

The Effect of Water Access on the Cognitive Development of Children Under 18: A Literature Research Review

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ABSTRACT

Globally, limited access to clean drinking water affects millions of children, especially during their early cognitive developmental stages. This lack of reliable access is connected to dehydration, waterborne illnesses, environmental challenges, and sociocultural barriers. A literature review was conducted using Google Scholar and PubMed to find studies published from 2002 onward with a primary focus on children aged zero to eighteen. Additionally, inclusion criteria included: research examining the relationship between clean water access and cognitive abilities such as memory, language, and motor development. Of the fourteen articles, cross-sectional studies, randomized controlled trials, and burden of disease assessments were included. Findings showed how dehydration negatively affected cognitive abilities including: attention, visual processing, and memory. In contrast, waterborne diseases were associated with reduced cognitive function and growth stunting. Environmental and sociocultural factors, including time spent collecting water rather than in school, significantly decreased children's academic outcomes. Inadequate water access negatively impacts early child development through biological, environmental, and sociocultural aspects. To prevent illness and death while supporting children's cognitive development and academic performance, it is important to make Water, Sanitation, and Hygiene (WASH) resources and clean drinking water accessible to everyone.

Keywords: Global Water Access; Child Cognitive Development; Cognitive Delay

INTRODUCTION

Clean drinking water is particularly important during the earliest developmental stages of childhood, which is a period with rapid brain development. Without reliable access to clean water, children face immediate challenges that can be detrimental to their cognitive health (1).

Existing research has consistently demonstrated the

direct relationship between dehydration, waterborne diseases, environmental factors, and sociocultural factors with the development of important cognitive abilities including memory, language acquisition, and cognitive performance. The consequences can affect the cognitive health of children as young as one-year old, potentially impacting their future well-being.

Given this significant impact on children's foundational development, a comprehensive analysis of existing data will provide more information. This literature review will summarize findings on the specific impact of inadequate access to clean water on various cognitive abilities. It will contribute to the fields of cognitive development and global public health. There is limited existing research focusing specifically on the

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relationship between water access and early childhood cognitive development. This literature review will provide an overview of current knowledge to support future research focused on children’s cognitive health.

METHODS AND MATERIALS

Database and Search Strategy

PubMed and Google Scholar were used to find peer-reviewed studies and articles published from 2002 to 2024. Specific search terms used included: childhood cognitive development, water access, and global health disparities. These articles were used to find empirical data and statistics about the impact of water access on specific cognitive abilities, before being summarized and presented concisely.

By searching online databases, Google Scholar and PubMed, experimental and observational research studies were identified. The search focused on finding literature addressing the direct, indirect, and environmental effects of water consumption and access on childhood cognitive development, specifically aspects such as memory and language skills.

Inclusion Criteria

The criteria for the research included: children from ages zero to eighteen, from different countries globally,

focusing on cognitive and academic performance, memory, language, and motor skill development.

Exclusion Criteria

The criteria for the research excluded: children older than eighteen years of age and studies that did not focus on the relationship between water access and cognitive abilities, or focused on general health impacts.

Data Extraction and Synthesis

For each study, the participant characteristics and key findings about specific cognitive abilities were recorded and summarized. This information was organized into subsections based on the different causes of unreliable water access that affect cognitive development.

RESULTS

Of the 40 articles screened, fourteen articles met inclusion criteria. Within these fourteen articles, three were cross-sectional studies, two were experimental studies, two were randomized controlled trials, two were burden of disease assessments, three were cohort studies, one was a surveillance report, and one was a quantitative study. Table 1 summarizes the characteristics of the included studies. Table 2 presents the primary outcomes and effect directions for each included study.

Table 1. Characteristics of Included Studies

Reference	Year	Country	Sample Size	Study Design
1	2023	South Africa	192	Cross-Sectional
2	2009	UK	58	Experimental
3	2015	USA (CA)	52	Experimental
4	2021	China	76	Randomized Controlled Trial
5	2023	Global	N/A	Burden of Disease Assessment
6	2019	Global	N/A	Burden of Disease Assessment
7	2024	USA	N/A	Surveillance Summary
8	2016	Brazil	131	Cohort
9	2002	Brazil	46	Cohort
10	2018	Kenya	8,246	Randomized Controlled Trial
11	2021	South Africa	404	Cohort
12	2021	India	Total: 23,439; Subsample (for math outcomes): 5,553	Cross-Sectional
13	2016	Brazil	N/A	Cross-Sectional
14	2021	India	21,431	Quantitative Study

Table 2. Primary Outcomes and Effect Directions of Included Studies

Reference	Primary Outcome	Effect Direction
1	Early childhood development was assessed using the International Development and Early Learning Assessment (IDELA) score, which measures performance across cognitive, socio-emotional, and motor domains.	Children living in households with an indoor tap had higher IDELA scores, suggesting a positive relationship between water access and better developmental outcomes.
2	Cognitive performance in children was measured using tasks assessing attention, visual processing, and short-term memory.	Children who drank more water performed better on several cognitive tasks, indicating a positive effect of water intake on cognitive performance.
3	Changes in each child’s performance in memory and attention tasks were measured over time to assess cognitive performance.	For children with smaller hydration changes, drinking water improved cognitive performance, whereas children with larger hydration changes performed worse on tasks, indicating a mixed effect depending on hydration status.
4	By using tasks involving processing speed, working and episodic memory, and mood ratings, cognitive performance and mood were assessed.	Dehydration worsened people’s moods and some aspects of their memory, while rehydration, especially with larger volumes of water, improved both cognitive performance and mood.
5	The global burden of disease in 2019, measured in number of deaths and disability-adjusted life years (DALYs) is attributable to unsafe drinking water, sanitation, and hygiene (WASH) across four areas: diarrhea, acute respiratory infections, malnutrition, and helminthiasis.	Improving WASH to the Sustainable Development Goal (SDG) levels would reduce disease burden and could have prevented an estimated 1.4 million deaths and 74 million disability-adjusted life-years (DALYs).
6	The global burden of disease in 2016, measured in number of deaths and disability-adjusted life-years (DALYs), is attributable to inadequate water, sanitation, and hygiene (WASH).	Inadequate WASH increases mortality rates across multiple diseases and improved WASH conditions consistently reduce disease burden, with estimates showing that better WASH resources could have prevented up to 1.6 million deaths and over 100 million DALYs.
7	From 2015-2020, 214 drinking water-associated outbreaks were reported across 28 U.S. states, most of which were caused by Legionella bacteria.	Legionella-associated outbreaks have increased over time, particularly because of issues in plumbing systems.
8	Child cognitive performance was measured using assessments including Test of Nonverbal Intelligence (TONI), Wechsler Intelligence Scale for Children (WISC-III) for coding tasks, and Developmental Neuropsychological Assessment (NEPSY) for verbal fluency.	More occurrences of early childhood diarrhea (ECD) and malnutrition is associated with lower cognitive performances and scores.
9	Early childhood diarrhea (ECD) could be used to predict future cognitive performance through standardized tests like the Test of Nonverbal Intelligence (TONI-III) and Wechsler Intelligence Scale for Children (WISC-III).	Higher frequencies of early childhood diarrhea were associated with lower cognitive scores 4-7 years later, even after controlling for maternal education, helminth infection, and nutritional status.
10	Developmental performance was measured using the Extended Ages and Stages Questionnaire (EASQ), assessing gross motor, communication, and personal-social skills.	The interventions—including chlorinated drinking water, improved sanitation, handwashing with soap, improved nutrition, and a combination of all interventions—produced short-term improvements in specific motor skills.

Continued Table 2. Primary Outcomes and Effect Directions of Included Studies

Reference	Primary Outcome	Effect Direction
11	Enteric pathogens like EAEC, EHEC/EPEC, and Giardia were measured in stool samples from children under 5 to determine enteric infection prevalence.	Factors like inconsistent municipal water distribution and household water storage had a bigger impact on enteric infection risk than the water source type.
12	Children's educational outcomes and performances were measured using study time, educational expenses, and math scores.	Women spending significant time on unpaid chores, including fetching water, negatively impacts educational outcomes.
13	Children's educational progress was measured by the number of completed school years.	Access to improved water and sanitation services increased children's completed years of schooling and had a stronger impact the longer children were exposed to these services.
14	Children's learning achievements and progress were measured through test scores in mathematics, reading, and writing.	Spending more time collecting water resulted in lower mathematics, reading, and writing test scores.

Dehydration

Consuming water significantly benefits children's cognitive performance. A study in London demonstrated that children who drink water perform better in visual tasks, such as spotting differences (2). Similar to prior research, which reported trends between better hydration and better performance on visual processing tasks, this study showed that perceptual discrimination and attention were improved with hydration (2). Another study conducted in California measured and controlled urine osmolality to assess changes in hydration status (3). Children who have a smaller decrease in urine osmolality after drinking water perform better on paired cancellation tasks as opposed to children who experience a larger decrease (3). Similarly, a study in China showed that after restricted water consumption, participants' episodic memory was weaker and their moods were negatively impacted (4).

Waterborne Diseases

Diseases such as diarrhea, gastrointestinal infections, systematic illnesses, hepatitis A, dermatitis, and more can be transmitted through drinking contaminated water. In 2019, 1.4 million deaths and 74 million disability-adjusted life-years (DALYs), were estimated to be preventable by safe Water, Sanitation, and Hygiene (WASH), resources, and services (5). An analysis focused on low- and middle-income countries estimated 829,000 deaths because of limited WASH resources and services. For children under five, 297,000 deaths were attributed to a lack of WASH (6). In higher income countries and regions, like the US and Europe, there is a negative

impact from diseases transmitted from contaminated water (7). Every year, in the US, there are around 7.15 million cases of diseases, 118,000 hospitalizations, and 6,630 fatalities due to waterborne illnesses (7).

Diarrhea can cause severe and acute dehydration because the body loses significant amounts of fluid and electrolytes. One study suggests that children with frequent diarrhea in early childhood may have lower scores on nonverbal intelligence tests (8). Particularly in the first two years of life, children with heavy diarrhea had lower scores on coding tests (8). Children with low, near normal, and normal weight appeared to have low verbal performance scores when suffering from diarrhea (8). A study conducted in Brazil found similar results: early childhood diarrhea was associated with reduced cognitive function four to seven years later (9). There was new evidence suggesting that severe diarrhea has lasting consequences. Long-term associations were seen through reduced fitness and cognitive function (9). Findings from the TONI-III, a non-verbal intelligence test, showed that children with an average of 10.2 episodes of diarrhea in their first two years of life were associated with a 5.6% reduction in test scores (9).

Enteric infections, which affect the stomach and intestines, and are often caused by viruses, bacteria, and parasites, can affect cognitive development. A study in Kenya found that frequent illnesses with fevers or inflammation were linked to poor cognitive, language, and motor development (10). Exposure to enteropathogens, which include various bacteria, could lead to a neuroinflammatory state (10). Not only does inflammation cause a decrease in iron concentrations,

but it also limits the availability for normal processes to occur, particularly those that depend on iron (10). Another study in South Africa focused on young children, who are especially at risk for enteric infections (11). Contaminated drinking water can affect environmental enteropathy, which is observed by increased intestinal permeability, impaired immune functions, and malabsorption (11). All of these factors can lead to child growth stunting. Across the groups studied, *E. coli* bacteria and *Giardia* infections were most commonly observed (11). Children who drank groundwater or relied on surface water were more likely to have higher rates of infection compared to those who drank municipal water (11).

Environmental & Sociocultural Factors

Environmental factors and community responsibilities, such as having to collect water daily, are associated with interruptions in schooling, which may correspond with differences in overall cognitive development. When parents or guardians spend time accessing water, it can decrease the time available for aiding children's cognitive development (12). Stimulation and interaction with surrounding environments is very important for a child's development. In particular, maternal time significantly influences children's cognitive growth, including basic foundations for later life outcomes (12). At times, children have to join their parents or guardians, resulting in less time for their own education, and possibly lower educational outcomes (12). A study in Brazil emphasized the negative impact a lack of access to sanitation and clean water has on the education of six- to ten-year old children (13). Some of the immediate effects of poor water access include failing to complete high school or failing to obtain higher education (13). Another study conducted in South Africa, with a focus on low-income areas within Cape Town, used the IDELA, or International Development and Early Learning Assessment as a tool to assess children's cognitive, social, emotional, and motor development (1). It found that children's IDELA scores tended to be lower in households that did not have an indoor tap and households that stored water (1).

Gender has a significant role in water collection. In India, a study found that 94.8% of the households observed involved women in collecting water, while only 70% of observed households involved men in this task (12). In terms of time spent for this task, women spend nearly twice the amount of time than men (12). An increase in a mother's time spent retrieving water negatively impacted children's math test scores and

overall educational performance (12). Another study, which was also conducted in India, studied the exchange of learning for water collection responsibilities (14). Analysis indicated that higher fetching times were associated with lower math, reading, and writing test scores (14). In particular, girls' test scores and cognitive performance were more affected by time spent retrieving water than boys were (14).

DISCUSSION

The studies related to dehydration were conducted in many different countries and focused on the relationship between dehydration and children's cognitive development. Even mild dehydration was shown to impact attention, visual processing, and memory (2). Additionally, mood and episodic memory were also affected (4). The studies and their results matter because children who are significantly under-hydrated fall behind academically and developmentally. It is important to ensure consistent access to sufficient amounts of water, not only for children's physical health, but for their long-term learning and mental well-being. The United Nations International Children's Emergency Fund (UNICEF) has framed WASH as crucial to improving child survival, nutrition, and early childhood development (15).

Contaminated water is one of the main causes for child deaths. This can be seen in many ways, including a lack of basic water facilities. High-income countries in Europe and the US have a significant number of annual deaths due to waterborne diseases and contaminated water sources (7). The Center for Disease Control and Prevention has highlighted that global safe water, sanitation, and hygiene access is one of the most impactful strategies to reduce risk of illness from contaminated water (16).

Waterborne illnesses include diarrhea, enteric infections (11), and exposure to various pathogens. They can cause immediate health risks, such as dehydration, but also long-term cognitive challenges, including growth stunting (11), and neuroinflammatory effects (10). These findings are significant because they demonstrate the importance of safe drinking water for the best cognitive and physical health. The World Health Organization (WHO) has emphasized that improved water quality is essential for reducing diseases from diarrhea, one of the leading causes of death for children under five (17).

Various studies focused on how environmental and sociocultural factors influence water access. Children, particularly girls, and caregivers spend significant time

collecting water (12). This can reduce time for educational engagement and cognitive stimulation, which are critical for early childhood development. These studies matter because they show how poor and limited water access affects children socially and academically.

Limitations

The majority of included studies were conducted in African and Asian countries, with limited representation from North American and European regions, which may limit the universality of the findings. All reviewed articles were published in English, resulting in possible language bias. Additionally, the search relied on Google Scholar and PubMed and was limited to publications from 2002 onward, meaning relevant research from other databases or earlier periods might have been missed. These factors limit the scope of the evidence in this review and allow for further exploration.

CONCLUSION

Globally, inadequate WASH resources contribute to the deaths of thousands of children, most of which are preventable. In particular, children under five are disproportionately affected.

In South Africa and Brazil, children living in households without indoor taps had noticeably lower cognitive, social, and motor development scores. Gender also had an impact on water collection. In India, it was observed that mothers spent significantly more time retrieving water than fathers. This was connected to lower academic performance in children, particularly girls.

The overall evidence highlights how an inadequate access to clean water influences childhood development through three connected pathways: biological, where dehydration and waterborne diseases directly and often immediately affect attention, memory, and long-term growth; environmental, where contaminated water sources increases risk of possibly fatal illnesses; and sociocultural, where the responsibility of water collection, which is mainly placed on women and girls, reduces time for schooling and cognitive stimulation.

Overall, this literature review highlights the urgent need to improve WASH resources, and address the gender and social disparities in collecting water. It is important to continue expanding access to safe and reliable water. This is not only a matter of public and physical health, but is significant for children's cognitive development, academic achievements, and overall well-being.

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CONFLICT OF INTEREST

The author declares that there are no conflicts of interest regarding the publication of this article.

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