Analysis of Liquid Medication Dose Errors Made by Patients and Caregivers Using Alternative Measuring Devices

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ABSTRACT

BACKGROUND: Patients use several types of devices to measure liquid medication. Using a criterion ranging from a 10% to 40% variation from a target 5 mL for a teaspoon dose, previous studies have found that a considerable proportion of patients or caregivers make errors when dosing liquid medication with measuring devices.

OBJECTIVE: To determine the rate and magnitude of liquid medication dose errors that occur with patient/caregiver use of various measuring devices in a community pharmacy.

METHODS: Liquid medication measurements by patients or caregivers were observed in a convenience sample of community pharmacy patrons in Korea during a 2-week period in March 2011. Participants included all patients or caregivers (N=300) who came to the pharmacy to buy over-the-counter liquid medication or to have a liquid medication prescription filled during the study period. The participants were instructed by an investigator who was also a pharmacist to select their preferred measuring devices from 6 alternatives (etched-calibration dosing cup, printed-calibration dosing cup, dosing spoon, syringe, dispensing bottle, or spoon with a bottle adapter) and measure a 5 mL dose of Coben (chlorpheniramine maleate/phenylephrine HCl, Daewoo Pharm. Co., Ltd) syrup using the device of their choice. The investigator used an ISOLAB graduated cylinder (Germany, blue grad, 10 mL) to measure the amount of syrup dispensed by the study participants. Participant characteristics were recorded including gender, age, education level, and relationship to the person for whom the medication was intended.

RESULTS: Of the 300 participants, 257 (85.7%) were female; 286 (95.3%) had at least a high school education; and 282 (94.0%) were caregivers (parent or grandparent) for the patient. The mean (SD) measured dose was 4.949 (0.378) mL for the 300 participants. In analysis of variance of the 6 measuring devices, the greatest difference from the 5 mL target was a mean 5.552 mL for 17 subjects who used the regular (etched) dosing cup and 4.660 mL for the dosing spoon (n=10; $P<0.001$). Doses were within 10% of the 5 mL target volume for 88.7% (n=266) of the participant samples. Only 34 cases (11.3%) had dose errors greater than 10%, and only 6 cases (2.0%) had a variance of more than 20% from the 5 mL target volume. Dose errors greater than 10% of the target volume were more common for the etched dosing cup (47.1%, n=8), the dosing spoon (50.0%, n=5), and the printed dosing cup (30.8%, n=4), but these 3 devices were used by only 13.3% of the study participants.

CONCLUSIONS: Approximately 1 in 10 participants measured doses of liquid medication with a volume error greater than 10%, and these dose errors were more common with the etched dosing cup, the dosing spoon, and the printed dosing cup. Pharmacists have an opportunity to counsel patients or caregivers regarding the appropriate use of measuring devices for liquid medication.

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What is already known about this subject

- Prescription and over-the-counter medications are often administered for adult and pediatric patients who have difficulty swallowing tablets or capsules.
- Sobhani et al. (2008) found that 67% of subjects measured an acceptable dose, defined as within 10% deviation from 5 mL, using an oral syringe versus 15% using a dosing cup. Simon et al. (1997) found that 67% of caregivers in a pediatric emergency center measured the amount of acetaminophen accurately (within $\pm 20\%$ of the intended dose) for their child. Among 302 parents in a public hospital pediatric clinic in New York City, Yin and Mendelsohn, et al. (2010) found a range of accurate dosing (within 20% of the 5 mL dose) from 31% to 94% for 6 measuring devices; “large” dose errors (greater than 40%) were made by 26% of parents using the dosing cup with printed markings and 23% of parents using the dosing cup with etched markings.
- Medication measuring devices that come in medication containers are regulated by the South Korea Food and Drug Administration, but there are no regulations for measuring devices such as dispensing bottles or oral syringes that pharmacists commonly provide to patients at the time of dispensing.

What this study adds

- The combined rate of errors in volume greater than 10% of medication for the 6 measuring devices used by the 300 study participants was 11.3%, but only 6 participants (2.0%) measured a volume error that was greater than 20% of the 5 mL target.
- Dosing spoons, regular dosing cups, and printed dosing cups, all of which are regulated by the South Korea Food and Drug Administration, were associated with relatively high rates of dose errors exceeding 10% by volume, but these 3 devices were used by only 13% of the participants for measuring liquid medication.

Oral medications are commonly prescribed in liquid form to facilitate administration, particularly for adult and pediatric patients who have difficulty swallowing tablets or capsules. Another advantage of liquid medications over tablets or capsules is the enhanced ability to determine individualized dosages.¹ Various types of liquid medications (e.g., antibiotics, digestive medicine, cold medicine, and fever reducers) are directly sold by pharmacies over the counter (OTC) or by prescription. According to the South Korea

Food and Drug Administration Notification of the Rules on Medication Safety Containers, Packaging, and Measuring Devices for Drug Administration, the accuracy of calibration for medication measuring devices is required to be within plus or minus 5% of the indicated value.² The rules are applied only to medication measuring devices that are manufactured in medication containers. According to the regulations, recommended doses in the prescription label directions should be marked on the enclosed medication measuring devices, and a visual test should be conducted for the devices to ensure that the amount of liquid medication measured can be seen clearly.

Yin et al. (2010) evaluated the prevalence of inconsistent dosing directions and measuring devices for pediatric OTC liquid medication and found that 98.6% of products examined had at least 1 inconsistency, such as superfluous markings and missing markings.³ Sobhani et al. (2008) compared the accuracy of an oral syringe with that of a dosing cup for Tylenol (acetaminophen) suspension and found that the mean (standard deviation [SD]) volumes measured with a syringe and cup were 4.5 (0.7) milliliters (mL) and 6.3 (0.7) mL, respectively.⁴ Simon and Weinkle (1997) evaluated caregivers' accuracy of OTC liquid medication dosing using acetaminophen in a pediatric emergency center. After conducting a mock dosing scenario with a convenience sampling of 100 caregivers, they found that only 67% of the caregivers measured the amount of acetaminophen accurately (within $\pm 20\%$ of the intended dose) for their children.⁵ Yin and Mendelsohn, et al. (2010) assessed parents' liquid medication dosing errors in a public hospital pediatric clinic in New York City and found accurate dosing (within 20% of the 5 mL dose) ranged from 31% to 94% for 6 measuring devices.⁶ Parents using the dosing cup with printed markings and the dosing cup with etched markings showed lower dosing accuracy rates (31% and 50%, respectively) relative to those with other measuring devices (more than 85%). Liquid medication dosing errors pose a risk to patients from subtherapeutic doses and overdoses.⁷⁻⁹

To determine the correct administration of liquid medication, it is necessary to identify the accuracy of patient measurements of liquid medications. Previous studies regarding liquid medication dosing errors did not evaluate the general characteristics of patients or caregivers as factors that could affect the dosing errors. Our purpose was to understand the various factors that might affect liquid medication measurement and to determine the correct administration and dosages by evaluating how the measurements made by patients and caregivers vary according to the medication measuring device used.

Methods

Study Subjects and Duration

This study was conducted in a community independent pharmacy in Anyang City, Kyunggido, South Korea, that dispensed

FIGURE 1 Medication Measuring Devices Used in the Study

Description:

- ① Etched calibration dosing cup (regular dosing cup): Dosing cup with etched calibration marks for every 1 milliliter (mL) to allow dosing up to 20 mL.
- ② Printed calibration dosing cup: Dosing cup with calibration marks printed in blue with calibration marks of 2.5 mL, 3.8 mL, 5 mL, 7.5 mL, and 10 mL in accordance with the dosing instructions for the medication.
- ③ Spoon with a bottle adapter: Medication measuring device with a spoon-like end and etched calibration marks for every 0.5 mL. Dosing up to 10 mL is possible.
- ④ Oral syringe: Measures liquid using the same principle as a syringe. The smallest dosing calibration mark is 1.25 mL, and calibration marks are printed for every 0.25 mL. Dosing up to 5 mL is possible.
- ⑤ Dosing spoon: Calibration marks for every 1 mL are etched as lines inside the spoon, and a 2.5-mL dosing line is indicated in the middle. Dosing up to 5 mL is possible.
- ⑥ Dispensing bottle: Calibration marks for every 1 mL and 2.5 mL are etched onto both sides, and dosing up to 12 mL is possible. The cap includes a long cylindrical inlet for the user's convenience during administration.

an average of 300 prescriptions daily. The pharmacy has 2 departments, for prescriptions and OTC medications, and the pharmacy employs 4 full-time pharmacists. The study was a convenience sample of adult patients and caregivers for pediatric patients who visited the pharmacy to purchase OTC medication or receive liquid medication prescribed by a doctor between March 7 and March 20, 2011. In this pharmacy, patients or caregivers who want OTC medications must interact with pharmacists because the purchase counter is located in the prescription section of the pharmacy. We were therefore able to ensure that every patient or caregiver who visited the pharmacy to purchase OTC medication or receive liquid prescription medication when the pharmacist-investigator (Gyeong Suk Ryu) was in the pharmacy was asked to participate in the study. Patients who received single-dose liquid pouches were excluded from the study.

TABLE 1 Participant Characteristics and Dose Error Rates (N= 300)

Participant Characteristics			No or Small Dose Errors		Large Dose Errors	
			< 5%	6%-10%	11%-20%	>20%
Gender ^a	Male	14.3 (43)	41.9 (18)	32.6 (14)	20.9 (9)	4.7 (2)
	Female	85.7 (257)	58.0 (149)	33.1 (85)	7.4 (19)	1.6 (4)
Age ^b (in years)	10-19	0.3 (1)	100.0 (1)	0.0 (0)	0.0 (0)	0.0 (0)
	20-29	7.7 (23)	65.2 (15)	34.8 (8)	0.0 (0)	0.0 (0)
	30-39	71.0 (213)	57.7 (123)	33.8 (72)	7.0 (15)	1.4 (3)
	40-49	15.0 (45)	46.7 (21)	35.6 (16)	13.3 (6)	4.4 (2)
	50-59	3.0 (9)	22.2 (2)	22.2 (2)	44.4 (4)	11.1 (1)
	60-69	3.0 (9)	55.6 (5)	11.1 (1)	33.3 (3)	0.0 (0)
Relationship to patient ^c	Father	9.7 (29)	48.3 (14)	37.9 (11)	13.8 (4)	0.0 (0)
	Mother	78.3 (235)	59.1 (139)	33.6 (79)	5.5 (13)	1.7 (4)
	Grandfather	0.3 (1)	0.0 (0)	100.0 (1)	0.0 (0)	0.0 (0)
	Grandmother	5.0 (15)	53.3 (8)	13.3 (2)	33.3 (5)	0.0 (0)
	Self	6.0 (18)	22.2 (4)	33.3 (6)	33.3 (6)	11.1 (2)
	Other	0.7 (2)	100.0 (2)	0.0 (0)	0.0 (0)	0.0 (0)
Education ^d	Elementary school graduate	0.3 (1)	0.0 (0)	0.0 (0)	100.0 (1)	0.0 (0)
	Middle school graduate	4.3 (13)	53.8 (7)	23.1 (3)	15.4 (2)	7.7 (1)
	High school graduate	29.0 (87)	63.2 (55)	23.0 (20)	10.3 (9)	3.4 (3)
	College graduate or higher	66.3 (199)	52.8 (105)	38.2 (76)	8.0 (16)	1.0 (2)

^aPearson chi-square test for the comparison of numbers of participants in 4 dose error rate categories according to gender, $P=0.013$.

^bPearson chi-square test for the comparison of numbers of participants in 4 dose error rate categories according to age, $P=0.004$.

^cPearson chi-square test for the comparison of numbers of participants in 4 dose error rate categories according to relationship to patient, $P<0.001$.

^dPearson chi-square test for the comparison of numbers of participants in 4 dose error rate categories according to education, $P=0.015$.

Research and Evaluation Methods

This study involved collection of participant characteristics and a liquid medication measurement experiment. Gender, age, education level, and relationship with the patient were reported by the participant, whereas information about the preferred medication measuring devices was acquired using a method in which the study subject made a selection and the researcher entered the choice.

For the liquid medication measurement experiment, the subjects used the preferred medication measuring devices they selected during the survey (an etched-calibration dosing cup [a regular dosing cup], a printed-calibration dosing cup, a dosing spoon, an oral syringe, a spoon with a bottle adapter, or a dispensing bottle) without any recommendations by the pharmacist. The participants were asked by the pharmacist-investigator to measure 5 mL of liquid medication with routine instructions, and their measurements were verified by the pharmacist-investigator (Gyeong Suk Ryu) measuring the same sample with a graduated cylinder. Of the medication measuring devices used in the experiment, 4 types (the regular dosing cup, the printed dosing cup, the dosing spoon, and the oral syringe) were packaged with the medicines in accordance with South Korea Food and Drug Administration provisions, whereas the dispensing bottle and the spoon with the bottle adapter were purchased separately by the pharmacy and provided to the patients free of charge (Figure 1).

For the liquid medication measurement experiment, we used Coben (chlorpheniramine maleate/phenylephrine HCl, Daewoo Pharmaceutical Co., Ltd, Busan, South Korea) syrup, which is the liquid medication that is most frequently prescribed and prepared at the pharmacy. It is available OTC as well as by prescription in South Korea. An ISOLAB graduated cylinder (Germany, blue grad, 10 mL) was used to measure the amount of syrup dispensed by the study participants. One researcher (Gyeong Suk Ryu) read the measured doses using the graduated cylinder.

Liquid medication dosing error rates were classified as less than 5%, 6% to 10%, 11% to 20%, and more than 20% (the base measured dose of 5 mL was the target). We defined volume errors of 10% or less as small and volume errors greater than 10% as large. The U.S. Pharmacopeia specifies that the volume error incurred in measuring 5 mL of liquid medication with calibrated devices "should be not greater than 10% of the indicated amount,"¹⁰ and Sobhani et al. defined "acceptable dose" as within 10% of the indicated amount.⁴

SPSS 18.0 (IBM SPSS, Armonk, NY) was used to perform a frequency analysis of demographic characteristics (gender, age, education level, and relationship with the patient) and the medication measuring device preferences, and the mean and SD were determined for the measured dose of the liquid. The Pearson chi-square test was performed for the differences in dosing error rates according to the participant characteristics,

TABLE 2 Mean Dose in Milliliters for the Medication Measuring Devices

Medication Measuring Device	Frequency	Mean [SD] Dose Dispensed ^a
Regular (etched) dosing cup	17	5.552 [0.554]
Oral syringe	8	5.188 [0.230]
Printed dosing cup	13	5.023 [0.497]
Dispensing bottle	202	4.919 [0.319]
Spoon with a bottle adapter	50	4.866 [0.227]
Dosing spoon	10	4.660 [0.626]
Total	300	4.949 [0.378]

^aAnalysis of variance (ANOVA) for the comparison of dispensed doses between medication measuring devices; $F = 13.711$, $P < 0.001$.

SD = standard deviation.

and analysis of variance (ANOVA) or an independent t test was performed for the differences in measured liquid medication doses according to the participant characteristics. In addition, a frequency analysis was performed for dosing error rates according to the preferred medication measuring device.

Results

General Characteristics of the Respondents

Of the 347 people asked by the pharmacist-investigator, 300 patients and caregivers agreed to participate in the study. The majority of the participants were female (85.7%, $n = 257$), and 97.0% ($n = 291$) were younger than age 60 (Table 1). In addition, most of the participants were the mothers of the patients for whom the medicine was intended (78.3%, $n = 235$), and only 18 (6.0%) of the participants were the patients themselves. All but 14 participants (4.7%) reported education level of at least high school.

Analysis of the Measured Dose by Device

The mean (SD) measured dose was 4.949 (0.378) mL for the 300 study subjects who were instructed to measure 5 mL of liquid medication (Table 2). The mean (SD) measured dose for males was 5.119 (0.505) mL versus 4.920 (0.346) mL for females ($P < 0.001$, data not presented in Table 2). The greatest difference from the 5 mL target was observed for the regular dosing cup, which had a mean measured dose of 5.552 mL. The dosing spoon showed the next highest difference from the target (−0.340 mL), and the printed dosing cup and dispensing bottle showed the least differences from the 5 mL target, +0.023 mL and −0.081 mL, respectively (Table 2).

Description of Dosing Errors by Participant Characteristics and Device

Two hundred sixty-six (88.7%) samples were within 10% of the 5 mL target volume, defined as no or small errors. Large errors greater than 10% from the target volume numbered 34 (11.3%, Table 3). There were statistically significant differences in dose

error rates based on gender, age, education level, or relationship to the patient (Table 1). Large dose errors greater than 10% were more common for males (25.6%, $n = 11$), patients aged 50–59 years (55.5%, $n = 5$), patient-self (44.4%, $n = 8$), and elementary school education level (100.0%, $n = 1$). However, the distribution of the study participants in each category of participant characteristic was quite variable.

Three devices had a high proportion of large volume errors: the dosing spoon (50%, $n = 5$), the regular (etched) dosing cup (47.1%, $n = 8$), and the printed dosing cup (30.8%, $n = 4$; Table 3). Volume errors greater than 20% of the 5 mL target occurred among only 6 participants (2.0% collectively for 3 devices), and none of these large dose errors occurred in the oldest age group (aged 60–69).

Discussion

In this study, the percentage of adults (patients themselves) was low because the majority of their prescribed liquid medications were single-dosage pouches; therefore, they were ineligible for participation, and the pharmacy primarily handled pediatric prescriptions. Most of the pediatric patient caregivers were in the age category of 30–39 years, and 95% of the participants had at least a high school education.

The mean measured dose for 8 (44%) of the adult patients themselves deviated from the target 5 mL amount by more than 10%, and 2 of these patients accounted for one-third of the total of 6 patients who had an error in dose-volume greater than 20%. This may have occurred because patients do not measure their own doses as carefully as parents and caregivers measure doses for children.^{11,12}

Compared with other studies of liquid medication dosing, our findings show relatively little variance from the 5 mL target volume. In our study, 266 participants (88.7%) measured a volume of liquid that was within 10% of the target, and 294 participants (98.0%) measured a volume that was within 20% of the target. Sobhani et al. found that 66.7% of subjects using the oral syringe and 14.6% of subjects using the dosing cup measured an acceptable dose, defined as no more than 10% deviation from 5 mL.⁴ Simon et al. found that 67% of caregivers in a pediatric emergency center measured the amount of acetaminophen accurately (within $\pm 20\%$ of the intended dose) for their children.⁵ Among 302 parents in a public hospital pediatric clinic in New York City, Yin and Mendelsohn, et al. found that a range from 31% to 94% measured an accurate dose (within 20% of the 5 mL dose) for 6 measuring devices; “large” dosing errors (greater than 40%) were made by 26% of parents using the dosing cup with printed markings and 23% of parents using the dosing cup with etched markings.⁶

Sobhani et al., comparing the accuracy of an oral syringe with a dosing cup, found that 66.7% of participants measured a dose within 10% of the indicated dose with the oral syringe versus 14.6% with the dosing cup.⁴ Our results were similar,

TABLE 3 Dose Error Rates by Medication Measuring Device

Medication Measuring Device	Range (in mL)	No or Small Dose Errors		Large Dose Errors	
		< 5%	6%-10%	11%-20%	> 20%
Regular (etched) dosing cup (n = 17)	4.6-6.4	29.4 (5)	23.5 (4)	23.5 (4)	23.5 (4)
Dosing spoon (n = 10)	3.7-5.6	30.0 (3)	20.0 (2)	40.0 (4)	10.0 (1)
Printed dosing cup (n = 13)	4.4-5.9	15.4 (2)	53.8 (7)	30.8 (4)	0.0 (0)
Dispensing bottle (n = 202)	3.8-5.7	59.9 (121)	32.7 (66)	6.9 (14)	0.5 (1)
Spoon with a bottle adapter (n = 50)	4.5-5.6	64.0 (32)	32.0 (16)	4.0 (2)	0.0 (0)
Oral syringe (n = 8)	4.8-5.4	50.0 (4)	50.0 (4)	0.0 (0)	0.0 (0)
All devices (N = 300)	3.7-6.4	55.7 (167)	33.0 (99)	9.3 (28)	2.0 (6)

mL = milliliters.

with no measured volumes outside of 10% of the 5 mL target for the oral syringe versus 47% for the regular (etched) dosing cup, but the number of cases for both devices was small in our study (n = 8 for each).

In our study, we found high rates of inaccurate dosing with the dosing spoon, the regular dosing cup, and the printed dosing cup, which may have resulted from difficulty in seeing the calibration markings while measuring. Variance in measured doses was low for the spoon with bottle adapter (SD = 0.227), oral syringe (SD = 0.2300), and dispensing bottle (SD = 0.319). Participants noted inconvenience using the oral syringe.

The definition of error in liquid medication dosing varies considerably among studies. Yin and Mendelsohn, et al. defined "accurate dosing" as within 20% of the target 5 mL volume, a "small error" as 20%-40% variance from the 5 mL target, and more than 40% from the target volume as a "large error."⁶ In our study, the mean (SD) measured dose with use of a regular dosing cup was 5.552 (0.554) mL, compared with 7.0 (3.2) mL in Yin and Mendelsohn, et al. Actual measured volumes not within 20% of the target were made by 49.8% of participants (n = 150) using a dosing cup with etched calibration markings in the study by Yin and Mendelsohn, et al., compared with 4 of 17 participants (23.5%) who had dosing errors greater than 20% with use of the dosing cup in our study. Dose errors greater than 20% for the dosing spoon and the oral syringe also occurred less frequently in our study (10.0% and 0.0%, respectively) than in Yin and Mendelsohn, et al. (14.0% and 8.6%, respectively⁶).

Frush et al. (2004) found that the mean deviation from the recommended dose range for OTC acetaminophen liquid was lower in the caregiver group given color coding of dose zones compared with conventional dosing methods (0.5% vs. 29%, respectively).¹³ Peacock et al. (2010) found that fewer patients made measurement errors after pharmacist instruction on the proper use of measurement devices; measurement error was less common with a pharmacist-supplied dose syringe compared with the manufacturer-supplied device; and the measurement error rate was higher for nystatin suspension than for the less-viscous digoxin elixir.¹⁴ With an error defined as

at least 20% deviation from the intended dose, errors in dose before and after pharmacist instruction were made by 88.0% and 85.6% of patients for nystatin, respectively, and by 24.8% and 4.0% of patients for digoxin elixir, respectively.¹⁴

When pharmacists administer liquid medications at pharmacies in South Korea, it is common practice to attach a label or write information on the container about the drug name and its purpose, dosage, and frequency. In addition, pharmacists in South Korea provide medication guidance and make efforts to reduce liquid medication dosing errors by highlighting important information (e.g., keeping the liquid refrigerated and dosage differences from other medications) with a colored pen, indicating the recommended dosage on the calibration markings on the medication measuring devices for older patients and dividing and packaging the prescription into individual doses for patients and caregivers who have difficulties with measurements. Pharmacists, however, do not know if patients get enough information on how to measure liquid medications accurately. There has been no study conducted in South Korea in terms of liquid medication dosing, but many patients either do not receive a sufficient explanation of how to read the calibration markings on the medication measuring devices, or their use of the information on the medicine containers is insufficient based on studies conducted in other countries.^{5,15,16} During the course of this study, we observed the study participants measuring liquid medication by placing the medication measuring devices on the counter and looking at the calibration markings from above or below rather than measuring the liquid with the calibration markings at eye level.

Of the 6 types of medication measuring devices used in the present study, the dosing spoon, regular dosing cup, and printed dosing cup are regulated by the South Korea Food and Drug Administration and had higher rates of dosing errors than the other measuring devices, but there were only 40 participants who used these 3 measuring devices. These 3 devices were selected less often compared with the spoon with bottle adapter (n = 50) and the dispensing bottle (n = 202).

Liquid dosing errors can be clinically significant, particularly for infants and the elderly. Underdosing can result in lack

of therapeutic response, and overdosing can result in adverse drug events.⁷ Medications with a narrow therapeutic index such as phenytoin or digoxin require particular attention to accurate dosing.¹⁷⁻²¹

Limitations

There are several threats to the validity of our findings. Foremost among the limitations is the convenience sample and the bias toward selection of adults with an education level that was on average much higher than that of the adult population in South Korea. In the present study sample, about 5% of participants had an elementary or middle-school education, compared with 20% in South Korea as a whole, and two-thirds had a college or higher-level education, compared with 39% in South Korea as a whole.²² The percentage of participants in the Yin and Mendelsohn, et al. study who had an educational level beyond high school was 51.0%, compared with 95.3% in our study. This difference is large and could have affected the results.

Second, there was nonrandom selection of measuring devices by study participants and a small sample size (less than 20) for each of 4 of the measuring devices. Third, there is the possibility that the participants measured the dose correctly based on the device used, but the device may have been calibrated incorrectly. Fourth, asking the subjects to measure the liquid in the presence of the pharmacist-investigator may have affected the dose error rates. Fifth, we may have underestimated the rate of dose errors because of the small number of older participants in the study. More studies of accuracy in liquid medication dosing may help identify risk factors for dose errors to help pharmacists target at-risk patients and caregivers.

Sixth, our results may have also been affected by the relatively low viscosity of the syrup used in this study and may not be representative of higher viscosity liquid medications. Finally, the generalizability of our findings is limited by the conduct of this study in 1 pharmacy located in a metropolitan area in South Korea.

Conclusions

The present study found that the dosing error rate was 11.3% for volume deviation greater than 10%, suggesting that most patients and caregivers accurately measured liquid medications. However, we observed differences in dosing error rates among the various medication measuring devices, with major (greater than 10% variance) volume errors occurring more often with dosing spoons (50%) or regular dosing cups (47%) compared with printed dosing cups (31%), dispensing bottles (7%), spoons with a bottle adapter (4%), and oral syringes (0%). There is an opportunity for community pharmacists to educate patients and caregivers on the accurate use of medication measuring devices.

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DISCLOSURES

This research was performed without external funding. Lee designed the study with the assistance of Ryu, and Ryu collected the data as the onsite pharmacist-investigator. Lee and Ryu interpreted the data and wrote and revised the manuscript.

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