Accuracy of Oral Liquid Measuring Devices: Comparison of Dosing Cup and Oral Dosing Syringe

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Abstract and Introduction

Abstract

Background: Previous studies have found that teaspoons are commonly used to administer liquid medications to children. The capacity of household teaspoons ranges from 1.5 mL to 9 mL, potentially leading to errors in dosing. There are few studies evaluating alternative measuring devices.

Objective: To assess adult consumers' previous experience with measuring devices for oral liquids, compare the accuracy of an oral syringe with that of a dosing cup, and determine consumer perceptions of accuracy and ease of use of an oral syringe and a dosing cup.

Methods: Individuals at least 18 years of age were shown a picture of 5 commonly used measurement devices and asked their perceptions of and experience with the devices. They were then asked to measure a 5 mL (1 teaspoon) dose of Tylenol (acetaminophen) suspension, using the EZY Dose oral syringe and the dosing cup provided by the manufacturer. An acceptable dose was defined as 5.0 ± 0.5 mL. Following the measurement, participants completed a 5 item survey that assessed their perceptions of the accuracy and ease of use of the syringe and dosing cup.

Results: A total of 96 subjects completed the study. Participants more commonly reported use of droppers (68%), dosing cups (67%), and teaspoons (62%) versus cylindrical spoons (49%) or oral syringes (49%) for measuring oral liquids. Sixty-four (66.7%) subjects measured an acceptable dose using the syringe versus 14 subjects (14.6%) using the cup (p < 0.001). The mean volumes ± SD measured with the syringe and cup were 4.5 ± 0.7 mL and 6.3 ± 0.7 mL, respectively (p < 0.001). After using both devices, the majority of subjects believed that the syringe (80%) and cup (71%) would measure an accurate dose. Most (87%) participants perceived that the cup was easy to use; 63% believed that the syringe was easy to use.

Conclusions: Droppers and dosing cups were the most commonly used devices in the home for measuring liquid medications. Subjects were more likely to measure an acceptable dose with an oral syringe when compared with a dosing cup. However, a large proportion of study participants were unable to measure an accurate dose with either device. Community pharmacists should educate caregivers on the selection and proper use of measuring devices to improve the accuracy of medication administration in the home.

Introduction

Many prescription and over-the-counter (OTC) medications are available in liquid formulations. Considering that more than 50% of 3-year-old children (68%) have received at least one OTC product, the potential for dosing and administration errors is great.[1] In an observational study, Li et al.[2] found that dosages of acetaminophen administered by parents were inaccurate 62% of the time due to both over- and underdosing. Not only are there multiple OTC liquid products and concentration differences among the same medications; there are also numerous measuring devices available, further amplifying the potential for medication errors.[3] Moreover, the pediatric population itself poses a challenge because of weight-based dosing.[4]

The subject of administration errors associated with measuring devices is not a new issue. In 1975, Mattar et al.
found that when liquid antibiotics or oral decongestants were not dispensed with a measuring device, 75% of parents used a household teaspoon or kitchen measuring spoon to administer the medication to their children. A 1992 report from the American Association of Poison Control Centers found that liquid drug dosing errors were commonly caused by teaspoon/tablespoon confusion and the assumption that the entire dosing cup (eg, filled to capacity) was the recommended dose. Furthermore, the measured capacity of a household teaspoon is highly variable, ranging from 1.5 mL to 9 mL, which may lead to inaccuracies in administering liquid medications. Potentially more accurate measuring devices include oral syringes, medication cups, cylindrical spoons, and droppers, when used appropriately.

Acetaminophen is one of the OTC products most commonly purchased by US consumers. Although acetaminophen is generally considered to be a safe and effective agent, one study found that 42% of admissions for acute liver failure among tertiary care medical centers in the US were associated with acetaminophen overdose. Most cases of accidental overdose among children are caused by the caregiver’s failure to read and understand the label instructions or use of an inappropriate (eg, more concentrated) preparation or incorrect measuring device. In one study, 6% of parents believed that acetaminophen was safe enough to give in unlimited amounts and nearly a third of parents gave more than the recommended dose of acetaminophen to their children.

Few studies evaluating techniques to prevent medication errors associated with liquid measuring devices have been conducted with consumers and further efforts to identify effective strategies to improve the accuracy of oral liquid medication administration in the home setting are warranted.

Our study objectives were to assess adult consumers’ previous experiences with oral liquid measuring devices, compare the accuracy of an oral syringe and dosing cup when used by adults, and determine consumer perceptions regarding the accuracy and ease of use of an oral syringe and a dosing cup.

Methods

We conducted our study at 2 baby-oriented health fairs open to the public in Los Angeles County (Long Beach and Torrance), California, during September and November 2006. All study procedures were approved by the Committee on Human Research at the University of California, San Francisco.

Subjects

Potential subjects who passed our booth were asked to participate in the study. Subjects were included in the study if they were at least 18 years of age and provided verbal consent. Individuals were excluded if they were unable to understand or answer survey questions due to language barriers or diminished capacity or unwilling or physically unable to participate in the measurement demonstration.

Study Design

The study consisted of a premeasurement survey to determine baseline perceptions and previous experience with liquid measuring devices, a measurement demonstration, and a postmeasurement survey to determine perceptions regarding the oral syringe and dosing cup.

For the premeasurement survey, participants were shown a picture (Figure 1) of 5 commonly used oral liquid measuring devices (dosing cup, oral syringe, dropper, cylindrical spoon, and household teaspoon). Investigators verbally asked 4 questions concerning participants’ experiences with and perceptions of these measuring devices. In the measurement portion of the study, participants were asked to measure a 5 mL (1 teaspoon) dose of Children’s Tylenol (acetaminophen) suspension (McNeil Consumer & Specialty Pharmaceuticals, Fort Washington, PA, lot MBM138) using the EZY Dose oral syringe with the included Dosage Korc (Apothecary Products Inc., Burnsville, MN, product number 67007) and the dosing cup provided by the manufacturer. The EZY Dose oral syringe was selected for comparison because previous reports have found it to be accurate when used by consumers and it is widely available for purchase in community pharmacies. Participants were given the EZY Dose oral syringe and Dosage Korc along with package directions. To simulate actual use conditions, no other information was provided to participants regarding use of the devices.
In the postmeasurement part of the study, subjects completed a written survey with 5 questions regarding their perceptions of the accuracy and ease of use of the oral syringe and the dosing cup and their willingness to purchase a reusable oral syringe. Participants checked appropriate boxes, using a 5 point Likert scale. Response options were strongly disagree, disagree, neutral/unsure, agree, and strongly agree. Six questions concerning sociodemographic factors (sex, age, race/ethnicity, education, responsibility for giving liquid medication in the household, and number and ages of children <18 y old living in the household) were included so that we could characterize the study population.

Study Outcomes

The volume of acetaminophen contained within the EZY Dose oral syringe as measured by study participants was assessed by removing the syringe from the Korc and using scored lines on the syringe after eliminating visible air bubbles. Technical data provided by the manufacturer demonstrate that the EZY Dose oral syringe meets industry standards\[16\] for hypodermic syringe volumetric accuracy (personal communication, Michael Cassola, Apothecary Products Inc., Sept 7, 2006). To determine the volume of suspension that participants measured using the dosing cup, the same investigator (PS) withdrew all of the remaining suspension into a 10 mL hypodermic syringe with Luer-Lok Tip (Becton, Dickinson and Co., product number 309604) and used the scoring on the syringe itself.

Boundaries for measurements were defined as follows: accurate dose (5 mL), acceptable dose (4.5-5.5 mL), excessive dose (>5.5 mL), underdose (<4.5 mL), supratherapeutic dose (≥10 mL), and subtherapeutic dose (≤2.5 mL).

Statistical Analysis

Standard descriptive statistics were used to characterize the study population and responses to survey items. Mc-Nemar's test was used to compare the proportion of subjects who measured an accurate and acceptable dose with the dosing cup and the oral syringe. The Wilcoxon signed-rank test was used to evaluate the difference in volume measurements between subjects' use of the oral syringe and the dosing cup. This nonparametric test was used to avoid any potential excessive influence of very large differences on the p value. All analyses were performed using SAS software, version 9.1 (SAS Institute, Cary, NC).

Results

Subject Characteristics
A total of 102 people consented to participate in the study; 96 completed all 3 components. Three participants did not complete the premeasurement survey or measurement demonstration portion and were excluded from the analysis (2 found the syringe difficult to use; 1 was paged but did not return). In addition, 3 other participants did not complete the oral syringe measurement demonstration portion due to difficulty with manipulating the syringe; however, since they completed the survey questions, their responses were included in the survey results (N = 99). Only participants who completed the study in its entirety were included in the accuracy of measurement analysis (n = 96). The majority of responders were highly educated females, with a mean age of 35.5 years and mean number of 1.1 children living in the household. Nearly 78% of participants were responsible for administering liquid medications in their households. Additional demographics of the study population are displayed in Table 1.

**Previous Experience with and Perceptions of Oral Liquid Measuring Devices**

Participants more commonly reported previous use of droppers (68%), dosing cups (67%), and teaspoons (62%) than of cylindrical spoons (49%) or oral syringes (49%) for measuring oral liquids. Before the measurement demonstration exercise, more participants believed that the dropper (30%) and the oral syringe (28%) would be easier to use when compared with the dosing cup (17%), cylindrical spoon (14%), or household teaspoon (10%). Fifty-eight percent of the subjects believed that the oral dosing syringe would produce the most accurate results; 13% believed that the dosing cup was the most accurate device.

**Measurement Accuracy**

Sixty-four (66.7%) subjects measured an acceptable dose (4.5-5.5 mL) using the syringe versus 14 (14.6%) subjects using the cup (p < 0.001). The mean ± SD volume measured for the syringe and cup was 4.5 ± 0.7 mL and 6.3 ± 0.7 mL, respectively (p < 0.001).

Twenty-three of 96 (24%) participants measured an accurate dose (5.0 mL) using the oral dosing syringe, and 4 of 96 (4.2%) measured an accurate dose using the dosing cup (p < 0.001). No participant measured a supratherapeutic dose (≥10 mL). None of the participants measured an excessive dose (>5.5 mL) when using the syringe compared with 82 (85.4%) participants with the dosing cup. Three (3.1%) subjects measured a subtherapeutic dose (<2.5 mL) with the syringe. In general, participants measured less than the intended dose with the oral syringe and more than the intended dose with the dosing cup (Figure 2).

![Figure 2](image-url)

**Figure 2.**

Actual volumes measured by study subjects (n = 96).
Accuracy in the use of the oral syringe and dosing cup did not significantly correlate with the participants’ age, sex, race, education, number of children in the household, or the person responsible for dosing oral liquid medications. However, confidence intervals were too wide to rule out substantial associations with these characteristics.

Postmeasurement Perceptions of Oral Syringe and Dosing Cup

After using both devices, the majority of subjects believed that the syringe (80%) and the cup (71%) would measure an accurate dose. Most (87%) subjects perceived that the cup was easy to use; 63% believed that the syringe was easy to use (Figure 3). More than 65% of the participants indicated that they would be willing to purchase a reusable oral dosing syringe for administering liquid drugs in their homes.

![Figure 3. Postmeasurement perceptions of the oral syringe and dosing cup (N = 99).](source)

Discussion

Our findings suggest that adults more commonly use droppers, dosing cups, and teaspoons when administering liquid medication to children. The use of more accurate measuring devices might increase the chance that children are given a correct dose. Prior to the measurement demonstration, more than half of the subjects believed that the syringe would be accurate, while only 13% felt that the cup would be an accurate device. Perceptions changed after actual use of the devices, with a majority of subjects feeling that both devices were accurate (80% and 71% for the syringe and cup, respectively). Although more subjects believed that the cup was easier to use than the syringe, participants were, on average, 5 times more likely to measure an acceptable dose with the syringe versus the dosing cup.

There are limited reports evaluating the accuracy of oral liquid measuring devices when used by consumers. Madlon-Kay and Mosch[12] observed subjects using a dosing cup, a cylindrical spoon, and an oral syringe and found that 85%, 92%, and 92% of subjects, respectively, were able to measure a correct dose. Another study assessed how accurately caregivers measured a dose of acetaminophen using a device of their choice (ie, teaspoon, syringe, dropper, dosing cup) and found that 67% accurately measured the amount of acetaminophen (within 20% of the intended dose). Although the majority of caregivers were accurate, there was wide variability...
among them, with measured doses ranging from 8% to 210% of the intended dose.[14] In a study comparing conventional dosing devices (eg, dosing cup, measuring spoon, household teaspoon, calibrated medication spoon, medication dropper) with color-coded oral syringes, 92% of caregivers using a syringe marked with colored lines were able to measure a dose of acetaminophen liquid (10-15 mg/kg) correctly compared with 50% of caregivers using a device of their choice.[15] McMahon et al.[13] found that when caregivers received patient-specific dosing instructions for use of an oral syringe in combination with demonstration, measurement accuracy (eg, measured dose within 0.2 mL of the intended dose) significantly improved from 37% to 100% (p = 0.0001). We are unable to compare our findings directly with earlier studies because previous investigators reported accuracy measurements as a combined aggregate of multiple devices.[14,15] did not specify the definition of a correct or accurate dose,[12,15] or did not evaluate a dosing cup device.[13] Strengths of our study relative to previous evaluations include the crossover design, consistent and clearly specified methods for quantitating the actual volume of liquid measured by the study subjects, and precise definitions of an accurate or acceptable dose.

Although our data suggest that the oral syringe is more accurate than the dosing cup, these results should be interpreted with caution. Our small study population predominantly consisted of highly educated females and our findings may not be generalizable to the average US consumer. As a measuring device, the oral syringe is not without limitations. Five subjects were unable to manipulate an EZY Dose syringe and dropped out of the study. Many participants expressed frustration with the device, citing that instructions were too long, the text font size was too small, or both. These individuals often improvised and proceeded to use the syringe without reading the directions. When participants did not follow the correct steps (ie, pulling on the plunger without inverting the acetaminophen bottle 180 degrees), the most common error noted was air in the syringe. As a result, the actual amount of acetaminophen in the syringe was less than intended; nevertheless, 64 participants were able to measure a dose within 0.5 mL of the correct dosage. Furthermore, the research setting (ie, a table at a busy health fair) may have affected participant performance during the measurement demonstration phase of the study, although distractions in the home setting could also occur. Indeed, participants often stated that they would be more careful (eg, placing the cup on a level field or pouring excess medication back into the container) if they were actually giving medication to a child. However, not all participants were caregivers or individuals responsible for administering liquid medication to children. Although our study was large enough to detect a statistically significant difference between the 2 measuring devices, it was not sufficiently powered to identify sociodemographic factors that could predict the accuracy of measurements.

Although we evaluated acetaminophen, our study has greater implications for other drugs available in liquid formulations including those with a narrow therapeutic window (eg, digoxin, phenytoin, carbamazepine, valproic acid). Our findings are particularly salient given the recent recommendation issued jointly by 2 Food and Drug Administration (FDA) advisory committees that OTC antihistamines, nasal decongestants, and antitussives not be labeled for use in children younger than 6 years of age due to concerns regarding the efficacy and safety of these agents in this population. Much of the discussions on safety centered around medication errors (eg, inaccurate measurement of doses) resulting in unintentional adverse events and poisonings in children.[17] While a final ruling by the FDA on this issue has not been released, the leading manufacturers of OTC cough and cold medications have voluntarily withdrawn infant formulations of cough and cold medications from the US OTC market, citing safety concerns associated with "rare patterns of misuse leading to overdose."[18] The potential for medication administration errors may be reduced, by using a device that is reliable and easy to use. Other suggestions to lessen the discrepancy between the intended and actual dose would be to include larger print, simplified language, and pictures on oral dosing syringe package directions or inserts. Healthcare professionals should routinely emphasize the importance of using accurate measuring devices when administering liquid medications and provide appropriate demonstration when possible given that this approach has been shown to significantly improve caregivers’ measurement accuracy.[13] Considering that oral liquid measuring devices are available in pharmacies, pharmacists are uniquely positioned to educate caregivers on the selection and proper use of measuring devices to improve the accuracy of medication administration in the home setting.

Conclusions

In our survey, adults more commonly reported use of droppers and dosing cups to measure oral liquid medications in the home. Study subjects were more likely to measure an acceptable dose with the EZY Dose oral syringe compared with the acetaminophen dosing cup. However, a large proportion of the participants were unable to measure an accurate dose with either device. In general, participants measured more than the intended dose when using the dosing cup and less than the intended dose with the oral syringe. Despite these findings, the majority of adults believed that the oral syringe and dosing cup would measure an accurate dose.
Table 1. Characteristics of the Study Population

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<td>Age (y), mean ± SD</td>
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<td>Children &lt;18 y of age living in the home, mean ± SD</td>
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</tr>
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</table>

\[^a\] N = 99.

\[^b\] Percentages may not sum to 100% due to rounding.

References

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