Out-of-Hospital Medication Errors Among Young Children in the United States, 2002–2012

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KEY WORDS

medication error, ingestion, NPDS, poisoning, poison control center

ABBREVIATIONS

AAPCC—American Association of Poison Control Centers
HCF—health care facility
NPDS—National Poison Data System
PCC—poison control center

Mr Smith conducted the data analysis, and drafted and revised the manuscript; Mr Chounthirath assisted in data analysis, and revised the manuscript; Drs Spiller and Xiang contributed to conceptualization of the study, assisted in data analysis, and critically reviewed the manuscript; Dr Casavant contributed to conceptualization of the study, assisted in data access and analysis, and critically reviewed the manuscript; Mr Brophy assisted in data analysis, and critically reviewed the manuscript; and all authors approved the final manuscript.

The inferences and conclusions expressed by the authors of this study do not necessarily represent those of the American Association of Poison Control Centers or its member centers.

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WHAT'S KNOWN ON THIS SUBJECT: Medication errors involving children represent a frequently occurring public health problem. Since 2003, >200 000 out-of-hospital medication errors have been reported to US poison control centers annually, and ~30% of these involve children <6 years of age.

WHAT THIS STUDY ADDS: During 2002–2012, an average of 63 358 children <6 years experienced out-of-hospital medication errors annually, or 1 child every 8 minutes. There was a significant increase in the number and rate of non–cough and cold medication errors during the study period.

abstract

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OBJECTIVE: To investigate out-of-hospital medication errors among young children in the United States.

METHODS: Using data from the National Poison Database System, a retrospective analysis of out-of-hospital medication errors among children <6 years old from 2002 through 2012 was conducted.

RESULTS: During 2002–2012, 696 937 children <6 years experienced out-of-hospital medication errors, averaging 63 358 episodes per year, or 1 child every 8 minutes. The average annual rate of medication errors was 26.42 per 10 000 population. Cough and cold medication errors decreased significantly, whereas the number (42.9% increase) and rate (37.2% increase) of all other medication errors rose significantly during the 11-year study period. The number and rate of medication error events decreased with increasing child age, with children <1 year accounting for 25.2% of episodes. Analgesics (25.2%) were most commonly involved in medication errors, followed by cough and cold preparations (24.6%). Ingestion accounted for 96.2% of events, and 27.0% of medication errors were attributed to inadvertently taking or being given medication twice. Most (93.5%) cases were managed outside of a health care facility; 4.4% were treated and released from a health care facility; 0.4% were admitted to a non–critical care unit; 0.3% were admitted to a critical care unit; and 25 children died.

CONCLUSIONS: This is the first comprehensive study to evaluate the epidemiologic characteristics of out-of-hospital medication errors among children <6 years of age on a national level. Increased efforts are needed to prevent medication errors, especially those involving non–cough and cold preparations, among young children. *Pediatrics* 2014;134:867–876

Medication errors have been identified as an important preventable cause of morbidity, mortality, and health care cost, but previous research has struggled to fully describe the scope of the problem.[1] The importance of this problem in hospitals is widely recognized; however, the magnitude of medication errors outside of hospitals may be even larger.[2]

A medication error is defined as "any preventable medication event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer."[3] Out-of-hospital medication errors involving children represent a frequently occurring public health issue. Since 2003, >200 000 out-of-hospital medication errors have been reported to poison control centers (PCCs) in the United States annually, and ~30% of these involve children <6 years of age.[4]

In contrast to hospital-based medication errors, comparatively few studies have examined medication errors in the out-of-hospital setting.[5–7] In addition, published research has often reported medication errors among adults or all age groups, rather than focusing on children.[6,8,9] Studies have examined errors associated with parental health literacy and numeracy and their ability to correctly measure doses of medications.[10–14] Numerous studies have investigated the dosing inaccuracies of various medication administration devices, such as an oral syringe, dosing spoon, dropper, and dosing cup,[11,15–19] whereas others have examined the variability of labeling and packaging of medications.[12,20,21] Most studies have been based on relatively small convenience samples, and only a few have used statewide or national databases.[6,8,9,22]

To our knowledge, this is the first comprehensive study to evaluate the epidemiologic characteristics of out-of-hospital medication errors among children <6 years of age on a national level.

METHODS

Design of Study and Study Population

This study retrospectively analyzes data from the National Poison Data System (NPDS) to evaluate characteristics and trends of out-of-hospital unintentional therapeutic pharmaceutical errors among US children <6 years of age reported to the NPDS during the 11-year period, 2002 through 2012. The NPDS is a proprietary database maintained by the American Association of Poison Control Centers (AAPCC) consisting of all poison exposure data from each of the regional PCCs in the United States. PCCs receive calls regarding exposures to potentially toxic materials and provide professional medical advice based on the specific circumstances. The NPDS is the only comprehensive poison exposure surveillance database in the United States, and has extensive quality control measures to ensure accuracy and completeness. The AAPCC defines an unintentional therapeutic pharmaceutical error as "an unintentional deviation from a proper therapeutic regimen that results in the wrong dose, incorrect route of administration, administration to the wrong person, or administration of the wrong substance."[4] These types of errors are referred to as "medication errors" in this article. Specifically excluded are exploratory ingestions, intentional misuse or abuse of pharmaceuticals, and malicious or suicidal exposures.

For reported events involving exposure to >1 pharmaceutical substance, the NPDS includes data regarding each substance, which results in the number of medication error exposures exceeding the total number of children. For calls involving multiple pharmaceuticals, each substance is ranked in order of its contribution to the reported clinical effects as determined by the PCC specialist managing the call. We limited data analysis in this study to the first-ranked pharmaceutical, which was judged to be the primary contributor to any clinical signs or symptoms experienced by the child. Therefore, unless noted otherwise, findings reported in this study will refer to the individual children who experienced the medication error and the first-ranked pharmaceutical agent involved.

Case Selection Criteria

The study population was limited to exposures from the 50 US states and the District of Columbia that involved only pharmaceutical substances with the reason for exposure coded as "unintentional therapeutic error." Pharmaceutical category was determined by the AAPCC generic coding system, which is maintained by Micromedex Poisindex System (Micromedex Healthcare Series [Internet database]; Truven Health Analytics, Inc, Greenwood Village, CO).[4] Single- and multiple-substance nonpharmaceuticals, such as batteries and chemicals, were excluded from the study. Cases also were excluded if the site of exposure was a health care facility (HCF), nursing home, or prison, or if on follow-up by a PCC professional, the event was confirmed as a nonexposure or the clinical effects were considered unrelated to the pharmaceutical agent.

Study Variables

Data were analyzed by child age and gender, year and month of exposure, exposure site, management site, type of medication error, category of pharmaceutical, number of pharmaceuticals involved in exposure, type of formulation, route of exposure, level of health care received, type of therapeutic intervention, chronicity, and medical outcome. Management at an HCF included treated and released, admitted, lost to follow-up, and left against medical advice. Medical

outcome was classified by PCC specialists as minor, moderate, or major according to standard NPDS definitions.[4] Minor effect results in the development of minimally bothersome symptoms; moderate effect results in more pronounced, more prolonged, or systemic symptoms, usually requiring some form of treatment; and major effect results in life-threatening symptoms or having significant residual disability or disfigurement. In this study, cases with serious outcomes were defined as those with moderate or major effects or death. Chronicity of exposure was classified as acute (a single, repeated, or continuous exposure occurring over a period ≤8 hours), acute-on-chronic (a single exposure that was preceded by a continuous, repeated, or intermittent exposure occurring over a period >8 hours), or chronic (a continuous, repeated, or intermittent exposure to the same substance lasting >8 hours).

Statistical Analysis and Ethical Statement

Data were analyzed by using SPSS 21.0 (IBM SPSS Statistics, IBM Corporation, Chicago, IL) and SAS 9.3 (SAS Institute, Inc, Cary, NC) statistical software. National rates were calculated based on July 1 US intercensal and postcensal estimates for residents <6 years from 2002 through 2012.[23] Linear regression was used to test for trends in the number and rate of medication errors. Pearson correlation analysis was used to determine the correlation between age and medication error rate, with r representing the Pearson product-moment correlation coefficient. Statistical significance was established at $\alpha = 0.05$. Any information identifying the exposed individuals or reporting PCCs was redacted by the AAPCC before receipt of the dataset by the investigators. This study was reviewed by the institutional review boards of the authors' institutions and judged to be exempt.

RESULTS

General Characteristics

From 2002 through 2012, US PCCs reported 696 937 out-of-hospital medication error exposures among children <6 years of age, which averages 63 358 exposures per year or 26.44 exposures per 10 000 population. The number of substances involved in each exposure episode ranged from 1 to 11. Single-substance exposures accounted for 651 039 (93.4%) cases and 42 517 (6.1%) cases were 2-substance exposures. There was seasonal variation in the incidence of reported medication errors, with the peak during winter months (Fig 1). This pattern was influenced most by seasonal variation in cough and cold medication errors. The same seasonal pattern also was seen for analgesics, asthma therapies, hormones, antimicrobial agents, and eye/ear/nose/throat preparations. Boys were involved in 54.1% of exposures (Table 1). Most (96.9%) children were exposed at their own residence, and most cases were managed on-site (93.5%) without referral to an HCF.

Medication error events ($r = -0.994$, $P < .001$) and rates ($r = -0.994$, $P < .001$) were negatively correlated with child age. Children <1 year of age accounted for more than one-fourth (25.2%) of exposures, whereas 5-year-olds accounted for 9.7%. The rate of medication errors was highest among children <1 year of age (39.64 per 10 000 population) and decreased with increasing child age, with 5-year-olds experiencing a rate of 15.45 per 10 000 population (Fig 2).

Characteristics of Medication Errors

Most medication errors involved liquid formulations (81.9%), followed by tablets/capsules/caplets (14.9%) (Table 1). Among errors involving 1-year-olds, 91.7% were liquid formulations compared with 63.1% in 5-year-olds. Exposures were acute in 81.9% of cases, and 96.2% of exposures were by ingestion (Table 2). Medication errors were commonly attributed to "inadvertently taking or being given medication twice" (27.0%), "other incorrect dose" (17.8%), "confused units of measure" (8.2%), and "wrong medication taken or given" (7.8%) (Table 2). The frequencies of "confused units of measure" and "wrong medication taken or given" increased by 67.0% and 83.5%, respectively, whereas the frequency of "inadvertently taking or being given medication twice" decreased by 17.2% during the study period (data not shown).

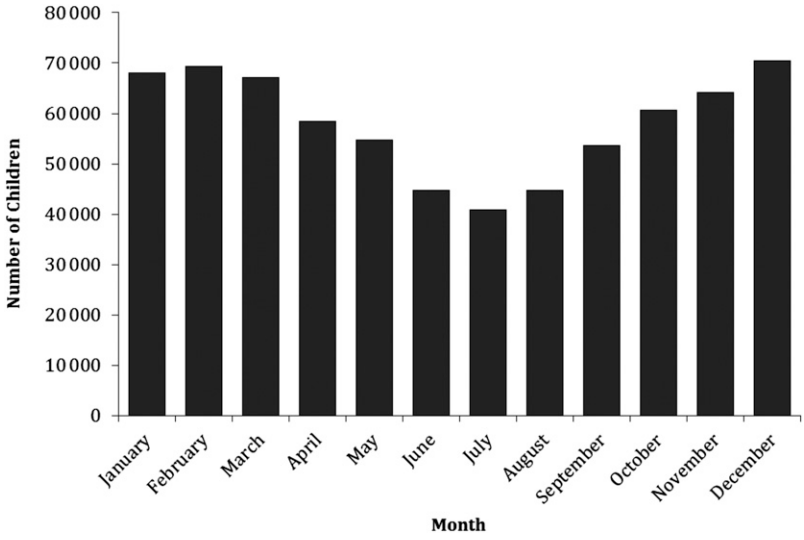

FIGURE 1
Number of cases of out-of-hospital medication errors among children <6 years of age by month, NPDS 2002–2012.

TABLE 1 Characteristics of Cases of Out-of-Hospital Medication Errors by Child Age, NPDS 2002–2012

Characteristics	Age, y							Total
	<1	1	2	3	4	5	<6[a]	
Gender								
Boys	95 262	76 432	66 516	53 618	45 662	38 653	828	376 971 (54.2)
Girls	79 266	67 120	59 080	46 021	37 069	28 979	677	318 212 (45.8)
Unknown/Missing[b]	771	272	211	143	108	62	187	1754
Formulation								
Liquid	160 689	128 384	100 539	75 343	58 319	42 702	1301	567 277 (81.9)
Solid (tablets/capsules/caplets)	7072	10 529	20 894	20 770	21 485	22 403	284	103 437 (14.9)
Cream/lotion /gel	3587	1822	1310	934	732	656	46	9087 (1.3)
Aerosol/mist/spray/gas	1318	808	802	840	795	814	19	5396 (0.8)
Powder/granules	662	540	417	339	306	257	13	2534 (0.4)
Patch	19	16	23	20	19	13	0	110 (0.0)
Other	875	865	1067	891	683	449	16	4846 (0.7)
Unknown/Missing[b]	1077	860	755	645	500	400	13	4250
Acuity/chronicity								
Acute	140 272	120 158	105 121	82 326	67 191	53 732	1344	570 144 (81.9)
Acute-on-chronic	27 278	19 867	17 823	15 255	13 912	12 471	250	106 856 (15.4)
Chronic	7503	3627	2699	2090	1630	1424	86	19 059 (2.7)
Unknown/Missing[b]	246	172	164	111	106	67	12	878
Exposure site								
Own residence	170 061	139 515	122 170	96 803	79 932	64 869	1628	674 978 (96.9)
Other residence	4158	3487	3008	2484	2332	2015	40	17 524 (2.5)
School	667	514	328	282	346	620	6	2763 (0.4)
Other	309	238	240	166	194	142	2	1291 (0.2)
Unknown/Missing[b]	104	70	61	47	35	48	16	381
Management site								
Managed on site at non-HCF	158 191	136 019	119 285	94 402	77 747	62 659	1521	649 824 (93.5)
Patient already in / en route to HCF	10 315	4264	3325	2677	2508	2522	91	25 702 (3.7)
Referred by PCC to a HCF	5205	2456	2256	1949	1876	1921	31	15 694 (2.3)
Other	1101	783	641	531	504	445	17	4022 (0.6)
Unknown/Missing[b]	487	302	300	223	204	147	32	1695
Level of health care received								
No HCF treatment received	159 778	137 104	120 226	95 156	78 455	63 251	1570	655 540 (94.1)
Treated/evaluated and released	11 482	5100	4116	3391	3158	3254	75	30 576 (4.4)
Lost to follow-up/against medical advice	1592	697	644	475	467	426	28	4329 (0.6)
Admitted to noncritical care unit	1095	400	295	314	321	329	5	2759 (0.4)
Admitted to critical care unit	801	246	228	205	210	203	6	1899 (0.3)
Refused referral/didn't arrive at HCF	544	275	297	241	226	230	8	1821 (0.3)
Other	7	2	1	0	2	1	0	13 (0.0)
Medical outcome								
Not followed, minimal clinical effects[c]	76 024	70 179	64 084	51 411	43 240	35 078	714	340 730 (48.9)
Not followed, nontoxic exposure[d]	47 738	37 060	29 947	22 580	17 770	13 549	609	169 253 (24.3)
No effect	38 761	28 102	23 646	18 827	15 577	13 163	259	138 335 (19.8)
Minor effect	9616	7018	6579	5689	4881	4561	62	38 406 (5.5)
Unable to follow [e]	1590	837	886	656	657	620	45	5291 (0.8)
Moderate effect	1417	571	612	586	677	683	3	4549 (0.7)
Major effect	142	55	49	29	34	39	0	348 (0.0)
Death	11	2	4	4	3	1	0	25 (0.0)
Total	175 299	143 824	125 807	99 782	82 839	67 694	1692	696 937

[a] <6 = Exact age unknown, but ≤5 y old.

[b] Not included in percentage calculations.

[c] Not followed, minimal clinical effects possible (no more than minor effect possible).

[d] Not followed, judged as nontoxic exposure (clinical effects not expected).

[e] Unable to follow, judged as a potentially toxic exposure.

Medication Categories

The major categories of medications involved with medication errors included analgesics (25.2%), cough and cold preparations (24.6%), antihistamines (15.0%), and antimicrobial agents (11.8%) (Table 3). The frequency of episodes increased for many of the pharmaceutical categories during the study period, most notably dietary supplements/herbals/homeopathics (765.3% increase), followed by cardiovascular drugs (87.5% increase), analgesics (69.6% increase), anticonvulsants (63.6% increase), antihistamines (61.8% increase), and muscle

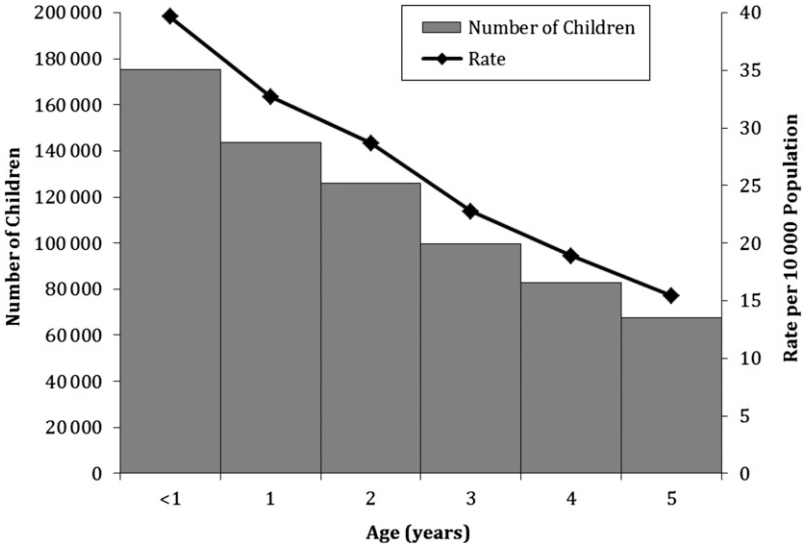

FIGURE 2
Average annual number and rate per 10 000 population of cases of out-of-hospital medication errors by child age, NPDS 2002–2012.

relaxants (55.6% increase). In contrast, medication errors involving cough and cold preparations and asthma therapies decreased by 59.1% and 32.3%, respectively (Fig 3).

A subset of medication categories accounted for a large proportion of observed adverse medical outcomes. Analgesics accounted for 40.0% (n = 10) of deaths, 7.2% of cases with major or moderate medical effects, and 13.5% of ICU admissions. Cough and cold preparations accounted for 20.0% of deaths (n = 5), 18.7% of major or moderate medical effects, and 7.9% of ICU admissions, whereas cardiovascular drugs accounted for 4.0% of fatalities (n = 1), 11.8% of major or moderate medical effects, and 21.6% of ICU admissions (Table 3).

Level of Care Received, Therapy Received, and Medical Outcome

Most (94.1%) medication error episodes did not receive treatment at an HCF; 4.4% were treated and released; 0.4% were admitted to a non–critical care unit; and 0.3% were admitted to a critical care unit (Table 1). During the study period, the number of cases managed at an HCF increased by 17.8%, from 3154 cases in 2002 to 3717 cases in 2012.

More than two-thirds (67.3%) of cases did not receive a therapeutic intervention. Among those receiving an intervention, single therapies included dilution/irrigation/wash (62.8% of cases), activated charcoal (0.8%), and emetics (0.4%). Most dilution/irrigation/wash was performed on-site, usually at the child's residence (data not shown).

Most exposure cases were not followed after initial contact with the PCC (73.2%) or resulted in no clinical effects (19.9%) (Table 1). Serious medical outcomes resulting from medication errors occurred in 0.7% of the cases (4549 cases with moderate effects, 348 cases with major effects, and 25 deaths) (Table 3). The number of exposures with moderate or major medical outcomes or death decreased by 19.5% during the study period, from 497 cases in 2002 to 400 cases in 2012.

Among pharmaceutical categories with >1000 exposures, muscle relaxants, cardiovascular drugs, and sedatives/hypnotics/antipsychotics had the highest proportions of hospitalization, with 11.5%, 7.7%, and 6.1%, respectively (data not shown). These 3 also had the highest proportion of serious medical outcomes (9.4% of muscle relaxants, 6.5% of sedatives/hypnotics/antipsychotics, and 5.6% of cardiovascular drug exposures). Medical outcome varied by child age, with children <1 year of age experiencing major or moderate medical outcomes 1.39 times more frequently than children 1 to 5 years of age. In addition, children <1 year had a 2.18 times higher proportion of ICU admissions and a 2.33 times higher proportion of fatal outcomes than older children (Table 3).

Secular Trends in Medication Errors

From 2002 through 2012, there was no statistically significant increase in the overall annual number or rate of medication errors. However, there were significant opposing trends in errors associated with cough and cold preparations versus non–cough and cold medications (Fig 4). From 2002 through 2005, there was no significant trend in the annual number (P = .053) or rate (P = .117) of cough and cold medication errors; however, the number and rate decreased significantly by 66.1% (P < .001) and 66.6% (P < .001), respectively, from 2005 through 2012. This decrease was primarily accounted for by the significant decrease in medication errors and rates among children <4 years of age. The decrease in rates ranged from 38.8% (P < .001) for 5-year-olds to 80.4% (P < .001) for children <1 year.

During the study period, the number and rate of non–cough and cold medication errors increased significantly by 42.9% (P < .001) and 37.2% (P < .001), respectively. Most of this increase was contributed by medication errors associated with analgesics and antihistamines (Fig 3). The rate of non–cough and cold medication errors increased significantly for all ages, with the increases ranging from 46.4% (P < .001) among

TABLE 2 Characteristics of Route of Exposure and Type of Medication Error by Child Age, NPDS 2002–2012

Characteristics	Age, y							Total
	<1	1	2	3	4	5	<6[a]	
Route of exposure								
Ingestion	167 530	138 558	121 538	96 437	79 796	64 927	1529	670 315 (96.2)
Ocular	2267	1942	1467	1084	1014	925	62	8761 (1.3)
Inhalation/nasal	2737	1157	974	920	867	843	22	7520 (1.1)
Rectal	502	551	495	332	210	116	10	2216 (0.3)
Two or more routes	412	275	363	297	290	275	6	1918 (0.3)
Parenteral	689	326	223	165	223	217	23	1866 (0.3)
Otic	334	504	344	239	208	164	21	1814 (0.3)
Dermal	545	391	286	222	163	163	11	1781 (0.3)
Vaginal	18	25	36	25	23	13	3	143 (0.0)
Aspiration (with ingestion)	14	7	6	3	0	0	0	30 (0.0)
Other	235	75	64	49	33	43	3	502 (0.1)
Unknown/Missing[b]	16	13	11	9	12	8	2	71
Type of medication error								
Inadvertently took/given medication twice	38 426	38 658	36 912	29 414	24 732	19 837	420	188 399 (27.0)
Confused units of measure	16 019	12 018	9963	7987	6507	4795	100	57 389 (8.2)
Wrong medication taken/given	14 862	11 012	8831	7153	6331	6208	96	54 493 (7.8)
Medication doses given/taken too close together	12 745	10 873	8074	6300	5329	4245	144	47 710 (6.8)
Inadvertently took/given someone else's medication	8830	9249	9424	7298	6422	6256	55	47 534 (6.8)
Dispensing cup error	9074	7383	6270	5112	4067	3095	46	35 047 (5.0)
Other/unknown therapeutic error	9135	6743	5972	4868	3841	3148	149	33 856 (4.9)
Incorrect formulation or concentration given	9395	7565	5600	4319	3298	2497	71	32 745 (4.7)
Two or more errors	8392	5561	4532	3578	3139	2849	87	28 138 (4.0)
More than 1 product containing same ingredient	1328	2586	2984	2565	2253	1873	33	13 622 (2.0)
Incorrect dosing route	3119	2132	1773	1287	1119	869	55	10 354 (1.5)
Health professional/iatrogenic error (pharmacist/nurse/physician)	3498	1419	970	685	676	618	51	7917 (1.1)
Tenfold dosing error	4940	693	454	321	287	219	19	6933 (1.0)
Incorrect formulation or concentration dispensed	1954	1412	1042	782	701	527	13	6431 (0.9)
Drug interaction	151	233	269	226	213	182	14	1288 (0.2)
Exposure through breast milk	827	116	23	10	3	1	26	1006 (0.1)
Other incorrect dose	32 597	26 164	22 706	17 874	13 918	10 469	313	124 041 (17.8)
Unknown/Missing[b]	7	7	8	3	3	6	0	34
Total	175 299	143 824	125 807	99 782	82 839	67 694	1692	69 6937

[a] <6 = Exact age unknown, but ≤5 y old.

[b] Not included in percentage calculations.

1-year-olds to 31.1% ($P < .001$) among 2-year-olds.

DISCUSSION

Out-of-hospital medication errors among young children result in more than 63 000 calls to US PCCs annually, or 1 child every 8 minutes. Most exposures are managed on-site at a non–health care facility and do not result in serious medical outcomes. These errors follow a seasonal pattern, peaking during the winter months. This is most likely attributable to the increased use of cough and cold preparations, analgesics, and other medications to treat viral illnesses among young children during that time of year. There was a significant increase in the number and rate of non–cough and cold medication errors during the study period. The reason for this observed increase could not be determined from study data; however, it may be associated with increasing use of analgesics and antihistamines among young children.

The number and rate of medication errors increased with decreasing child age, with children <1 year accounting for more than one-fourth of episodes. This is of concern because the proportions of children who died or who were admitted to the ICU were >2 times higher among children <1 year of age compared with older children. It is unclear why younger children had a higher frequency and rate of reported medication error exposures than older children, but it is likely multifactorial. Older children are able to communicate better with caregivers, indicating whether they have already taken the medication, and thereby avoiding taking medication twice. Children <2 years old experienced a larger proportion of medication errors associated with liquid formulations. These liquid medications may lead to medication errors not experienced with other formulations, such as confusing units of measure or an incorrect amount dispensed. Parents also may

TABLE 3 Number of Cases of Out-of-Hospital Medication Errors Among Children <6 Years of Age by Major Pharmaceutical Category, Medical Outcome, HCF Level of Care, and Age Group, NPDS 2002–2012

Major Pharmaceutical Category	Cases, *n* (%)	Medical Outcomes by Age Group[a]								HCF Level by Age Group[a]			
		Death		Major		Moderate		Other		ICU		Other	
		<1	1–5	<1	1–5	<1	1–5	<1	1–5	<1	1–5	<1	1–5
Analgesics	175 733 (25.2)	4	6	40	40	94	178	54 987	119 959	125	130	55 000	120 053
Cough and cold preparations	171 380 (24.6)	3	2	16	17	229	654	26 212	144 028	71	79	26 389	144 622
Antihistamines	104 382 (15.0)	1	1	3	6	114	192	26 001	77 897	52	21	26 067	78 075
Antimicrobials	82 401 (11.8)	2		9	7	79	129	21 685	60 101	66	28	21 709	60 209
Gastrointestinal preparations	28 993 (4.2)	1		26	5	392	109	18 311	10 067	134	22	18 596	10 159
Asthma therapies	27 076 (3.9)			1	5	152	165	4060	22 631	18	10	4195	22 791
Vitamins	20 259 (2.9)					17	12	3914	16 255	9	2	3922	16 265
Hormones and hormone antagonists	12 857 (1.8)				5	10	44	2642	10 093	7	19	2645	10 123
Eye/Ear/Nose/Throat preparations	11 551 (1.7)			2		24	41	3776	7659	12	5	3790	7695
Cardiovascular drugs	10 256 (1.5)		1	9	20	81	466	1775	7887	124	284	1741	8090
Anticonvulsants	8649 (1.2)		1	5	38	36	244	819	7495	29	131	831	7647
Sedative/Hypnotics/Antipsychotics	6957 (1.0)			5	20	34	391	787	5705	44	141	782	5975
Electrolytes and minerals	6608 (0.9)		1	3		13	17	2187	4359	17	10	2186	4367
Topical preparations	5187 (0.7)			1		12	30	1524	3597	5	6	1532	3621
Stimulants	4772 (0.7)			4	4	11	227	240	4280	8	29	247	4482
Dietary supplements/Herbals/Homeopathic	4752 (0.7)		1	1		6	8	1052	3662	2	4	1057	3667
Antidepressants	3685 (0.5)				4	20	56	223	3376	9	46	234	3390
Miscellaneous drugs	2656 (0.4)			5	1	14	34	490	2105	21	14	488	2126
Anesthetics	2631 (0.4)		1	2	14	14	24	1408	1167	6	18	1418	1188
Diuretics	1244 (0.2)			1		29	6	570	636	15	6	585	636
Muscle relaxants	1090 (0.2)			4	18	12	69	73	914	11	65	78	936
Serums, toxoids, vaccines	997 (0.1)					2	3	365	609	1	1	366	611
Anticholinergic drugs	565 (0.1)			2	1	11	11	255	282	6	3	262	291
Veterinary drugs	212 (0.0)						1	50	160	2		48	161
Anticoagulants	169 (0.0)			1		4	3	39	122	4	2	40	123
Antineoplastics	151 (0.0)					1	2	9	138	2	5	8	135
Diagnostic agents	45 (0.0)						1	11	32		3	11	30
Narcotic antagonists	9 (0.0)							1	8			1	8
Radiopharmaceuticals	4 (0.0)							3	1			3	1
Unknown drug	1666 (0.2)			2	1	6	12	260	1372	1	8	267	1377
Total	696 937 (100.0)	11	14	142	206	1417	3129	173 729	516 597	801	1092	174 498	518 854

[a] Medical outcomes and HCF level by age group totals do not sum to major pharmaceutical category totals due to the exclusion of cases with unknown age.

have a lower threshold for calling a PCC when a medication error involves a young child compared with older children.

Contrary to the observed overall pattern, some medication categories demonstrated increased frequency of errors with increasing child age, including antidepressants, sedatives/hypnotics/antipsychotics, and stimulants. These observed trends are likely due to age-related prescribing practices.[12]

From 2005 through 2012, there was a significant decline of >60% in both the frequency and rate of errors involving cough and cold preparations. This decline has been well-documented in other research,[9,22] and has largely been attributed to the combined actions of the US Food and Drug Administration, manufacturers, and other groups, such as the American Academy of Pediatrics. The recommendation against the routine use of cough and cold preparations among young children was based on the lack of evidence of effectiveness and the common occurrence of side effects.[23]

A similar case could be made against the routine use of a number of the other medications associated with pediatric medication errors. For example, analgesics, which was the leading medication category implicated in medication errors in this study (accounting for more than one-fourth of these errors, as well as 10 of the 25 deaths), are most often given to children for their antipyretic effect. However, it is widely known that parents overtreat fever during childhood.[24–26] Therefore, an opportunity exists to decrease unnecessary exposure to analgesics and the medication errors that occur with analgesic use. Furthermore, it is also well established that antimicrobial agents are overprescribed by medical professionals, and antihistamines are frequently used inappropriately to treat nonallergic upper respiratory congestion.[27–30] The largest increase in medication errors was observed for dietary supplements, herbals, and homeopathic agents, the use of which is generally not based on strong scientific evidence. The use of all pharmaceuticals, especially among young children, should be based on the best available medical evidence,

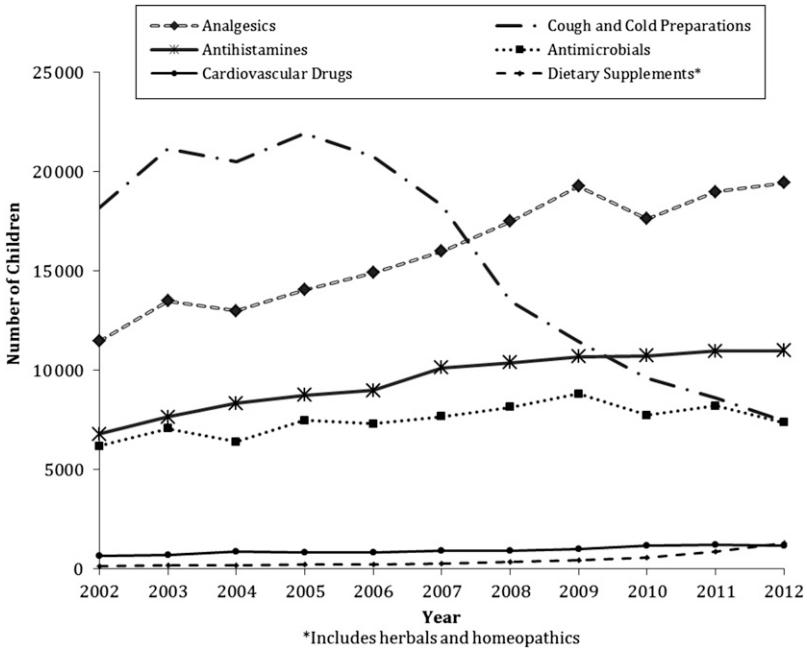

FIGURE 3

Number of cases of out-of-hospital medication errors among children <6 years of age by year for selected major pharmaceutical categories, NPDS 2002–2012.

weighing effectiveness against the potential for adverse effects, including those from unintentional medication error. We should apply to other categories of medications what we learned from the success of efforts to decrease unnecessary use of cough and cold preparations among young children.

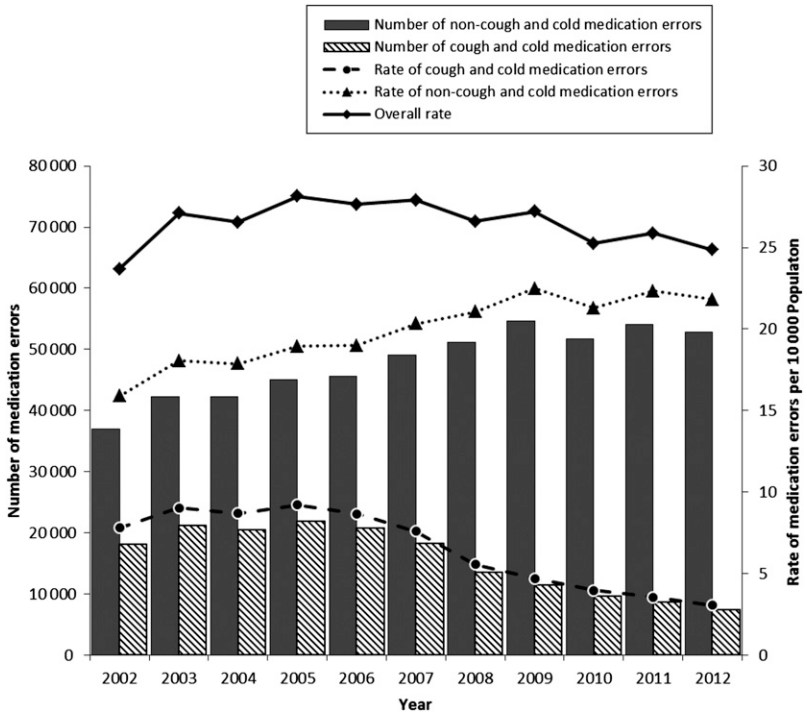

FIGURE 4

Number and rate of cases of out-of-hospital medication errors among children <6 years of age for cough and cold preparations and non–cough and cold preparations, NPDS 2002–2012.

Prevention

The Centers for Disease Control and Prevention, in collaboration with leaders from industry, academia, professional organizations, and health agencies, developed the PROTECT Initiative, which has outlined priorities aimed at preventing both medication errors and unsupervised ingestions.[31,32] Priorities addressing medication errors include an educational campaign and the refining of dosing measures and instructions on medication packaging and labeling to reduce errors made by parents and child caregivers. Recommendations include using only milliliters as a measure for liquid medications. Leading zeros before the decimal point are recommended; trailing zeros after a decimal point are not. The Institute for Safe Medication Practices has similar recommendations and also advocates using only kilograms for patient weights.[33] To reduce potential dosing errors, manufactures of over-the-counter single-ingredient liquid pediatric acetaminophen medications voluntary converted these medications to 1 concentration.[34] A study of adherence to recommendations by the Food and Drug Administration and Consumer Healthcare Products Association regarding dosing instructions and dosing devices for oral liquid medications found relatively high adherence but room for improvement, particularly in the expression of decimals and fractions in instructions.[35] This study was limited to over-the-counter analgesic/antipyretic, cough/cold, and allergy medications. Yin and colleagues[36] evaluated the effect of both advanced counseling and provision of the dosing instruments in an emergency department setting. Both interventions were necessary to reduce dosing errors, and among low-literacy caregivers and Spanish-speaking caregivers, neither intervention nor the combination affected a change in dosing errors.

In this study, more than one-fourth of all medication errors were due to "inadvertently took/given medication twice." Possible prevention strategies might include a programmable timer application for a smart phone that receives a signal from the medication container when it is accessed. Lower-technology strategies might use a simple child-resistant scheduling box for nonliquid medications.

Other prevention efforts have included the introduction of less-toxic medications, which decreases the consequences of medication errors, such as the substitution of selective serotonin reuptake inhibitors for tricyclic antidepressants as appropriate.[37] Future research should garner parent and child-caregiver feedback about the ways packaging, labeling, and dosing devices contribute to errors[35] and address health care provider communication to low-literacy and non–English speaking caregivers.[36]

Limitations

This study has a number of limitations. The numbers reported in this study underestimate the true magnitude of medication errors involving young children in the United States, because the NPDS only captures cases reported to member PCCs. It is likely that many medication errors are made without recognition, and even errors that are recognized may still not be reported to PCCs because the individuals involved may decline to call a PCC or seek information from other sources, such as online resources. Other cases may be treated in HCFs or private physician offices without a report being made to a PCC, and some children may not receive any medical attention. Information is based on self-reports from parents, child caregivers, and health care professionals, and cannot be completely verified by the AAPCC or reporting PCC. Exposures do not necessarily represent a poisoning or overdose, and some cases involve exposure to multiple medications, leading to the potential for error when PCC specialists rank drugs as being most responsible for clinical effects. However, because 93.4% of calls are single-substance reports, the overall error in identifying the most responsible medication is likely to be very small.

NPDS data are available only as categorized variables, without a descriptive narrative available to more completely describe the circumstances of the event. Despite these limitations, the NPDS is a nationally representative, cumulative database with extensive information about exposures to a wide array of substances, including those associated with medication errors. It is the most comprehensive and accurate database available for investigation of pediatric out-of-hospital medication errors in the United States.

CONCLUSIONS

To our knowledge, this is the first comprehensive study to evaluate the epidemiologic characteristics of out-of-hospital medication errors among children <6 years of age on a national level. Although medication errors involving young children occur frequently, serious medical outcomes are rare. Cough and cold medication errors declined significantly starting in 2005; however, non–cough and cold medication errors increased significantly during the study period. Learning from the success in decreasing cough and cold medication errors, increased efforts are needed to prevent non–cough and cold medication errors among young children.

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