

Unit of Measurement Used and Parent Medication Dosing Errors



WHAT'S KNOWN ON THIS SUBJECT: There is growing support for adopting the milliliter as the standard unit for liquid medication instruction; teaspoon and tablespoon units can be confusing and may endorse kitchen spoon use. There are concerns that parents may not understand milliliter-based instructions.



WHAT THIS STUDY ADDS: Parents who used milliliter-only units made fewer dosing errors than those who used teaspoon or tablespoon units. Moving to a milliliter-only standard could reduce confusion and decrease medication errors, especially for parents with low health literacy and non-English speakers.

abstract



BACKGROUND AND OBJECTIVES: Adopting the milliliter as the preferred unit of measurement has been suggested as a strategy to improve the clarity of medication instructions; teaspoon and tablespoon units may inadvertently endorse nonstandard kitchen spoon use. We examined the association between unit used and parent medication errors and whether nonstandard instruments mediate this relationship.

METHODS: Cross-sectional analysis of baseline data from a larger study of provider communication and medication errors. English- or Spanish-speaking parents ($n = 287$) whose children were prescribed liquid medications in 2 emergency departments were enrolled. Medication error defined as: error in knowledge of prescribed dose, error in observed dose measurement (compared to intended or prescribed dose); $>20\%$ deviation threshold for error. Multiple logistic regression performed adjusting for parent age, language, country, race/ethnicity, socioeconomic status, education, health literacy (Short Test of Functional Health Literacy in Adults); child age, chronic disease; site.

RESULTS: Medication errors were common: 39.4% of parents made an error in measurement of the intended dose, 41.1% made an error in the prescribed dose. Furthermore, 16.7% used a nonstandard instrument. Compared with parents who used milliliter-only, parents who used teaspoon or tablespoon units had twice the odds of making an error with the intended (42.5% vs 27.6%, $P = .02$; adjusted odds ratio=2.3; 95% confidence interval, 1.2–4.4) and prescribed (45.1% vs 31.4%, $P = .04$; adjusted odds ratio=1.9; 95% confidence interval, 1.03–3.5) dose; associations greater for parents with low health literacy and non-English speakers. Nonstandard instrument use partially mediated teaspoon and tablespoon-associated measurement errors.

CONCLUSIONS: Findings support a milliliter-only standard to reduce medication errors. *Pediatrics* 2014;134:e354–e361

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KEY WORDS

medication errors, health literacy, ambulatory care, health communication

ABBREVIATIONS

AOR—adjusted odds ratio

CDC—Centers for Disease Control and Prevention

HL—health literacy

SES—socioeconomic status

STOFHLA—Short Test of Functional Health Literacy in Adults

Dr Yin conceptualized and designed the study, analyzed and interpreted the data, drafted the initial manuscript, critically revised the manuscript, and provided study supervision; Drs Dreyer and Mendelsohn helped conceptualize and design the study, analyzed and interpreted the data, critically revised the manuscript, and provided study supervision; Ms Ugboaja, Ms Sanchez, and Ms Moreira participated in the conceptualization and design of the study, assisted in data acquisition, analysis, and interpretation, and helped draft the manuscript; Dr Paul participated in the conceptualization and design of the study, assisted in data analysis and interpretation, and critically revised the manuscript; Dr Rodriguez participated in the conceptualization and design of the study, assisted in study supervision at one study site, assisted in data analysis and interpretation, and critically revised the manuscript; and all authors approved the final manuscript as submitted.

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Parent medication administration error rates are high, with >40% making dosing errors involving oral liquid medications^{1–3}; confusion related to units of measurement is a contributor, accounting for >10 000 annual poison center calls.^{4,5} Milliliter (mL), teaspoon, tablespoon, and less common terms such as milligrams, dropperfuls, and cubic centimeters are among the units parents may encounter as part of: 1) verbal counseling by their doctor, pharmacist or other provider; 2) written instructions on prescriptions, bottle labels, and associated packaging; or 3) doses printed on measuring devices.^{6–8} For a single prescribed medication, ≥ 1 units may be included in each setting that dosing instructions are presented.^{8,9} Ultimately, this information is incorporated by the parent, contributing to his or her knowledge of the correct dose and ability to accurately administer the medication to their child.

Using the milliliter as the single standard unit of measurement for pediatric liquid medications has been suggested as a strategy to improve the clarity and consistency of dosing instructions by the US Centers for Disease Control and Prevention (CDC) (PROTECT¹⁰ initiative), the US Food and Drug Administration, the Institute for Safe Medication Practices, and the American Academy of Pediatrics.^{11–15} While health care providers should avoid using atypical terms such as cubic centimeters, there are concerns about eliminating familiar terms such as teaspoon or tablespoon. Although parents may be comfortable using teaspoon and tablespoon units, parents mix up these terms, contributing to threefold errors (1 teaspoon = 5 mL; 1 tablespoon = 15 mL)^{16–19}; abbreviations are easily confused (eg, tsp versus tbs).^{10,16} In addition, teaspoon and tablespoon units may inadvertently endorse the use of kitchen spoons, which vary widely in size and shape, making it difficult for parents to measure their

intended dose.^{18,20} Parents with low health literacy (HL) and limited English proficiency, who are at particular risk for making medication errors, may especially benefit from a move to a consistent, single unit system.^{6,7,9} To date, there has been limited study of the degree to which use of specific units of measurement promotes or reduces the rate of parent errors and whether this relationship is mediated by nonstandard instrument use or varies by HL and language.

METHODS

Participants and Setting

This was a cross-sectional analysis of baseline data collected as part of a pre-implementation/post-implementation study of a low-literacy intervention to improve provider medication counseling.¹ Data were collected from parents of children seen in 2 public hospital pediatric emergency departments (Bellevue Hospital, Woodhull Medical Center) between May 31, 2010 and September 10, 2011.

Bilingual (English- and Spanish-speaking) research assistants assessed families systematically for eligibility first by chart review, then by phone. At chart review, inclusion criteria were child <9 years, and prescribed a daily oral liquid medication (≥ 1 dose/day) for a duration of ≤ 14 days. Exclusion criteria were caregiver not legal guardian, not English- or Spanish-speaking, non-New York City resident, hospital admission, psychiatric or child protection-related issue, and no phone number. Those eligible by chart review were contacted by phone to confirm eligibility, including ensuring that the person enrolled was the person counseled in the emergency department.

Parents and legal guardians are referred to as parents for the remainder of this article. Parents were contacted by phone beginning 4 days after the end date of the prescribed medication course, with a plan to reach them within 2 weeks of the projected end date of the medi-

cation. Given a larger number of eligible families at Woodhull, every fourth parent was systematically contacted beginning in October 2010. Trained research assistants completed assessments by phone and scheduled an in-person follow-up appointment within 8 weeks of the end date of the prescribed medication course. Verbal consent was obtained for those enrolled by telephone, and written informed consent was obtained for those who returned for follow-up. A \$20 gift card was given to parents as an incentive. The study was approved by the New York University School of Medicine Institutional Review Board and the Bellevue and Woodhull facility research review committees.

Measures

Data were collected by chart review, phone interviews, and in-person assessments. The primary outcome variable was medication error. The mediating variable was use of a nonstandard dosing instrument. The primary predictor variable was unit of measurement. Several patients were prescribed multiple daily-dose medications ($n = 7$). For these patients, only the first medication listed in the chart was included in analyses.

Primary Outcome Variable: Medication Error

We collected data on the child's prescribed dose, asked parents to report the dose they gave their child, and performed an observed dosing assessment. Medication errors included error in knowledge of the child's prescribed dose and error in dose measurement. Two types of measurement error were evaluated: error in comparison with the parent's intended dose (dose parent reported giving) and error in comparison with the prescribed dose. Intended dose best reflects a parent's ability to measure a dose without having to account for his or her ability to remember the dose indicated by the provider.

Errors in prescribed dose best reflect clinically relevant errors. The primary criterion used for errors was whether the amount was within 20% of the dose, chosen based on other studies examining dosing accuracy.^{1,21,22}

The prescribed medication dose was obtained by chart review. To determine error in knowledge, the parent-reported dose was compared with the prescribed dose; parents who deviated by >20% were categorized as making an error.

The observed dosing assessment was performed at the time of in-person follow-up.¹ Caregivers were asked to dose the medication as they would at home, using a standard medication bottle (Children's Tylenol) and their dosing instrument. Those who did not bring in their instrument were asked to select a comparable one from a set provided by research staff (included kitchen teaspoon, kitchen tablespoon, dosing spoon, measuring spoon, dosing cup, 5-mL dropper, acetaminophen infant dropper, ibuprofen-specific dropper, and 1-, 3-, 5-, 10-, and 12-mL oral syringes).

Error in measurement compared with the intended dose was determined by comparing the parent-reported dose with the dose measured in the observed assessment; parents who deviated by >20% were categorized as making an error. Error in measurement compared with the prescribed dose was determined by comparing the parent-measured dose with the dose prescribed; parents who deviated by >20% were categorized as making an error. Interrater reliability, measured by having 2 raters assess errors in measurement of the prescribed dose using the 20% criterion for a subsample of 150 parents, was high ($\kappa > 0.9$).

Mediating Variable: Use of Nonstandard Dosing Instrument

Parents were asked to report which instrument they used to measure the

medication. Those who reported use of a kitchen teaspoon or tablespoon were categorized as using a nonstandard instrument.

Predictor Variable: Unit of Measurement

Unit of measurement was assessed for 3 contexts: the prescription, medication bottle label, and parent report. The unit associated with the prescription was obtained by chart review. Partway through the study, we began to request that parents bring in bottles. For this subset of parents ($n = 60$), the unit on the label was recorded. The unit or units used by the parent in reporting the dose was also recorded. Because parents were likely to have been exposed to different units as part of verbal counseling and from the prescription and bottle label,⁸ the unit(s) used by the parent to report the dose was considered the main predictor variable, because it most likely best reflected the parent's understanding of the dose.

Unit(s) of measurement used was categorized as milliliter-only, teaspoon or tablespoon (alone or in combination with another unit), and other. The milliliter-only group included those who used only the term milliliter (full word or abbreviation). The teaspoon or tablespoon group included those who used the full word (eg, teaspoonful) or abbreviation (eg, tsp, tbsp). The other category included all other possibilities, including milligram, or parent inability to indicate a unit (grouped together because of small numbers). Language used on the bottle was recorded; prescriptions were all written in English.

Sociodemographic Data, Health Literacy, and Child Health Status

Sociodemographic data were obtained by chart review and parent interview and included child and parent age and gender, parent-preferred language (English or Spanish; interview language),

ethnicity (Latino or non-Latino), country of birth (US born or not), level of education (based on high school graduation), and socioeconomic status (SES) (Hollingshead Four Factor Index of Social Status²³ 4 or 5 versus all others [scale 1–5; 5 = fewest resources]). Parent HL level was assessed by using the Short Test of Functional Health Literacy in Adults (STOFHLA)²⁴ (inadequate or marginal versus adequate^{25–27}). Child's chronic disease status was assessed by using the Children With Special Health Care Needs screener (any versus none).²⁸

Statistical Analyses

Data were analyzed by using SPSS 20.0 (IBM SPSS Statistics, IBM Corporation, Armonk, NY). For all analyses, a 2-tailed $P < .05$ was considered statistically significant. χ^2 analyses were used to examine unadjusted associations between unit of measurement of prescription, bottle label, and parent; medication errors; and associations between unit, use of nonstandard instrument, and errors. The independent variables (ie, parent unit, nonstandard instrument) found to be significantly related to errors were examined in adjusted analyses; adjusted and subgroup analyses were performed to examine independent associations and moderators, respectively. To assess whether independent associations between unit and errors were seen after inclusion of potential confounders, multiple logistic regression was performed. Potential confounders were included a priori (parent age, race/ethnicity, language, country of birth, SES, education, and HL; child age and chronic disease status; and site).^{7,29,30} We performed exploratory subgroup analyses by HL and language. We also tested for an interaction between teaspoon or tablespoon use and both HL and language. We ran additional models controlling for use of a nonstandard instrument. Path analysis was used to examine whether nonstandard instrument use mediated unit-associated error rates (Baron and Kenny³¹). Finally,

analyses were performed to examine only those who used standardized instruments to see whether the relationship between unit and errors remained; sample size limited our ability to perform analyses among nonstandard kitchen spoon users ($n = 48$). In all regression analyses, “teaspoon/tablespoon” and “other” categories were each dummy coded, with milliliter-only as the reference group. Because the “other” group was small, our ability to draw conclusions from this group was limited; we therefore focused on analyses comparing milliliter-only and teaspoon or tablespoon groups.

RESULTS

Of 400 enrolled parents, 113 did not return for follow-up (28.3%); the sample included in analyses consists of 287 parents (Table 1). There were no differences between those who did and did not follow up. The majority of medications prescribed were antibiotics (80.5%) and steroids (17.4%).

Nearly a third (31.7%) of parents made an error in knowledge of the prescribed dose. About 40% made each type of error in measurement. About 1 in 6 parents (16.7%) used a kitchen spoon rather than a standard instrument (38.0% oral syringe, 16.0% dropper, 13.9% dosing cup, 13.6% dosing spoon, 1.7% measuring spoon).

There was variability in the manner in which units were used on the prescription, on the bottle label, and by the parent (Table 2). More than one-third of the time (36.7%), the label did not contain the same units as the prescription. Of prescriptions using milliliter-only, 41.7% of associated labels had milliliter-only, 50.0% teaspoon-only, and the remainder added teaspoon to the milliliter unit. Parents often did not use the unit listed on the prescription or label. For example, when a prescription used milliliters, 45.0% of parents did not use milliliters. When a prescription used teaspoon, 36.7% did not use teaspoon.

TABLE 1 Characteristics of Study Population ($n = 287$)

	Mean (SD) or n (%)
Child characteristics	
Age, mean (SD), y	3.5 (2.4)
Chronic medical problem, n (%)	67 (23.3)
Parent characteristics	
Age, mean (SD), y	32.2 (8.0) ^a
Relationship to child, n (%)	
Mother	259 (90.2)
Marital status single, n (%)	119 (41.5)
Hollingshead SES level 4 or 5, n (%) ^b	237 (82.6)
Country of birth: non-US born, n (%)	176 (61.3)
Race/ethnicity, n (%)	
Hispanic	212 (73.9)
Non-Hispanic	
White, non-Hispanic	8 (2.8)
Black, non-Hispanic	52 (18.1)
Asian, non-Hispanic	11 (3.8)
Other, non-Hispanic	4 (1.4)
Language Spanish, n (%) ^c	134 (46.7)
Education, n (%)	
Less than high school graduate	138 (48.1)
High school graduate or equivalent	72 (25.1)
Higher than high school graduate	77 (26.8)
Health literacy, n (%) ^d	
Inadequate health literacy	71 (24.9)
Marginal health literacy	34 (11.9)
Adequate health literacy	180 (63.2)

^a Missing for 4 parents.

^b Lower number represents higher SES and greater family resources.

^c Language of survey administration.

^d HL measured by using STOFHLA. Data missing for 2 subjects who did not complete the STOFHLA.

TABLE 2 Units of Measurement Used on the Prescription, on the Bottle Label, and by Parent Report

Source	n	Milliliter ^a	Teaspoon or Tablespoon ^b	Other
		n (%)	n (%)	n (%)
Prescription	287	109 (38.0)	151 (52.6) ^c	27 (9.4) ^d
Bottle label	60 ^e	12 (20.0)	48 (80.0) ^f	0 (0)
Parent report	285 ^g	105 (36.8)	153 (53.7) ^h	27 (9.5) ⁱ

^a Milliliter-only.

^b Teaspoon or tablespoon alone or in combination.

^c Including 148 using teaspoon only, 2 using tablespoon only, 1 using milliliters and tablespoon.

^d Including 1 using milliliters and milligrams; remainder milligrams only.

^e Total of 60 bottles brought in by parents; 2 in Spanish.

^f Including 43 using teaspoon only and 5 using milliliters and teaspoon.

^g 2 parents did not remember the dose amount.

^h Including 145 using teaspoon only, 6 using tablespoon only, 1 using milliliters and teaspoon, 1 using milliliters and tablespoon.

ⁱ Including 13 using milligrams, 1 “spoon,” and 13 able to mention a dose amount but without an associated unit.

Parent Medication Error and Unit of Measurement Used

Although the unit used on the prescription or bottle label was not associated with errors in knowledge or measurement, the unit used by the parent was associated with both types of measurement error. Compared with those who used milliliter-only, parents

who used teaspoon or tablespoon were more likely to make errors in their intended (adjusted odds ratio [AOR] = 2.3; 95% confidence interval [CI], 1.2–4.4) and prescribed (AOR = 1.9; 95% CI, 1.03–3.5) dose (Table 3).

Teaspoon or tablespoon-associated errors in the intended dose were found for those with low HL ($P = .002$) but not for

those with adequate HL ($P = .6$) (Table 3) (interaction significant; $P = .02$). No clear pattern by HL was found for prescribed dose. There were some differences in teaspoon or tablespoon-associated errors in measurement by language (Table 3). Adjusted odds were similar between English- and Spanish-speaking parents when intended dose was examined, although statistical significance was seen only for Spanish speakers (Spanish speakers, $P = .045$; English speakers, $P = .08$). Among Spanish speakers, a trend was seen for prescribed dose ($P = .06$); the association was not significant for English speakers. Interaction terms between language and teaspoon or tablespoon use were not significant.

Role of Dosing Instrument in Associations Between Unit of Measurement and Errors

Parents who reported their dose using teaspoon or tablespoon units were more likely to use a nonstandard instrument (30.7% vs 1.0%, $P < .001$) than those who used milliliter-only. Parents who used a nonstandard instrument had more than twice the odds of making an error in measurement compared with both their intended (AOR = 2.4; 95% CI, 1.1–5.0) and prescribed (AOR = 2.6; 95% CI, 1.2–5.5) doses. In path analyses to determine whether use of a nonstandard instrument mediated unit-of-measurement effects on error rates, the 4 Baron and Kenny³¹ criteria for mediation were met for both types of measurement error (Figure 1). However, even in the subgroup that used standardized instruments, parents who used teaspoon or tablespoon units had twice the odds of making an error in measuring their intended dose (AOR = 2.3; 95% CI, 1.4–4.9); no difference was seen for prescribed dose.

DISCUSSION

To our knowledge, this is the first study to examine the association between units of measurement and pediatric liquid med-

TABLE 3 Multiple Regression Analyses for Associations Between Parent Use of Teaspoon or Tablespoon Units (vs Milliliter-Only Units) and Errors in Measurement^a

	<i>n</i>	Error in Measurement Compared With Intended Dose		Error in Measurement Compared With Prescribed Dose		
		AOR ^b	95% CI	AOR ^b	95% CI	
Entire parent sample	287	2.3	1.2–4.4	1.9	1.03–3.5	
Subgroup by HL	Adequate	180	1.3	0.6–2.8	1.9	0.8–4.3
	Low	105	5.9	1.9–18.5	2.0	0.7–5.8
Subgroup by language	English	153	2.3	0.9–5.7	1.6	0.7–3.8
	Spanish	134	2.5	1.02–6.2	2.4	0.98–5.7

^a Controlling for parent age, race/ethnicity, language, country of birth, SES, education, health literacy; child age and child chronic disease; and site.

^b AOR for error comparing parents using teaspoon or tablespoon units, with parent using milliliter-only units as reference group. AORs for parents who used “other” units not shown because of small *n*.

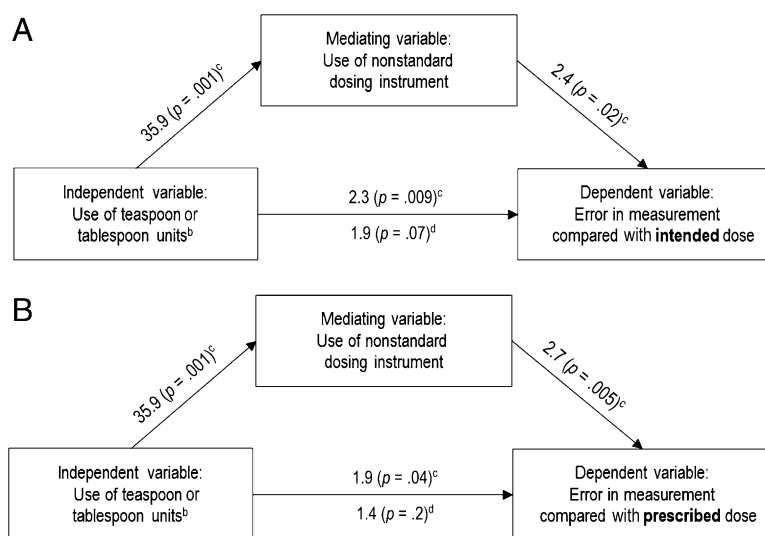


FIGURE 1

Path analysis: Use of nonstandard dosing instrument as a mediator of teaspoon or tablespoon unit-associated errors in measurement compared with the intended (A) and prescribed (B) dose.^a

^aBaron and Kenny criteria for mediation met: teaspoon or tablespoon use associated with measurement error in analyses without nonstandard instrument in model, teaspoon or tablespoon use associated with use of nonstandard instrument, nonstandard instrument associated with errors, and teaspoon or tablespoon no longer significantly associated with error after adjustment for nonstandard instrument. ^bTeaspoon or tablespoon units used alone or in combination. ^cMultiple logistic regression analysis adjusting for parent age, race/ethnicity, language, country of birth, socioeconomic status, education, and HL; child age and child chronic disease; and site. ^dMultiple logistic regression analysis with nonstandard instrument included in the model and adjusting for variables listed in footnote c.

ication errors. Compared with parents who used milliliter-only, parents who used teaspoon or tablespoon units had twice the odds of making a measurement error. These findings suggest that many parents understand how to dose using milliliter units and that a move to a milliliter-preferred system is likely to improve the clarity of dosing instructions, contributing to a reduction in parent medication administration errors.

Similar to other studies, our study found that variability exists in the manner in which dosing instructions are presented^{6,8}; nearly one-third of bottle labels in our study were inconsistent with the prescription. These changes may have arisen because of perceptions that parents do not understand how to dose using milliliter units. Outreach to pharmacists and other health professionals is needed to promote the consistent use

of milliliter units between prescriptions and bottle labels.⁸

A significant proportion of parents did not use the same unit as the prescription or bottle label, indicating that parents were likely to have been exposed to different units of measurement across settings, including instructions on the prescription, bottle label, and supplemental written instructions, as well as from verbal counseling.

Our study findings directly address concerns some have raised about how a milliliter-only standard for pediatric liquid medications in the United States could increase error rates. These concerns center on the idea that parents are likely to be comfortable dosing using teaspoon or tablespoon units and that a term such as mL could increase confusion. We found the opposite to be true. There were fewer errors among those who used milliliters than those who used teaspoon or tablespoon units. A move to a milliliter-only standard has garnered increasing support from government agencies such as the CDC and the Food and Drug Administration, as well as organizations such as the American Academy of Pediatrics, the American Academy of Family Physicians, US Pharmacopeia, and the American Association of Poison Control Centers.^{11–15,32–34}

Path analyses conducted as part of our study revealed that the association between teaspoon or tablespoon units and error was mediated in part by the use of nonstandard dosing instruments. Terms such as teaspoon and tablespoon are an inadvertent endorsement for kitchen spoon use.²⁰ Parents in our study who used teaspoon or tablespoon terms had >30 times the odds of using a kitchen spoon to measure their child's medication. A move to a milliliter-only system would likely promote the use of standardized instruments, including oral

syringes, droppers, and dosing cups. If a move to a milliliter-preferred system occurs, standardized instruments should be routinely provided to parents.¹⁵ However, our finding of a higher rate of error in association with use of teaspoon or tablespoon units even when standardized instruments were used suggests that promotion of standardized instruments without a move to a milliliter-only system probably would not fully address the problem of teaspoon and tablespoon unit-associated dosing errors.

We found that the association between teaspoon or tablespoon use and medication errors was stronger among those with low HL and non-English speakers, groups known to be at risk for medication errors.^{17,35} Simplifying instructions by moving to a milliliter-only standard will likely benefit these at-risk groups.³⁶ A move to a single unit system could reduce confusion among health care providers as well. Elimination of teaspoon and tablespoon terms would decrease the complexity of prescriber dosing calculations, a task that can already be challenging because of the need for weight-based dosing for many pediatric medications. The process of dispensing medications would also be simplified; cases have been documented in which a pharmacist dispensed an amount in teaspoons when the amount was prescribed in milliliters, resulting in a fivefold parent dosing error.^{37–39}

There are limitations to our study. This was a cross-sectional study in which we examined associations between units of measurement and dosing error; conclusions about causality cannot be made. Our observed dosing assessment was performed as part of a follow-up visit, up to 8 weeks from the projected end date of the child's prescribed medication, and may not reflect how parents actually dosed at home. This may explain why our findings were

more closely associated with errors with the intended rather than prescribed dose; future study in which assessments are performed earlier could reduce the impact of memory as a confounding issue. We focused our analyses on parent-reported dose as a reflection of how parents ultimately understood the dose, and we were not able to examine the use of specific units across the full range of settings where dosing instructions are provided, including provider counseling. We also did not collect bottles until partway through the study, which limits our ability to look at implications of inconsistency between prescriptions and labels.

CONCLUSIONS

Parent use of teaspoon or tablespoon units was associated with higher odds of medication error than when milliliter-only units were used. Our findings provide evidence in support of a growing national initiative to move to a milliliter-only standard and may allay fears about the elimination of teaspoon and tablespoon terms. A move to a milliliter-only standard may promote the safe use of pediatric liquid medications among groups at particular risk for misunderstanding medication instructions, such as those with low HL and non-English speakers.

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