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Human Behavior in a Matrix of Hazards: Risk, Rules, and Ratio in Biomedical Laboratory Safety

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Abstract

Laboratory safety presents special challenges in occupational safety and health management around the world. In scientific laboratories, all kinds of hazardous materials (biological, chemical, and radiological) are present—either individually or in some combination. Additionally, physical hazards in laboratories are ubiquitous and add to the overall risk faced by scientists, students, and the environment in all but the most benign settings. Managing the risks found in laboratories encompasses many aspects including safety rules, attitudes, opinions, and hazard and risk perception.

A comparative look at the safety and health concerns of biomedical research scientists in The Netherlands and the United States lead the authors to take a broad, international view of laboratory safety management. One empirical finding, a regulatory context, and one assumption underly this viewpoint. First, the safety and health concerns of biomedical research scientists in a Dutch research institution and an American research institution turn out to be similar in many respects. Second, the relevant laws and regulations in the European Union (EU) and the United States (US) form the basis of "rules" intended to address biomedical laboratory safety concerns. Rules, however, tend to cover only a portion of the concerns expressed by biomedical research scientists. Our assumption is that attitudes and opinions are also important determinants in the establishment of a balance—a ratio—between the hazards and the rules intended to manage those risks.

Based on this international view, the authors propose the development of a consensus-based international training curriculum and introductory program for biomedical research scientists covering relevant issues in health, safety, and environmental protection.

Introduction

Investigating the perception of risk and hazard from the perspective of the persons involved is a powerful tool for the safety advisor. With this tool, he or she can more accurately capture what defines risk in the workplace and how to manage safety and health programs. Including the perception of those served adds a descriptive element to what is an otherwise prescriptive activity. This study compares the perception of hazards and risks in biomedical research of biomedical scientists in two biomedical research institutions—one in The Netherlands and one in the United States.

In this article, a *hazard* is the potential for injury/illness, damage, or loss. *Risk* is the chance (likelihood of occurrence) of injury/illness, damage, or loss. Creating an inventory of risk is not straightforward, even for a well-trained safety advisor or an experienced scientist since the inventory must take into account an unlimited number of scenarios, each with some chance of occurrence. As safety advisors, we feel that the real (objective) risks (specifically, risk as defined in this article) can be elucidated by a ranked analysis of several individual (subjective) per-

ceptions, using a measurable risk most people accept—flying on a commercial airplane—for context. A knowledge of individual (subjective) perception is not only essential in finding the real (objective) risk, it is also important in the process of controlling risk through the creation of effective safety management strategies.

Materials and Methods

A questionnaire was developed and sent to biomedical scientists at Erasmus Universiteit Rotterdam and Dartmouth College in the fall of 2001. The research departments surveyed—organized differently at each institution—included the following disciplines: anatomy/pathology, biochemistry, genetics, microbiology/immunology, and pharmacology/toxicology. The questionnaire consisted of three sections: (1) thoughts and opinions related to laboratory safety; (2) hazard and risk perception in biomedical research laboratories; and (3) demographics. Data collection included Likert-type scales, numerical rankings, and categorical and numerical responses. A survey package consisted of a cover letter, a questionnaire, and a preaddressed reply envelope. By design, the survey distribution occurred within a day or two at each institution. Participation was strictly voluntary; there was no tracking or follow-up and all responses were anonymous.

Three hundred and eighty two questionnaires were completed and returned with an overall response rate of 50% (Erasmus N=212 and Dartmouth N=170). After twice checking for errors and omissions, a professional statistician analyzed the data using a PC-based version of SAS® Version 8 (Cary, North Carolina). The primary statistical methods included descriptive statistics (frequency and percentages), chi-square tests, and t-tests for differences between the two institutions among the demographic variables. Nonparametric tests calculated scale differences between Dartmouth and Erasmus for the risk and hazard survey questions (Conover, 1980). The accepted convention of any probability (p) less than 0.05 defined statistical significance.

Results

Characteristics of the Study Group: Demographics

Forty-eight percent (48%) reported working in an Erasmus or Dartmouth laboratory between zero and 3 years. Thirty-three percent (33%) were PhDs, 53% were supervisors, and 52% were male. The average age of the participants was 35. The average number of years in research science was 12.

The Perception of Risk

Assuming safety and health advisors in biomedical research universities agree that there is a substantial risk in laboratory science—do biomedical scientists share this view? Using a Likert-type scale, we asked if "concerns about laboratory safety are overstated" (Question 1). Twenty-nine percent (29%) felt to a greater extent that "Concerns...are overstated." Seven percent (7%) agreed and 1% strongly agreed with this statement. When asked about the safety practices of others, we found that 76% mildly agreed, agreed, or strongly agreed they were "sometimes concerned about the safety practices of others in [their] building" (Question 3).

Beyond individual perception of laboratory safety or concerns about their colleagues, we wanted to know how specific hazards and risks were likely to rank. The questionnaire included six activities common in biomedical laboratories covered (to a greater or lesser extent) by various rules and regulations in both the EU and US. How would biomedical research scientists rank these as hazards and risks and how they would perceive the differences among risks relative to each other?

While the responses to Question 13 were similar to the hazard rankings in Question 12, the perceived risks posed by laboratory chemicals were nearly tied with blood, body fluids, and unfixed tissues as the second greatest risk or alone as the fourth greatest risk. Similarly, radioactive materials nearly tied blood, body fluids, and unfixed tissues as the second greatest or third greatest risk. Finally, recombinant DNA technology (rDNA) and computer use ranked fifth and sixth, respectively. The usefulness of this finding resides in the discrepancy between perceived hazard and perceived risk for a specific issue—not the

Figure 1

Responses for Question 12 expressed as the percentage of individuals indicating that a given activity was a greater or lesser hazard.

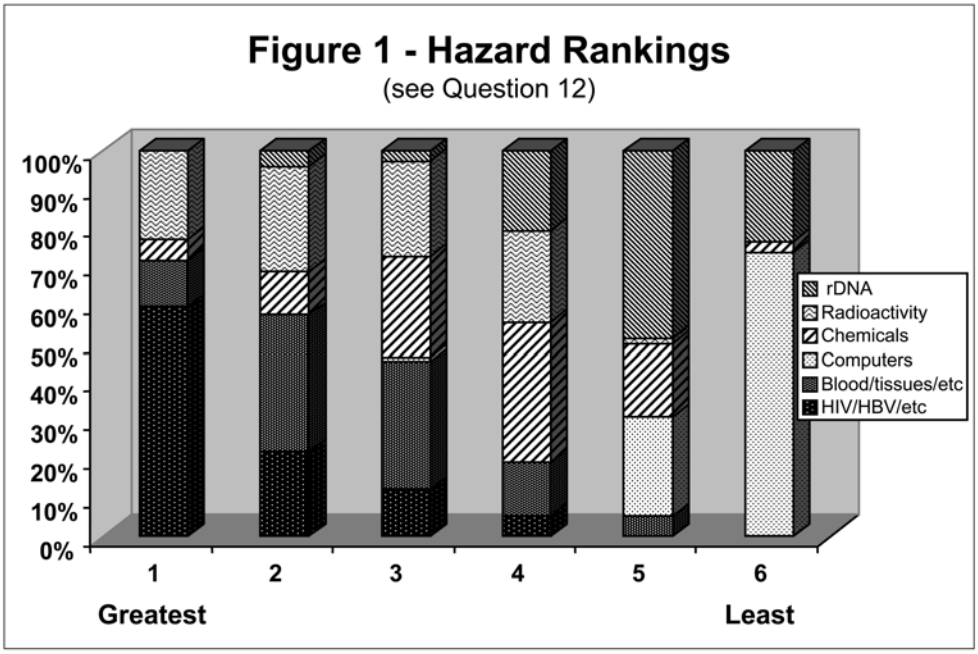
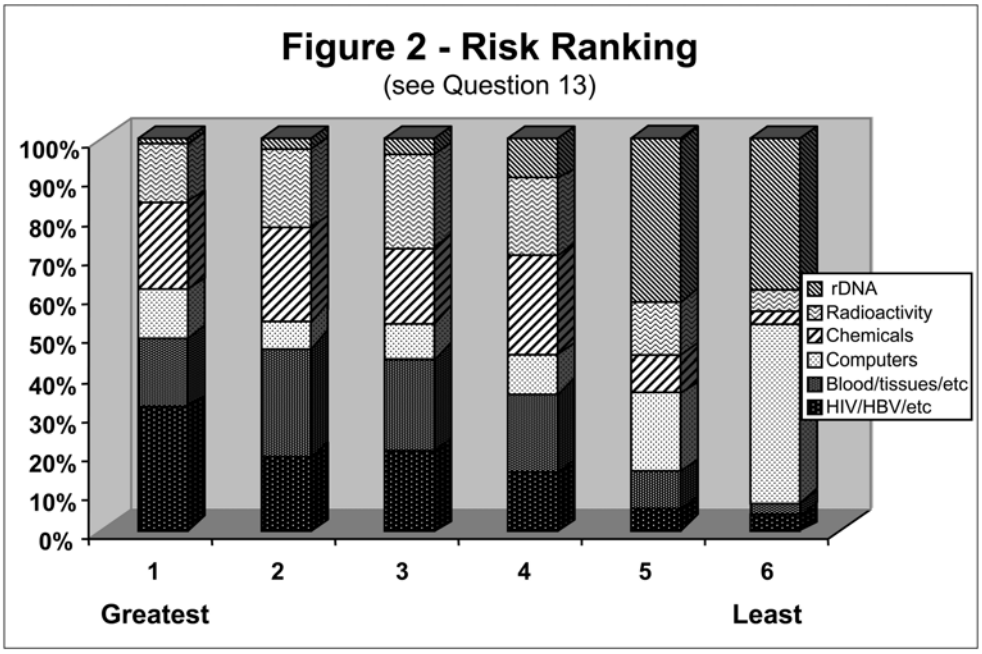


Figure 2

Responses for Question 13 expressed as the percentage of individuals indicating that a given activity was a greater or lesser risk.



relative ranking of one issue verses another. For example, take the issue of working on a computer more than 2 hours per day. While most of the scientists indicated that this was not especially hazardous when compared to the other issues, there was a discrepancy when it came to how it ranked as a risk. A reasonable conclusion from this difference is that too much computer use (repetitive strain injuries) is a potential concern to biomedical scientists.

We were also interested in the participants' views of the differences between the ranked risks. As an approximation, we asked if the highest risk was at least 100 times higher, about 10 times higher than the lowest, or just slightly higher. Fifty-one percent (51%) felt that the risk they ranked the highest was at least 100 times greater than the lowest. With this relative "risk-to-risk" ratio, we then asked the participants to compare their highest risk to a more objective and well-known risk—flying on a commercial airliner. Sixty-six percent (66%) felt that their highest risk posed a greater risk than flying on a commercial airliner once a year. Only 14% felt that their highest risk posed less of a risk than flying. [Note: The risk of death (death risk per flight) on a domestic commercial airliner in the first world from 1990-1999 was 1 in 13 million (Barnett, 2005).]

The Perception of the Safety Management System

A safety management "system" typically consists of several elements in greater or lesser proportion to one another. These elements include rules, inspections, management commitment, training, and adequate facilities. Thirty-five percent (35%) agreed to greater or lesser extent that "the government's rules and regulations of laboratories are burdensome and excessive" (Question 5). In Question 7, 87% felt that "periodic laboratory safety inspections" were either very important (43%) or somewhat important (44%). In Question 6, 82% felt that their "department (afdeling)" had "made a commitment to ensuring laboratory safety."

Sixty-four percent (64%) felt that "laboratory safety training (instruction)" is very important (Question 8). The three most preferred methods for laboratory safety training (in order) are: (1) web-based; (2) lecture; and (3) mentor (Question 9). Scientists at Erasmus preferred having a safety mentor while scientists at Dartmouth preferred web-based training ($p < 0.0001$). Not surprisingly, mentors play an important role in laboratory safety training at Erasmus, and web-based instruction at Dartmouth was well into its second year at the time of the survey. Eighty-three percent (83%) felt that their "laboratory facilities" were adequate (Question 10). Scientists at Dartmouth were generally happier with their laboratory facilities when compared to their colleagues at Erasmus ($p < 0.0001$).

Discussion

Biomedical research scientists and their safety and health advisors share the need for safety management programs in biomedical research laboratories. More than two-thirds (71%) of the respondents felt that "concerns...about laboratory safety" are ***not*** overstated." Ninety-five percent (95%) of the biomedical scientists we questioned felt laboratory safety training (instruction) was important and provided feedback on how they wanted to receive it. Ninety percent (90%) of the respondents also felt that periodic laboratory safety inspections are important.

In our study, biomedical scientists at Dartmouth and Erasmus ranked various risks in their work and indicated that they are not equal or inconsequential. The scientists surveyed ranked work with infectious agents and human-derived materials as the two greatest hazards in a biomedical research laboratory, feeling that their relative risk is between 10 to 100 times greater than excessive computer use (> 2 hours per day) or recombinant DNA technology.

Our results also indicate that the risks associated with the use of laboratory chemicals and excessive computer use (repetitive strain injuries) may merit more attention based on the discrepancy between their hazard and risk rankings. The relationship between hazard and risk ranking for radioactive materials is essentially the same. There is little concern over the hazard and risk of recombinant DNA.

Conclusion

Safety advisors managing laboratory safety in biomedical research laboratories may find that gauging the perceptions of those served insightful and potentially useful. Asking simple and probing questions is a good way to approximate the real (objective) risks in a research laboratory using a quantitative analysis of individual (subjective) replies and perceptions. Knowledge of individual (subjective) perception is not only essential in finding the real (objective) risk, it is also important in the process of controlling risk through the creation of effective safety management strategies. The collection and analysis of perceptions are especially useful in setting priorities and in gathering support for new programs and initiatives. The goal should be to create a balance or "ratio" between the "risks" and the "rules" (or means) to ensure an adequate research safety program. Based on this work, the authors believe that an internationally standardized curriculum for biomedical laboratory safety represents the best means to convey this balance. An updated curriculum and a new training program are under development by the authors. The training program will be available in late 2006 or early 2007. Individuals interested in learning more about this project are encouraged to contact one of the authors.

Acknowledgements

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Authors' Note

Parts of this study were included in a poster at the XVI World Congress on Safety and Health at Work in Vienna, Austria in May 2002.

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ERASMUS UNIVERSITEIT ROTTERDAM

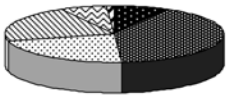
Dartmouth College

Directions: For each question below, please check the box or write your response as appropriate. Please complete each item. When finished, please return the form to us using the pre-addressed envelope provided. All the information is confidential–and once collected–cannot be linked to you or your laboratory. Your thoughtful responses to each question are valued and important. Thank you for your help.

Thoughts and Opinions
Please indicate your opinion in response to the following statements or questions…

1) Concerns about laboratory safety are overstated.

▨ Strongly Agree	**(1%)**	▩ Mildly Disagree	**(22%)**
▨ Agree	**(7%)**	■ Disagree	**(41%)**
▨ Mildly Agree	**(21%)**	■ Strongly Disagree	**(8%)**

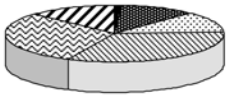


2) An introductory program in laboratory safety should be mandatory for all new research personnel at Dartmouth or Erasmus.

▨ Strongly Agree	**(36%)**	▩ Mildly Disagree	**(2%)**
▨ Agree	**(45%)**	■ Disagree	**(2%)**
▨ Mildly Agree	**(14%)**	■ Strongly Disagree	**(1%)**

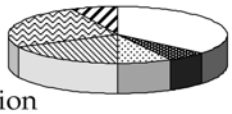
3) I am sometimes concerned about the safety practices of others in my building.

▨ Strongly Agree	**(13%)**	▩ Mildly Disagree	**(12%)**
▨ Agree	**(30%)**	■ Disagree	**(11%)**
▨ Mildly Agree	**(33%)**	■ Strongly Disagree	**(1%)**



4) The undergraduate curriculum at Dartmouth or Erasmus should include a greater emphasis on laboratory safety.

▨ Strongly Agree	**(7%)**	▩ Mildly Disagree	**(8%)**		
▨ Agree	**(25%)**	■ Disagree	**(6%)**		
▨ Mildly Agree	**(18%)**	■ Strongly Disagree	**(0%)**	☐ No Opinion	**(36%)**



5) The government's rules and regulations of laboratories are burdensome and excessive.

▨ Strongly Agree	**(3%)**	▩ Mildly Disagree	**(27%)**
▨ Agree	**(6%)**	■ Disagree	**(34%)**
▨ Mildly Agree	**(26%)**	■ Strongly Disagree	**(4%)**

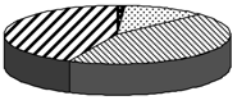
Note: Percentages were rounded as necessary.

6) My department ("Afdeling") has made a commitment to ensuring laboratory safety.

Strongly Agree	(7%)	Mildly Disagree	(10%)
Agree	(46%)	Disagree	(6%)
Mildly Agree	(29%)	Strongly Disagree	(2%)

7) How important are periodic laboratory safety inspections?

Very Important	(43%)	Little Importance	(12%)
Somewhat Important	(44%)	Not Needed	(1%)



8) How important is laboratory safety training (instruction)?

Very Important	(64%)	Little Importance	(5%)
Somewhat Important	(31%)	Not Needed	(0%)

9) Which two (2) of the following instructional methods would you prefer most for laboratory safety training? Frequency (F)

☐ Web Based	(152)	☐ Video	
☐ Written Materials		☐ Lecture	(147)
☐ Mentor	(101)	☐ Other_____	

10) My laboratory facilities are adequate.

Strongly Agree	(11%)	Mildly Disagree	(11%)
Agree	(50%)	Disagree	(5%)
Mildly Agree	(22%)	Strongly Disagree	(1%)

Perceptions on Laboratory Hazards and Risks

In this section we are interested in understanding your thoughts on the hazards and risks in your research.

For the following questions please use these definitions to guide your responses:

Hazard: the potential for injury/illness, damage or loss.

We use the term ***hazard*** if there is potential for an injury/illness, damage or loss, ignoring the likelihood of occurrence (chance).

Risk: the chance (likelihood of occurrence) of injury/illness, damage or loss.

We use the term ***risk*** if the chance of an injury/illness, damage or loss is too great to be ignored.

Taking these two definitions together . . .
Flying on a commercial airline is hazardous because the airplane might crash. Fortunately, numerous safety precautions are taken to reduce the risk.

A high hazard activity can therefore pose a low risk, assuming that enough precautions are taken. On the other hand, a low hazard activity can be a moderate or even high risk if inadequate precautions are taken.

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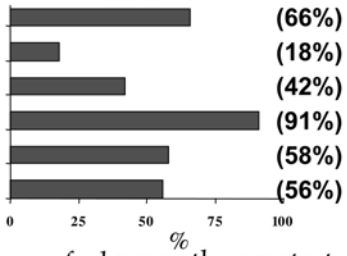
11) Does your work involve any of the following activities? (Please check all that apply.)

- ☐ Working on a computer more than two hours per day **(66%)**
- ☐ Culturing or manipulating infectious agents (HIV, HBV, etc.) **(18%)**
- ☐ Handling human blood, body fluids, unfixed tissues, etc. **(42%)**
- ☐ Handling laboratory chemicals **(91%)**
- ☐ Handling radioactive materials **(58%)**
- ☐ Use of recombinant DNA molecules **(56%)**



12) Please rank the follwing items by placing the number 1 by the activity you feel poses the greatest ***hazard.***

Please continue to rank the other activities by placing the number 2 by the second greatest hazard, the number 3 by the third and so forth. Please rank all the items. **See Figure 1**

- **6** Working on a computer more than two hours per day
- **1** Culturing or manipulating infectious agents (HIV, HBV, etc.)
- **2** Handling human blood, body fluids, unfixed tissues, etc.
- **4** Handling laboratory chemicals
- **3** Handling radioactive materials
- **5** Use of recombinant DNA molecules

13) Please rank the following items by placing the number 1 by the activity you feel poses the greatest ***risk.***

Please continue to rank the other activities by placing the number 2 by the second greatest risk, the number 3 by the third and so forth. Please rank all the items. **See Figure 2**

- **5/6** Working on a computer more than two hours per day
- **1** Culturing or manipulating infectious agents (HIV, HBV, etc.)
- **2/3** Handling human blood, body fluids, unfixed tissues, etc.
- **2/4** Handling laboratory chemicals
- **3** Handling radioactive materials
- **5/6** Use of recombinant DNA molecules

14) In this question we are interested in knowing how you feel the greatest risk (indicated by the number 1) in Question 13 compares with the lowest.

- ■ The highest risk is at least 100 times greater than the lowest **(51%)**
- ■ The highest risk is about 10 times greater than the lowest **(41%)**
- ▨ Just slightly higher than the lowest **(8%)**

15) In your opinion, the highest risk you indicated in Question 13 . . .

- Poses a greater risk than flying on a commercial airliner once a year **(66%)**
- Poses the same risk as flying on a commercial airliner once a year **(20%)**
- Is less risky than flying on a commercial airliner once a year **(14%)**

If there are other hazards and risks you feel are important to mention, then please attach a note to this form.

Demographic Data

How many years have you been working in a laboratory at Dartmouth or Erasmus?

- 0-3 **(48%)**
- 4-5 **(11%)**
- 6-10 **(16%)**
- 11-20 **(13%)**
- 20+ **(12%)**

Highest Education

- High School (HAVO/VWO) **(1%)**
- AA (HBO/HTO) **(27%)**
- BA/BS (Kandidaats) **(15%)**
- MA/MS (drs) **(17%)**
- PHD (Dr, Ir) **(33%)**
- MD (arts) **(5%)**
- Other **(2%)**

Total number of years in research science. $\bar{X} = 12$

Does your position involve supervising others in your lab? Yes **53%** No **47%**

Please indicate your age in years. $\bar{X} = 35$

Sex Male **52%** Female **48%**