Future Directions in Exercise and Recreation Technology for People with Spinal Cord Injury and Other Disabilities: Perspectives from the Rehabilitation Engineering Research Center on Recreational Technologies and Exercise Physiology for People with Disabilities

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Opportunities to participate in regular exercise and recreational activities are especially important for people with spinal cord injury (SCI). They are less physically active than the general population, and secondary conditions associated with their disability (e.g., pain, deconditioning, fatigue), in combination with chronic conditions such as type 2 diabetes, obesity, and depression, severely compromise their overall health status. One way to alter this downward spiral of health is for engineers, exercise physiologists, and other scientists to provide more opportunities for people with SCI and other disabilities to engage in healthful exercise and recreation. This article proposes a conceptual framework for addressing the many barriers that people with SCI and other disabilities face when attempting to engage in these important areas of community living. The framework identifies four key areas necessary for an enriching and healthful experience in exercise and recreation: access, participation, adherence, and health and function. The significance of each of these elements is discussed along with a description of how this conceptual framework guides the research and development efforts of the Rehabilitation Engineering Research Center on Recreational Technologies and Exercise Physiology for People with Disabilities (RERC RecTech). **Key words:** *disability, exercise, physical activity, recreation technology*

The Internet is now a routine part of American life. There are dramatic changes in information access, because of convergence in the communications industries, which brings telephone, cable television, Internet services, and hosts of on-demand features into the home in increasing variety and at decreasing costs. Whether seen as revolutionary or evolutionary, technology is certain to eliminate many of the barriers

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that people with disabilities face when trying to lead an active lifestyle. This article provides the perspective of researchers in the Rehabilitation Engineering Research Center on Recreational Technologies and Exercise Physiology for People with Disabilities (RecTech), which is focusing on how new and emerging technologies can be used to provide greater and more enjoyable opportunities in exercise and recreation for people with spinal cord injury (SCI) and other disabilities. RecTech's primary focus is to enhance universal design features of equipment, programs, and facilities by encouraging engineers, researchers, exercise physiologists, entrepreneurs, industry professionals, and people with disabilities to work collaboratively to research, develop, demonstrate, evaluate, and adopt new approaches to increasing access to and participation in exercise and recreational activities among people with disabilities.

More Barriers Lead to Less Activity

Changes in the American economy and the widespread availability of "labor-saving" devices have led to increasingly more sedentary lifestyles for most Americans. In 2001, the Centers for Disease Control and Prevention reported that less than half of the population regularly engages in the recommended level of physical activity (30 minutes or more of moderate physical activity 5 days a week) and more than a quarter of the population is physically inactive (reporting no leisure time physical activity). People with disabilities are currently much less active than their nondisabled counterparts and participate in less regular and vigorous physical activity.[1,2] Because most Americans can participate in beneficial physical activity with no more planning or effort than walking out the door and through their neighborhood or driving to a local park or community center, it should come as no surprise that the additional preparation time for people with SCI (i.e., dressing, transfers, accessible transportation, etc.) results in substantially lower levels of physical activity.[3] The energy required to exercise in a gym or local recreation facility may also de-motivate many people with SCI who either do not have the time to prepare for exercise (i.e., dress and undress) or the energy level to transfer on and off exercise equipment, get in and out of a swimming pool, or use certain parts of the facility that are not fully accessible (i.e., bathrooms, locker rooms, showers).[4,5]

Wheeling outdoors may not be any more accessible than going to a fitness or recreation facility. Many neighborhoods either lack sidewalks or have surfaces that are badly damaged; high traffic volume makes it cumbersome to cross streets; hilly terrain may be too difficult to traverse; and manually pushing a wheelchair for exercise in addition to the daily routine of getting to and from places (e.g., work) may precipitate or worsen shoulder pain.[6,7] These and other barriers can be very difficult for many people with SCI to overcome and can lead to a higher prevalence of sedentary behavior.[3]

A Framework for the Infusion of Technology into Exercise and Recreation

Figure 1 illustrates what we consider to be the four essential elements of an enjoyable and healthful experience in exercise and recreation: *access, participation, adherence,* and *health and function.* From the standpoint of the consumer, there is a logical progres-

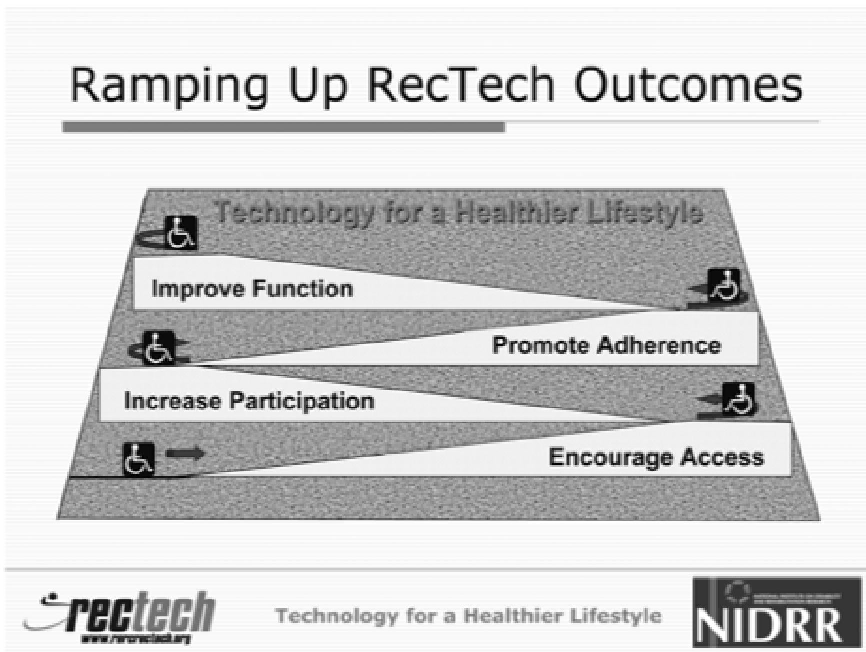

Figure 1. RecTech conceptual model for enhancing recreational and exercise opportunities for people with disabilities.

sion through these elements, and the model presents this progression through the metaphor of "ramping up" to successive levels. We will begin with a brief review of these elements and their relationship to successful outcomes. Then we will address specific ways in which current and future technologies can be used to improve the experience for people with disabilities, especially people with SCI.

The most fundamental requirement is *access*. For the purposes of our discussion, *access* means allowing the individual to experience typical use of the environment or equipment. There is a pervasive lack of accessible sports and fitness facilities, gyms, parks, trails, and pools, which precludes many people with SCI from engaging in these activities.[8,9] The most common access issues for people with disabilities involve physical access – getting into the building; having full use of available facilities; ensuring proper positioning to use equipment; and having information available in various formats. A more subtle aspect of access is information on the availability of facilities, services, programs, and equipment. If the user does not have at least an awareness of the options available, the options are functionally unavailable.

Second, people with SCI need to be able to *participate* in the activities to which they have access. Having access to a facility (e.g., swimming pool, weight training room) is a necessary but not sufficient condition for a satisfactory and beneficial experience. The user must have the opportunity for full participation in the programs that are offered in these settings. For example, someone with SCI may be able to get into the weight room but have little or no access to the equipment or training programs (e.g., circuit training class). A pool lift allows someone to enter the water (access) but is of little utility if the person is unable to participate in the aqua-aerobics class due to a lack of adaptive equipment. Group exercise classes (e.g., tai chi, yoga, aerobics), team sports (e.g., basketball, softball), exercise rooms (e.g., cardio and strength equipment), and outdoor recreation programs (e.g., cycling, climbing) often must be modified for people with SCI to allow them to have similar experiences as other participants.

The third element, *adherence* to exercise, is the most challenging aspect of beneficial recreation and exercise activities. Although adherence is a chronic problem for everyone, it poses substantially greater difficulties for people with SCI because of their limited opportunities in regard to access and participation. The most common strategies for increasing adherence to beneficial recreation and exercise programs are varying the activities or locations and developing social support networks. Limited access and participation options make these strategies far less useful for people with disabilities.

Finally, at the top of the model we have the impact on *health and function*. It is almost universally accepted that participation in recreation and physical activity improves both quality of life and health status. Even though we recognize that there are significant quality of life benefits that can be derived from participation in activities such as board games, card games, spectator sports, and a host of other low-activity recreational pursuits, our focus is restricted to recreation and leisure-time pursuits that involve sufficient physical activity to impact health status.

In considering the impact of recreation and physical activity on health status, it is important to recognize that our knowledge of this impact for people with disabilities is not nearly as well understood as it is for the general population. Consider the example mentioned in our brief discussion of barriers. For the general population of people who are able to walk, walking for mobility and walking to obtain a health benefit can both be accomplished with little risk. By contrast, there is evidence that for people who use manual wheelchairs for mobility, wheeling for exercise may increase their risk of overuse injuries to the shoulder[7] and that it may be better to vary the muscle groups used for exercise by engaging in such activities as rowing and swimming. Therefore, consideration of health and function must be a prominent part of the outcome evaluation process.

Technology to increase access

At the most basic level, access to recreation and fitness facilities refers to the ability of individuals with SCI to enter or exit various aspects of the built environment. Although the Americans with Disabilities Act (ADA) requires public facilities to be accessible, many areas of indoor and outdoor fitness and recreation facilities do not fall under the purview of the ADA and may not be accessible. Locker rooms, trails, beach fronts, boating docks, playgrounds, swimming pools, saunas, whirlpools, and many other fitness and recreation venues include features that limit their accessibility to people with SCI.[4,10] These outdoor venues typically do not consider how an individual who uses a wheelchair would be able to access these facilities. Even in those instances where accessibility is required by the

ADA, a lack of knowledge concerning the details of compliance on the part of consumers or owners of these facilities can result in some or all of the features of the facility being functionally inaccessible. There is a need to raise the accessibility standards of fitness and recreation facilities to a level comparable to that of other private and public facilities (i.e., businesses, restaurants, retail stores). Until that is done, these barriers will continue to reduce personal choice options; inhibit participation in healthy, active lifestyles; and prevent people with SCI and other disabilities from fully participating in recreational activities.

One way to increase the accessibility of fitness and recreation venues is to develop partnerships between people with SCI and facility owners/managers to identify existing barriers and develop cost-effective solutions. Such partnerships provide an incentive to facilities by highlighting the fact that poor accessibility features preclude usage by a substantial number of potential customers. Working together reduces the adversarial aspects of ADA compliance and, in turn, presents accessibility as a win-win proposition for both consumers and facility managers or owners.

The difficulty with this approach is that it requires specialized knowledge and experience to conduct such surveys and identify cost-effective accessibility solutions. The costs associated with bringing together such expertise to conduct a survey make it prohibitively expensive for many smaller community facilities. Information technology offers a promising approach to addressing this problem. It is currently possible to use relatively inexpensive information technology to conduct accessibility assessments at a distance. One such procedure, using a videophone operating over plain old telephone service (POTS), demonstrated results equivalent to an on-site survey in conducting an assessment for home modifications.[11] Recently, we have used a camera cell phone in conjunction with a paper-based instrument[12] to conduct accessibility surveys of recreation and fitness facilities in three states. Whenever an item on the accessibility instrument requires expert guidance or analysis, the local surveyor photographs the area of concern and uploads the photos to a Website for viewing by content area experts. By using a Web-based location for the photos, experts who are geographically distant from the assessment site and from one another can work together at low cost.

As the next logical step in the development of this approach, we are currently developing a computerized version of our accessibility instruments that runs on a tablet PC equipped with a Web cam and wireless Internet access in anticipation of widespread broadband access in the near future. Information from previous assessments will be analyzed to identify common access issues and prioritize potential remedies based on successfully completed modifications. This material will be used to develop an automated report generator that can suggest initial steps to address identified problems and provide links directly to vendors or other resources where appropriate.

There are hundreds of adaptations that have been developed that allow individuals with SCI to engage in sports, recreation, and exercise programs. Unfortunately, most people who need these adaptations are unaware that they exist. There is a large and growing information gap between available recreational and fitness technology and awareness of this technology by professionals and persons with disabilities. As the demand for such technology has grown with the increasing use of assistive technology in adaptive sports and recreation,[13] more and more items are available. There have been attempts to catalog such devices,[14] but this is an area that is growing and evolving and most of the manufacturers and vendors are small businesses so the information in printed volumes is often outdated before it is published.

Fortunately, information technology offers a solution to this problem. Just as printed encyclopedias and catalogs have been replaced by databases, the printed compendium of adapted recreation and fitness technology is being replaced by online resources. As one step toward closing this information gap, RERC-RecTech is identifying, collecting, and cataloguing information on currently available sports, fitness, and recreational technologies and is maintaining this information in a Web-searchable database readily available to professionals and the public at www.rectech.org. The use of an electronic database allows the entries to be updated without the time and expense associated with creating, editing, printing, and distributing hard copies. Further, the information is readily available to anyone with Web access from anywhere and at anytime. This allows RecTech to directly address the awareness issue and produce a rapid, beneficial impact by making available solutions more accessible to professionals and consumers.

The exact structure of the solutions database was created through an interactive development process in which RecTech database specialists worked with people with disabilities in determining what information was of greatest use and value to consumers. The products in the database are divided into three main categories: fitness, recreation, and sports. These categories are further classified into a number of subcategories based on the activities in each category. Products are then classified as an equipment adaptation (e.g., bowling ramps, handcyles, adaptive strength machines) or personal adaptation (e.g., specialized gloves to allow persons with limited use of their hands to lift weights, a baseball bat adaptation for persons with below the elbow prosthesis, a body flotation device that allows a person to swim with the use of only one arm). Manufacturer and distributor details for each product are also provided. The database currently contains more than 1,000 entries for adaptive fitness, sports, and recreational equipment and technologies. Searches for additional entries are made weekly, and entries for existing records are updated quarterly.

Access to exercise, recreation, and sports activities will be enhanced through on-demand delivery as broadband technology reaches into more and more homes. This new delivery mechanism will provide opportunities for dynamic, interactive, and enriched information presentations. As an example of one such presentation, RecTech is currently developing a Web application illustrating key elements of an accessible fitness center, park, and pool by graphically illustrating common problems and how they can be resolved. Included in the visual representation of these areas will be information concerning the accessibility features for each area of the facility. Where appropriate, the models will provide animations of persons with various disabling conditions accessing the facility, as a means of illustrating the importance of various accessibility features. Persons interested in specific adaptations or accommodations included in the model will be able to click on that portion for more specific information, such as manufacturers of accessible exercise equipment. There also will be ancillary information regarding accessibility issues related to professional behavior, knowledge, and attitudes and facility policies and procedures. Finally, recommendations for implementing specific adaptations and accommodations, including the estimated cost of these modifications, will be provided. Computer models of accessible fitness and recreation facilities will provide architects, park and city planners, and fitness and recreation professionals with an online, interactive tool that contains both visual and regulatory data on the requirements of these types of facilities, and these models will guide future empirical work aimed at facilitating the process of improving environmental access and participation for persons with disabilities. These models will also provide a basis for the development of standards for recreation and fitness facilities.

Technology to increase participation

Participation goes one step beyond *access* by recognizing the need for users to interact/engage with a specific venue, either with a machine or another person (e.g., instructor). Ideally, a person with SCI should be able to participate in most, if not all, of the activities offered in a facility. This means being able to participate in group exercise classes such as Pilates, Yoga, Tai Chi, or aerobic dance; having a similar experience as the other members using cardiovascular or strength equipment (and not requiring assistance from staff to use the equipment); and having similar outdoor adventures in classes such as kayaking, softball, and downhill skiing. Whereas *access* allows the user to enter and exit all areas of a facility, *participation* goes one step further and allows the person to have unobstructed use of the equipment or full participation in the programs offered in these facilities. This requires technological solutions to make equipment and programs usable by people with SCI.

As is the case with most products designed for a broad consumer base, equipment is designed by the recreation and fitness industries to be used by a wide range of people. As a result, commercial exercise machines designed for use in fitness facilities and equipment designed for home use typically require some adjustment and configuration for each individual. Further, the nature of certain equipment, such as strength training devices, requires the users to make adjustments in the course of each session. Unfortunately, few if any designers include people with disabilities in their group of target users. This results in a number of barriers in addition to the obvious height/reach/positioning issues, such as the cognitive load to recall settings for multiple machines, the expenditure of energy to locate and make adjustments, availability of feedback from the device for people with sensory disabilities, additional time needed to configure each machine, and often the need for some assistance in accomplishing even relatively simple tasks. Fortunately, this is an area in which technology holds great promise for change and the integration of universal design.

A common feature on many higher end automobiles today is automatic configuration of the important controls for each primary driver. By pressing a button or placing your key in the ignition, the control area adjusts to your preferences for positioning the seat, the interior and exterior mirrors, the steering wheel, the pedals, the display lighting, and even the sound system. If your car is able to remember you and adjust to your requirements, why can't your exercise equipment do the same thing?

The idea of having exercise or recreational devices adjust themselves to the requirements of the user is a process we refer to as *autoconfiguration.* A personal automobile is typically driven on a regular basis by only a few people, so it makes sense to have each user adjust the controls to her/his preferences, then store those preferences on the device for later retrieval when that driver returns. Similarly, once those preferences are set, most of them are unlikely to vary from use to use. By contrast, many different people typically use exercise and recreational equipment, and the settings on the equipment are often adjusted multiple times in the course of a session with a single user. As a result, the technology for autoconfiguration of exercise and recreation equipment must be more flexible and more robust than the technology used in our automotive example. Exercise and recreation equipment vary substantially in the number of configurable components available. For example, if the equipment has a display, the display could change modalities to accommodate users with different sensory requirements, change size/brightness/color for users with visual requirements, or change complexity for users with cognitive requirements. If the equipment has a seat, the seat may need to adjust or relocate to accommodate a user with mobility requirements. Control surfaces and operating handles also must adjust to the location, reach, strength, and range of motion requirements of the user.

It should be clear from these few examples that the technology for autoconfiguration must be capable of meeting a diverse set of requirements. The ideal solution would be to have a standard communication protocol and a standard set of device control codes. Each user would carry information about his/her specific long-term (e.g., sensory or mobility) and short-term (e.g., current workout goals, time since last use, etc.) requirements in a device that is capable of communicating with all exercise and recreation equipment conforming to the standard. When the user approaches a piece of equipment, the user's device queries the equipment to learn what autoconfiguration capabilities it has available, matches them to the stored requirements of the user, and requests the machine to adjust itself accordingly. This approach is similar, although with a more restricted universe of equipment, to the approach being taken in the InterNational Committee for Information Technology Standards (INCITS) V2 project. Although our work in this area is still in the early stages, we are encouraged by the progress being made. Perhaps of more importance to the ultimate goal, autoconfiguration offers the opportunity for unprecedented levels of individualized fitness and recreation programming for everyone. As a result, it is an excellent example of how the application of universal design concepts can provide added value for all users.

Technology to increase adherence

Regular exercise has the potential to be a health panacea, yet the majority of the population does not benefit from it. Most people report they get "some" exercise, but the key for health benefit is regular exercise. The Surgeon General's guideline calls for 30 minutes or more of moderate physical activity at least 5 days a week. A quick Internet search of "common New Year's resolutions" will return hundreds of articles and lists, most including something like "get more exercise" as one of the top 10 resolutions. Research shows the importance of regular exercise for attaining and maintaining optimal health, and the public is clearly aware that they need more exercise. Despite this, less than one third of the population gets even the minimal amount of exercise recommended. Finding ways to promote *adherence* to exercise remains one of the great health promotion challenges. Our efforts in applying technology to promote adherence to exercise focus on what we believe to be two of the key elements of adherence: *engagement* and *social support.*

Engaging people in the exercise experience

People who are engaged in physically active sports or recreational activities such as skiing, hiking, canoeing, kayaking, rugby, basketball, or soccer rarely seem concerned about whether they have put in the requisite time so they can stop. Far more often, the opposite is true; they are disappointed that they must stop the activity to go on to other life tasks. For people in these activities, adherence is not an issue. The reason seems obvious. People in these pursuits are not being physically active for its own sake, but rather as the means to some end. Whether the end is competition, curiosity, or personal satisfaction, the person's attention is focused on something other than simply staying moderately active for at least 30 minutes.

It is a truism that time seems to pass more quickly when you are not watching the clock. Finding something to distract you is a common strategy people have used to relieve the tedium of repetitious boring tasks. Unfortunately for many people, 30 minutes of exercise is a boring and repetitive task. A visit to any fitness facility will find people using cardiovascular equipment wearing headphones, reading, or watching television while they exercise. Although people who exercise outdoors are not likely to read or watch television, many if not most will listen to music, radio, or recorded books while they work out. There are even waterproof mp3 players for swimmers and others who exercise in the water.

Although engagement and distraction both promote adherence, there is a crucial difference between them. People seeking distraction from an activity want the time to go more quickly and want to get the activity over. People engaged in an activity want the time to go more slowly and the activity to continue. Distraction helps people tolerate an unpleasant activity. Engagement makes people seek out the activity. If our goal is to promote long-term adherence to at least moderate levels of physical activity, then clearly engagement is the preferred approach.

Using technology to make exercise more engaging

One of the most promising approaches to promoting exercise adherence is through the use of virtual reality (VR) technology. In recent years, manufacturers of exercise equipment have begun to explore simple applications of VR technology to add variety or motivational support to their equipment. The development of VR technology in exercise equipment is still in its early stages, but VR technology has already demonstrated effectiveness and is rapidly becoming used in rehabilitation applications that have many similarities to mainstream exercise equipment.[15,16]

A clever alternative approach is the development of exercise equipment that can be interfaced to control popular game platforms, turning the exercise device into a controller for the game platform and allowing users to select from the large catalog of existing games. Two recent commercial examples of this approach are the GameCycle™ developed by Michael Boninger, Rory Cooper, and associates at the University of Pittsburgh[17] for the Nintendo GameCube platform and the EyeToy® for the Sony Playstation II platform.* The GameCycle™ is a straightforward exercise device based on a specially designed arm ergometer that offers users an opportunity to obtain a healthful cardiovascular workout while being engaged in their favorite GameCube racing game. The EyeToy® is a more general active recreation device that uses a novel approach to controlling the game functions in a set of specifically adapted games. A Universal Serial Bus (USB) camera and microphone are used to capture the user's movements and sound as the primary means of controlling movement in the games. The camera is also used to capture the likeness of the user and present that image onscreen during gameplay. Thus, the user sees himself or herself in the action of the game and interacts with the game environment from a third-person view. The games support a variety of active play elements, such as boxing, dancing, and playing goalie in a soccer match.

RecTech is currently exploring several approaches to using VR technology to increase adherence to exercise for people with disabilities. More immersive VR environments are rapidly moving from the computer graphics laboratory and high-end commercial applications to consumer products. We believe that virtual exercise environments (VEE) have the potential to dramatically impact the low level of exercise commonly seen among the general population and people with disabilities in particular by changing the fundamental focus from exercise to immersive engagement in activity. This technology can be used to create interactive, motivating, and enjoyable VEE and can allow users with SCI to participate in activities that may be difficult or not possible in the real world.

Technology to increase health and function

At the top of our model is *health and function.* It is well-established that regular moderate exercise can yield substantial health benefits for the general population. But vital observational and longitudinal research on health and function outcomes of exercise for people with disabilities is needed. Our understanding of the dose/response levels for physical activity in persons with SCI is inadequate. Similarly, information on the safest and most effective forms of exercise for persons with SCI is very limited. Technology can play a central role in helping to answer these and many other important research issues regarding physical activity for persons with SCI and other disabilities.

One of the most exciting developments in health care and rehabilitation today is the growing use of telecommunication technologies to provide health information, assessment, monitoring, and treatment to individuals with chronic health conditions.[18] This merger of health care and telecommunications is known as *telehealth* and is one of the most exciting and rapidly growing areas of

*Manufacturer information for GameCycle and EyeToy: Three Rivers Holdings, LLC; 1826 W. Broadway Rd. Suite 43; Mesa, AZ 85202; Phone: 480-833-1829; Fax: 480-833-1837; email: support@3rivers.com. http://www.3rivers.com/. EyeToy by Sony Computer Entertainment: http://www.eyetoy.com.

health care technology. RecTech has been pioneering a corresponding health promotion approach focused on home exercise for persons with SCI, which we call *teleexercise*.

The RecTech teleexercise program includes three essential features: monitoring, feedback, and education. Teleexercise monitoring is used to evaluate physiologic responses to the recommended exercise and self-reported indicators, such as symptom index and personal well being, to ensure that the exercise is safe and effective for the participant. Feedback is given to participants at regular intervals via a messaging system that provides notification of when the criteria of their exercise program have been met, such as dose (duration, frequency) and intensity (including target heart rate). The teleexercise device provides users with educational guidance regarding proper mechanics of exercise and safety precautions.

There are various commercial products that can be used to customize a home exercise program for teleexercise monitoring. The unit currently being used in RecTech is the Health Buddy system (Health Hero, Mountain View, CA), which is an in-home, point-of care device that allows daily monitoring, education, and feedback. The technology is simple, compact, and easy to use. It operates via conventional telephone service technology and only requires a telephone and electric outlet for operation. Each day, the participant responds to a brief series of questions about his or her behaviors, symptoms, and vital signs that are presented through the Health Buddy. The software supporting the device ensures that each participant is presented with appropriate questions to secure the requisite monitoring data and allow clinicians working with the project to request further information or provide specific education based on participant response. The device also offers individualized programming for content and clinician review/criteria.

Professional staff are able to access participant teleexercise data remotely and almost immediately. The information is transmitted nightly and is available through a secure, Web-based platform so that each participant can be remotely monitored with biweekly scheduled "visits" and additional interaction as needed. The participant management software allows viewing and reporting by individual or group. The ease of monitoring coupled with the education and feedback aspects of this teleexercise program have proven effective in monitoring the health and function of participants.

A Bright Future for Exercise and Recreation Technology

Technology offers new and powerful approaches to addressing the many barriers people with SCI and other disabilities face in pursuing healthful, physically active lifestyles. Autoconfigured machines, virtual exercise environments, online and interactive tailored programming, exercising with a virtual partner in your own living space, and many other exciting possibilities are moving rapidly from vision to reality. We have described only a sample of the potential applications of technology to address the key elements of *access*, *participation*, *adherence*, and *health and function*. Our hope is that it will stimulate more engineers, scientists, and researchers to apply their technological skills toward building universally designed inclusive exercise and recreation environments.

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