Reference values for the water load test in healthy school children and adolescents

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Abstract

Background and study aim : **The water load test (WLT) is an easy and cheap tool, useful in evaluating gastric accommodation and visceral hypersensitivity. This test can be used in diagnosing functional gastrointestinal disorders, like functional dyspepsia. Our main aim was to propose reference values for the WLT. Our secondary aim was to correlate the water volume drunk with the students' gender, age, and anthropometric measures.**

Patients and methods : **We performed the WLT in students aged 8 to 17 years. Students drank water *ad libitum* for 3 minutes or until pain, satiety or vomiting occurred. We correlated anthropometric variables with water volumes drunk. Upper and lower limit for the maximum tolerated volume were calculated as the 5th and 95th percentile. Pain and nausea were recorded before and after the test.**

Results : **We evaluated 99 students, with a median age (interquartile range) of 11 years (10-13 years) and 55.6 % were girls. Median water volume drank was 380 ml (190-540 ml). Boys (523 ml, interquartile range : 275-760 ml) drank more water than girls (380 ml, interquartile range : 190-570 ml) (p = 0.016). There was a significant correlation between water volume drank and students´ age, weight, height, and body mass index. Of the students that completed the WLT, 22.2 % had nausea and 30.3 % had mild abdominal pain after the test.**

Conclusions : **We proposed reference values for the WLT in children aged 8 to 17 years. Adverse effects are minimal, it is safe to perform, and well tolerated.** (Acta gastroenterol. belg., **2021**, 84, **299-303**).

Key words : Gastrointestinal diseases, diagnostic procedure, water consumption, reference values.

Introduction

Functional gastrointestinal disorders are frequent in schoolchildren and adolescents, with a prevalence ranging from 9.9% to 30% (1,2). Functional dyspepsia is one of the most prevalent disorders, presenting in 2.4% of schoolchildren and adolescents (1). These disorders are associated with low quality of life, psychological distress, school absenteeism, and poor physical and social functioning (3). Diagnose of these disorders is achieved after ruling out an organic cause and with the help of tools, such as the Rome questionnaire.

Functional gastrointestinal disorders are characterized by symptoms related to any combination of disturbed motility, visceral hypersensitivity, altered mucosal immune function, changes in gut microbiota, and altered antral nervous system processing (4). Patients with functional dyspepsia may have impaired gastric accommodation, visceral hypersensitivity, and delayed gastric emptying (5-9). These can be assessed with the barostat (5,10,11), stomach ultrasonography (10,12), single-photon emission computed tomography (13), and electrogastrography (14). But these tests are expensive, invasive, and uncomfortable for many patients.

The water load test (WLT) is an easy and cheap tool, useful in evaluating gastric accommodation and visceral hypersensitivity (5,13). This test is not standardized and its technique differs depending on the study, such as the liquid used or the time for carrying it out. Among the different methods, two are the most widely used. In the first one, subject drinks water at a fixed rate (100 ml/min) until feeling full (15,16). In the second, subject drinks water *ad libitum* in a 3-5-minute period or until perceiving satiety, pain or nausea (17). The WLT has been used both in adults and children, and normal values for this test have been proposed in pediatric subjects in two studies using different techniques (18,19).

Gastric accommodation and gastric emptying determine how much volume a person can drink. With the WLT *ad libitum* method, the test is completed in 3-5-minutes or until perceiving satiety, pain or nausea. We hypothesized that bigger students should drink more water than smaller ones. Since gastric motility is complex, test performance time plays an important role in the assessment with the WLT. We also hypothesized, children that complete the test in less than one-minute drink less volume, which may affect the WLT reference values. Our main aim was to propose reference values in schoolchildren and adolescents. Our secondary aim was to correlate the water volume drank with the students' gender, age, and anthropometric measures. Our third aim was to compare volumes drank in two performance time (less than a minute versus 1-3-minutes).

Materials and methods

Participants in the study

Study protocol was approved by the *HOMI-Fundación Hospital Pediátrico la Misericordia* ethics committee in Bogota, Colombia. We invited students aged 8 to 17 years, from two schools in Cundinamarca, Colombia. School principals gave their permission for the study.

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We sent students´ parents or legal guardians a documents package including an invitation letter, study purpose explanation, and informed consent. We excluded students with antecedents of abdominal surgery, gastrointestinal disorders (organic or functional), and ingestion of drugs that may affect gastrointestinal function (anticholinergics, antihistamines, corticoids, anti-inflammatory drugs, steroids, antiepileptics, antidepressants, laxatives, acid secretion inhibitors, antacids, antispasmodics, and prokinetics).

Instruments and procedure

Avoiding competition between the students, we transferred groups of students from the same classroom to the library. Then students were transferred one by one to the school infirmary and then back to their classrooms, without having communication with their classmates pending to do the test. Weight was determined using a standing digital scale with a 150-kg maximum capacity and 100-g precision. Height was measured with a portable stadiometer with a 2-m maximum capacity and a 1-mm sensitivity. Students fasted for at least four hours before the WLT. For the test, they were instructed to ingest as much water as possible in three minutes or until they felt full, with abdominal pain or nausea. Pure water was used at a temperature of 25°C. Two glasses were used, each with a 190 ml capacity. While the student ingested from a glass of water, another was filled. We determined the water volume drank by counting the glasses of water ingested plus the result of subtracting the water volume remaining in the last glass from 190 ml. Students were asked about symptoms, before and five minutes after the test, using an analogous pain scale, and a dichotomous question (Yes or No) for the presence of nausea.

Data and Statistical analysis

We presented students´ gender as proportions. We presented students´ weight, age, height, body mass index (BMI), and water volume drunk as median (interquartile range). Normality was determined by Kolmogorov-Smirnov with Lilliefors correction test, only height data were normally distributed. Mann-Whitney U test was used to compare age, weight, and BMI between the different groups analyzed. This test also was applied to analyze correlation between gender and water volume drunk. Student t-test was used to compare height between the different groups analyzed. We used Spearman´s correlation coefficient to correlate weight, age, height, and BMI with water volume drunk. Upper and lower limit for the maximum tolerated volume were calculated as the 5th and 95th percentile. A Chi-square test was used to evaluate the relationship between gender and age groups (8-11 versus 12-17 years) and nausea and abdominal pain after the WLT. Statistical analysis was performed using SPSS software (IBM SPSS Statistics for Windows, Version 22.0, Armonk, NY : IBM Corp). Significance level was set at less than 0.05.

Results

Students' characteristics

Ninety-nine healthy students gave informed consent to participate in our study and performed the WLT. All students´ median age was 11 years (10-13 years), 55.6% were girls. Students´ median anthropometric measurements were : 36.9 kg (31.7-45.8 kg) of weight, 143 cm (133.5-152 cm) of height, and 17.8 kg/m^2 (16.5-20.4 kg/m^2) of BMI. There was no significant difference between girls and boys in age, weight, BMI, and height; results presented in table 1. When comparing two age groups (8-11 versus 12-17 years), there was significant difference in weight, BMI, and height; and no significant difference in gender proportions. In table 2 we present the comparison between age groups.

Table 1. — **Age, anthropometric measures and results of the water load test per gender**

	Girls (n = 55) Median (IQR)	Boys (n = 44) Median (IQR)	p-value
Age (years)	11 (10-14)	11 (10-12)	0.980*
Weight (kg)	38 (31.7-45.8)	34.6 (30.9-47.9)	0.483*
Height (kg)	148 (135.5-53.5)	141.3 (135.8-149.4)	0.967**
BMI (kg/m^2)	17.9 (16.6-20.5)	17.7 (16-20.4)	0.486*
Volume (ml)	380 (190-570)	523 (275-760)	0.016*

IQR, Interquartile range. BMI, body mass index. * Mann-Whitney U test. ** Student's t-test.

Table 2. — **Age, gender, anthropometric measures and results of the water load test per age groups**

	8-11 years (n = 59)	12-17 years (n = 40)	p-value
	n (%)	n (%)	
Girls	31 (52.5 %)	24 (60 %)	0.464*
Boys	28 (47.5 %)	16 (40%)	
	Median (IQR)	Median (IQR)	
Age (years)	10 (9-11)	13.5 (12-15)	0.000**
Weight (kg)	33.5 (27.9-38.9)	44 (37.3-54)	0.000**
Height (kg)	138.5 (132-145.7)	153 (147.6-157.5)	0.000***
BMI (kg/m^2)	17.3 (15.6-18.8)	18.9 (17.2-21.3)	0.001**
Volume (ml)	335 (190-545)	570 (380-682.5)	0.002**

IQR, Interquartile range; BMI, body mass index. * Chi-square test. ** Mann-Whitney U test. *** Student's t-test.

Water load test

Students drank a median water volume of 380 ml (190-570 ml). Boys significantly drank more water (table 1). We found a correlation between water volume ingestion and age, weight, height, and BMI in all the students and girls. There was no correlation between water volume ingestion and BMI in boys.

Test performing time

We compared data of students that completed de WLT in less than a minute versus those that completed it in

Table 3. — **Correlations of water volumes drank with students´ anthropometric measures**

	Total (n = 99)	Girls (n = 55)	Boys (n = 44)
Age (SCC, p-value*)	0.463; 0.000	0.583; 0.000	0.343; 0.023
Weight (SCC, p-value*)	0.360; 0.000	0.489; 0.000	0.320; 0.034
Height (SCC, p-value*)	0.432; 0.000	0.545; 0.000	0.327; 0.030
BMI (SCC, p-value*)	0.201; 0.047	0.286; 0.034	0.179; 0.244

BMI, body mass index. SCC, Spearman´s correlation coefficient. * Spearman´s correlation.

Table 4. — **Percentiles of water load test in healthy children as per gender and age group**

	Water load test volume (mL)								
	Age 8-17 years			Age 8-11 years			Age 12-17 years		
Percentiles	Total (n = 99)	Girls (n = 55)	Boys (n = 44)	Total (n = 59)	Girls (n = 31)	Boys (n = 28)	Total (n = 40)	Girls (n = 24)	Boys (n = 16)
5th	130	128	141	120	104	109	190	145	190
25th	190	190	275	190	190	203	380	335	380
50th	380	380	522	335	278	408	570	490	570
75th	570	570	760	545	380	719	683	570	760
95th	950	798	1059	760	570	1055	950	950	986

Table 5. — **Students´ age, anthropometric measures, and results of the water load test comparing different test times (Less than a minute versus 1-3-minutes)**

	Time the test was completed		
	Less than a minute (n = 43) Median (IQR)	One to three minutes (n = 56) Median (IQR)	p-value
Age (years)	10 (9-11)	12 (11-14)	0.000*
Weight (kg)	33.5 (27.9-40.7)	39.8 (33.7-50)	0.001*
Height (kg)	136.5 (132-149)	148.1 (140-155.5)	0.000**
BMI (kg/m^2)	17.3 (15.7-18.8)	18 (16.7-21.2)	0.036*
Volume (ml)	190 (190-310)	570 (380-760)	0.000*

IQR, Interquartile range. BMI, body mass index. * Mann Whitney test. ** Student's t-test.

1-3-minutes. Fifty-six students (57%) completed the test in 1-3-minutes. Those who completed the test in less than a minute where significantly smaller, younger, and drank less water volumes. In table 5, we describe differences in the students according to the test performing time.

Adverse effects after the test

Of the students that completed the WLT, 22.2% had nausea after the test, none had nausea before the test. The proportion of nausea was not significantly different between boys and girls (29.5% versus 16.4%, p = 0.117), or between the age groups (8-11 years: 23.7 % versus 12-17 years : 20 %, p = 0.661). But when analyzing nausea proportion in genders in each age group, 8-11 years boys had significantly more nausea (35.7% versus 12.9%, p = 0.040). No student vomited during or after the test. After the test, 30.3% of the students had abdominal pain. The proportion of abdominal pain was not significantly different between boys and girls (36.4% versus 25.5%, p = 0.241), but 8-11 years boys had significantly more abdominal pain (8-11 years: 40.7% versus 12-17 years: 15%, p = 0.006). There was no significant difference in the abdominal pain proportion in genders in each age group. Abdominal pain resolved spontaneously in all students.

Discussion

Drink tests are performed in patients with functional dyspepsia or gastroparesis, as many of these will achieve satiation or develop symptoms at smaller ingested volumes compared to healthy controls (15,16,20-23). These tests are easy to perform, more available, cheaper, and well tolerated; using either water or nutrient drinks, administered at different rates. Nevertheless, it remains unclear exactly what physiologic processes are assessed by the drink tests (16,20), thus limiting its standardization and endorse for clinical practice. Our median of the water volume drank in all the healthy schoolchildren and adolescents was 380 ml (190-570 ml), with 130 ml as the least volume (5th percentile) drank by all the students.

We hypothesized that bigger students drink more water than smaller ones. We found a correlation with gender, age, and anthropometric measures. Our correlation with volumes drank and age was similar to other studies (18,19,24). We also found a correlation with volume ingestion and weight, height, and BMI. When comparing our results with other studies, some present similar results (18,24) and others do not (19).

Studies in adolescents have shown gender-related differences in maximum tolerated volume, being significantly higher in boys than girls (14,25). When analyzing younger children, no difference between gender and volume drank was reported (18,19). This difference between genders in adolescents and even adults, suggests that hormonal factors may play a role (26). We found significant differences between gender and maximum tolerated volume in all our students (p = 0.016). When correlating water volumes ingestion with gender in each age group (8-11 versus 12-17 years), boys drank more water in both groups, with a significant difference in the younger age group (p = 0.007) in contrast to the older group (p = 0.370). These results must be analyzed carefully, the number of male adolescents was smaller.

Drinking tests studies are not uniform and different methodologies have been proposed. No method has proven superior, so there is limited data concerning the drink test performance for the liquid type and drinking speed (23). The WLT purpose is to offer an easy and cheap tool for gastric accommodation and visceral hypersensitivity assessment. It can also be an alternative for more expensive, invasive, and uncomfortable procedures like the barostat. Our WLT measured the volume drank *ad libitum* in 3-minutes. We also compared the volumes drank in two performing times: test completed in less than one minute versus 1-3-minutes. Students who completed the test in less than one minute, significantly drank less water than those who completed the test in more time. Our results can be explained by understanding gastric accommodation. This is a reduction in gastric tone and increased compliance in response to food intake, allowing an increase in fundic volume without increasing intragastric pressure (27). Gastric accommodation has two components: receptive relaxation and adaptative relaxation. Receptive relaxation occurs in the first seconds (6-10 seconds) after ingestion, with passage of food through the pharynx and esophagus, achieving a recovery between 30-40 seconds (28). So, if we measured the water volume drank in less than a minute, we could make the mistake of only measuring receptive relaxation. Adaptive relaxation is a slower response, reaching maximum gastric volumes in approximately 10-15 minutes after food ingestion (27,29).

For our test, we considered gastric emptying. Liquid gastric emptying is determined by the volume, time in the stomach, and caloric composition. When assessing the distribution of water ingested in the stomach, water was distributed in the proximal stomach after administration of up to 400 ml of water, the antrum size did not change until they infused more than 400 ml of water, triggering gastric emptying (30). For healthy subjects, the liquid water half-emptying time ranges from 6 to 20 min (14.3 ± 4.1 min) (31). We used a non-calorie liquid, which empty faster than high calorie liquid (32,33). Performing a WLT for more than 5 minutes may trigger gastric emptying, resulting in higher volume ingestion. A study that compared volumes ingested at different rates (100 ml/minute versus *ad libitum* ingestion for five minutes or until fulness), found higher volumes with the 100 ml/minute water test when compared to the *ad libitum* technique ($p = 0.002$). They also compared volumes drank with different caloric content (water versus high calorie liquid), being significantly less in high calorie liquids compared with the two previous water methods (p-value of 0.0003 and 0.0360, respectively) (34). Comparison of water and nutrient drink ingestion at the same rate (100 ml/minutes), found that healthy subjects can drink more water than nutrient drink, suggesting that feedback mechanisms triggered by nutrients are more pronounced or take place before the activation of distension mediated reflex (16).

Certain factors may influence our results and were not evaluated, such as physiological, personal, and affective factors. There could be potential physiological sources of error in the WLT like the initial volume of gastric contents prior the water ingestion, gastric and swallowed secretions during the test, and gastric emptying rate (18). Personal aspects such as self-efficacy, which is a perceived capability to perform a specific behavior and therefore the amount of effort on performing the behavior; can be determinant in the water volume ingested (18). We were able to intervene in affective factors, such as excitement, by discouraging competition among the participants and measuring each student individually; but not in anxiety and fear, that have shown to inhibit gastric emptying and reduce voluntary oral intake (34,35).

Normal values for the maximum volume ingested are different in children and adults (25). However normative data for drink test in children is scarce and published studies evaluated North American (18), European, and Asian children (24), with no data available in Latin American children. Our main aim was to propose WLT normal values in healthy schoolchildren and adolescents, evaluating its correlation with other variables. Our small sample size is a limitation and could influence our results, explaining the differences in volumes ingested according to previous studies. The WLT may be a potential tool for future studies evaluating children with functional dyspepsia or to evaluate the effect of new treatments in these patient management.

In conclusion, we found,

- Median of the water volume drank in all the healthy schoolchildren and adolescents was 380 ml (190-570 ml), with 130 ml as the least volume drank by all the students
- Water load test may require a minimum time of one minute for an adequate performance.
- Boys drank more water than girls.
- There was a significant correlation between volumes drank with age and anthropometric measures.

Conflicting interest

None of the authors has any type of conflict of interest to declare.

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Ethics Committee Approval

Ethics committee approval was received for this study from the Ethics Committee of *HOMI Fundación Hospital Pediátrico la Misericordia*, 10/17/2017, ethic number CEI 67-17.

Author contributions

Conceptualization : all authors. Methodology : all authors. Investigation : all authors. Writing - original

draft : all authors. Writing - review and editing : all authors. Approval of final manuscript : all authors.

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