CHAPTER 40

Research to Practice in Solving Ergonomic Problems*

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*The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

40.1 INTRODUCTION

For research to benefit society, it needs to be shared, communicated, and translated into policy and practice. Moving occupational ergonomic research effectively into practical application is a process that combines the generation of knowledge with the adoption of that knowledge in the workplace to enhance worker health and prevent injury and illness. Research that is not used cannot fulfill the twin goals of ergonomics: health and productivity.

Although still relatively new, the strategy of *research to practice (r2p)* is applied in various contexts within public health, medicine, and community action. It is increasingly called for in agency mandates and in organizational missions, strategic plans, priorities, and initiatives. This growing demand demonstrates the significance of ensuring that what is known is practiced to advance societal welfare. *r2p* is a strategy to ensure that research has an impact or makes a difference.

Not all research immediately results in changes in workplace practice. Often it takes incremental steps over time to change work practices to impact the safety and health of the entire workforce. Surveillance research leads to problem identification; basic research ultimately leads to intervention. Over time, our fund of knowledge increases, which can result in changes in workplace policies, programs, and practices. Being successful in getting one workplace at a time to implement change may influence further changes over the entire workforce. A broad understanding of how research can be applied to the workforce will help researchers design more research with greater impact.

The purpose of this chapter is to introduce the concept of *r2p* as it is conceived and implemented in the National Institute for Occupational Safety and Health (NIOSH), to describe r2p components, to share alternative models of research to practice, to present examples of how r2p concepts are applied to physical hazards by NIOSH scientists, and to provide a list of references.

The information presented in this chapter is primarily written from the NIOSH perspective of r2p. However, concepts of *r2p* from other science research agencies are also provided. When the term *r2p* is used in this chapter it represents the NIOSH view; when the term *research to practice* is used, it represents a view other than that of NIOSH.

40.1.1 Introduction to Research to Practice at NIOSH

In 2004, NIOSH, a part of the Centers for Disease Control and Prevention (CDC) in the U.S. Department of Health and Human Services (HHS), established an initiative that focused on the translation of research findings, technologies, and information into effective occupational safety and health policies, programs, practices, and products [1]. This initiative was referred to as *Research to Practice,* or *r2p.* NIOSH defines *r2p* as an interactive process in which occupational safety and health communities—research organizations, academic institutions, industry, trade associations, employers, and employees—work collaboratively to (1) prioritize research needs; (2) design, plan, and conduct research; (3) transfer research findings into the practice of occupational safety and health; and (4) evaluate results to determine the impact on the risk of injury and illness in the workplace. This process was designed with the intent to ensure NIOSH research has relevance, quality, and impact.

Since its inception at NIOSH, r2p has evolved and become well-integrated into the mission, intramural and extramural research programs, strategic plans, and National Occupational Research Agenda, called NORA [2].

The foundation for all r2p efforts is *collaboration with partners.* In occupational safety and health, a partner is an organization or person who is actively involved in efforts to help promote the movement of research into practice to prevent work-related injury or illness. A checklist of r2p components is provided in Table 40.1. It includes the major elements researchers may want to consider when planning for or describing their *r2p* efforts.

40.1.2 Alternative Models of Research to Practice

As many research institutions begin to transform the way they conduct and use their research, it is important to recognize how research to practice is conceptualized and operationalized in other research organizations.

At the Canadian Institutes for Health Research (CIHR), research to practice is conceptualized by the term *knowledge translation* (KT). Integrated in the CIHR mandate and strategic plan, KT is broadly conceived and is widely used in their 13 institutes to encompass all steps between the creation of new knowledge and its application to yield beneficial outcomes to society. KT is defined as the exchange, synthesis, and ethically sound application of knowledge, within a complex set of interactions among researchers and users [3]. The definition emphasizes the active exchange between creators of knowledge and users of knowledge during all stages of the research cycle. Effective and meaningful partnerships are emphasized in every KT activity. The seven stages of KT are research priority setting, research, knowledge priority setting, knowledge synthesis, knowledge distribution and application, use, and evaluation of uptake.

At the National Institutes of Health (NIH), the movement of research into practice is conceptualized by the term *translational research.* Translational research, designed around the biomedical research model, is infused as a priority in the *roadmap to medical research* [4], an NIH initiative to address barriers to research and to transform the way biomedical research is conducted by overcoming specific hurdles or filling defined knowledge gaps. Although each stage appears to work harmoniously, each phase differs in scientific context, partners, institutional support, goals, settings, study designs, and investigator skills [5]. As one of the 46 NIH Centers for Clinical and Translational Science, The Ohio State University Medical Center (OSUMC) envisions translational research as having up to four different yet interrelated phases. Phase 1 is often referred to as "bench to bedside" and seeks to move a basic discovery of disease mechanisms (i.e., basic science) into initial testing in humans (i.e., bedside). Phase 2 assesses the value of phase 1 applications for health practice, leading to the development of evidence-based guidelines. Phase 3 attempts to move evidence-based guidelines or practice-based research into practice through delivery, dissemination, and diffusion of research. Phase 4, translational research, seeks to evaluate the real-world health outcomes of a phase 1 application in practice [6].

Table 40.2 illustrates the core components of each of these three frameworks. Although not easily depicted, each framework conceptualizes research to practice as a nonlinear,

TABLE 40.1 Research to Practice Checklist: Components of Planning and Reporting

Partners

Partners for the research process (*may include different partners for each step*)

- Have a philosophy, a mission, and goals complementary to yours
- Are recognized as opinion leaders in their area of expertise
- Represent a diversity of thought and opinions
- Are trustworthy
- Will influence others
- Will contribute resources, either direct or in-kind
- Will benefit from the partnership

Funding source (*check one or more*)

- Employing agency or organization
- Partner(s), partially or in total
  - No conflicts of interest related to partner funding
  - Resolve existing conflicts of interest

Priority research needs (*check one or more*)

- Address an organizational priority need
- Address recognized gap in knowledge or practice
- Are based on surveillance or other data
- Are determined in collaboration with partners (*preferable*)

Research collaborators

- Involve in conduct of the research
- Determined to be scientifically competent and ethical

Transfer of knowledge and technology (*select the path to practice appropriate for research findings*)

Basic and applied research knowledge translation (*when pooled with other research knowledge and/or ready for workplace implementation*)

- Target audience
  - Identify
  - Needs, desires, and values
  - Motivations for change
  - Sources of influence
- Partners to assist
- Desired change
- Research translation methods
  - Diffusion
  - Dissemination of results
    - Submit to peer-reviewed scientific journal
    - Make available to other researchers via conference presentations and related mechanisms
    - Make available to standard-setting organizations, as appropriate
    - Engage partners in process

Research technology

- Report discovery or invention to employing organization
- Assess discovery or invention as to patentability and marketability
- Develop invention without assistance from external partners

or

- Seek partner(s) to develop invention
  - Acquire partners' signature on confidential disclosure agreement
  - Secure partnership intermediary
- Determine whether to patent
  - Is product or process unique?
  - Will patent advance goals of organization?
  - Market analysis
  - Economic analysis
  - Industry investigation
- Develop prototype or working model
- Identify target companies who may be intereste commercializing product

TABLE 40.1 (continued) Research to Practice Checklist: Components of Planning and Reporting

Social networks (e.g., blogs, Wikipedia)	Seek assistance from partnership intermediary
Multichannel communication	Prepare "sales" plan
Health communication/marketing	Authorize personnel to negotiate licensing agreements
Integrated knowledge translation	Collect royalties
Implementation science	
Unified strategic plan: develop and communicate to all parties	
Challenges and opportunities	
Goals	
Measureable outcomes	
Communication strategy	
Evaluation measures	
Resources	
Impact	
Involve partners in evaluation effort	
Determine and implement evaluation measures	

TABLE 40.2 Frameworks of Three Health-Research Agencies, Designed for Moving Research into Practice

	Framework of Agency Concept		
Phase	**NIOSH [1] Research to Practice**	**CIHR [3] Knowledge Translation**	**NIH [4] Translational Research**
1	Prioritization of research needs	Research prioritization	Bench to bedside
2	Designing, planning, and conducting research	Research	Health application to evidence-based practice guidelines
3	Transfer of knowledge and technology	Knowledge prioritization	Practice guidelines to health practices
4	Evaluation of impact	Knowledge synthesis	Practice to population impact
5	None	Knowledge distribution and application	None
6	None	Use	None
7	None	Evaluation of uptake	None

iterative process. Each framework also emphasizes partnerships and the need to bring together creators and users of knowledge at each phase within the process.

All phases, in both r2p and KT, are cyclical and can be applied to both basic sciences and applied sciences. In translational research, the phases differ according to scientific context and are specific to the type of research being conducted. In addition, the types of research, users, and products are distinctive. For example, phase 1 involves basic research, phase 2 involves applied science, and phase 3 involves implementation science.

In the frameworks of both NIOSH and CIHR, the process starts with prioritizing research needs and the second phase involves conducting research. It is in the subsequent phases that the two frameworks start to move in different directions. NIOSH moves to knowledge transfer, but CIHR cycles back to prioritizing research-based knowledge and then moves to knowledge synthesis. CIHR begins to disseminate or distribute the information to users in

phase 5, which is similar to the NIOSH phase 3 (knowledge transfer). The transfer mechanism in NIH translational research is not explicit and appears to be inherent in the process. Evaluation consistently is the last component; in the NIOSH framework, this is the fourth and final phase, involving evaluation of impact. In the CIHR framework, it is the sixth phase, involving evaluation of the uptake of research. And in the NIH framework, it is the fourth phase in which evaluation of health outcomes actively involves another phase of research (implementation research).

Other notable differences between the three programs may be related to their origins and ideology and to their financial, legal, and organizational support for *r2p* initiatives. These and other combined elements affect the extent to which a researcher, a program manager, or an institution can have an impact on health outcomes. As the previous comparisons illustrate, the concept of research to practice has evolved within and throughout health science research organizations. These large, health-related organizations continue to build upon their institutional frameworks to transform the way research is conducted.

40.2 PARTNERSHIPS

Collaboration with partners is a basic tenet of NIOSH r2p. Partnerships support, enhance, and advance research. Forming long-lasting, productive partnerships is essential in demonstrating and sustaining impact in the workplace [7,8].

A partnership is a collaboration, either formal or informal, between two or more individuals or organizations to work together toward mutually beneficial goal(s). Partners can contribute to the goals by sharing people, funds, property, or knowledge. There are many types of collaborations for mutual benefit, for example, partnerships, coalitions, or alliances. Unless it is a legal partnership, the label is not as important as how the collaboration is defined by the partners. Formal partnerships generally are bound by a written agreement in which the roles and responsibilities of each partner are delineated. Informal partnerships involve no signed agreement, and the roles and responsibilities of each party are more flexible.

The ultimate goal of partnerships is to identify and advance research and/or implementation objectives. The most fruitful partnerships are those in which all partners have the same vision and work together to accomplish more than any party could on its own. Every successful partnership takes time to develop and may be difficult to maintain [7]. Certain questions should arise when individuals and groups are considering a partnership [7,9]:

1. Are the philosophy, mission, and goals of all the partners compatible?
2. Are the partners recognized as thought leaders in their areas of expertise? Will they bring credibility to the project? Can they contribute intellectually? At what stage of research are the potential partners most needed?
3. Do the partners represent a diversity of thought and opinion? Have partners from government, academia, industry, labor, and professional practice associations been considered? Is there added value in including international partners?
4. Can you rely on partners to maintain confidentiality, protect proprietary information, and contribute fairly to the contributions, risks, and rewards of the activity?

5. Can the partners bring other necessary collaborators to the partnership? Will all partners advocate for and support change in the way people think and act as related to worker safety and health?
6. Are the partners potential diffusers of knowledge?
7. Do the partners have the necessary resources, either direct or in-kind, to contribute? Will the partners support scientific independence if they also provide funding? [10,11]

Having a diverse cadre of partners is a valuable asset to any research organization. Although it is tempting to rely on people who are "friends" of the scientist or research institution, the added value of bringing in new thoughts and perspectives in solving a problem from outside the scientists' circle cannot be overstated.

For r2p efforts to be most successful in protecting workers, partners should be involved throughout the research process. The right partners must be matched to each stage of research. For example, a partner who helps define the scope of the research may not be qualified to be involved in the actual conduct of the research. Similarly, a collaborating scientist who helps conduct the research may not be the best partner to assist in developing the dissemination strategy. Partnering with subject matter experts—who may not be scientists, but might be the workers themselves—always helps to ensure a successful r2p venture. Table 40.3 shows the different roles of partners and describes some common concerns with the involvement of partners in the research cycle.

TABLE 40.3 Involving Partners in Each Stage of Research to Practice: Roles, Concerns, and Strategies

Stage of Research to Practice	Role of Partner	Concern and Strategy
Identifying priority research needs: identify the most important occupational health and injury issues facing workers	Identify the problem to be addressed; help to demonstrate need for research; or help articulate a specific research or practice gap	Partner may focus on personal interests and needs rather than research priorities; address this risk by including a range of partners with varying interests
Designing and conducting research	Assist in planning the research protocol and/or serve as a member of the research team	Scientific integrity may be compromised or research ideas may be taken; carefully select and monitor partners to prevent this occurrence
Transferring knowledge and technology: use communication science (for knowledge) and technology transfer principles (for inventions) to guide the movement of research into the workplace	Synthesize and convert the research findings into regulatory requirements, consensus standards, professional practices, other workplace recommendations, or equipment or processes; distribute research findings to specific target audiences	Partner may overemphasize or underemphasize certain research findings; address this risk by including a range of partners with varying interests
Evaluating impact: build data collection into each research effort to determine effectiveness in preventing workplace injury and illness	Assess the research to determine workplace impact	Partner may try to sabotage, distort, or discredit research findings; avoid this by resolving conflicts as they occur

40.3 IDENTIFY PRIORITY RESEARCH NEEDS

Involving partners in the research process begins by identifying a research topic in cooperation with those who will be affected by or will use the research findings. Traditionally, new research ideas emerge from a variety of sources, including personal or organizational interests, surveillance data, recognized knowledge or practice gaps, and literature reviews. Following the r2p concepts, researchers work in collaboration with partners to use traditional methods in identifying research topics. Jointly identifying and agreeing on a research topic and research approach with partners can help to further refine the topic and increase its relevance to those who will benefit from or use the findings.

Obtaining or combining research funds from outside partners is an obvious way to expand research dollars. Researchers must use caution when accepting funds from commercial partners, to avoid or minimize conflicts of interest. Full disclosure of the role of each funding party must be made at the time of publication.

r2p IN ACTION

Physical hazard: Nurses and other health care workers have reported thumb and wrist issues related to opening pill packages (personal communication)

r2p Component addressed: Identify priority research needs

Description: A NIOSH partner, an occupational health supervisor, reported to NIOSH that many nurses and pharmacists in her health care system had described thumb and wrist issues resulting from opening pill packages and containers. These issues were especially noted by workers who are required to open many pill packages each day. The nurses use force to push the pills through the packaging because they are not allowed to use a knife or other implement to open the packages. In addition, the lids on pill containers often are tight and require extreme effort to open. The partner wondered whether NIOSH would be interested in researching this issue to identify preventive strategies.

Following the r2p concepts, NIOSH investigated whether this issue was a priority research need. The investigation was accomplished by reviewing national surveillance data to determine whether such injuries were commonly reported. No such surveillance data were found. NIOSH also contacted other partners, such as a national nurses association and a national association representing occupational health professionals, to learn if their constituents had reported this problem; it was not a known concern for either association. The Food and Drug Administration (FDA) was consulted and referred NIOSH to pharmaceutical manufacturers, because it does not deal with packaging. An Internet search identified two patents for devices to open pill (compressed tablet) containers and two inexpensive devices that were marketed as solutions for individuals taking medications. In conversations with pharmaceutical companies, NIOSH learned that developing a tool to assist with opening the containers would not be easy, because of variations in sizes from different vendors. NIOSH also learned that research was already being conducted elsewhere to address this problem.

NIOSH, in collaboration with many partners, determined that thumb and wrist issues related to opening pill packages were not a priority research topic at the time.

40.4 DESIGN AND CONDUCT RESEARCH

Involving partners in the conduct of the research can lend credibility among the target audience, which may help when research results are translated into practical solutions. Another benefit of involving partners in this stage of the research is that they may facilitate access to the study cohort. Maintaining scientific integrity is essential during this phase, and many scientists are hesitant to allow outside partners to participate in the actual research process so as not to taint the research findings. In addition, researchers do not want to take the chance of having their work or ideas stolen. Carefully selecting partners and monitoring their involvement can alleviate the concern.

r2p IN ACTION

Physical hazard: Occupational lower-back disorders are among the most common health problems facing society [12].

r2p Component addressed: Design and conduct research

Description: NIOSH formed a research team to develop a revised lifting equation as a practical analysis tool for evaluating the physical demands of two-handed manual lifting tasks. The research team included NIOSH scientists, academicians, and industry professionals, including national and international subject matter experts in the fields of biomechanics, epidemiology, and ergonomics. The research team collaboratively reviewed scientific literature, developed the lifting equation, and disseminated the tool.

The research team decided on the format and scope of the equation and chose the critical factors to be included. In addition, a series of evaluations and a peer review were conducted to examine the reliability and accuracy of the equation.

The result of this collaboration was the revised NIOSH *lifting* equation [13], an analysis tool consisting of two equations for estimating the recommended weight limit for a specified manual lifting task and a lifting index for estimating the physical demands of the job.

40.5 TRANSFER KNOWLEDGE AND TECHNOLOGY

To produce high-impact outcomes, it is necessary to carefully plan the transfer of research-based knowledge and technology. The transfer of knowledge or technology involves sharing and exchanging information among all relevant parties. However, there are distinct differences between knowledge transfer and technology transfer. The following introduces these two areas of research transfer and the necessary steps to plan for effective outcomes.

40.5.1 Knowledge Translation

As described earlier in the chapter, knowledge translation and research to practice may be perceived as having the same meaning, but they may have slight differences according to their organizational processes and scientific context. Knowledge translation is broadly conceived as a comprehensive process that includes dissemination, communication, technology transfer, knowledge utilization, implementation research, and exchanges between researchers and those who apply the knowledge [3]. The term *knowledge translation* is

widely applied within multiple disciplines, such as medicine, public and global health, health services, and disability and rehabilitation.

As the research to practice process grows to engage multiple disciplines, the terminology used to describe the process and the associated activities evolves to become more refined and precise. The processes are often tailored to the areas of specialty, which can lead to confusion in thinking and speaking about the concepts. Terms frequently used in scientific literature and in academia to describe research to practice activities include diffusion, knowledge transfer, communication, research utilization, knowledge exchange, and dissemination. These terms are interrelated and may often be interpreted as having the same meaning; however, there are some distinctions between the terms and in how they are used in describing research to practice activities. These terms, defined in Table 40.4, will become more useful and relevant during the planning and discussing activities related to research to practice.

The goal of all occupational research to practice efforts is to improve worker safety and health. Achieving this goal will require incremental steps, such as first getting one company—and then many—to implement a workplace intervention. To achieve either the incremental or ultimate goals, social change principles can be used. Adapted from Siegel and Doner [14], the remainder of this section provides guidance on how to plan the transfer research knowledge using the seven social change principles.

40.5.1.1 Craft an Intervention That Will Impact Behavior

When research is created without considering its relevance to all users at each stage of the research process, a gap can be created between what is known in the research community

TABLE 40.4 Research to Practice Terminology

Terminology	Definition
Communication	A process in which participants create and share information with one another in order to reach a mutual understanding
Diffusion	A process by which an innovation is communicated through certain channels over time [15]
Dissemination	A function of communication; the process through which tailored information about research-based knowledge, interventions, or technologies is transferred to target audiences through preidentified communication channels
Knowledge exchange	A collaborative problem-solving between researchers and decision-makers that happens through linkage and exchange. Effective knowledge exchange involves interaction between decision-makers and researchers and results in mutual learning through the process of planning, producing, disseminating, and applying existing or new research in decision-making [3]
Knowledge transfer	A broad, overarching term describing the exchange of research results, skills, or good ideas between research organizations, industry, and other relevant parties to enable the development of innovations aimed to improve occupational safety and health for all workers [1]
Research utilization or knowledge utilization	The uptake of research findings; a complex process in which research-based knowledge is transformed from the findings of one or more studies into instrumental, conceptual, or persuasive utilization

and what is practiced in the workplace. The challenge for researchers is to think beyond the end points of the originating research stage (e.g., the technology development). Another challenge researchers may face is the balance between promoting research (selling what you can make) and marketing research (making what you can sell). Moving research through each stage, from basic to applied research and then to organizational practice, requires futuristic thinking. It involves understanding the relevance of the research to all potential users. Comprehensive planning of research translation requires

- Iterative planning
- Effective partners at each stage
- An understanding of the environment in which the innovation and intervention will operate
- An understanding of the innovation
- Identifying and understanding the target audiences

40.5.1.2 Be Theory Driven

Theories and frameworks can play important roles in shaping how occupational safety and health knowledge, interventions, and technologies are used. Theories are helpful for explaining how a worker, work organization, or industry may respond to a new technology, recommended work practice, or recently identified hazard. Frameworks are helpful for developing strategies for improving worker health, selecting the optimal target audience, setting reasonable objectives, and tailoring interventions to the unique needs of the target population. Both theories and frameworks can be used to effectively transfer research at each stage of the research process. Two of the most popular and widely used theories are described hereafter.

40.5.1.2.1 Diffusion of Innovations Developed by Everett Rogers in 1964, the diffusion of innovations theory [15] has been widely studied in a variety of settings and disciplines. It consists of four main elements: an innovation, communication channels, time, and a social system. Combined, these elements explain a process by which an innovation is communicated through certain channels over time among members of a social system. When innovations are preventive (e.g., industry work practices to prevent back injury), the rate of adoption is expected to be slow. Variables determining the rate of an innovation's adoption include the following: perceived attributes (i.e., relative advantage, compatibility, complexity, trialability, and observability); type of innovation decision (e.g., optional, collective, or authority); communication channels; nature of social system; and extent of the change agents' promotion efforts.

The innovation-decision process involves the time component and explains at which of these five time-ordered steps individuals or decision-making units occur: knowledge, persuasion, decision, implementation, or confirmation. Populations (individuals or decision-making units) are divided into six categories based upon their rate of adoption: innovators, earlier adopters, early majority, later majority, late adopters, and laggards.

A researcher may consider using Rogers' diffusion of innovations theory in the planning stages to help identify the innovation's rate of adoption, where the target audiences are in terms of adopter categories and in the innovation-decision process, and what type of diffusion network exists for seeking potential partners.

40.5.1.2.2 Social Marketing Social marketing provides an audience-focused and theory-driven approach to developing and implementing a research program, technology, or intervention. On the basis of commercial marketing principles, social marketing can be used to transfer occupational safety and health research. Although there are several extensive, comprehensive frameworks for applying social marketing theory, only the key concepts of social marketing are discussed here. These are the five key principles [16]:

1. Understand everything from your audience's perspective—including your partners'. This is the consumer orientation of social marketing. Understand how consumers think, what they do, what they value, and what they like and dislike about the innovation.
2. Define a specific, simple action that you want your audience to take.
3. Understand the exchange. What is it that you want your audience to give up in order to adopt your research or technology? What are the benefits that matter to them? What is the competition for the behavior you are encouraging?
4. Define the marketing mix, otherwise known as the 4 Ps:
   a. Product: the behavior, idea, good, or service that is exchanged with the target audience for a price and may be tangible or intangible.
   b. Price: the target audience's cost for making the behavioral change.
   c. Promotion: the selected media of communication for behavioral change.
   d. Place: where the target audience members will be when they engage with the product.
5. Monitor and evaluate the progress of your efforts. This will help you determine whether the directions and decisions you made are moving in the expected direction.

40.5.1.3 Know Your Target Audience

A target audience is a small part of the population that shares similar characteristics, such as demographics, perceptions, behaviors, wants, readiness to change, and channels [17]. Target audiences inform the researcher on how the innovation or research is perceived in the desired setting and may provide insight into how likely the research is to be adopted or received. Segments are subgroups of the target audience that have similarities in a variety of dimensions (e.g., geography, lifestyle, and behavioral characteristics).

At each stage in the research cycle it is important to understand and select the target audiences that will likely be impacted by the research. These are some questions to ask: (1) Who are the potential target audiences? (2) what are the sizes of these audiences?

TABLE 40.5 Potential and Existing Target Audiences of Occupational Safety and Health Research and Rationales for Engaging Each Group

Target Audience	Rationale
Academia	Potential collaborators
Employers	Key decision-makers in the workplace
General public	Advocates to decision-makers
Government agencies	Potential collaborators; regulators
Industry associations	Potential collaborators, adding credibility and prestige; key influencers of the workplace
International health organizations	Potential collaborators, adding credibility and prestige
Labor organizations	Potential collaborators, adding credibility and prestige; key influencers of the workplace; provide access to new audiences
News media	Communication networks
Nongovernment organizations (private and not for profit)	Potential collaborators; have established communication networks with decision-makers
Policy-making officials and organizations conducting similar research	Potential collaborators; have established communication networks with decision-makers
Professional organizations	Potential collaborators, adding credibility and prestige; provide access to new audiences
Worker advocacy groups	Potential collaborators, adding credibility to audiences; key influencers of the workplace; have established communication networks with decision-makers; provide access to new audiences
Workers	Key influencers in the workplace

Source: Canadian Population Health Initiative, An environmental scan of research transfer strategies, http://secure.cihi.ca/cihiweb/products/EnviroScan.pdf, (accessed January 30, 2011), 2001; National Institute for Occupational Safety and Health, Research to practice at NIOSH, http://www.cdc.gov/niosh/r2p, 2009.

(3) why does each target audience engage in its respective behavior? (4) what are their needs, desires, and values? (5) what is the cost to the audiences for exchanging their current behavior for the desired behavior? and (6) who is most likely to influence the audiences to accept research-based knowledge or adopt recommended behavior?

Table 40.5 shows potential and existing target audiences of occupational safety and health research and a brief rationale for engaging the groups. This list was modified on the basis of findings from the Canadian Population Health Initiative [18] and NIOSH [1].

40.5.1.4 Set Realistic Expectations

Establishing occupation-based social change takes time, especially for innovations providing longer-term benefits (e.g., use of a computer keyboard). When developing a plan for change or implementing research into practice, researchers need to consider three factors that influence the uptake of research: the innovation, the potential adopter(s), and the setting or social context [19]. These factors, combined with external, uncontrollable factors, may affect the success or failure of the effort.

40.5.1.5 Create a Unified Strategic Plan

A strategic plan describes how the innovation, intervention, or research-based knowledge is expected to work. It identifies who it should reach, what action people are expected to take, and how the strategies are expected to bring about action [14]. A strategic plan helps

all parties involved understand their role and what is planned. This is meant to change over time to reflect current knowledge. The components of a comprehensive strategic plan include the executive summary, background and mission challenges and opportunities, goals, measurable outcomes, communication strategy, and components for implementing and evaluating the strategy. When developing a strategic plan with partners, it is critical to (1) ensure agreement of all players on the need for change; (2) define the nature of the evidence for change; (3) describe the methods, including evaluation of the impact of the change; and (4) determine who is responsible for each of the components.

A communication strategy is a subcomponent of the strategic plan and describes how the research-based knowledge, technology, or innovation will be framed or positioned for target audiences. Communication specialists may help researchers develop effective communication strategies for transferring their innovations.

TABLE 40.6 Hierarchy of Knowledge Translation Methods, Based upon Normative Standards at NIOSH

Knowledge Translation Method	Rationale
Diffusion	A one-way, passive form of communication. Focusing on reach and access, it is used to ensure research is accessible and available for wider, undefined audiences. Content is informative and broad in context. Examples include press releases, television, and Web site postings
Dissemination	A one-way, targeted, active form of communication. Also focusing on reach and access, it is used to ensure research is available and accessible for audiences that are more defined. Examples include trade publications, professional presentations, and peer-reviewed publications
Social media	A newer and advancing means of communication, emphasizing a two-way exchange of information that focuses on depth and credibility. Audiences are defined according to channel style and access to information; thus, they are segmented by their likelihood to seek, receive, and interact with information initially sent. Examples include blogs, Wikipedia, Flickr®, Facebook, and Twitter
Multichannel communication	A combination of the previous methodologies, with the intent to address all or most factors of communication (access, reach, target audience, depth, credibility, and agenda setting). It is known to have more success in reaching a broad audience
Health marketing and communication	Creating, communicating, and delivering health information and interventions by means of customer-centered and science-based strategies to protect and promote the health of diverse populations [34]. It involves a planned application of behavioral and/or organizational change theories
Integrated knowledge translation	The shaping of the exchange of research-based knowledge by senders and users. Stakeholders or potential research users are engaged in the entire research process [35]
Implementation science	The scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, hence to improve the relevance and impact of occupational safety and health research. It assesses and explains questions pertaining to the design, administration, operations, and outcomes of social programs: What is happening? Is this happening expected or desired? And why is it happening as it is?[a]

[a] Unpublished material.

Table 40.6 provides a description of knowledge translation methods. These general communication strategies provide a hierarchical approach, where the complexity of communication exchange (to educate or to persuade) increases between the senders and receivers of information in each consecutive stage. More planning and technical skills are also needed as the stages progress.

40.5.1.6 Leverage Resources and Relationships

Many scientists agree that involving partners at the transfer stage is crucial. Fundamental to understanding and enhancing the process of transferring research to practice is a comprehensive understanding of how all stakeholders at each stage of the research cycle receive and interpret research-based knowledge. Partnerships and collaborations with stakeholders are critical to help bring about change. Partners can provide additional resources, reach audience members, and add credibility and expertise that your organization may not possess [14]. Effective partnerships take time to form and build trust. Refer to the partnership section for questions to consider when selecting and planning for partners.

40.5.1.7 Build in Evaluation from the Start

Research programs are increasingly called upon to demonstrate their value or impact. When developing an r2p plan at the start of the research effort, it is important to build in evaluation. It is also important to involve partners in evaluation planning to help ensure shared goals and successes. During this planning stage, determine what you will measure, how you will measure, and when you will measure your success.

r2p IN ACTION

Physical hazard: Patient handling and movement are recognized as the primary causes of musculoskeletal disorders in nurses [12].

r2p Component addressed: Transfer knowledge

Description: NIOSH partnered with a national nursing association, external researchers, and schools of nursing to develop, evaluate, and transfer an evidence-based training program targeted to educators at schools of nursing. NIOSH researchers, in collaboration with partners, designed the *safe patient handling and movement curriculum* [20] to teach nursing students about the risks involved in manually lifting patients and to educate students on safe patient handling and movement. The new curriculum moved away from the traditional curriculum of body mechanics and manual lifting to an evidence-based curriculum that focused on equipment-assisted safe patient lifting.

The research products were theory driven, guided by the theory of planned behavior [21]. Products were targeted to two specific audiences: nurse educators and students at schools of nursing throughout the United States. The knowledge transfer occurred through peer-reviewed journal articles [22,23], presentations at the Safe Patient Handling and Movement Conference, and curriculum modules posted on the Web sites of NIOSH and various partners.

40.5.2 Technology Transfer

The following section relies heavily on information contained in the *FLC technology transfer desk reference*, as prepared by the Federal Laboratory Consortium for Technology Transfer (FLC) [24].

One important tool for moving research findings into practice is technology transfer. As defined by the FLC, technology transfer is a process by which an invention or innovation developed in one place or for one purpose is applied and used in another place. The U.S. government has actively supported and encouraged the transfer of federally generated technologies, with the ultimate purpose of fulfilling public and private needs. The phrase *technology transfer* most often refers to transfers occurring between federal laboratories and any nonfederal organization, including private industry, academia, and state and local governments. The technology transfer process is not solely limited to the transfer of federal research but encompasses the general transfer of innovations and discoveries from inventors to the marketplace.

Technology transfer programs help to maximize the impact of research activities and to increase the return on investment of the research and development budget. For federal research laboratories, technology transfer programs assist in meeting agency mission requirements and enhance the competitiveness of the United States in the world economy.

The technology transfer process involves a research laboratory, a user of technology, and an interface that connects the two to facilitate movement of the technology from one organization to the other. Sharing among federal laboratories, private industry, and academia includes not only technologies, but personnel, facilities, methods, expertise, and technical information. This process has been made easier through the use of the Internet. Many individuals and organizations seek assistance in promoting and sharing inventions through Web sites dedicated to matching inventors with organizations that can produce and market the product.

40.5.2.1 Technology Transfer Benefits

According to the FLC, technology transfer has had an impact on fostering mutually beneficial partnerships between industry and federal laboratories. Government, industry, and academia all benefit from a strong technology transfer program:

Government: Technology transfer activities can be used to assist in accomplishing mission-related activities by moving technology out of the laboratories and moving technical expertise into the laboratories.

Industry: The business partner can leverage research and development (R&D) costs by building on the relevant R&D already done in federal laboratories.

Universities and nonprofit organizations: These entities can benefit financially from technology transfer partnerships. Individual researchers may benefit intellectually from the close contact with leading researchers in both government and industry.

40.5.2.2 r2p Technology Transfer Procedure

An invention can be either a product or a process. Every research laboratory and organization should have an established process for bringing inventions to market. What follows is

a simplified, generic description of the technology transfer procedure for an invention, as implemented at NIOSH. The step-by-step process in the example is only for illustration; in actuality, the steps may be combined or followed in a different order.

Step 1: Report the discovery or invention

A scientist believes he or she has discovered a new product or process and reports it to the employer. An assessment is made of the patentability and marketability of the invention. A comprehensive market and economic analysis is conducted. The market analysis will determine whether the product or process is already in the market, whether it can significantly improve what is available, and whether the market will welcome the invention. The economic analysis will determine whether the cost of producing the product or process is comparable to what it might yield in income [25].

Step 2: Seek partners

After the product or process has been identified as novel, it can now be developed in-house or in collaboration with external partners. If seeking external partners, the scientist will look for partners with common research goals and, to protect the invention, will require potential partners to sign a confidential disclosure agreement. In such an agreement, each party agrees to recognize the confidential information and employ all reasonable efforts to maintain the confidential information of the other parties. A confidential disclosure agreement is critical to preserving U.S. and international patent rights [26].

Step 3: Decide whether to seek patent protection

A patent for an invention is the grant of a property right to the inventor, issued by the U.S. Patent and Trademark Office (USPTO) [27]. Generally, the term of a new patent is 20 years from the date on which the application for the patent was filed in the United States or, in special cases, from the date an earlier related application was filed, subject to the payment of maintenance fees. U.S. patent grants are effective only within the United States, U.S. territories, and U.S. possessions. Under certain circumstances, patent term extensions or adjustments may be available. A U.S. patent does not protect an invention internationally; additional procedures and costs are associated with an international patent [27].

The inventor and the employer may seek assistance from public or private individuals or companies who will conduct patent searches and provide assistance in the patent process.

Not all inventions can or should be patented. The patent process is long and costly. Many more products or processes are invented than can be supported in the market. When deciding whether or not to patent, consider the following [25]:

1. Is the product or process unique? To be patentable, a product or process must be novel. Also determine the potential life expectancy of the product or process. If the market for the invention is volatile or quickly advancing, it may not be cost-effective to patent the invention.
2. Has a market analysis been conducted? If there will be insurmountable hurdles to getting the product to market, it may not be feasible to seek patent protection.

3. Has an economic analysis been completed?

4. Will the patent be of value to a commercial partner?

Step 4: Commercialize the product or process
To begin the commercialization process, the inventor develops a prototype (usually functional) to show to companies to solicit interest. The prototype might not be the version that becomes commercialized, if its architecture is cost prohibitive [28].

If appropriate patent protection of the discovery has not been filed, company representatives should be asked to sign a confidentiality agreement before the scientist divulges the full details. Generally, it is necessary to discuss the invention in broad terms to solicit interest but to save detailed information until after the nondisclosure form is signed. If patent protection has been filed, the confidentiality agreement is not necessary [26].

When a private company decides to commercialize an invention, a complex series of negotiations follow. These negotiations are generally handled by those experienced in them. The negotiations form the foundation for developing the licensing terms and include the plans for commercializing the invention [26].

Step 5: Collect royalties
The company sends royalty payments as agreed upon in the licensing agreement, which may include payments before the product is commercially available.

r2p IN ACTION

Physical hazard: Musculoskeletal stress during hand-intensive work

r2p Component addressed: Transfer technology

Description: NIOSH scientists invented an ergonomically designed handle to maximize the power of the hand yet minimize musculoskeletal stress during hand-intensive work. The handle was originally designed to reduce the physical stressors associated with terminal insertion for factory workers, but it was found to have broader application for gardening hand tools, knives, box cutters, screwdrivers, and other handled tools for pushing, pulling, or turning.

The inventors, working without external partners, reported the design innovation to the CDC Technology Transfer Office, who conducted a patentability search and marketability analysis. Patent protection was pursued because the innovation was unique and the commercial applications were broad. Both U.S. and international patent protections were obtained (US 6,094,780, issued August 1, 2000; Australian patent 698779, issued February 18, 1999).

The NIOSH inventors developed a prototype and promotional material and sought commercial vendors. The potential vendors were identified through an Internet search, perusal of trade publications, and personal contacts at trade shows. Although many industry candidates expressed interest in this discovery and agreed on its need, none committed to manufacturing it. Interest in commercializing this invention waned when the Occupational Safety and Health Administration (OSHA) rescinded the ergonomics standard. If OSHA revisits the ergonomics standard, NIOSH may consider engaging an external organization to further explore the commercial viability of this innovation.

40.6 EVALUATE IMPACT

Improving the health and productivity of workers is what occupational ergonomists strive to accomplish. Without evaluation, one cannot determine whether the efforts are effective or perhaps even harmful [29]. According to the CDC [30], "effective program evaluation is a systematic way to improve and account for public health actions by involving procedures that are useful, feasible, ethical, and accurate." Evaluation generally answers questions related to the quality, cost-effectiveness, and importance of the effort.

In 2004, NIOSH contracted with the National Academies to conduct a series of independent evaluations on eight NIOSH research programs, focusing on the relevance and impact of those programs on reducing work-related injuries, illnesses, and hazardous exposures. NIOSH used this as an instructive activity in which it judged each program's activities and outputs on the following criteria: (1) its contribution, if any, to scientific knowledge and (2) the extent to which it was making a significant and important contribution to improving worker safety and health [31]. These evaluations yielded a number of recommendations to improve the NIOSH programs.

The CDC *framework for evaluation in public health* [30] is directed toward evaluating large public health programs; however, the concepts can be applied in evaluating the effectiveness of r2p efforts. CDC notes that the six steps it mandates for any evaluation are interdependent and may be taken in a nonlinear sequence. The steps are outlined in Table 40.7.

The NIOSH experience with the national academies and the CDC framework are two examples of large evaluation efforts. Evaluations on a much smaller scale or in combination with other evaluation efforts will still be effective in determining whether what you set out to do has been accomplished.

40.7 CHAPTER SUMMARY

This chapter outlined the four basic components of r2p at NIOSH: identification of research needs, design and conduct of research, transfer of knowledge and technology, and evaluation of impact. These components are seen and interpreted differently in other institutional models. Partnerships are at the heart of the NIOSH r2p framework. Careful selection of partners for each stage of research is essential. Partners may help with all of these basic components while also lending credibility to the appropriate audiences and providing resources. Comprehensive planning for the transfer of research knowledge or technology aids both the researcher and the practitioner and increases the likelihood that the research findings will be adopted for the benefit of workers. Evaluation ensures accountability by focusing on measurable health and productivity outcomes.

In occupational ergonomic research, the application and understanding of transferring research into practice is just beginning. The gap between "what is known" and "what is practiced" will narrow as the knowledge gained from research to practice continues to mature. Further understanding of how research moves into practice to benefit society is needed. Following the principles outlined in this chapter will help ensure ergonomic research contributes to the improvement of health and productivity.

TABLE 40.7 Steps in Program Evaluation, as Outlined in the Framework for Program Evaluation in Public Health

Step	Description
Engage stakeholders	Stakeholders (the persons or organizations having an investment in what will be learned from an evaluation and what will be done with the knowledge) must be engaged in the inquiry to ensure that their perspectives are understood. When stakeholders are not engaged, an evaluation might not address important elements of a program's objectives, operations, and outcomes. Therefore, evaluation findings might be ignored, criticized, or resisted because the evaluation did not address the stakeholders' concerns or values
Describe the program	Program descriptions convey the mission and objectives of the program being evaluated. Descriptions should be sufficiently detailed to ensure understanding of program goals and strategies. Aspects to include in a program description are need, expected effects, activities, resources, stages of development, context, and logic model
Focus the evaluation design	The evaluation must be focused to assess the issues of greatest concern to stakeholders yet use time and resources as efficiently as possible. A thorough plan anticipates intended uses and creates an evaluation strategy with the greatest chance of being useful, feasible, ethical, and accurate. Among the items to consider when focusing an evaluation are purpose, users, uses, questions, methods, and agreements
Gather credible evidence	An evaluation should strive to collect information that will convey a well-rounded picture of the program so that the information is seen as credible by the evaluation's primary users
Justify conclusions	The evaluation conclusions are justified when they are linked to the evidence gathered and judged against agreed-upon values or standards set by the stakeholders. Stakeholders must agree that conclusions are justified before they will use the evaluation results with confidence. Justifying conclusions on the basis of evidence includes the use of standards, analysis and synthesis, interpretation, judgment, and recommendations
Ensure use and share lessons learned	Deliberate effort is needed to ensure that the evaluation processes and findings are used and disseminated appropriately. Preparing for use involves strategic thinking and continued vigilance, both of which begin in the earliest stages of stakeholder engagement and continue throughout the evaluation process. Five elements are critical for ensuring use of an evaluation: design, preparation, feedback, follow-up, and dissemination

Source: Centers for Disease Control and Prevention, Framework for program evaluation in public health, *MMWR Recommendations and Reports* 48(RR11), 1–40, 1999.

r2p IN ACTION

Physical hazard: Previous work with California wine grape vineyard workers has indicated high rates of musculoskeletal disorders in this population [32].

r2p Component addressed: Evaluate impact

Description: Researchers partnered with vineyard owners/operators, vineyard workers, and external ergonomics researchers to compare the use of a small picking tub with the use of

known alternative technologies for handling cut grapes during harvest. The evaluation compared preintervention and postintervention ergonomic stress data, musculoskeletal disorder–related pain, symptom data, and adoptability data.

Surveillance data collected subsequent to the evaluation project demonstrated that management and workers in wine grape production adopted the smaller, lighter picking tubs (>3000 tubs in 2002; 3400 in 2003). The only incentive for adoption was improved working conditions [33].

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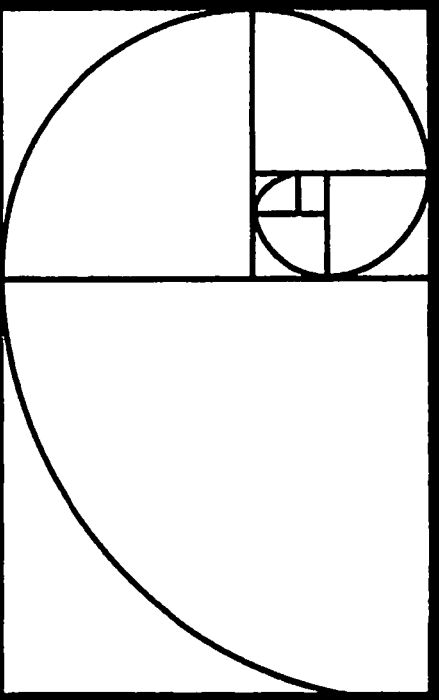

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CRC Press

Taylor & Francis Group

Occupational Ergonomics

Theory and Applications

Second Edition

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an Informa business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
Version Date: 20120112

International Standard Book Number: 978-1-4398-1934-0 (Hardback)

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In the fifteen years since the publication of **Occupational Ergonomics: Theory and Applications**, significant advances have been made in this field. These advances include the impact of aging and obesity on workplace, the role of ergonomics in promoting healthy workplaces and healthy life styles, the role of ergonomic science in the design of consumer products, and much more. The caliber of information and the simple, practical ergonomics solutions in the second edition of this groundbreaking resource, though, haven't changed.

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