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Data from the 2005 Youth Risk Behavior Surveillance System reveal that 28.8% of American adolescents were overweight or at risk of being overweight (Eaton et al. 2006), and the percentage of overweight adolescents in the United States has more than doubled in the past twenty years (Centers for Disease Prevention and Control 2004). Video games have been singled out as a major culprit in this increase; the amount of time that young people spent playing video games nearly doubled between 1999 and 2003, from 29 to 49 minutes per day (Roberts, Foehr, and Rideout 2005), occupying time that may otherwise have been spent engaging in physical activity (Vandewater, Shim, and Caplovitz 2004). Interventions designed to reduce the time that children spend playing video games have yielded significant reductions in obesity-related health measures (Robinson 1999).

Video games, then, have been identified as a large part of the problem of rising rates of child obesity; however, a new genre of video games, aptly termed *exergames* or *exertainment*, could become part of the solution. While traditional video games are controlled with handheld keypads, exergames rely on sensing technologies that integrate physical movement with virtual activities. For instance, low-cost cameras and advanced video-processing algorithms allow video games to be controlled with body movements, and touch-sensitive floor mats allow players to dance in virtual spaces. Although such games are admittedly not an ideal solution to the complex problem of childhood obesity, exergames are arguably a healthier alternative to traditional video games. Furthermore, exergames may provide motivation for youngsters who do not typically exercise. Children who are already video game enthusiasts may voluntarily engage in physical activity when it becomes part of a virtual experience; those who find traditional exercise boring or intimidating may be motivated to play video games that ask them to dance, do yoga with a virtual trainer, or ride virtual surfboards. In this way, exergaming offers a means of channeling in healthy directions behaviors that usually exclude physical exertion.

This article considers how exergaming can improve the health and fitness of children. A survey of current exergames is followed by a consideration of how exergames could connect this generation of children with healthy physical activity. The article concludes with a discussion of issues in need of further research.

Introduction

Among American youngsters between 8 and 18, 83% own one or more video game consoles (e.g., Sony PlayStation, Microsoft Xbox, and Nintendo GameCube) (Roberts, Foehr, and Rideout 2005). Most children (86%) also have access to computers at home and 91% of these play video games on their PCs (DeBell and Chapman 2003). The video gaming industry is staggeringly huge, with 248 million computer and video games sold in 2004 (Entertainment Software Association 2005), and growing.

Exergames may offer a way for parents and educators to capitalize on the explosive popularity of video games. Konami's *Dance Dance Revolution* (DDR) has become the prototypical example of an exergame. In DDR, players move to music, stepping on dance pads that are connected to game consoles. Arrows that flash on the TV screen cue players when to take steps; higher scores are awarded when players' steps match the tempo of the flashing arrows. Anecdotal evidence suggests that the exertion required to play the game has contributed to improved fitness among some players. On numerous fan sites (e.g., www.ddr4health.com and www.getupmove.com), players describe losing weight after playing DDR for extended periods:

I lost about 140-150lbs with the help of DDR and a weight bench. But before I found DDR I tried walking and a weight bench and I only lost 20lbs, then after DDR it melted off in under a year. So the main factor of my weight loss is the intensive cardio workout that is DDR. (Keene 2004, ¶1)

It wasn't until I went to an arcade that I had a solution to my weight problem. One day my friends and I passed by the Dance Dance Revolution Extreme. . . . After playing the game, we enjoyed it and continued to play it every week. After two months, I noticed my weight dropped to 247 and I knew it was because of DDR. I chose to purchase the home version and a dance pad and it really made the game part of my weight loss routine. After a year, I now weigh around 200 lbs and I owe much thanks of it to DDR. The reason DDR was so effective was because it's simple to learn but hard to master the game which has you move your body and everyone can enjoy it. (Duhlin 2004)

Stories like these suggest the potential of exergames, and some school districts are capitalizing upon these new possibilities. School districts in California (Kohler 2005), West Virginia (CBS News 2006), Virginia (Fernald 2004), and elsewhere, seeking to attract students who avoid physical education classes, are adding nontraditional forms of exercise, including exergaming technologies like *Dance Dance Revolution* and EyeToy, to their physical education curricula as a way to motivate children who prefer to play video games in their leisure time.

Exergaming Technologies

We have reviewed and identified exergaming innovations in three categories of gaming technology: game controllers, software, and game systems (Yang, Smith, and Graham n.d.).

Game Controllers

Innovations in human-computer interaction technologies have led to the creation of novel game controllers that can sense the movements of a player's body. In addition to dance pads for games like *Dance Dance Revolution*, controllers come in the form of USB cameras, stationary bicycles, golf clubs, and drums.

Sony's EyeToy camera plugs into Playstation 2 consoles, allowing players to control games with upper body gestures. In most cases, players see mirror images of themselves on the screen as they interact with virtual characters and backgrounds. The first software for the camera, *EyeToy: Play*, consists of a number of mini-games focused on activities that demand strenuous aerobic responses, such as martial arts, boxing, and dancing. In a later version, *EyeToy: AntiGrav*, players gesture to control on-screen avatars. Nike Motionworks's *EyeToy: Kinetic* provides players with a virtual personal trainer and conditioning exercises drawn from Tai Chi, kickboxing, or aerobics to create an immersive physical experience. All of these games use the camera's image processing routines to track body movements that allow players to interact with virtual worlds and increase physical activity.

Cateye Fitness's GameBike is a stationary bicycle with rotation sensors connected to the handlebars and pedals. The sensors allow players to control racing games by steering and pedaling instead of pushing buttons and joysticks. The GameBike is available in three versions. Two are dedicated stationary bicycles, one designed for homes and one with more advanced features that make it more suited (and priced) for health clubs; the third incorporates the hardware into a small platform that rests beneath the wheel of an ordinary bicycle.

Powergrid Fitness's Kilowatt game controller is designed for isometric exercise, in which muscles are used in ways that involve little or no joint movement (Fleck and Kraemer 2003). Pushing and pulling against a steel resistance rod attached to the controller allows the torso to move and achieve isometric muscle contractions.

Software

Some exergames create unique experiences via software that makes use of existing hardware. For example, responDESIGN's *Yourself!Fitness* brings the expertise of a personal trainer and nutritionist to game consoles. The virtual trainer, Maya, leads users through personalized workouts, stretches, yoga, meditation, and nutrition planning.

CycleScore is an MIT research project that pairs a motivational game with fitness equipment, in this case a recumbent bike. The goal is to keep a hot-air balloon afloat by pedaling and to earn bonus points by shooting at targets with a button mounted on the bicycle handle. The game is played through a PC hooked up to the bike; the designers hope to have the product on the market within the year.

Dance Dance Revolution has inspired numerous rhythm games such as Andamiro's *Pump It Up* and Sony's *EyeToy: Groove*. These dancing games have players move their bodies to music, controlling the game with their feet (on dance pad controllers) or hands (e.g., *EyeToy: Groove*, which tracks upper body motion with a camera). This is arguably the most popular genre of exergames at present, as well as the first to receive attention from health researchers.

Game Systems

Several companies have designed their own consoles to compete with Microsoft, Nintendo, and Sony. These proprietary systems offer fewer game titles than the major consoles, but they focus exclusively on physical interactions.

Cybex TRAZER is a performance assessment and training simulator that demands some of the footwork required in *Dance Dance Revolution* but without the dance pad. Using position tracking devices, TRAZER provides instantaneous feedback on a player's position, speed, and heart rate during any of the many three-dimensional games.

A virtual-reality cycling game system, VCycling, gives players the opportunity to race world-class cyclists or their friends on courses from around the world. As a player goes up a hill, the braking system mimics the effects of cycling up an incline. A player can use VCycling's patented steering and braking systems to connect his own racing bike to a PC or use a fitness club system with six bikes hooked up to PCs and an overhead projector.

XaviXPORT is a new game console that comes with physical controllers that translate player movements into on-screen movements. Baseball, bowling, and tennis were among the first XaviX releases. Jackie Chan has recently endorsed two new products for XaviXPORT called *Powerboxing* and *J-Mat*, both designed to improve cardiovascular fitness. XaviX also sells Lifestyle Manager, a scale that wirelessly transmits weight data to the XaviXPORT and displays personalized health and nutrition activities based on the measurements from the scale and a player's stated goals.

Nintendo released the Wii game console in November 2006. The Wii is the first major gaming system to emphasize physical interactions with virtual worlds. The Wii controller has a traditional set of buttons, but it also includes accelerometers and infrared sensors to detect the controller's position in and movement through three-dimensional space. The sensor system allows players to hit tennis balls, throw footballs, and swing swords by moving the controller through the air. It is too early to tell if Wii games will contribute to physical fitness, but it already seems that some games (e.g., *Wii Sports*) require more exertion than others (e.g., *Rampage: Total Destruction*). Nintendo will release a dedicated fitness game, Wii Fit, in May 2008 that will use a balance board to control gaming interactions and track body mass index (BMI). Because of its innovative controller, the Wii is likely to be the target of future research on exergaming's effects on physical health.

All of these games involve using physical movement to control on-screen actions, but some may be better

suited than others for sustaining moderate to vigorous levels of exercise. Users claim that *Dance Dance Revolution* can lead to weight loss, but Smith (2005) found variations in cardiovascular output when comparing games played with three different controllers (dance pads, cameras, and bicycles). More research is needed to distinguish between exergames that actually contribute to increased fitness and those that simply offer novel ways to control virtual characters.

Studying Exergames

Player anecdotes on the Web suggest that weight loss is possible, and more rigorous evidence is being collected. Tan, Aziz, and Teh (2002) found that DDR players' heart rates averaged 137 beats per minute over 10 minutes. In a more recent study, heart rates averaged between 138 and 147 beats per minute (resting heart rates typically average between 60 and 80 beats per minute) and, significantly, participants averaged 44 minutes of voluntary game time (Yang and Graham 2005). Computer-vision-based games have also been shown to yield heart rates comparable with aerobic exercise (Hämäläinen et al., 2005; Höysniemi 2006; Lanningham-Foster et al. 2006), and pilot work by Smith (2005) suggests that exergaming may affect weight and blood glucose levels over time.

Additional studies are needed to understand the long-term effects of these games on health and fitness. For instance, the studies cited above have found that participants are motivated to engage in strenuous activity for short periods of time, on the order of one to two weeks. It is not clear whether this motivation would continue for longer durations. Will children ultimately tire of working to play games and revert to couch-potato forms of entertainment? If so, are there ways to design exergames that adapt to player achievements and continue to challenge players over time?

At the same time, the value of exergames for school physical education programs must be closely examined. Physical education programs seem to be ideal venues for introducing youngsters to the wide variety of exergames available, but we need to consider whether the costs of exergames outweigh their benefits. For instance, a four-person *Dance Dance Revolution* setup costs approximately $400 ($150 for the game console, $50 for the game software, and $200 for four dance pads). This is more expensive than jump ropes and basketballs, but it is similar in cost to gym equipment like stationary bicycles, rowing machines, and other fitness devices. Funding grants like the Carol M. White Physical Education Program can help schools afford exergames, but the initial equipment costs may still limit adoption of these technologies. Maintenance and upgrade costs of game consoles and exergaming peripherals also need to be considered. For instance, inexpensive dance pads may be easily damaged when used by hundreds of students multiple times per week. In the worst case, a game like *Dance Dance Revolution* may lose its appeal over time, leaving schools with expensive equipment that students do not use.

Conclusion

Research studies that consider changes in weight, BMI, and related measures over extended time frames are needed to determine whether exergames can impact childhood obesity. Additional studies are needed to determine which types of exergames lead to measurable changes in fitness. But it is also important to remember that exercise is only one part of achieving good health. Exergames may motivate children to become physically active, but we also need to develop techniques to engage children in learning and adopting healthy diet and nutrition habits. Creating integrated curricula for schools around physical and nutrition education may facilitate the broader adoption of exergaming and increase its value for teachers and students.

Exergaming is in its infancy, but innovations are developing rapidly, opening new possibilities for combining gaming with physical activity and offering a new way of combating an alarming problem at the intersection of education and public health. Whether in homes or in schools, these games may inspire normally sedentary

youth to regard exergames and other forms of physical fitness as fun and motivate them to improve their health as a result. The ultimate goal is to encourage youngsters to be physically active on their own time. The next step for researchers is to assess the effects of these games on fitness and motivation in order to suggest implementation practices for parents and teachers.

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