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# Annual Risk of Death Resulting From Short Falls Among Young Children: Less Than 1 in 1 Million

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## ABSTRACT

**OBJECTIVE.** The objective of the work was to develop an estimate of the risk of death resulting from short falls of <1.5 m in vertical height, affecting infants and young children between birth and the fifth birthday.

**METHODS.** A review of published materials, including 5 book chapters, 2 medical society statements, 7 major literature reviews, 3 public injury databases, and 177 peer-reviewed, published articles indexed in the National Library of Medicine, was performed.

**RESULTS.** The California Epidemiology and Prevention for Injury Control Branch injury database yielded 6 possible fall-related fatalities of young children in a population of 2.5 million young children over a 5-year period. The other databases and the literature review produced no data that would indicate a higher short-fall mortality rate. Most publications that discuss the risk of death resulting from short falls say that such deaths are rare. No deaths resulting from falls have been reliably reported from day care centers.

**CONCLUSIONS.** The best current estimate of the mortality rate for short falls affecting infants and young children is <0.48 deaths per 1 million young children per year. Additional research is suggested. *Pediatrics* 2008;121:1213–1224

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### Key Words

abuse, accident, fall, injury, fatality

### Abbreviations

EPIC—Epidemiology and Prevention for Injury Control Branch

ICD-10—International Classification of Diseases, 10th Revision

NEISS—National Electronic Injury Surveillance System

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GENERALLY, WHEN A child between the ages of birth and 5 years is brought for medical care (or otherwise presented) with an injury that is fatal and a history of a short fall, abuse is suspected and an investigation ensues.<sup>1,2</sup> This may not always occur, and such histories were often accepted in the past. In such cases, a substantial proportion of the histories given are incorrect.<sup>3</sup> Often the only witness to the event is the person who was caring for the child at the time. In many cases, there are other injuries suggesting abuse. In some cases, the caretakers confess to shaking or other abusive actions that may explain the injuries in part or in whole. The forensic issue that arises in such cases is that of whether abuse occurred and whether that is sufficiently certain to justify an intervention to protect a surviving child or to pursue a criminal proceeding.

Reliable quantitative knowledge of the likelihood of a short-fall death occurring in the population is important for both forensic reasons and injury prevention. If short falls of <1.5 m frequently cause death in infants and young children, then there would be serious implications for the design and construction of children's environments. The importance of the question favored the inclusion of most articles that might bear on it.

Cases of injuries associated with short-fall histories arise in a variety of settings. The reliability of the determination of the reported fall height varies in different settings. Falls occurring in hospital settings are the most reliable, because the fall height is easy to measure, the injuries that occur are usually well documented, and the event is usually known. The next best class of settings is large, licensed, child care centers in which >1 caretaker is present. However, most of the cases that are included in clinical study populations or entered into public databases are not known to be reliably witnessed.

Textbook chapters,<sup>4-7</sup> statements of medical societies,<sup>8,9</sup> and many major reviews<sup>10-17</sup> state that serious head injury resulting from a short fall is rare. However, those chapters, reviews, and statements did not attempt to develop a quantitative estimate of the risk of short-fall death. If the subject is to be pursued scientifically and if comparisons are to be made over time and between geographic areas, then quantitative estimates are needed. This study sought to review critically the pediatric fall literature and 3 relevant, public, injury databases, in an effort to approximate the incidence of child deaths resulting from short falls in the population of young children.

## METHODS

### Definitions

Although we adopted certain definitions, the articles we reviewed did not necessarily conform to them. For purposes of this review, a short fall is a fall of <1.5 m (<4.7 ft) in vertical height, not involving horizontal velocity beyond what a young child can achieve alone. Fall height may best be defined as the difference in the positions of the child's center of gravity at the start and end of the fall; however, consistent definitions were not found in this literature review. The definition of a fatal case is 1 in which the injury that occurred in a fall was the proximate cause of death. Young children are infants and children between birth and the fifth birthday.

### Design

A review of the published literature and public databases on injuries resulting from children's falls was performed, with selection of articles that provided data pertaining to the issue of short-fall injury and death.

### Procedure

An initial search of National Library of Medicine was conducted by using the terms "child" and "fall" and "injury" and specifying "any field" for each category. On September 19, 2007, this search yielded 814 titles. No early-year boundary was specified, and a number of articles from the middle 1960s were found. In addition, 3 large, public, injury databases were studied. Two of the databases<sup>18,19</sup> provide an estimate of the risks of death resulting from falls for young children.

All titles and abstracts were reviewed for relevance to the short-fall fatality question; ultimately, the full texts of 188 references were reviewed by  $\geq 1$  author, and an analysis was written for each. This large set of analyses is available from the authors on request.

Articles were judged to be relevant if they contained data about falls among young children (as defined), information about fall height, and information about injury outcomes. Articles were excluded if they emphasized injuries among adults or adolescents or sports injuries, including ball game injuries, equestrian injuries, skiing injuries, and mountain or rock-climbing injuries. Articles about transport-related injuries generally were also excluded. The articles were divided into 20 classes, and an analysis was written for each class. The classification of articles and other data sources is shown in Table 1.

## RESULTS

### Analyses of Large Injury Databases and Populations

#### EPIC Database Findings

The most-detailed, population-based data available are those derived from the State of California Epidemiology and Prevention for Injury Control Branch (EPIC) database.<sup>18</sup> These data are compiled and published by staff members of the California Department of Health Services, using discharge data submitted by all California hospitals and death certificate data submitted by all Cal-

TABLE 1 Classification of Articles

Publication Class	No. Reviewed
Analyses of large injury databases and populations	2
Study based on Consumer Product Safety Commission data on playground fatalities	1
Population-based clinical studies	15
Studies of multiply and reliably witnessed falls	5
Studies of child care-related injuries	24
Studies of large clinical populations (>50 cases)	24
Studies of long falls	17
Articles addressing short-fall deaths specifically	6
Studies comparing abusive and unintentional injuries	7
Single cases and small series (<50 cases)	19
Studies using biomechanical analyses	11
Pathologic and cadaver studies	8
Studies focusing on fractures	7
Studies of injuries occurring on playgrounds	7
Book chapters and major reviews	10
Falls down stairs	2
Parents' observations of infant's falls	2
Walker-related falls	4
Cervical spine and cord injuries	1
Observational studies of child behavior	2
Total	177 <sup>a</sup>

<sup>a</sup> A number of book chapters, society statements, and literature reviews are not included in the table.

ifornia county medical examiners. The data are stratified according to E-codes from the *International Classification of Diseases, Ninth Revision, Clinical Modification*,<sup>20</sup> for surviving cases and W-codes from the *International Classification of Diseases, 10th Revision (ICD-10)*,<sup>21</sup> for fatalities. ICD-10 codes provide finer detail about fall types and heights, which allowed further classification of fall types into probable fall heights (Table 2). In the most recent 5-year period (1999–2003) for which data are available, a maximum of 13 short-fall deaths might have occurred among 2.5 million California children <5 years of age. The California EPIC database data are summarized in Table 3.

Death certificates for the 13 possible short-fall fatalities in the EPIC database were obtained and reviewed. When the 13 death certificates were reviewed, however, 2 cases were attributed to suffocation and the "fall" was an event that preceded suffocation, rather than the direct cause of death. One fatal case was attributed to a second-story window fall, and another was called "fall from a height." Another involved a fall onto rocks in the arms of an adult. Two cases involved crush injuries from heavy furniture falling. Six cases remained possibly valid short falls, resulting in an annual incidence of 6 cases per 2.5 million children per 5 years or 0.48 cases per 1 million children per year. Because some of the short-fall histories in this set were incorrect, the true incidence of short-fall deaths is less than this value.

The Web-based Injury Statistics Query and Reporting System of the Centers for Disease Control and Prevention<sup>19</sup> allows determination of the total fall death rate for children <4 years of age but does not provide stratification according to fall type/height. The "all fall" death rate was 3 cases per 1 million young children per year.

**TABLE 2 ICD-10 Codes for Events Causing Injury**

ICD-10 Code	Definition	Long	Short (<1.5 m)	Not Applicable
W-00	Fall on same level involving ice and snow		X	
W-01	Fall on same level from slipping, tripping, and stumbling		X	
W-02	Fall involving ice skates, skis, roller skates, or skateboards			X
W-03	Other fall on same level attributable to collision with, or pushing by, another person		X	
W-04	Fall while being carried		X	
W-05	Fall involving wheelchair		X	
W-06	Fall involving bed		X	
W-07	Fall involving chair		X	
W-08	Fall involving other furniture		X	
W-09	Fall involving playground equipment			X
W-10	Fall on and from stairs and steps		X	
W-11	Fall on and from ladder	X		
W-12	Fall on and from scaffolding	X		
W-13	Fall from, out of, or through building or structure	X		
W-14	Fall from tree	X		
W-15	Fall from cliff	X		
W-16	Diving or jumping into water causing injury			X
W-17	Other fall from one level to another	X		
W-18	Other fall on same level		X	
W-19	Unspecified fall			X

In the most recent 5-year period (1999–2003) for which data are available, a maximum of 13 short-fall deaths might have occurred among 2.5 million California children <5 years of age. The California EPIC data are summarized in Table 3.

#### Study Based on Consumer Product Safety Commission Data

The Consumer Product Safety Commission collects injury data through active surveillance of a sample of hospital emergency departments that covers ~1 of 50 US hospitals.<sup>22</sup> This is known as the National Electronic Injury Surveillance System (NEISS). Wissow and Wilson<sup>23</sup> suggested that some of their data might be used as a reference for determining whether injuries were inflicted or accidental. Chadwick<sup>24</sup> pointed out that the

**TABLE 3 Numbers of Deaths Attributed to Short Falls in EPIC Database**

ICD-10 Code (Fatalities)	Definition	No. of Fatal Cases (1999–2003)
W-01	Fall on same level from slipping, tripping, and stumbling	1
W-03	Other fall on same level attributable to collision with, or pushing by, another person	0
W-04	Fall while being carried	0
W-06	Fall involving bed	3
W-07	Fall involving chair	1
W-08	Fall involving other furniture	1
W-10	Fall on and from stairs and steps	4
W-18	Other fall on same level	3
	Total possible short-fall deaths	13

**TABLE 4 Studies of Reliably Witnessed Falls Occurring in Hospitalized Young Children**

Authors and Year	No.		
	Falls in Hospital	Injuries	Death or Brain Damage
Helper et al, <sup>27</sup> 1977	85	Skull fracture (1)	0
Nimityongskul and Anderson, <sup>28</sup> 1987	76	Skull fracture (1)	0
Levene and Bonfield, <sup>29</sup> 1991	192	Skull fracture and limb fracture (2 each)	0
Lyons and Oates, <sup>30</sup> 1993	207	Skull fracture and clavicle fracture (1 each)	0
Total falls (<5 y of age)	560 <sup>a</sup>		0 <sup>a</sup>

<sup>a</sup> 95% confidence interval: 0–1 cases per 186 children.

NEISS data might not be sufficiently reliable for that purpose.

Plunkett<sup>22</sup> set out to prove the likelihood of short-fall death and concluded that death in falls of <3 m is “possible,” on the basis of the occurrence of 18 head injury deaths resulting from falls in playground injuries in the NEISS database over 12 years (1988–1999). Nine of the 18 children who died were >5 years of age. Among the 9 young children, 4 cases were not witnessed at all, even by other children. Of the remaining 5 cases, 1 fall height was estimated at >2.0 m. Of the remaining 4 cases, 1 had no autopsy, and the cause of death in that case was uncertain.

The population base for the NEISS sample can be estimated as 1/50th of the US population or ~400 000 children 0 to 5 years of age.<sup>25</sup> With the determination that 3 of the cases were valid, the annual population risk for a short-fall death of a young child in this (playground) sample can be calculated as 3 fatalities/(400 000 × 12) = 0.625 cases per 1 million young children per year.

The database provided by the Consumer Product Safety Commission<sup>25,26</sup> has the additional limitation of specialized selectivity. It is compiled by coders assigned to a sample of hospital emergency departments, using a data dictionary that provides >800 product-related elements but few or no elements that allow for the inclusion of cases with false fall histories. The result is a data set that captures almost all product-related injuries but is not adapted for violence-related data acquisition. It also may fail to capture deaths resulting from short falls that are not involved with products.

#### Studies of Multiply and Reliably Witnessed Falls

Five articles described reliably witnessed falls with known medical outcomes.<sup>27–31</sup> The results from the 4 comparable studies of hospital falls are shown in Table 4. These 4 studies collected a total of 560 falls from beds, cribs, examining tables, and gurneys that occurred in hospitals but caused no deaths. Three children had linear parietal skull fractures. None were unconscious and none required intensive care. The fifth study<sup>31</sup> collected multiply witnessed falls occurring in the community and reached the same conclusion, that short falls are benign.

**TABLE 5 Studies of Child Care-Related Injuries**

Authors and Year	Population	Focus	No. of Fatal Falls
Aronson, <sup>55</sup> 1983	All of United States	Concern about injury risk	Not studied
Elardo et al, <sup>36</sup> 1987	1 center; 1 y	Accidents	None (very small sample)
Landman and Landman, <sup>37</sup> 1987	523 centers; 1 y	29 medically attended injuries	0
Chang et al, <sup>38</sup> 1989	90 centers; 10 000 children; 2 y	423 injuries, 55 medically attended	0; none hospitalized
Rivara et al, <sup>39</sup> 1989	Emergency department injury visits	Child care vs home injuries	0
Sacks, <sup>40</sup> 1989	71 centers; 5300 children; 6 mo	143 medically attended injuries	0
Sacks, <sup>41</sup> 1990	Atlanta centers	Playground equipment	Not studied
Gunn et al, <sup>42</sup> 1991	Unknown	All injuries and poisonings; child care v home care	0
Runyan et al, <sup>43</sup> 1991	Unknown	Effectiveness of regulation	Not studied
Thacker, 1992 <sup>191</sup>	Literature review	Infections and injuries in child care	None mentioned
Leland, 1993 <sup>192</sup>	4 centers; 527 children; 1 y	1000 injuries noted by staff members	0
Chadwick and Salerno, <sup>33</sup> 1993	338 children, 0–5 y of age, with serious head injuries, including 41 who died	Functional site of injury; child care center v all other	0 in child care center
Kotch et al, <sup>34</sup> 1993	656 families	Minor injury incidence in home, center care, and other care	Not studied (small sample)
MacKenzie and Sherman, <sup>35</sup> 1994	1008 children injured in child care settings and seen in emergency departments	Risk of injury in child care v other settings	0
Good et al, <sup>32</sup> 1994	520 000 young children in child care	Deaths from all causes; 9 deaths found	0
Briss et al, <sup>49</sup> 1994	138 404 children in multiple centers	556 injuries requiring medical attention	0
Rivara and Sacks, <sup>46</sup> 1994	Literature review; 27 articles on day care injury	Medically attended injuries	Not mentioned
Alkon et al, <sup>47</sup> 1994	141 children in care studied intensively for 12 mo	886 visible or symptomatic injuries, none serious	0
Sellstrom et al, <sup>48</sup> 1994	76 659 young children; 1 y	Risk of injury in child care v home	0
Briss et al, <sup>45</sup> 1995	1740 child care centers	Regulatory strategy and injury risk	Not studied and not mentioned
Cummings et al, <sup>50</sup> 1996	133 child care sites; 1 y	53 medically attended injuries	0
Kopjar and Wickizer, <sup>51</sup> 1996	9454 young children; 1 y	Risk of injury in child care	0
Kotch et al, <sup>44</sup> 1997	State of North Carolina; all child care 3.5 y of age	Risk of injury	0
Alkon et al, <sup>52</sup> 2000	362 children; 2 y	1886 injuries noted	0
Kruse, <sup>53</sup> 2001	Denmark, all children; 8 y	All day care injuries	Not mentioned
Wrigley and Dreby, <sup>56</sup> 2005	United States, all child care; 18 y (1985–2003); 6.6 million young children	All child care injuries; compare forms of child care	2 fatal falls per 18 y per 6.6 million young children

The numbers of observations were relatively small, and falls of these types in hospitals are not common. Extending the studies by using this design would require many years. A search of the National Library of Medicine and an inquiry to the National Association of Children's Hospitals and Related Institutions failed to produce a reviewed article describing a fall-related death occurring in a children's hospital.

### Studies of Child Care-Related Injuries

The 25 studies of child care-related injuries<sup>32–56</sup> are summarized in Table 5. Fourteen of the 25 cited articles were population-based<sup>32,37,38,40,41,44–46,48–51,53,56,57</sup> and reflect the injury experiences of millions of infants and young children in large child care centers and other forms of child care.

Large, licensed, child care centers usually attempt to provide line-of-sight visibility, such that workers can see each other and supervisors can easily observe operations. Isolation of caretakers is deliberately avoided.<sup>58</sup> This fact contributes to the reliability of witnessing of injury incidents in these settings and improves the validity of case histories coming from them.

The 2 studies that looked specifically at deaths in day care centers found only 2 attributed to falls (both re-

ported in newspaper articles) in a population of >6 million children, 0 to 5 years of age, in day care over periods of 5 and 18 years.<sup>32,56</sup> Licensed day care centers are generally required to limit opportunities for long falls; however, short falls (and minor injuries) are very common in such centers.<sup>54</sup>

The studies that investigated serious injuries in child care centers found very few. The studies that compared risk of injury in home versus child care centers showed somewhat mixed results, but a majority found child care centers to be safer, on the basis of the incidence of minor injuries. When serious injuries and death were considered, large child care centers emerged as vastly safer than all other sites.<sup>56</sup> The extent to which child care centers protect children from injury seems to be related to the severity of injury. Injuries resulting in death were either extremely rare or absent in the samples studied, and injuries resulting in hospitalization were very rare. The studies described in this section used differing injury definitions, but most used definitions that were used by the staff members of day care centers (ie, injuries that the staff members could recognize). Many also recorded medically attended injuries.

There is no published, peer-reviewed, medical report of a fall-related death occurring in a large, licensed, child

**TABLE 6 Studies of Large Clinical Populations (> 50 Cases)**

Authors and Year	No. of Cases	Principal Focus	Inflicted Injuries Recognized	Valid Short Falls Causing Death
Hendrick et al, <sup>73</sup> 1964	4465	Children's head injuries	None	Uncertain
Williamson and Lowdon, <sup>74</sup> 1988	281	Children's arm fractures	Uncertain	No deaths
King, <sup>75</sup> 1991	1077	All children's injuries in trauma center	Yes	No fall deaths
Schutzman et al, <sup>76</sup> 1993	53	Epidural hematoma	None; 24 of 53 had short-fall histories	No deaths
Howard et al, <sup>77</sup> 1993	100	Children's head injuries and racial predilection	Yes	Deaths not analyzed
Sharma and Sharma, <sup>78</sup> 1994	312	Children's head injury treatment	Yes; low incidence	No
Mosenthal et al, <sup>79</sup> 1995	356	Head injuries	No	No
Smith et al, <sup>80</sup> 1996	62	Shopping cart falls	No	No deaths
Shugerman et al, <sup>81</sup> 1996	93	Subdural and epidural bleeding	Yes	No
Canty et al, <sup>82</sup> 1999	102	Children's intestinal injuries	Yes	No
Solheim, <sup>83</sup> 1998	64	Children's falls	Yes	No
Adesunkanmi et al, <sup>84</sup> 1999	305	Children's falls with injury	No	No
Paret et al, <sup>85</sup> 1999	61	Falls with injury	No	No
Murray et al, <sup>86</sup> 2000	177	Falls of <15 ft	No	No
Pillai et al, <sup>87</sup> 2000	127	Falls of >9 ft	No	No
Sawyer et al, <sup>88</sup> 2000	110	Falls of >10 ft	Yes	No
Macgregor, <sup>89</sup> 2000	85	Falls from bunks, beds, and cots	No	No deaths
Wang et al, <sup>90</sup> 2001	729	Children's trauma center injuries	Yes	No, but some serious injuries
Mooney, <sup>91</sup> 2002		Liver and spleen injuries	No	No
Belechri et al, <sup>92</sup> 2002	1881	Bed falls and bunk falls	No	No deaths
Park et al, <sup>93</sup> 2004	193	Head injuries	No	No
Balci et al, <sup>94</sup> 2004	137	Children's blunt thoracic trauma	No	No
Yagmur et al, <sup>95</sup> 2004	1643	Children's falls from rooftops (Turkey)	No	No
Laloo and van As, <sup>96</sup> 2004	37 610	Children's trauma center head injuries	Not assessed	Not assessed
Pitone and Attia, <sup>97</sup> 2006	787	Trauma center, "routine" childhood falls	Excluded	No deaths
Total cases	50 810			

care center. In recent years, however, ~300 000 infants <1 year of age and ~6.6 million preschool-aged children are being provided with care in child care centers in the United States.<sup>58,59</sup> The evidence from the child care injury literature indicates that the probability of a short fall resulting in death in a large, licensed, child care center is <1 per 1 million exposed young children per year. The risk of an injury requiring hospitalization is also small. Short falls abound in child care centers, and the centers offer good opportunities for efficient observation of these events and their consequences.

#### Studies Using Biomechanical Analyses

The roots of biomechanical study of injuries are largely in the study of car crashes, and studies have been aimed at improving safety. In this area, analysts have the advantage of dealing with an event that cannot be concealed and often can be analyzed quite accurately. Although a similar approach to children's falls is possible, it has not been undertaken, with the single exception of the 1970 study by Snyder.<sup>60</sup> The field still suffers from an almost-total lack of data on the injury tolerances of living infants and children. None of the published studies<sup>60-72</sup> allows any quantitative estimate of the risk of death in a short fall, although the works by Bertocci et al<sup>65</sup> and Margulies and Thibault<sup>72</sup> provide significant steps in the right direction. The real-world falls of young children are complex events, and the effects of these events on various body parts, including the brain, are even more complex. The pathophysiological events that lead from mechanical injury to death introduce another

layer of complexity. The idea that fall fatality risks can be determined by examining the tensile strength of tissues obtained at autopsies or by using computer models informed largely by adult cadaver studies may be difficult to prove. One biomechanical review article<sup>71</sup> stated that the "belief that short fall deaths are rare . . . requires validation." The present work responds to that challenge.

An important research objective of the biomechanical approach to the short-fall question is the capability of event reconstruction based on observed pathologic findings, as recommended by Ommaya et al.<sup>71</sup> This might be achieved if much more data on the actual injury tolerances of young children could be acquired. Data on minor events and resulting injuries could be acquired quickly through systematic observations in child care centers. Data on high-energy events could be acquired slowly from automobile crashes and pedestrian events involving young children.

#### Studies of Large Clinical Populations (> 50 Cases)

The major features of these articles<sup>73-97</sup> are summarized in Table 6. These 25 articles, with >50 000 medically attended injury cases, report on a variety of different types of injuries and concerns. Most articles of this type did not attempt to confirm historical validity, but this literature generally supports the position that deaths resulting from short falls are rare. A single article found no correlation of fall height with severity of injury and concluded that a short-fall history should not affect tri-

**TABLE 7 Articles Addressing Short-Fall Death Specifically**

Authors and Year	Article Type	Comment
Hall et al, <sup>121</sup> 1989	Retrospective review of medical examiner files	Fall histories not validated
Chadwick et al, <sup>3</sup> 1991	Retrospective review of hospital records of cases of short- and long-fall deaths	Short falls seem 7 times more likely to cause death than long falls; better explanation of this finding is that histories are incorrect
Duhaime et al, <sup>122</sup> 1992	Prospective clinical analysis of 100 infants with serious head injuries; developed algorithm to distinguish abuse from accident cases	Short fall with serious head injury is element of algorithm
Reiber, <sup>124</sup> 1993	Retrospective review of personal experience; described 2 cases of short-fall deaths	Fall histories not validated
Reece and Sege, <sup>12</sup> 2000	Retrospective analysis of large clinical population, using precise definitions	Fall histories may not be validated
Plunkett, <sup>22</sup> 2001	Analysis of large, public, injury database of playground equipment-related injuries (NEISS)	Concludes that death is possible in falls of <3 m; limited relevance
Denton and Mileusnic, <sup>123</sup> 2003	Single case report from authors' experience	History not validated and pathologic findings inconsistent with history

age processes.<sup>90</sup> The validity of histories in that study was not discussed.

### Studies Comparing Abusive and Unintentional Injuries

All 7 of these studies<sup>12,98–103</sup> indicated a very low frequency of short-fall death; however, none involved large populations, and their conclusions were not quantitative. All studies were based on clinical populations and contained cases with incorrect histories.

### Studies of Long Falls

Studies of long falls of children<sup>17,104–120</sup> do not apply directly to the issue of short-fall injuries; however, these studies largely support the theory that the risk of a fatal outcome is related to fall height and the nature of the impacting surface. Several studies also support the theory that smaller persons fare better than larger ones. There are no published studies that demonstrate real-world correlations of body mass, fall height, nature of impacting surface and injury severity in short falls. Two studies found no deaths in children who fell <3 stories.<sup>107,109</sup>

### Articles Addressing Short-Fall Death Specifically

The number of articles addressing the specific issue of the likelihood of short-fall death<sup>3,12,22,121–124</sup> is small, given the importance of the problem. These articles are summarized in Table 7. None allows a quantitative estimate of the risk of short-fall death.

### Pathologic and Cadaver Studies

Challenges exist in attempting to draw conclusions regarding risks of fatal injury from cadaver studies.<sup>125–132</sup> The information such studies provide about tissue strength may be difficult to apply to the issue of injury tolerance of whole living subjects. Most young children who die after head injuries do so because of brain swelling and loss of brain circulation, and the mechanisms leading to this phenomenon are variable and complex. Therefore, the study by Weber<sup>127</sup> of skull fractures in infant cadavers is of little help. Gentry et al<sup>128</sup> showed that callosal tears require high-energy events, and all of

the fatal child cases from motor vehicle-related dynamic events described by Gorrie et al<sup>129</sup> underwent extreme linear acceleration far beyond what might occur in a short fall. Krous and Byard<sup>132</sup> included the short-fall issue as a continuing controversy, but the articles describing pathologic or cadaver experiments do not establish that short-fall death could occur at a frequency of >1 case per 1 million young children per year.

### Studies Focusing on Fractures

Fractures per se are rarely fatal, but they often accompany fatal head injuries and they require consideration in this review. The present literature<sup>65,67,133–137</sup> supports the possibility of extremity fractures (including femur and humerus fractures) occurring as a result of falls of ambulatory toddlers and young children from low heights; however, all of the observations were history-dependent, and the observations of documented short falls in hospitals do not confirm a risk for femur or humerus fractures resulting from short falls. Additional studies are needed, and the best method would be prospective observational studies of falls occurring in child care centers.

### Population-Based Clinical Studies of Injuries and Falls

Table 8 summarizes data from published, population-based, clinical studies.<sup>57,138–151</sup> These are studies in which all of the medically attended injuries occurring in a defined population in a defined period of time are reviewed, and the data are summarized. Such studies are valuable, because they provide risk estimations for certain types of injuries. In almost all cases, however, the mechanism of injury is the 1 that was provided by the caretaker of the child, who provided the history. When inflicted injuries are distinguished, the issue of the risk of fatal short falls cannot be addressed without resorting to circular reasoning. Most studies were concerned with other questions but still found few or no short-fall deaths in large sets of injured children.

### Studies of Injuries Occurring on Playgrounds

Injuries that occur on public playgrounds<sup>22,138,152–156</sup> are rarely if ever suspected of being caused by child abuse.

**TABLE 8 Population-Based Studies of Injuries and Falls**

Authors and Year	Population	Focus	No. of Short-Fall Deaths
Kraus et al, <sup>141</sup> 1986	0–16 y; 500 000	Brain injury rate	0
Gallagher et al, <sup>140</sup> 1984	0–19 y; 87 022	Injury and death	0 fall deaths
Chalmers and Langley, <sup>138</sup> 1990	All New Zealand public hospital discharges	1125 playground injuries	0 deaths
Tursz et al, <sup>144</sup> 1990, France	0–2 y; 13 849	641 “home accidents”	0 deaths
Smith, <sup>143</sup> 1991, Scotland	0–14 y; 70 609	Injuries and falls	0
Rivara et al, <sup>57</sup> 1993	0–19 y; 1.35 million; 2 y	All injuries and falls; 2 y; 11 fall deaths; 10 >10 y of age	Uncertain but ≤1
Jayawant et al, <sup>146</sup> 1998	0–2 y; south Wales and southwestern England	Subdural hematoma; 12.8 cases per 100 000 per y	Not determined
Kypri et al, <sup>145</sup> 2001	New Zealand; ~600 000	106 666 injuries in 10 y	Not determined
Smith et al, <sup>142</sup> 1995	United States; 0–14 y; 60 253 375 (population-y)	Shopping cart falls, with 25 000 injuries estimated	2, undocumented
Qazi et al, <sup>150</sup> 1998	0–14 y; 192 injured children	Transport	0
Kozik et al, <sup>148</sup> 1999, Thailand	School age; 40 000	Importance of injury	Not determined
Jones et al, <sup>147</sup> 2000	3–15 y with forearm fractures	Forearm fracture incidence of 10.4 cases per 1000 per y with low-energy events	No deaths
Agran et al, <sup>139</sup> 2003	0–4 y; injury hospitalization or death by 3 mo; age groups; 2 300 000	Changing risks in early months of life	Not determined
Pickett et al, <sup>149</sup> 2003	All ages; 176 000	Brain injury at all ages	Not determined
Morrison et al, <sup>151</sup> 2002, New Zealand	0–5 y; 240 000	Infant furniture injuries; 43 fatalities, none from falls	0

This may be because the public setting reduces the likelihood of an abusive act and because the involved children are older. Nonetheless, these injuries might offer some insight into children’s injury tolerance if all of the events and all of the resulting injuries were documented. Playground equipment in private locations in the yards of homes is more likely to be blamed for some injuries and, in such cases, the only witness may be the caretaker.

#### Falls Down Stairs

Falls down stairs may be a series of short falls, as conceptualized by Joffe and Ludwig,<sup>157</sup> or a type of longer fall, as modeled by Bertocci et al,<sup>63</sup> and the difference seems to be a matter of the pitch of the stairs. Neither study documented deaths in falls down stairs by young children. Falls down stairs in walkers may be different and are becoming rare, and stairway falls in the arms of an adult pose uncertain risks.

#### Parents’ Observations of Infants’ Falls

Kravitz et al<sup>158</sup> queried mothers with 1-year-old infants and found that more than one half of them had fallen from an elevated surface during the first year after birth. None sustained fatal injuries, and very few injuries were serious. In the Avon Longitudinal Study of Parents and Children, Warrington et al<sup>159</sup> found similar data in a very large sample of British mothers of infants. These studies show that infants fall from low elevated surfaces very frequently and rarely die as a result.

#### Walker-Related Falls

There is little doubt that the use of a walker increases the risks associated with a fall down stairs by an infant or toddler.<sup>160–164</sup> However, it should not be concluded that there is a proven risk of fatal injury through this mech-

anism. The number of cases was very small, and the history validity was not established.

#### Cervical Spine and Cord Injuries

The rarity of cervical spine and cord injuries in infants and young children<sup>165</sup> limits the ability to study the risk of such injuries from short falls at the present time.

#### Single Cases and Small Series (<50 Cases)

These single cases and small series<sup>123,124,166–184</sup> provide little additional evidence regarding the main issue. Without exception, they present the problem of uncertain historical validation.

#### Observational Studies of Children’s Behavior

The 2 articles<sup>185,186</sup> reviewed observed risky behaviors of children but not actual falls.

#### Mortality Rate in Perspective

The observed short-fall mortality rate of 0.48 cases per 1 million young children per year in California is based on the occurrence of 6 possible short-fall deaths occurring in 5 years in a population of 2.5 million young children. In the larger picture of infant and young child deaths, this is a very small proportion. In the most recent year for which statistics are available (2004), there were a total of 3377 deaths of infants and young children in the California population of 2.5 million.<sup>187</sup> The overall death rate for the first 5 years of life in the state is 1351 deaths per 1 million per year. The mortality rates for some specific conditions of infancy and childhood are shown in Table 9. These rates are based on California data from 2004.<sup>187</sup>



**TABLE 9** Some Specific Conditions Causing Death in Infants and Young Children in California

Condition	Deaths per 1 Million Young Children per year
Prematurity (all deaths recorded in first year of life)	165
Congenital malformations	316
Neoplasms	33
Respiratory diseases	38
Accidents	121
Short Falls	0.48
Homicide <sup>a</sup>	22

<sup>a</sup>It is likely that the incidence of homicide affecting infants and young children is still underestimated.<sup>188,189</sup>

## DISCUSSION

There is an inherent difficulty involved in determining the likelihood of death resulting from a short fall for an infant or young child. The difficulty is that it is almost impossible in any given case to determine the accuracy of the history that accompanies the injured child coming into care. This difficulty led Helfer et al<sup>27</sup> to observe the effects of short falls that occurred in hospitals, where the event was well observed and well recorded and the consequences well known. However, the numbers of cases that could be observed in hospitals was relatively small, and the need for a high level of certainty about the basic issue is great. The best solution to this problem is the ongoing collection of data on hospitalized and fatal injuries from large numbers of injury events affecting infants and young children in large states. Data collected in this way may still include instances in which false histories of short falls connected to fatal outcomes occur, but they can yield estimates of the maximal likelihood of short-fall death in a population. As diagnostic accuracy increases, the numbers of false short-fall deaths of this sort should decrease.

Data definitions are very important, and the use of ICD-10 codes<sup>21</sup> is a major advance that makes it possible to classify falls according to type and height. Unfortunately, in California, ICD-10 codes are used only for fatal cases. When such coding becomes the standard for hospital discharges, the same method will be applicable to serious but survivable injuries.

The incidence of short-fall deaths based on numbers of falls also might be determined. That determination will require observations of the numbers of short falls that are actually occurring in infants and young children, stratified according to age groups. The incidence of falling changes rapidly over the first months and years of life, and no reliable data are yet available.

A major limitation of this study is the lack of uniform definitions and a uniform focus in the many studies reviewed. Another limitation is that of the apparent low frequency of deaths resulting from short falls. When the numerator of a fraction is 0 or a small number and the denominator is large, the "stability" of the proportion may be limited.<sup>190</sup> It is recognized that the conclusion that short-fall death never occurs requires an infinite number of "observations of opportunity."

## CONCLUSIONS

The following conclusions can be made. (1) The best current evidence indicates that the population-based risk of a short-fall death for an infant or a young child is <1 per 1 million young children per year. (2) The quantitative estimate is based on the California EPIC database for the years 1999–2003; however, no evidence can be found in the rich literature on children's fall-related injuries or in other public databases to support a higher incidence. (3) Most publications that discuss the risk of death resulting from short falls state that it is rare. No deaths resulting from falls at large, licensed, day care centers have been reported in peer-reviewed articles indexed in the National Library of Medicine.

Some recommendations for future research can be made. If short-fall deaths occur at some very low frequency, then a prospective search for such occurrences in large child care centers should reveal them and is feasible. In these settings, falls from low elevated surfaces are common, and the exposed population is very large and can be stratified according to age. Child care centers can be sites for epidemiological, observational, and biomechanical studies at reasonable costs. Falls of young children in hospitals are less frequent, but they also could be captured in prospective studies and would provide the best reliability. The finding of short-fall deaths occurring in prospective studies of child care centers or hospitals would be much more convincing than the case reports published in the past. Continued collection of data in the California EPIC database would be a simple and inexpensive method to improve the precision of the estimate of the risk of death resulting from short falls.

It also will be important to expand knowledge about the actual injury tolerances of infants and young children in high-energy events, such as events involving pedestrians and automobiles and other motor vehicle accidents. Without data from real events involving real children, all estimates based on dummies and computer models are of limited validity.

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