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Epidemiologic principles applied to injury prevention

by Patrick J Coleman, PhD [1]

COLEMAN PJ. Epidemiologic principles applied to injury prevention. *Scand j work environ health* 7 (1981): suppl 4, 91—96. An analysis of injuries resulting from falls from ladders was carried out with the following objectives: to reveal potential causal factors of such injuries and to test epidemiologic concepts for improved design of a case-comparison study of such injuries. The study observations consisted of 1,419 workers injured in ladder-related accidents who responded to a Work Injury Report Survey questionnaire. This survey, designed jointly by the National Institute for Occupational Safety and Health, the Occupational Safety and Health Administration, and the Bureau of Labor Statistics, included questions on the design, composition, and condition of the ladder, the task being attempted by the injured, the condition of the worker's shoes, the amount and kind of training, and other factors. After the identification of one group of injured workers (those injured while working from the ladder) as referents and a second group (those injured while climbing the ladder) as cases, a case-comparison analysis of other factors was carried out. The conclusions drawn were that the differences between the case and comparison groups were design- and task-related, while other factors were not directly comparable. This analysis points the way for designing a more carefully controlled study of such injuries.

Key terms: case-referent, falls, ladder, Work Injury Report Survey.

While a number of studies reported in the accident research literature have applied epidemiologic methods to the scientific study of injury (2, 5, 6), only a few (6, 7) have treated occupational injuries. Haddon (3, 4, 5) pioneered a number of applications in the area of motor vehicle and sports injuries, while Baker (1) and Waller (8) have contributed much to injury epidemiology in the public health arena. With few exceptions, however, occupational accidents and injuries have not been researched with accepted scientific methods of collecting carefully controlled observations, formulating hypotheses, and designing studies capable of proving or disproving these hypotheses. Rather, there is evidence that cost considerations, the relative rarity of significant job injuries, and the belief, in many cases, that a given accident has been sufficiently understood in a causal sense to prevent its recurrence have resulted in no perceived need for job injury applications of epidemiologic methods and principles. Instead, job accidents and injuries have been viewed as unique events, each having emergent characteristics sharing few common or underlying necessary conditions and antecedents. A possible consequence of these assumptions is that collective learning about accident and injury causes and their control has proceeded more slowly than it might, given the benefit of systematic, scientifically designed studies.

This report presents a controlled analysis of cases of one specific job accident type — falls from ladders. With the use of this analysis as an illustration of the application of epidemiologic methods, several principles are developed which should guide further studies in this field.

[1] Division of Safety Research, National Institute for Occupational Safety and Health (NIOSH), Morgantown, West Virginia, United States.

Reprint requests to: Dr. PJ Coleman, Division of Safety Research, National Institute for Occupational Safety and Health, 944 Chestnut Ridge Road, Morgantown, WV 26505, USA.

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Background

Falls from ladders were chosen for study for several reasons. First they are a ubiquitous accident type, occurring in all industries and occupations. Estimates based on consolidated workers' compensation statistics from 26 states for 1977 project a US annual total of roughly 20,000 to 25,000 injuries resulting from such falls in the workplace. Second they were the subject of one of the work injury report surveys designed jointly by the National Institute for Occupational Safety and Health (NIOSH) and the US Department of Labor and conducted by the Bureau of Labor Statistics in that department. Third, and possibly most important from a research design point of view, exposure to a potential fall from a ladder can be more easily quantified than can, say, exposure to a falling or flying object. Because merely being on a ladder constitutes a necessary condition for falling from it, this accident type lends itself to a case-referent study design in a way few other accident types do.

The work injury report (WIR) survey of ladder accidents referred to was conducted in 1978. Questionnaires were mailed to over 2,000 injured workers; 1,419, roughly 70 %, responded. The questionnaire contained 26 multiple questions on activity at the time of the accident, a description of the ladder involved in the accident, placement of nonfixed (hand-portable or movable) ladders, training information, and a question about other factors related to the accident.

Since the WIR survey was designed not as an epidemiologic study, but as an attempt to obtain a broad picture of ladder-related injuries including details such as activity when injured, occupation, ladder type and condition, and kind and amount of training, some examination and sorting of cases was necessary to ensure at least superficial uniformity. Thus, when significant numbers of cases appeared to involve workers being hit by a falling ladder rather than their falling from it, or other nonfall types of events, these cases were excluded from further analysis.

A brief review of the overall features of the remaining cases is in order to provide a background for the analysis. Based on tables and copies of survey returns supplied by the Bureau of Labor Statistics, the following patterns or clusters emerged: (i) farm laborers using straight ladders to pick fruit often carry bags up and down ladders propped against a tree limb; (ii) truck drivers climb in and out of truck cabs via fixed ladders and also climb fixed ladders on the tanks of tanker trucks, but they use these only as access means, and not as working platforms; (iii) stock clerks, warehouse workers, and other retail business personnel use stepladders to load and unload items from shelves; and (iv) mechanics, carpenters, painters, construction laborers, and laborers in general use a variety of ladders for diverse tasks and purposes.

Given the diversity of factors suggested by these work situations, it is easy to understand why they are viewed as unique events. Yet it is in discovering unifying and common conditions that may precede these events that the promise of a more rigorous epidemiologic approach lies, and this approach gets its power from the aggregation of data, rather than the analysis of each case. Haddon (3) and others have emphasized the point that we already know, at one level of generality, the underlying agent in most injuries — energy, in one of its many forms, is transferred to human tissue in amounts that necessarily cause damage. In the analysis of the WIR data, one objective was to focus on an intermediate level between energy — the most general agent — and the numerous detailed features of individual ladders, workers, tasks, and environments. If constraints or clusters could be found in this large set of circumstances, perhaps more general countermeasures would emerge also.

What posed the greatest problem for this analysis was the lack of a referent group, ie, workers who successfully worked on ladders without falling off. A compromise which allowed the successful application of statistical tests to the data was chosen, based on accepted practice in case-referent studies of disease — that of comparing cancer victims to hospital patients with diseases or problems other than cancer or of denoting liver cancer patients as cases and comparing them to patients with cancer of other body sites as referents. In this study, the cases were selected as those workers injured while climbing a ladder, and the referents were those workers who fell while working from a ladder.

At first glance this may seem an arbitrary basis for distinguishing cases from referents, but it is based logically, if not empirically, on the activities under investigation. The rationale is simply that the referent — the worker who falls while working directly from the ladder — has in some sense avoided the hazards of climbing the ladder, while the worker designated as a case has not. Clearly, this division entails several assumptions which can be called into question if analysis warrants. For example, if referents were injured partly as a result of events occurring *after* they safely climbed the ladder to the work site (eg, a gust of wind, extra weight added to the ladder), some of the differences, if any, would be accounted for. Thus one implicit assumption is that contributory causal factors are distributed equally over the time period encompassing the climbing and work activities. This point will be examined further in the discussion section.

Methods

Specifically, the sequence of steps followed in the analysis was the following:

1. All 1,419 observations were screened to ensure that those analyzed were homogeneous with respect to two factors, the type of accident (fall from ladder) and the distance fallen [4 feet (1.2 m) or greater]. This screening yielded 863 observations.

2. Further restrictions were applied to the 863 cases. A total of 174 was found to be coded as a fall while a worker climbed a ladder, and these 174 were designated as cases. Those coded as falls while a person worked directly from a ladder, 441 observations, were selected as the comparison or reference group. The combined case-referent series totaled 615 observations.

3. Tables were produced by a computer using the Statistical Analysis System (SAS 79) to compare cases and referents for each of the 64 remaining items of information.

4. The tables were produced a second time for all 64 items on the questionnaire, the ladder type being restricted to straight ladders only. This subgroup of 262 straight ladder observations was the largest single ladder type category within the 615 case-referent series.

Results

Tables 1 and 2 show that only 2 out of the 64 questions had answers differing significantly between falls while a worker climbed a ladder and falls while a person worked from a ladder. The first factor was ladder type, shown in table 1.

The percentage differences between the cases and referents shown in this table were the largest for step ladders and straight ladders, but permanently fixed ladders was the only category with a smaller frequency in the reference group than in the case group.

Table 1. Type of ladder by activity.

Ladder type	Activity at time of injury	
	Climbing ladder	Working from ladder
Step ladder	37	202
Job-made ladder	13	34
Permanently fixed ladder	21	8
Straight ladder	94	168
Other	9	29
Total	174	441

a Other includes side rolling ladders, type not specified, and type specified as other.
Chi-square = 54.999, significant at level p = 0.0001.

Table 2. Hardhat wearers versus nonwearers by activity.

	Activity at time of injury	
	Climbing ladder	Working from ladder
Hardhat wearers	58	81
Hardhat nonwearers	116	360
Total	174	441

Chi-square = 15.975, significant at level p = 0.0001.

Table 2 presents a comparison of the wearing of a hard hat between the cases and referents. Thirty-three percent (58 of 174) of those who fell while climbing wore hard hats, whereas only 18 % of the referents wore such hats. It should be noted that the question on the use or nonuse of a hard hat did not allow an interpretation of the role of hard hat use in causing or contributing to the accident.

A more suggestive factor is that shown in table 3, the nature of the surface supporting the bottom of the ladder. While

Table 3. Surface supporting bottom of ladder.

Surface	Activity at time of injury	
	Climbing ladder	Working from ladder
Soft surface (such as loose dirt)	13	71
Other surface [a]	161	370
Total	174	441

[a] Other surfaces include hard surface, slick surface, unstable base, nonlevel base, unknown, and other.

Chi-square = 7.877, significant at level p = .0050.

Table 4. Factors significant in the comparison of falls of persons climbing a ladder versus falls of persons working from a ladder, for straight ladders only.

Factor	Significance level
Wearing hard hat	$p < 0.02$
Surface supporting bottom of ladder	$p < 0.02$

Table 5. Use of hands on ladder by activity, for straight ladders only.

	Activity at time of injury	
	Climbing ladder	Working from ladder
Not holding on to ladder	9	64
Holding onto ladder with one hand	39	96
Holding onto ladder with both hands	46	8
Total	94	168

Chi-square = 77.530, significant at level p = 0.0001.

not as statistically significant as the factors of tables 1 and 2, the nature of the surface is a more likely candidate for a truly "causal" factor in the sense that changing or offsetting this condition prior to use of the ladder appears to be a plausible preventive action. Clearly, variables such as the use of hard hats and ladder type are structural antecedents to the task requiring a ladder, and as such are indirect statistical associations. It is not at all likely that donning a hard hat for a task not requiring one, or removing one where it is usually worn, would have an impact on the hazards of climbing or working from ladders.

Table 4 illustrates that, when the group of injuries was sorted and straight ladders were considered alone as a more homogeneous subgroup, both remaining factors from tables 2 and 3 remained significant, although at reduced levels of probability.

Table 5 shows a highly significant factor which, unfortunately, could not be evaluated in this study. Before the use of hands could be properly compared, the referents (workers who fell while working directly from the ladder) would have had to answer the question: "Were you holding on to the ladder while climbing it?" Since the question was not asked this way, it and several other questions relating to activity at the time of the accident could not be evaluated with this method.

Discussion

The results presented suggest several first-order conclusions: one, that falls from ladders are a diverse set of events which, nevertheless, can be studied fruitfully as a statistical aggregate if proper care is taken in the analysis; two, that, with respect to the characteristics covered by this survey, falls while a worker climbs a ladder are similar to falls while a person works directly from a ladder. One implication is that, on the average, many features of the work situation which might increase the risk of a fall are the same for these two activities.

A closer look at the results, however, reveals some methodological difficulties what warrant further discussion. Table 1 indicated that straight ladders were associated with falls while climbing, as were permanently fixed ladders, while falls from stepladders were distinctly associated with the reference group. Again, a first impression response is that straight ladders, and especially permanently fixed ladders, are often used for access alone and not as a work base, whereas stepladders are designed exclusively for their use as work platforms. This situation implies task and occupation differences which are, themselves, correlated with selection of ladder type and of course indicates that ladder type is not a causal factor as much as an explanatory variable.

Much the same can be said for the wearing of hard hats (table 2). Thirty-three percent of those injured while climbing wore hard hats, while only 18 % of the referents did. Aside from unlikely arguments that hard hats could restrict visibility or promote imbalance in the climber, this association is an explanatory one which suggests other differences, such as occupation, industry, or task, that could account for the outcome. Hardhat-wearing construction laborers and mechanics might often use ladders for access, while fruit pickers and other agricultural workers, not requiring head protection, work continuously on ladders as platforms.

One additional variable not available in this survey, that of exposure or time spent doing the designated activities, would undoubtedly add revealing information, and it is a basic epidemiologic study requirement in any case. But an argument can also be made that when design differences emerge in a case-referent study, they imply so many other potential differences that perhaps they should have been controlled for in the study design itself. That is, if matching of cases with referents is to be done, matching on designed or planned characteristics of the work situation should be a primary consideration.

In contrast with the previously presented logic, unplanned features of the work situation might not be expected by themselves to imply differences in other variables, at least not in the sense that major design factors do. The extension of this argument to the study outcome indicates that, if unplanned factors emerge as contributory conditions to accidents, they offer ready candidates for change or future preventive action. In this sense, they correspond to the highly variable, rapidly changing features characteristic of interacting systems of humans and the physical elements of the workplace. A suggestive analogy, furnished by Jorma Saari of the Finnish Institute of Occupational Health (personel communication), views these variable features as "software," as opposed to "hardware" — the fixed or slowly changing structural features of the workplace.

The nature of the surface supporting the bottom of the ladder is one illustration. Nonslip ladder feet represent one response to problems of slippage on hard floors, whereas tie-off means provide control when ladders are used on slippery or soft surfaces, such as soil or loose dirt. Table 3 showed that 8 % of the cases were soft surfaces at the time of the fall, while 16 % of the referents were on similar surfaces. This finding does not suggest that soft surfaces are created simply so that ladders can be climbed, but that compensation for the surface condition is a safety measure that perhaps needs more emphasis in all ladder-using tasks.

Table 4 illustrated that the factors distinguishing the cases from the referents for all ladder types remained significant when ladder types were controlled for. This result suggests that for straight ladders alone, major structural differences in occupation, industry, and task may have to be controlled before other contributory factors emerge.

A peculiarity of accident research as opposed to disease studies appears to be that the former requires that sequences of events and dynamic changes in the work situation be focused on, whereas disease studies, concerned primarily with health outcomes, rely more often on cumulative conditions and fixed physiological states. This situation is best illustrated by table 5, which points out the difficulty in comparing events at two points in time. The question as to the use of the hands during the use of a ladder is certainly one of the most suggestive factors included in the survey, but it could not be legitimately compared between the cases and the referents. There is no guarantee that a worker who fell while working from a ladder, partly because his hands were full when he slipped, was not holding on when he climbed the ladder.

This sequential characteristic of most industrial accidents and injuries has implications for study design and for generating hypotheses about accident causes. When a group of events or sequences of events, such as falls from ladders, are viewed as common expressions of underlying causal factors, cases that are alike in at least one particular — the event of the fall itself — are being categorized into one class. Yet as is clear from the data of this study and others, falls result in a variety of injuries and outcomes. Similarly, there is significant variety in the tasks, occupations, and other fixed features of the cases, even though they converge in sharing the fall-from-a-ladder characteristic.

For these reasons, it would appear to be critical to define beforehand whether event sequences with at least one common element or individuals who have been injured versus those not injured are being studied. The choice of comparison groups depends entirely on this decision, since a person not injured today could have been injured yesterday, or last month or last year. It seems clear that if referents are to be defined as those exposed for, eg, 3 a and never injured, the cases should perhaps be redefined as those injured for the first time in a similar period. To the extent that today's referent could have been yesterday's case, only the software aspects of causation can be studied — the dynamic, day-to-day changes and circumstances that are not predictable from the fixed structural features of the work.

Conclusions

Based on the analysis and the discussion presented, the following guidelines are suggested as working foundations for future case-referent studies of job injuries and accidents:

(a) Careful attention to sequences of events. Time relationships between causal events and outcomes demand close attention to exact details in the accident description.

(b) Consistency in defining cases and referents. To ensure that the study is comparing individuals, for example, cases and referents may have to be matched not only with respect to past exposure, but also to past history of accidents and injuries.

(c) Definition of what constitutes a case. Homogeneity among the injured persons studied with respect to demographic and stable features of work life should minimize design factors as direct causal factors and reveal instead those unplanned features that enter the causal chain to produce accidents.

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