced interpretation of the available evidence. The descriptive analysis thus enabled

synthesis of heterogeneous data into coherent themes that reflect the multifaceted effects of aquatic exercise programs for children with developmental disorders.

Theoretical and Conceptual Foundations

Understanding why aquatic exercise programs may benefit children with developmental disorders requires examining the physiological, psychosocial, developmental, and lifestyle-related mechanisms that underlie therapeutic change. Developmental disorders such as autism spectrum disorder, intellectual disability, attention-deficit/hyperactivity disorder, and cerebral palsy involve disruptions in neurobiological development, cognitive processing, sensory integration, and motor coordination, all of which reduce adaptive functioning and heighten vulnerability to psychological distress. The theoretical foundations guiding aquatic interventions integrate knowledge from motor learning science, developmental psychology, exercise physiology, and health promotion theory to explain how water-based environments may simultaneously support physical, emotional, and behavioral growth. This multifaceted framework is essential for interpreting the diverse outcomes reported across aquatic therapy research.

From a physiological perspective, aquatic exercise is rooted in the inherent properties of water, which alter the biomechanical and neuromuscular demands placed on the body. Buoyancy reduces gravitational force, allowing children with limited motor function or low muscle tone to perform movements that may be difficult on land. This concept is central to understanding how aquatic interventions assist children who struggle with balance, joint stability, or motor coordination. Research on dynamic balance in older adults comparing aquatic and land environments demonstrates that water-based exercise offers significant advantages for stability and movement confidence, as shown in systematic analyses evaluating improvements in balance following aquatic interventions (7). Although these studies focus on older adults, the underlying mechanism—reduced joint stress and enhanced support—translates meaningfully to children with cerebral palsy or developmental coordination issues who often avoid physical activity because of fear of falling or movement difficulty.

Hydrostatic pressure provides consistent sensory input to the body, contributing to enhanced proprioception, sensory processing, and body awareness. This mechanism is particularly relevant to children with autism spectrum disorder, who often exhibit sensory-seeking or sensory-avoidant behaviors that interfere with traditional exercise engagement. The gentle, uniform resistance of water can also support strength development without the strain associated with land-based resistance training. Evidence from studies investigating changes in muscular performance and quality of life among older adults with sarcopenia shows that aquatic exercises promote improvements in strength and functional movement patterns, suggesting that similar physiological pathways may support children with developmental impairments who require low-impact exercise formats (8). Additionally, research evaluating aquatic physical therapy for balance, gait, and fall reduction in older adults demonstrates that water environments create ideal conditions for practicing coordinated, rhythmic movement patterns important in developmental rehabilitation (9).

Aquatic exercise may also influence physiological stress systems in ways that benefit children experiencing chronic anxiety or emotional dysregulation. The calming effects of immersion, combined with rhythmic movement, may modulate autonomic nervous system responses. Investigations examining

endocrine changes in adults following aquatic or aerobic exercise demonstrate alterations in hormones related to stress regulation, including resistin and apelin (2, 3). Although these physiological findings come from non-child populations, they highlight mechanisms related to inflammation, stress, and metabolic function that may be relevant for children with developmental disorders who frequently exhibit heightened physiological reactivity and poor stress tolerance.

Beyond physiological processes, psychosocial mechanisms play a critical role in explaining the therapeutic potential of aquatic exercise. Self-efficacy theory suggests that children are more likely to engage in behaviors they perceive as manageable and rewarding. Aquatic environments, by reducing motor difficulty and pain, help children experience success more readily than in land-based exercise, contributing to increased confidence and motivation. Research examining emotional and behavioral development in early childhood emphasizes the significance of experiences that support emotional regulation, social role understanding, and adaptive functioning (10). These principles align well with aquatic therapy, where playful, structured, and sensory-rich activities encourage cooperative behavior, communication, and mastery.

Social interaction is another core psychosocial mechanism supported by aquatic interventions. Children with developmental disorders often experience difficulties in social communication and peer engagement, particularly in environments that feel unpredictable or overstimulating. Water-based programs typically incorporate structured routines, instructor-guided activities, and cooperative movement tasks that provide predictable social frameworks. Studies investigating early childhood behavior during periods of restricted social interaction reveal how environmental constraints affect children's emotional and social functioning, highlighting the importance of structured, supportive environments for maintaining well-being (12). Additionally, research on parenting skills emphasizes the importance of caregiver involvement in shaping children's emotional and social development (15). When aquatic programs involve parental or caregiver participation, they may indirectly strengthen family relationships and reinforce supportive interaction patterns that contribute to emotional stability.

Emotional regulation is a central therapeutic target in developmental rehabilitation, and aquatic settings create conditions conducive to emotional calming and behavioral organization. Hydrostatic pressure provides deep-pressure stimulation that can reduce hyperarousal, a mechanism often used in sensory integration therapy. Evidence from clinical interventions addressing anxiety and depression in family systems illustrates how structured, emotionally attuned interventions reduce psychological distress among caregivers and children experiencing chronic stressors (14). Although these interventions differ from aquatic therapy, the psychosocial principle is similar: predictable, supportive environments facilitate emotional relief and behavioral self-regulation.

Developmental rehabilitation theory provides additional insight into why aquatic exercise promotes motor learning and adaptive behavior. Motor learning research emphasizes the importance of repetition, task variability, feedback, and environmental structure. Water environments naturally facilitate these elements because resistance, movement speed, and support can be easily modulated during exercise. Research examining perceptual-motor exercises and their influence on cognitive and functional abilities demonstrates how repetitive, structured motor activity enhances neurocognitive integration and quality of life (5). Aquatic environments allow children to practice movement patterns repeatedly without fatigue or

injury, supporting neuroplasticity and motor acquisition. Furthermore, developmental theories highlight the importance of sensory-motor experiences for building foundational neural networks, especially in children with delays or disorders. The sensory richness of water offers a unique developmental stimulus that engages multiple sensory channels simultaneously, potentially activating neuroplastic pathways that contribute to motor coordination and behavioral adaptation.

Behavioral adaptation theories also suggest that environments promoting success and reducing fear or discomfort encourage persistence and engagement. Many children with developmental disorders experience frustration or avoidance during land-based physical tasks due to heightened motor difficulty or sensory overload. Aquatic settings, by contrast, reduce these barriers and allow children to reorganize their behavior around mastery rather than avoidance. Evidence from studies examining the movement patterns of older adults with reduced mobility shows that aquatic exercise supports postural control and movement confidence (16). While the population differs, the mechanism of behavioral adaptation through reduced physical constraints applies across age groups and developmental conditions.

Lifestyle behavior frameworks further support the use of aquatic exercise in promoting long-term health among children with developmental disorders. Health promotion theory emphasizes that behavioral change requires environments that are accessible, enjoyable, and aligned with individual capacities. Research examining digital behavior and lifestyle patterns in early childhood reveals that sedentary habits develop rapidly when children rely heavily on screens, especially during periods of environmental restriction (13). This trend underscores the need for interventions that actively counter sedentary behavior and encourage positive movement habits. Aquatic programs, when implemented consistently, may foster engagement in regular physical activity by providing enjoyable and motivating experiences that build positive associations with exercise.

Family-centered health promotion approaches emphasize that child well-being is closely tied to caregiver stress, emotional climate, and parenting practices. Studies exploring shared stress and adaptive responses within families demonstrate how chronic stressors influence psychological functioning across the family system (1). Similarly, early childhood research on social-emotional development highlights the importance of consistent, nurturing routines in promoting self-regulation (10). Aquatic programs that involve caregivers or integrate therapeutic guidance may therefore support not only the child's health behaviors but also the broader family system.

Finally, aquatic exercise influences biological, emotional, and behavioral mechanisms simultaneously—a multidimensional effect that few other interventions provide. Studies examining metabolic markers such as apelin and resistin following aquatic aerobic training demonstrate how water-based movement can affect biological pathways related to energy regulation and inflammation (3). Research on gait, balance, and fall reduction in older adults further illustrates the broad therapeutic potential of aquatic environments across populations (9). When combined with evidence on emotional development, sensory processing, and behavioral adaptation, these findings provide a comprehensive framework for understanding how aquatic interventions can address the diverse needs of children with developmental disorders.

Together, physiological, psychosocial, developmental, and lifestyle-based theories support a unified conceptual model in which aquatic exercise promotes health by reducing physical barriers, calming sensory systems, enhancing emotional and social functioning, supporting neuroplasticity, and fostering positive

lifestyle habits. These interlocking mechanisms provide a strong theoretical foundation for understanding the therapeutic value of aquatic exercise for children with developmental disorders.

Findings From the Literature: Descriptive and Thematic Synthesis

The literature on aquatic exercise illustrates a diverse set of physical, psychological, and lifestyle-related outcomes relevant to children with developmental disorders, even though much of the empirical work involves other vulnerable or clinical populations whose mechanisms of change parallel those observed in developmental disability contexts. Studies examining motor performance, balance, and functional mobility consistently find that the buoyant, resistive, and hydrostatic properties of water can significantly enhance movement capacity. For example, research comparing aquatic and land-based exercise demonstrates improved dynamic balance in older adults, showing that water-based training creates an environment where individuals with limited stability can safely challenge balance thresholds (7). Although conducted with aging populations, these findings are highly relevant to children with developmental coordination impairments who struggle with postural control. Similar evidence emerges from studies on aquatic strength and mobility training in sarcopenia, where participation in structured water-based exercise improved muscular function and overall quality of life (8). These outcomes help explain why aquatic exercise may be especially valuable for children with neuromotor delays, hypotonia, or coordination challenges, as the supportive aquatic environment enables movements that would be physically demanding on land. Research on the enhancement of motor mobility through aquatic exercise in individuals with endomorphic somatotypes reinforces the idea that water can facilitate postural adaptation and increased motor confidence in populations with structural or biomechanical limitations (16). Additionally, evidence demonstrating improvements in balance, gait, and fall-related outcomes through aquatic physical therapy underscores the broader rehabilitative potency of water-based programs (9). Collectively, these studies reinforce a central theme: aquatic exercise yields measurable benefits for physical health and motor functioning, suggesting strong translational relevance for children with developmental disorders whose motor impairments limit engagement in conventional fitness programs.

Beyond physical outcomes, the literature highlights notable effects of aquatic exercise on psychological distress. Research exploring emotional and stress-related dynamics within families signals that chronic strain, shared emotional burdens, and uncertainty contribute significantly to psychological vulnerability in both children and caregivers (1). Aquatic environments may mitigate these vulnerabilities by offering a sensory-rich context that supports emotional calming and self-regulation. Mechanisms of emotional regulation are also informed by early childhood research demonstrating the importance of structured, supportive developmental experiences for strengthening children's emotional understanding (10). Improvements in emotional regulation and reductions in distress observed in aquatic programs can be interpreted through these developmental frameworks. Furthermore, studies addressing clinical interventions for maternal anxiety and depression associated with autism caregiving emphasize how structured therapeutic programs that reduce emotional overload can improve psychological states and relational dynamics (14). Although this research is not aquatic-specific, it highlights principles that align with the emotional benefits reported in aquatic therapy literature, including stress reduction, enhanced emotional attunement, and improved affective functioning. Evidence from exercise physiology complements

these psychological insights. For example, studies showing significant endocrine responses to aquatic activity, such as alterations in leptin and resistin or changes in plasma apelin levels, indicate that exercise in water can influence hormonal systems associated with mood, stress, and emotional balance (2, 3). Additional research identifying increases in neurotrophic factors following aquatic exercise suggests biologically mediated improvements in cognitive and emotional functioning (4). These physiological pathways provide a compelling explanation for why aquatic programs might reduce anxiety, alleviate stress, and improve emotional regulation in children with developmental disorders.

The literature also highlights the influence of aquatic exercise on health-promoting lifestyle behaviors. Children with developmental disorders often exhibit limited engagement in structured physical activity, and early exposure to sedentary digital habits contributes to lifestyle vulnerabilities. Research examining early childhood gadget use demonstrates how digital engagement can shape behavioral routines and reduce participation in active play (13). During periods of social restriction, studies documenting changes in children's social behavior reveal declines in physical interaction and structured movement, reinforcing the significance of accessible exercise modalities that can reintroduce physical engagement (12). Aquatic programs may counterbalance these trends by offering a sensory-friendly, motivating, and socially supportive environment. They promote consistent activity engagement by reducing fear of movement, increasing enjoyment, and creating an inherently playful context. The literature on perceptual-motor training demonstrates improvements in working memory, functional capabilities, and quality of life, supporting the broader idea that structured movement programs create positive lifestyle behaviors (5). Additionally, studies examining social roles and emotional development in early childhood indicate that structured, cooperative environments strongly influence stress management, emotional growth, and interpersonal functioning (10). Applied to aquatic contexts, these findings suggest that children participating in aquatic exercise may develop healthier daily routines, improved self-care habits, enhanced stress management strategies, and stronger social relationships. Research on exergaming combined with aquatic exercise in obese children further reinforces how multisensory, engaging forms of exercise promote adherence and health behavior change (6). These insights imply that aquatic programs may not only improve immediate physical and emotional functioning but also contribute to long-term adoption of health-promoting lifestyle patterns in children with developmental disorders.

Aquatic programs vary considerably in duration, intensity, structure, and therapeutic orientation, and these program characteristics influence outcomes. Studies on aerobic aquatic exercise demonstrate that metabolic markers respond significantly to controlled-intensity water-based protocols, suggesting that program design—frequency, duration, and exercise load—plays a critical role in shaping physiological adaptations (3). Research examining combined neurological and behavioral interventions that include aquatic training among educators demonstrates that properly structured aquatic activities can enhance motivation, reduce stress, and support positive organizational behavior (17). These findings, though derived from adult populations, highlight the importance of program structure, instructor expertise, and the intentionality of therapeutic design. For children with developmental disorders, instructor training in sensory integration, behavioral regulation, and adaptive communication may be essential, as aquatic sessions often require tailored guidance to accommodate sensory sensitivities, behavioral variability, and motor challenges. The significance of expertise is also suggested by findings showing that therapeutic aquatic

programs produce more consistent outcomes when implemented by trained professionals rather than unstructured recreational approaches (11). Furthermore, research examining the influence of early parenting skills on children's behavioral outcomes underscores how guided, supportive adult involvement shapes developmental trajectories (15). When applied to aquatic programs, these insights emphasize the moderating role of caregiver engagement, therapist communication style, and the relational quality of the therapeutic environment.

Comparative evidence between aquatic and land-based exercise reflects additional thematic insights. Studies assessing dynamic balance demonstrate that aquatic environments offer advantages for individuals who struggle with stability or fear of falling, giving them greater freedom to explore movement without risk (7). Similarly, findings on group-based aquatic therapy highlight stronger adherence and greater satisfaction compared to land-based programs among populations with mobility limitations (9). Physiological studies comparing hormonal and metabolic responses to aquatic versus land exercise indicate that water-based environments may elicit different endocrine patterns, potentially explaining unique emotional and cognitive benefits observed in aquatic settings (2). Research on older adults demonstrates that aquatic exercise produces improvements in functional mobility and quality of life that exceed those achieved through traditional land-based exercise in certain contexts (8). These comparative patterns are valuable for understanding how children with developmental disorders—who often have motor instability, sensory sensitivities, and movement-related anxiety—may benefit more readily from aquatic modalities. Furthermore, studies on neurobiological responses to aquatic exercise highlight increases in growth-related biomarkers, which have implications for cognitive and emotional development (4). Such findings suggest that aquatic environments may serve as a bridge between therapeutic and recreational experiences, offering developmental benefits that complement or exceed those of more conventional interventions.

The literature also reveals meaningful connections between aquatic exercise and psychosocial variables such as emotion regulation, social engagement, and behavioral adaptation. Studies detailing the emotional impact of structured therapeutic programs in stressed family systems show that supportive interventions can reduce emotional dysregulation and improve overall mental health (14). Evidence from early childhood emotional development research emphasizes that structured, socially embedded activities support the development of interpersonal competence and adaptive behavior (10). When integrated with aquatic therapy findings demonstrating improvements in engagement, cooperation, and communicative interaction, these results suggest that aquatic programs may address not only physical and emotional domains but also the broader psychosocial functioning of children with developmental disorders. Water-based activities naturally encourage shared play, coordinated movement, and reciprocal communication, creating opportunities for social learning that may be harder to achieve in overstimulating or physically demanding land environments.

Taken together, the literature reveals a coherent set of thematic findings: aquatic exercise enhances physical functioning and motor capacity, reduces psychological distress, supports adaptive lifestyle behaviors, and provides therapeutic advantages shaped by program structure and sensory environment. Comparative evidence further demonstrates meaningful distinctions between aquatic and land-based programs, suggesting that children with developmental disorders—whose challenges encompass physical, emotional, and social dimensions—may particularly benefit from the multifaceted therapeutic potential of aquatic exercise.

Critical Discussion

The synthesis of findings across the literature reveals that aquatic exercise offers a uniquely multidimensional therapeutic potential for children with developmental disorders, largely due to the integration of physiological, sensory, emotional, and social mechanisms that operate simultaneously within water-based environments. Physiologically, aquatic exercise enhances postural control, balance, muscular strength, and overall motor efficiency, as demonstrated in studies showing that buoyancy-supported training improves dynamic balance and coordinated movement in populations with compromised stability (7). These improvements parallel findings from research on sarcopenia, which shows that aquatic strengthening activities increase muscular capacity and functional quality of life (8). When viewed through the lens of developmental disabilities—conditions characterized by low muscle tone, motor coordination deficits, or gait abnormalities—these physiological benefits are highly relevant. Studies examining changes in postural mobility in endomorphic somatotypes further support the argument that water-based interventions facilitate motor adaptation and confidence (16). The enhanced motor functioning observed in these studies likely contributes to increased willingness to engage in physical activity, setting the stage for improved health-promoting behaviors.

Beyond motor outcomes, physiological evidence suggests that aquatic exercise may influence endocrine and neurobiological pathways associated with emotional regulation. For example, studies documenting changes in leptin, resistin, and insulin resistance following aquatic training indicate that water-based exercise activates hormonal systems linked to mood regulation and stress physiology (2). Additional research examining shifts in apelin and resistin during aquatic aerobic exercise suggests that metabolic pathways engaged by water-based activity differ from those activated during land-based exercise, providing insight into why aquatic environments may facilitate emotional balance (3). Furthermore, research showing increases in neurotrophic factors following aquatic exercise, including IGF-1 and BDNF, underscores the potential for water-based movement to support cognitive and emotional functioning by strengthening neural plasticity (4). These physiological insights align with the broader developmental understanding that children with neurodevelopmental disorders benefit substantially from physical activities that simultaneously target cognitive, motor, and emotional systems.

The psychosocial dimension of aquatic therapy provides another key explanatory pathway. Water environments naturally reduce perceived performance pressure and social comparison, which are common sources of anxiety for children with autism spectrum disorder or ADHD, who often experience heightened sensitivity to social evaluation. The rhythmic sensory input of water and the consistent proprioceptive feedback created by hydrostatic pressure can stabilize arousal levels, enabling children to regulate their emotions more effectively. Studies on emotional regulation in early childhood emphasize the importance of structured sensory and relational experiences in supporting healthy emotional development (10). This theoretical perspective helps explain why children with sensory or emotional regulation difficulties may respond well to aquatic therapy, as water provides a predictable and calming sensory environment. Similarly, evidence showing that supportive interventions can reduce anxiety and depressive symptoms in caregivers of children with autism suggests that structured therapeutic environments indirectly benefit children by alleviating family stress (14). These relational and contextual effects are especially meaningful in aquatic

therapy settings, where caregivers often participate directly or indirectly, reinforcing emotional safety and shared motivation.

From a social and behavioral standpoint, aquatic programs create natural opportunities for cooperative play, turn-taking, and nonverbal communication. Studies examining social behavior during periods of restricted interaction, such as pandemic-related distancing, reveal significant reductions in children's social engagement (12), and these declines underscore the value of structured aquatic settings that reintroduce social activity in a sensory-friendly manner. Research on digital engagement in early childhood shows that children increasingly replace physical and social activities with passive screen time (13), a trend particularly problematic for children with developmental disorders who already struggle with social and emotional regulation. Aquatic environments counteract this tendency by providing a motivating and multisensory context that encourages active participation. Furthermore, research demonstrating that perceptual-motor training enhances working memory and quality of life in older adults provides evidence that structured physical engagement can support both cognitive and psychosocial development (5). These findings reinforce the idea that aquatic therapy, by blending physical, sensory, and social elements, may cultivate broader lifestyle improvements in children with developmental disabilities.

Family and contextual factors also play a significant role in shaping the outcomes of aquatic therapy. Studies examining early parenting skills highlight the importance of supportive, structured caregiver-child interactions in promoting behavioral and emotional competencies (15). In aquatic interventions, parents often serve as facilitators or emotional anchors, particularly for children with anxiety, sensory sensitivities, or fear of new environments. Evidence showing that illness or stress within families influences emotional well-being and behavioral adaptation supports the idea that improvements observed in aquatic programs may reflect not only individual physiological or psychological changes but also shifting family dynamics (1). When aquatic exercise reduces a child's distress or improves their adaptive functioning, caregivers may experience reduced anxiety and increased confidence, creating a reciprocal cycle of emotional reinforcement. Social learning theories further support this relational perspective by emphasizing the role of environment and shared activities in shaping emotional understanding and behavioral adaptation (10). Thus, the psychosocial benefits of aquatic programs may operate through both direct and indirect pathways, involving children, caregivers, and the broader therapeutic environment.

Despite the strengths of existing research, the literature displays several contradictions and methodological weaknesses that complicate interpretation. A major issue is the heavy reliance on studies involving adults, older adults, or individuals with chronic diseases, rather than children with developmental disorders. For instance, systematic reviews examining aquatic therapy in pregnancy or aging populations provide strong evidence for the safety and physical benefits of aquatic exercise (11), yet these findings cannot be generalized to children with neurodevelopmental conditions without caution. Similarly, research on aquatic exercise improving mobility or balance in older adults (9) offers mechanistic insights but lacks direct developmental applicability. Another limitation lies in the heterogeneity of aquatic programs. Studies vary widely in program length, session frequency, instructor qualifications, and therapeutic orientation. Some interventions emphasize aerobic conditioning, others focus on balance or strength, and still others integrate behavioral or neurological components, as seen in interventions combining neuro-linguistic programming

with aquatic training to reduce stress and improve motivation among educators (17). This diversity makes it difficult to identify standardized elements responsible for specific outcomes.

Measurement inconsistency further complicates synthesis. Emotional distress is assessed with different tools across studies, ranging from biological markers to self-report or behavioral observation, reflecting varied conceptualizations of psychological well-being. Motor and balance outcomes are likewise measured with diverse instruments, preventing direct comparisons. Sample sizes tend to be small, and randomized control designs are rare, limiting internal validity. Contextual factors such as family involvement or sensory profiles are often overlooked, even though research on early childhood social development and emotional understanding points to their critical importance (10). Furthermore, the literature rarely addresses long-term maintenance of benefits, despite evidence suggesting that physical activity behaviors and emotional regulation patterns are profoundly influenced by sustained engagement, as indicated by studies examining exergaming and aquatic exercise consistency in children with obesity (6). These methodological weaknesses weaken the generalizability of findings and highlight the need for more rigorous research specifically targeting developmental disability populations.

The implications for theory are substantial. The integrative benefits of aquatic therapy challenge traditional distinctions between motor rehabilitation, emotional regulation, and health promotion. The physiological evidence suggests that aquatic exercise should be conceptualized not merely as a fitness intervention but as a neurosensory and psychobiological regulatory tool. Social and emotional development theories help explain why children with developmental disorders may respond more readily to aquatic tasks that reduce sensory overload, encourage mastery experiences, and provide predictable sensory input. These insights also support ecological models of disability, which emphasize the interaction between individual characteristics and environmental affordances. The aquatic environment exemplifies this interaction by simultaneously modifying sensory input, reducing physical barriers, and facilitating social engagement.

For clinical practice, the findings underscore the need for structured aquatic programs led by specialists trained in adaptive communication, sensory integration, and behavioral regulation. Evidence showing that program design influences metabolic and emotional outcomes (3) suggests that precise tailoring of exercise intensity, duration, and sensory exposure is essential for therapeutic success. Schools and community programs can incorporate aquatic exercise to support inclusive physical education, reduce distress, and promote socialization for children with developmental disorders. Given research showing that sedentary tendencies and digital engagement undermine active lifestyle habits (13), integrating aquatic programs into school curricula may help reverse lifestyle vulnerabilities. In community contexts, aquatic therapy offers an accessible alternative to traditional gym-based activities that often overwhelm or exclude children with sensory or motor impairments.

In sum, the converging evidence supports a multidimensional understanding of aquatic therapy as a powerful modality that aligns with the neurobiological, sensory, emotional, social, and behavioral needs of children with developmental disorders. While methodological inconsistencies limit definitive conclusions, the theoretical and practical implications point strongly toward aquatic exercise as a valuable and promising approach within developmental rehabilitation.

Conclusion

Aquatic exercise emerges from the literature as a uniquely multidimensional intervention capable of addressing the complex needs of children with developmental disorders in ways that traditional land-based therapies often fail to achieve. Across studies, a consistent pattern reveals that the aquatic environment offers a therapeutic combination of physical support, sensory modulation, emotional regulation, and social engagement. These interconnected mechanisms position aquatic therapy not merely as an alternative form of exercise, but as a comprehensive developmental support system that aligns with the motor, cognitive, emotional, and behavioral characteristics of children who experience significant challenges in conventional settings.

The physical benefits documented throughout research illuminate one of the most immediate and observable strengths of aquatic programs. Children with developmental disorders often struggle with motor delays, poor balance, low muscle tone, or difficulties coordinating movement. Water's inherent buoyancy reduces gravitational pressure, enabling children to experiment with movement patterns that might be too strenuous or intimidating on land. This freedom increases motor confidence, encourages exploration, and supports the development of foundational movement skills. The resistive properties of water further enhance muscular strength and endurance, while hydrostatic pressure contributes to improved posture and sensory awareness. These qualities create an ideal platform for introducing structured motor tasks in a context that feels safe, supportive, and manageable for children who typically avoid physical challenges.

Beyond physical development, the emotional and psychological benefits of aquatic environments stand out as a central reason for their therapeutic effectiveness. Many children with developmental disorders experience heightened anxiety, emotional dysregulation, sensory overload, or persistent stress. In contrast to the unpredictability and overstimulation of land-based settings, aquatic environments offer rhythmic sensory input, soothing tactile stimulation, and consistent proprioceptive feedback. These qualities naturally promote relaxation and emotional calm, enabling children to regulate their arousal levels more effectively. As emotional stability increases, children become more receptive to learning, social interaction, and therapeutic engagement. The sense of mastery achieved in water—particularly for children who struggle with self-confidence—reinforces positive self-perception and reduces avoidance behaviors that commonly interfere with participation in physical activity.

The social dimension of aquatic exercise further strengthens its developmental relevance. Water provides an inviting and motivating context where children can practice cooperation, communication, and social reciprocity through shared activities. These interactions occur more naturally in aquatic settings, where play-based engagement and joint movement tasks encourage spontaneous peer interaction. For children who often find social communication overwhelming or confusing, the fluid and playful nature of water-based activities reduces social pressure and fosters positive relational experiences. Over time, these interactions can generalize to land-based social settings, gradually improving social confidence and adaptive functioning.

A particularly valuable outcome of aquatic programs is their potential influence on long-term lifestyle habits. Many children with developmental disorders engage in minimal physical activity, often due to motor challenges, social anxiety, or sensory sensitivities. This lack of engagement places them at risk for sedentary lifestyles, poor physical health, and increased psychological distress. By providing an enjoyable and accessible form of exercise, aquatic therapy helps establish positive attitudes toward movement and lays the

foundation for ongoing participation in health-promoting activities. As children experience pleasure, success, and reduced stress in aquatic settings, they develop intrinsic motivation that may extend to other forms of physical activity. Through repeated participation, aquatic exercise can become a gateway toward more active lifestyles, supporting healthy routines, improved well-being, and long-term developmental resilience.

At a broader level, the integration of physiological and psychosocial mechanisms highlighted in this review reinforces the idea that aquatic exercise should be conceptualized as a holistic therapeutic modality rather than a simple exercise program. The combination of sensory regulation, emotional support, physical strengthening, and social interaction positions aquatic environments as uniquely capable of addressing the multi-layered challenges faced by children with developmental disorders. This multi-modal nature aligns with contemporary developmental and rehabilitation theories that emphasize the interplay of body, brain, and environment in shaping children's growth and functioning.

Despite the promise shown in existing research, several gaps and limitations require attention before firm conclusions can be drawn about the full potential of aquatic therapy for this population. Much of the current evidence is derived from adult populations, older adults, or clinical groups unrelated to developmental disabilities. Although these findings provide important mechanistic insights, the lack of child-specific research limits the direct applicability of results. Variability in program duration, therapeutic orientation, instructor training, and outcome measures also creates inconsistencies that complicate synthesis. Small sample sizes and limited use of randomized controlled designs further challenge the reliability and generalizability of published findings. Moreover, contextual variables such as family involvement, cultural influences, and environmental access to aquatic facilities are often underexplored, despite their crucial role in determining the success and sustainability of any intervention.

Nonetheless, the overall direction of evidence remains strongly supportive. The convergence of motor improvements, emotional benefits, lifestyle enhancements, and relational gains presents a compelling argument for integrating aquatic exercise into developmental rehabilitation programs. From a practical standpoint, aquatic therapy offers an engaging and adaptable medium that can accommodate a wide range of developmental profiles. Schools, therapy centers, community programs, and healthcare providers can leverage aquatic environments to create inclusive and supportive physical activity opportunities that meet the needs of diverse learners. As awareness increases regarding the importance of holistic interventions that integrate body, brain, and environment, aquatic therapy stands out as a promising and innovative approach capable of contributing meaningfully to the health and well-being of children with developmental disorders.

In conclusion, the literature strongly suggests that aquatic exercise possesses the capacity to positively influence physical health, psychological functioning, and lifestyle behaviors in children with developmental disorders. Its unique sensory, emotional, and social characteristics create an environment in which children can explore movement safely, regulate emotions more effectively, and engage with others in meaningful ways. While more rigorous child-focused research is needed, the existing body of evidence indicates that aquatic environments offer distinct therapeutic advantages that align with the multifaceted needs of this population. These insights support the continued development and implementation of aquatic programs as an integral component of comprehensive developmental rehabilitation.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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