The Effects of Water Provision and Education on Students' Hydration Status, Cognitive Abilities, and Fine Motor Function in A Full-Day Primary School

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Abstracs

Background/aim: Dehydration due to inadequate water intake in children may disrupt brain functions. This study aimed to investigate the effects of hydration education with water provision on hydration status, cognitive functions and motor performance.

Materials and Methods: Forty-eight children in primary full-day school (age 8 – 11 years) were recruited in this study. The intervention of hydration education was performed for two days, both for students and teachers. The water was provision for 12 days. Letter cancellation task (LCT), symbol digit modalities test (SDMT), and direct image different test (DIDT) were used to assess cognitive functions. Motor performance was evaluated using a finger tapping test (FTT). Hydration status was determined with urine specific gravity (USG) and urine color (UC). Before and after interventions, all parameters were evaluated.

Results: Most students found dehydrated (>65%). The students had lower USG and UC after the intervention and it was correlated with each other (before; r_s=0.45, P = 0.001 and after; r_s=0.82, P = 0.001). All cognitive and motor functions were significantly higher after an intervention ($P < 0.05$).

Conclusion: Hydration education to students and teachers combined with water provision at primary full-day school increases hydration status and enhances cognitive and fine motor skills.

Keywords*: Urine color, Attention, Motor function, Dehydration*

Background

Growing evidence shows an increasingly widespread lack of total fluid intake, mostly water, among children worldwide(1–4). Children and adolescents (aged 4–17) drank less than 500 mL of water daily(3,4). Besides, the fact that water is the most abundant part of the body of children places them at a high risk of dehydration(5,6).

Increased awareness of the inadequate water intake induces dehydration of school-aged children, and access to water in schools has been raised (7). Stookey and Konig found significant variations in fluid availability for school-aged children in Mexico,

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Brazil, Argentina, China, and Indonesia. In some states, more than half of students do not have free access to drinking water while in school[8], particullary in hot and dry areas[7]. According to Kausik et al., promoting adequate school water intake can help students' biological functioning[9].

Several investigations discovered that dehydration could impair cognitive function[10,11]. In addition, education intervention[12]and water supplementation were sufficient to prevent dehydration[11,13]. Acute water supplementation increases the student's visual focus and motor abilities[13].Therefore, the effect of combining intervention (education and water provision) on cognitive and fine motor functions have not been explicitly studied in primary full-day school.

The current study examined the effects of hydration education and water provision for 12 days on urine hydration markers (USG and UC), cognitive functions (LCT, SDMT, and DIDT), and fine motor performance (FTT). We used all parameters as a baseline before the intervention. The degree of change in each parameter was measured after the intervention.

Methods

Participants

This study was carried out in September 2019 in Masohi, Central Maluku, Indonesia. Before collecting data, primary school principals were asked for permission. Selection criteria included grade (4-6) and health. Chronic disease or medication use were excluded. Their teachers informed their parents about the research. Before data collection, participants and their guardians signed consent forms. Only 48 of the 58 participants with parental consent completed the study. In this study, the Helsinki Declaration's ethical principles were followed (1964). All PoltekkesKemenkes Maluku procedures were approved by the Ethical Committee (LB.02.02/6.2/2910/2019).

Study design and education intervention

The study was quasi-experimental. All participants received hydration education and water provision. The research had three stages. Pre-intervention assessments included hydration, cognition, and fine motor. This lasted only one day. After that, teachers and participants learned about daily fluid requirements, dehydration symptoms, and rehydration options. Participants' water intake was monitored for two weeks by trained teachers who also drank water at school. Participants were observed at school from 7:00 am to 4:00 pm. Each class got refillable water. A 500 mL water bottle from home was also required. All school activities resume as scheduled. On the last day, we did post-intervention. Pre-intervention parameters were assessed.

Hydration status assessment

Pre- and post-intervention hydration status was assessed between 3:30 and 4:00 p.m. using USG and UC. Each participant received one sterile urine container. USG was measured twice with a portable refractometer (Cole-Parmer RSA-BR82T). Between samples, the refractometer was calibrated with distilled water. The sample was placed in a transparent container against a white background to calculate UC using a validated eight-color scale.

Cognitive and motor assessments

Letter cancellation task

The LTC requires participants to locate and cross a target letter within a grid of distractor letters. This test measured visual attention. This study used the one-letter version. Subjects had to cancel 'U' between O and V letters. Participants had 60 seconds to hit all targets. Scores were calculated by subtracting errors from the number of correct targets.

Symbol digit modalities test

The SDMT's cognitive demand is on visual information processing speed and attention. The top of the paper sheet has nine stimulus symbols and nine Arabic numbers from 1 to 9. Above the key were 120 blank boxes with a single pattern. Initial practice (5 min) for each participant, with orders. Participants have 90 seconds to fill in the blank boxes with the key. The number of empty squares that could be filled with the correct symbol determined the score.

Direct image difference test

This test was for visual attention. Two similar images were shown side by side. Participants had 60 seconds to spot the differences between the two images. In this case, more correct differences found meant better results (maximum =12).

Finger tapping test

Fine motor assessment was done by tapping digitally (CNS-Finger Tapping Test, Tushar Kalra). Participants had 60 seconds to practice with the instrument before the test. The digital app records several taps in a 3-trial by a preferred hand (10 s for each). On the digital screen until the trial is finished. The fine motor score was the average of three taps.

Statistical Analysis

The statistical analyses were performed using GraphPad Prism 9.0.0 and SPSS version 21 software programs. The data were presented in means ± standard deviation (SD) or median ± interquartile range (IQR) based on the normality distribution. Significance levels were set at $p<0.05$.

The participants' characteristics were analyzed between males and females using unpaired t-test or Mann-Whitney test, and Kolmogorov-Smirnov test. The mean difference of participants' scores on FTT was analyzed with paired t-test. The mean rank differences of UC, USG, and cognitive assessments test pre and post-intervention using Wilcoxon test. The differences of cognitive and motor assessments between hydration status were analyzed using one-way ANOVA or Kruskal Wallis test. Spearman correlation test was used to assess the correlation between US and USG levels.

Results

Participantcharacteristics

Table 1 shows participant characteristics for boys and girls. The Kolmogorov-Smirnov test revealed that both boys and girls had similar school grades ($p>0.05$). Age, weight, BMI, and hydration status were not different between genders ($p>0.05$). Only 22% of boys and 33% of girls had well-hydrated urine color samples. According to USG, one-third of boys and one-quarter of girls were severely dehydrated($\geq$1.030).

Hydration status based on urinary markers

Figure 1 presents data on the effect of hydration education and water provision at class on participants' urine hydration markers. There was a significant difference in the UC ($p<0.0001$) and USG ($p<0.0001$) between pre (Fig. 2a) and post interventions (Fig.2b). Both urine hydration marker values were lower after intervention than that before the intervention.

Spearman correlation test showed a significantly positive correlation between the US and USG levels on pre and post-intervention ($p = 0.001$). The correlation coefficient between the US and USG levels before treatment with hydration education and water provision was moderate ($r_s = 0.45$), while after treatment was intense ($r_s = 0.82$).

Cognitive and motor performances

The results of LCT, SDMT, DIDT, and FTT before and after treatment are presented in Figure 2. There were significant differences in the mean rank of LCT, SDMT, and DIDT between pre and post-intervention (p< 0.0001). All cognitive performances improved after treatment. The paired t-test also found significant differences in the mean of FTT between the time of assessments (p<0.0001).

The cognitive and motor performances pre and post-intervention were also analyzed based on hydration status, specifically USG value (Table 2). The LCT values pre and post-treatment with hydration education and water provision were significantly differences (one-way ANOVA, $F3, 44 = 3.84$; p=0.016 and $F3, 44 = 2.86$; p=0.048, respectively). Post-hoc analyses of these data revealed that the significant dehydration group showed a significant decrease in LCT than well-hydrated (p=0.003 and p=0.005, pre and post) and minimal dehydration (p=0.008 and p=0.040, pre, and poet) groups. Interestingly, there was no significant decrease in LCT scores on the serious dehydration group than the well-hydrated group, both pre and post-intervention.

The SDMT mean rank did not change significantly between pre- and post-treatment (p>0.005). Dehydration also reduces DIDT score post-intervention (p=0.041). The FTT data showed a significant difference between groups post-intervention (one-way ANOVA, F3, 44 = 6.99; p=0.001) but not pre-intervention. The serious dehydration group had significantly fewer FTT scores than the well-hydrated (p<0.0001), minimal dehydrated (p<0.0001), and significant dehydrated (p=0.001) groups.

Table 1 Characteristics of participants between male and female

Characteristics	Boy (n = 27)	Girl (n=21)	P value
Age (years)a	10± 3	9 ± 1	0.135*
8 – 9	12 (44%)	12 (57%)	
10 – 11	15 (56%)	9 (43%)	
Grades at school			
4th grade	11 (41%)	13 (62%)	
5th grade	9 (33%)	7 (33%)	0.665#
6th grade	8 (26%)	1 (5%)	
Body weight (Kg)b	28.3±14	27.5± 10.5	0.442*
BMI-b	-0.28 ± 1.7	0.54± 0.9	0.435ǂ
Underweight	3 (11%)	0	
Normalweight	16 (59%)	21 (100%)	
Overweight	4 (15%)	0	
Obese	4 (15%)	0	

[a]Data presented as mean ± SD. [b]Data presented as median ± IQR.

[*]Mann-Whitney test. [#]Kolmogorov-Smirnov test. [ǂ]Unpaired t-test. n=number of participant.

Table 2. Cognitive and fine motor performances of participants in pre and post intervention based on USG

Cognitive and motor assesments		Hydration status based on USG				p value
		WH	MD	SiD	SeD	
	n Pre/post	15/36	13/16	6/4	14/2	
LCT	Pre	29.8 ± 4.4	28.9 ± 6.2	20.5 ± 9.3*#	25.7 ± 6.4	0.016a
	Post	33.1 ± 4.6	32.3 ± 3.8	25.6 ± 7.9*#	33.0 ± 2.8	0.046a
SDMT	Pre	21 ± 25	13 ± 24	17 ± 12.3	20 ± 11.3	0.426b
	Post	25 ± 9.8	30.5 ± 19.8	25.3 ± 6.3	19	0.207b
DIDT	Pre	7± 3	5 ± 2	6 ± 2	5 ± 3	0.041b
	Post	7± 3	8.5 ± 1	8.5 ± 6	5	0.161b
FTT	Pre	51.3± 6.9	48.8± 8.9	48.3± 6.2	48.6± 4.9	0.685a
	Post	53.4± 5.5	52.2± 3.1	52± 4.5	41.5± 3.5*#$	0.026a

[a]The data were analyzed using One-way Anova. [b]The data were analyzed using Kruskallwallis test. *<0.05 vs. WH ;#<0.05 vs. MD ; $^{\$}$<0.05 vs. SiD. WH, Well-hydrated; MD, Mild dehydration; SiD, Significant dehydration; SeD, Serious dehydration; LCT, Letter cancelation task; SDMT, Symbol digit modalities test (SDMT); DIDT, Direct image difference test; FTT, Finger tapping test.

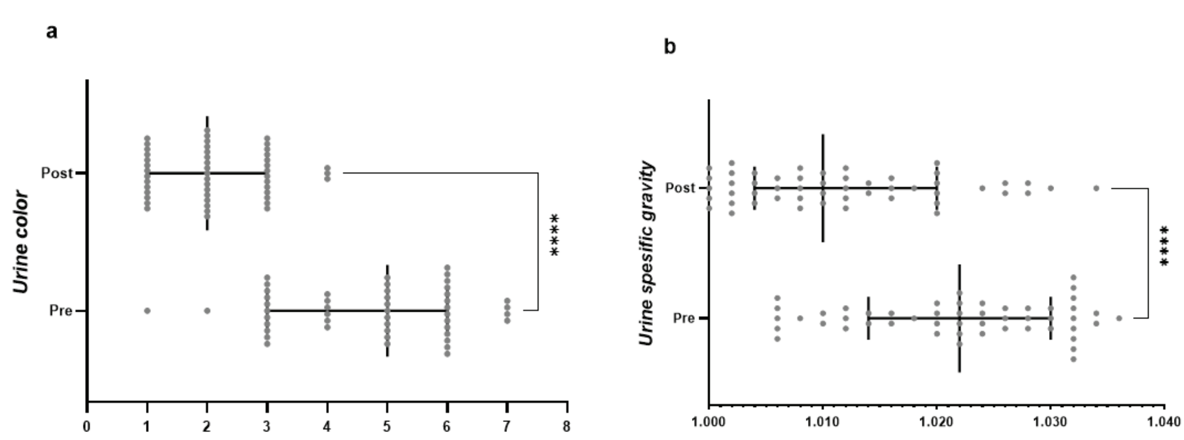

Figure 1

The effect of hydration education and water provision of drinking water at class on participants' urine hydration markers. a. Urine color. b. Urine specific gravity.The data are presented as median±IQR (n=51). ****p<0.0001 (Wilcoxon test).rs, Spearman rank correlation coefficient. p, p-value

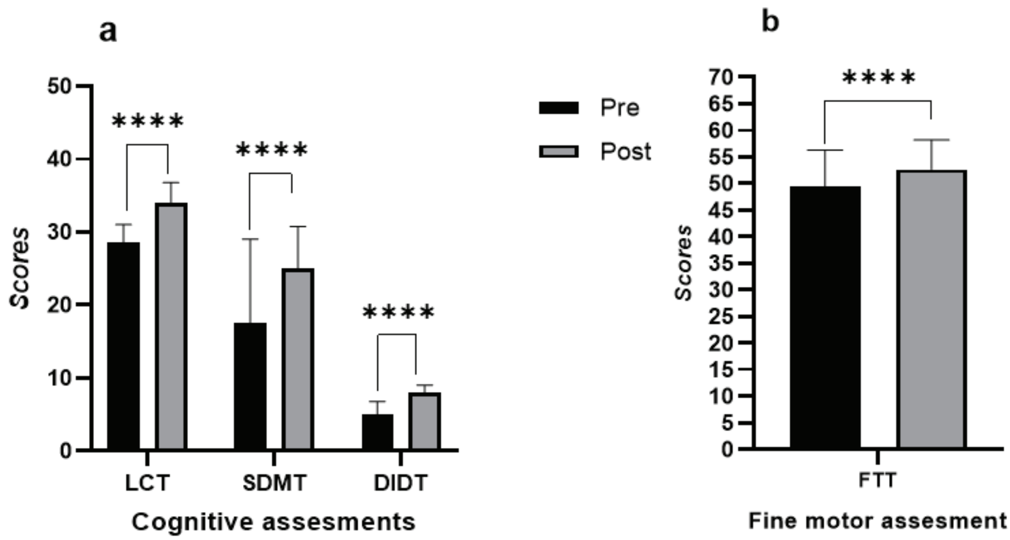

Figure 2

The effect of hydration education on cognitive and motor performances of participants. a. Cognitive assesments. The data are presented as median±IQR (n=48). ****p<0.0001 (Wilcoxon test). b. Fine motor assessment. The data are presented as mean±SD (n=48). ****p<0.0001 (Paired t-test).

LCT, Letter cancelation task; SDMT, Symbol digit modalities test (SDMT); DIDT, Direct image difference test; FTT, Finger tapping test.

The effect of hydration education and water provision of drinking water at class on participants' urine hydration markers. a. Urine color. b. Urine specific gravity.The data are presented as median±IQR (n=51). ****p<0.0001 (Wilcoxon test).$r_{s,}$ Spearman rank correlation coefficient. *p*, *p*-value

Discussion

The current study found that two weeks of hydration education and water provision improved students' hydration and cognitive abilities in primary full-day school. Improved hydration status (lower USG and UC values) influenced cognitive and fine motor performance based on dehydration levels.

Our study had shown that the incidence of dehydration before the intervention was high (68% - 73%). This research finding was consistent with previous studies[10,14,15]. These findings show that once children have reached school, they do not drink enough water[13]. As a result, the risk of dehydration increases with extended schooling time.

The hydration status of boys and girls did not differ statistically (Table 1). Some experiments had varying results. They found that boys' urine osmolality and USG were higher than girls'[16–19]. The reason for our result remains uncertain at present since we did not perform a drinking diary or food recall, but it may be linked to variations in the race or ethnicity of participants[20] in this study compared to those previous reports[16–19].

The current study found that after two weeks of intervention, USG and UC decreased significantly (p<0.05), indicating an increase in school-based water intake. It has been proposed that increasing water consumption is more important than other drinks in reducing dehydration[20]. It is well-known that providing water at school increases student water intake and hydration[11,13,15,21]. Water access and verbal hydration education reduced urine osmolality, USG, and UC in children attending sports camps[12]. However, teachers' role as role models and monitoring student hydration seems to have helped improve students' hydration status. According to Schätzer et al., healthy school hydration initiatives should help empower teachers[22]. A lower urine osmolality or adequate hydration were found in schools that provided water, drinking education, and structured drinking agreements[23]. This study's approach to reducing child dehydration includes both hydration education and teacher empowerment.

It has been conveyed that a loss of 2% of body weight due to inadequate hydration could detriments cognitive and psychomotor performances[24]. Kozioł-Kozakowska and colleagues reported that dehydration was demonstrated as a risk factor (Odds Ratio= 2.85) for impairment of students' attention[25]. These dehydration effects on brain function have been restored during water intake[26]. Along with improved hydration, the study found improved cognitive function on the LCT, SDMT, and DIDT scores (Fig. 2a) and fine motor abilities FTT (Fig. 2b). The LCT, SDMT, and DIDT are recognized for determining visual attention(14). Our results matched those of previous studies[15,21,27,28].

As shown in Table 2, there were statistically significant ($p<0.05$) differences in mean LCT scores between groups of hydration status. Also, the SDMT scores were identical in both studies. Pre-intervention DIDT test scores showed a significant difference between hydration status groups, whereas post-intervention FTT scores showed no difference. This result suggests that hydration status specifically affected cognitive performances. Previous research found that body water adequacy was domain-specific rather than generalized[21,29].

The group with the worst attention scores on LCT pre- and post-intervention was significantly dehydrated ($p<0.05$), according to post hoc analysis (Table 2). Surprisingly, the LCT score was similar in both groups ($p>0.05$). The severe dehydration group also had shallow fine motor performances on FTT post-intervention. Extreme dehydration affected children's fine motor skills ($p>0.05$), indicating that dehydration affects children's fine motor skills. Previously, studies evaluating dehydration-related mental performance showed a dose-response relationship. The more body fluids are lost because of dehydration, the worse the performance will be[30,31]. Our FTT results support these viewpoints, but not for LCT scores. In children with extreme dehydration, the attention is well-preserved on LCT after the intervention is possibly attributable to physiological mechanisms of adaptation. They were experienced extreme and severe dehydration since the pre-intervention period. Physiological systems respond acutely to hypohydration to reduce homeostatic disruption and probably adjust to chronic water deficit to increase tolerance[32].

Conclusion

Hydration education to student and teacher combined with water provision for 12 days at primary full-day school may return student USG and UC to well-hydrated levels. Improving the hydration status of students has been shown to enhance cognitive and motor skills. Our study's limitation does not consider the calculation of the daily amount of intake of water or other beverages and provided a control group. Further investigations on the effects of hydration education with water supplementation on different aspects or parameters of children's brain function are also warranted.

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Conflict of Interest Nil

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