Exergames for Physical Education Courses: Physical, Social, and Cognitive Benefits

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ABSTRACT—***Digital games combining exercise with game play, known as exergames, can improve youths' health status and provide social and academic benefits. Exergame play increases caloric expenditure, heart rate, and coordination. Psychosocial and cognitive impacts of exergame play may include increased self-esteem, social interaction, motivation, attention, and visual–spatial skills. This article summarizes the literature on exergames, with a special emphasis on physical education courses and the potential of exergames to improve students' physical health, as well as transfer effects that may benefit related physical, social, and academic outcomes.***

KEYWORDS—*exergames; youth; obesity control; social development; cognitive development*

As obesity rates skyrocket in the United States (McGinnis et al., 2006), exergames that provide both exercise and gaming have emerged as an innovative tool for combating the crisis. Exergames are not only prevalent in homes but are also becoming part of students' physical education classes, such as West Virginia's statewide exergame curriculum (Schiesel, 2007). This article summarizes the literature on exergames, with an emphasis on (a) their development; (b) their potential to improve students' physical health, social activity, and academic performance, including transfer effects; and (c) their use in physical education courses. It concludes with recommendations to enhance exergame effectiveness.

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DEVELOPMENT OF EXERGAMES AND INTEGRATION INTO YOUTHS' ENVIRONMENTS

Video game play is nearly universal among 12- to 17-year-olds: 99% of boys and 94% of girls play them (Lenhart, 2008). They are enjoyable and sustainable activities, with exergames emerging as a profitable market. The Nintendo Wii exergame contributed to a 73% increase in Nintendo's net sales, with 24.5 million consoles and 148.4 million software units sold to date (Nintendo, 2008), making it the second highest selling video game in 2007 (Entertainment Software Association [ESA], 2008). Thirty-six percent of 8- to 18-year-old youth had Wii game consoles in their homes in 2009 (Rideout, Foehr, & Roberts, 2010). Dance and rhythm exergames such as *Dance Dance Revolution* (DDR) and sedentary games such as *Guitar Hero* and *Lumines* are played by 61% of teenagers (Lenhart, 2008). Boys (58%) and girls (64%) and frequent gamers and nongamers play rhythm exergames (Lenhart, 2008).

The skills that youth acquire during exergame play can transfer to other activities, thereby benefiting physical, social, and cognitive development. According to Greenfield (1993), a video game player becomes an onscreen producer of content, a process heightened in exergame play when the player uses body movements to control the onscreen character's movements. Exergames interpret a player's bodily movements as inputs associated with specific meanings for game play, translating movement in three-dimensional space onto the two-dimensional screen. Because the exergame player is distanced from the character on the screen, he or she must use visual–spatial skills, hand–eye or foot–eye coordination, and quick reaction time to operate and successfully play the game. Moreover, exergame play allows multiple players to compete or cooperate on a team, thereby providing both a virtual and a real social interaction. These social and cognitive impacts of exergames provide additional potential benefits to the physical activity required for game play.

In order for exergames to influence physical development, designers developed systems to track and respond to players' gross motor movements. These games first emerged in the 1980s as stationary bicycles connected to game consoles that required pedaling and steering on a handlebar-mounted gamepad. They were unsuccessful because of high cost and interfaces that were complicated, easily broken, and unengaging. In the second-generation exergames of the late 1990s, DDR emerged as the first cost-effective exergame that produced significant caloric expenditure (Lanningham-Foster et al., 2006). Foot-operated pads, which DDR popularized, made foot movement an integral part of a commercially successful game. As foot movement required caloric expenditure, some schools began to use DDR in their physical education courses as an engaging way for youth to exercise (Schiesel, 2007).

Motion sensor technology, an alternative to foot-operated pads, uses a camera interface or controller device to transfer a player's image or movement to a screen (Lieberman, 2006). A major breakthrough in motion sensor technology was the Nintendo Wii, which uses an accelerometer within the Wii remote and a sensor bar to detect movement. For example, virtual Wii baseball requires the player to swing a Wii remote controller at a symbolic ball thrown by an animated onscreen character; the sensor bar picks up these actions, and the game displays them onscreen to represent the player.

Exergames are increasingly used as health tools. Gyms and health clubs, for instance, integrate gaming consoles into their equipment, such as Concept II's rowing machine that increases motivation through competition. Virtual personal trainers motivate players by monitoring progress on specific activities and encouraging them to proceed to the next level (Lieberman, 2006). In *Wii Fit*, the virtual trainer admonishes a player who stops mid-exercise and congratulates the successful player.

Exergames initially developed from technological advancements designed to make video games more fun (Parker-Pope, 2005). Exergames can now track full-body movement in three dimensions, accurately measure reaction time and acceleration, and capture the speed and power of a player's movement. Schools and fitness centers are gradually integrating these exergames into their curriculum and equipment. Exergames have clearly come of age in the commercial market. However, critics charge that exergames produce no health benefits, encourage screen time that displaces exercise, and produce insufficient motivation to sustain exercise for a long period of time (Lyons, 2009). There is also limited evidence of weight loss from exergame play (Maloney et al., 2008; Mhurchu et al., 2008; but see Staiano et al., 2011), and reading is more effective than gaming in developing certain cognitive skills such as reflection and imagination (Greenfield, 2009). How well do exergames meet the physical, social, and cognitive needs of young players?

PHYSICAL OUTCOMES

Exergames can provide both direct physical benefits for youth and transfer of athletic skills to other activities. This development comes at a time when obesity has reached epidemic proportions in the United States, where pediatric obesity rates doubled over the past 30 years (McGinnis et al., 2006), in part because of insufficient physical activity. Only 35.8% of adolescents met the 2005 U.S. Dietary Guidelines for physical activity (Eaton et al., 2006). In contrast, 50% of teen gamers play video games more than 1 hr a day (Lenhart, 2008). Transforming sedentary video game play into active exergame play could increase caloric expenditure and improve coordination and athletic skills, thereby combating obesity.

Caloric Expenditure and Heart Rate Increases

Playing exergames can yield light to moderate energy expenditure similar to walking, skipping, and jogging. Preadolecent and adolescent youth (n = 21) increased their energy expenditure from 129% to 400% while playing Sony *EyeToy* games (Maddison et al., 2007). Similarly, 12 college-aged students who played *Wii Sports* games expended energy comparable with walking at 3.0 miles per hour (Bausch, Beran, Cahanes, & Krug, 2008). Although participants who played *EyeToy Groove* expended enough energy to meet requirements for moderate exertion, energy expenditure came in short bursts followed by sizable breaks (Luke, 2005). Energy bursts are useful in exercise, but maximum physical fitness requires playing exergames that demand sustained moderate to vigorous exercise.

Exergame play doubled energy expenditure when compared with sedentary screen time for twenty-five 8- to 12-year-old children who played *EyeToy* and DDR (Lanningham-Foster et al., 2006), and 11 adolescent athletes expended more calories when playing Nintendo Wii than when playing a sedentary video game (Graves, Stratton, Ridgers, & Cable, 2007). Low-income African American adolescents (n = 74) who played *Wii Sports* tennis expended more calories than a control group that was working on a computer activity, particularly when they competed against peers rather than virtual characters (Exner et al., 2009).

Exergame play also increases heart rate, a facet of aerobic activity needed for physical fitness (Unnithan, Houser, & Fernhall, 2006). DDR play doubled 35 adolescents' resting level heart rates during a 45-min period (Hindery, 2005). Playing at the medium level of DDR intensity met standards for cardiorespiratory fitness in an active and fit sample of 40 young adults (Tan, Aziz, Chua, & The, 2002). DDR play also increases heart rate for less fit participants. Twenty-two overweight and normal weight adolescents who played DDR increased their heart rates enough for cardiorespiratory fitness, even at the lowest level of game play (Unnithan et al., 2006).

Frequent exergame play can contribute to fitness and weight loss over time (Unnithan et al., 2006). Playing *Wii Active* cooperatively with peers over a 7-month period resulted in weight loss for overweight and obese youth when compared with a control condition (Staiano et al., 2011). Regular *EyeToy* play also increased 20 children's total physical activity in sports and exercise, a transfer effect (Mhurchu et al., 2008).

Playing the *GameBike* exergame improved attendance in activity training for 14 college males (Warburton et al., 2007), suggesting that exergames are engaging and fun. Indeed, exergame play is often more engaging than sedentary game play. They seem particularly well suited for overweight adolescents, as energy expenditure is higher during DDR play for overweight than normal weight children (Unnithan et al., 2006), as well as for heavier adolescents who play *Wii Sports* tennis (Exner et al., 2009).

Coordination

Video game skills can transfer to real-world situations. Fery and Ponserre (2001) found that 62 male college students who learned to putt a golf ball from playing a golf exergame transferred the skill best when they concentrated on a certain goal, such as putting a virtual golf ball into an onscreen virtual hole.

Because many exergames such as DDR or *Wii Sports* tennis require rapid hand–eye or foot–eye coordination, they may improve general coordination skills. However, the majority of research on coordination benefits involves elderly people playing sedentary video games, not exergames. Video game play increased perceptual-motor skills including hand–eye coordination, dexterity, and fine motor ability (Drew & Waters, 1986). At present, there is no exergame research on this topic.

PSYCHOSOCIAL OUTCOMES

Gaming is often a social experience for teenagers. Seventy-six percent of teenagers play games against others at least occasionally, and 65% of teen gamers play against other people in the same room (Lenhart, 2008). Because video game play, including exergame play, often occurs with peers, opportunities for social interaction may influence friendship selection, self-esteem, moods, and motivation.

Social Interaction

Leisure activities, including exergames, can foster friendships among players, thereby reducing the risk of social isolation and loneliness (Mueller, Agamanolis, & Picard, 2003). DDR provides social interaction during actual game play, and a DDR culture formed as a result of the popularity of face-to-face or online tournaments, message boards, and chat rooms (Lieberman, 2006). Young adults ranked having fun as the primary reason for playing DDR, followed by social interaction, working out, dancing, meeting other people who play, enjoying the game's challenge, and seeking admiration for their skills (Lieberman, 2006). Young adults who ranked staying fit as a top reason for playing reported the most enjoyment and developed more friendships via DDR than other players. This preference for social interaction is also apparent in preadolescent children's preference for multiplayer and group game play over solitary exercise, as when twenty-seven 9- to 12-year-olds consistently chose a dance exergame (Chin A Paw, Jacobs, Vaessen, Titze, & van Mechelen, 2008).

Self-Esteem and Self-Efficacy

Adolescents report that teasing and criticism by peers and teachers are barriers to physical activity (O'Dea, 2003). Because exergame play allows youth to take their eyes off their peers and direct their attention toward a screen, game play may reduce body self-consciousness during physical activity. Indeed, 35 overweight preadolescent children who frequently played DDR had increased self-esteem (Brubaker, 2006). The self-efficacy scores from a sample of 74 overweight and obese adolescents who played *Wii Active* over time also improved (Staiano et al., 2011).

Mood

Exercise improves moods (Plante, Coscarelli, & Ford, 2001), and exergame play that provides physical activity may produce similar benefits. Among 168 college students, exercise groups who played an exergame or who used a regular cycle ergometer maintained higher positive moods for 10 min after completing the exercise than did a control group who played the video game without exercise (Russell & Newton, 2008). This improved mood during exergaming may transfer to other exercise activities. For instance, children and adolescents enjoyed and sustained exercise more after they began using exergames (Lieberman, 2006).

Motivation

Video games are intrinsically motivating, responding to a player's actions and challenging them at multiple levels of expertise (Malone, 1981). These qualities may explain why many youth choose video game play over traditional exercise (Parker, 2007). Factors associated with video game enjoyment often occur in exergame play, including perceptions that a game is interesting, energizing, visually appealing, interactive, challenging, and rewarding (Baranowski, Buday, Thompson, & Baranowski, 2008).

Exergame play may also motivate other physical activities. Fourteen preadolescent children, who chose between riding a stationary bike to gain access to entertainment media (TV, VCR, or video game) and doing a sedentary activity (reading or drawing), preferred to work out (Saelens & Epstein, 1998). Similarly, 34 obese preadolescent children who obtained points on a pedometer engaged in physical activity to use media (Goldfield, Kalakanis, Ernst, & Epstein, 2000).

COGNITIVE AND ACADEMIC OUTCOMES

The limited available research suggests that exergame play could enhance academic performance and that skills might transfer to other cognitive activities. In particular, exergames develop spatial awareness, attention, and understanding of cause–effect relationships; they also teach players to manipulate a tool (a controller), respond to visual feedback, plan actions, understand spatial constraints, and create a cognitive map of their bodily movements in relation to game play (Höysniemi, 2006).

Exergame play may also directly improve cognitive functioning, in particular executive control skills, by providing aerobic activity (Hertzog, Kramer, Wilson, & Lindenberger, 2009; Staiano, Abraham, & Calvert, 2010). A meta-analysis of aerobic activity interventions found cognitive and executive functioning benefits in elderly samples; aerobic exercise also affects the morphology and function of brain structures in humans and animals, potentially because of enhanced cardiorespiratory functioning, decreased risk for disease, and enriched environments that promote healthy structural, molecular, and neurochemical changes (Hertzog et al., 2009). A meta-analysis documented that physical activity enhanced cognitive performance among adolescents, including improved perceptual skills, intelligence quotient, achievement scores, verbal tests, mathematics tests, and developmental level, and academic readiness (Etnier, Nowell, Landers, & Sibley, 2006). Playing exergames against peers also increased obese and overweight adolescents' executive control skills over those of a control group (Staiano et al., 2010). These improvements are predicted to occur because aerobic fitness leads to physiological changes that improve cognitive performance via increased cerebral circulation, increased neurotransmitter availability, and enhanced physiological and neurological mechanisms that occur during physical activity (Etnier et al., 2006).

Attention

Bouts of high levels of aerobic activity that happen during exergame play could also improve cognitive control of attention, which could improve cognitive functioning (Hillman, Pontiflex, Raine, Hall, & Kramer, 2009). Sedentary video game play improves general attention capacities by requiring players to monitor a number of tasks for success. Compared to nongamers, young adult male video game players had higher processing and visual attention capacity, increased task-switching ability, and enhanced ability to process information over time (Green & Bavelier, 2003). Moreover, training nongamers on an action game for 10 days increased their visual attention capacity (Green & Bavelier, 2003). Although there is no current research on attention and exergame play, the amount of information that players monitor for successful play of DDR, Nintendo *Wii Active*, and other exergames could enhance attention during game play and transfer to other tasks.

Visual–Spatial Skills

Sedentary video game play improves visual–spatial skills including spatial relations, visualization, perceptual speed, and 3D rotation skills (Subrahmanyam & Greenfield, 1994). For instance, a brief video game intervention improved spatial skills for 61 fifth-grade students who initially had lower spatial skills than their peers (Subrahmanyam & Greenfield, 1994). The cognitive mapping required for games such as DDR, in which players must learn and retain the locations and patterns of onscreen arrows and footpad positions, may also enhance visual–spatial skills.

Academic Performance

Because video games are engaging and motivating, and they provide repeated practices and rewards (Höysniemi, 2006), gaming could improve academic performance. Specifically, video games improve cognitive outcomes that are beneficial for academic success, including problem solving, hypothesis testing, estimation, pattern recognition, memory, and judgment (Sheff, 1994). Indeed, 120 third- and fourth-grade students who played a dance-pad game demonstrated improved academic performance and social success (Shasek, 2004).

EXERGAMES FOR PHYSICAL EDUCATION COURSES

Physical education courses are a promising venue for youth to play exergames (Yang, Smith, & Graham, 2008). Digital games are already present in academic settings: 34% of teenagers report playing a computer or console game at school for an assignment (Lenhart, 2008). Throughout the United States, exergames like DDR are being incorporated into physical education classes, recesses, lunchtimes, and after-school programs; these games have received positive feedback from students, parents, and teachers (Hindery, 2005). Some students lost 5–10 pounds after daily DDR game play when 20 West Virginia schools used it in physical education classes (Barker, 2005). DDR is now in the physical education curriculum of all 765 West Virginia public schools (Lieberman, 2006). Even one gaming unit can benefit an entire class, as students can perform the footwork on dance pads even when they are not connected to the console (Lieberman, 2006).

In a study that used the *In the Groove* dance-pad game in third- and fourth-grade classrooms, highly "at-risk" students were appointed as "Groove Masters" to mentor other students (Chamberlin & Gallagher, 2008). Their absenteeism dropped by more than 50%, 85% of them developed better social skills, and 94% of them showed increased leadership skills, self-esteem, and enhanced academic performance. Moreover, the fourth-grade students improved their performance on a mile run by 13.8%, and students' enthusiasm toward sports, fitness, and dance increased.

Exergames offer activity opportunities for youth who live in dangerous neighborhoods with limited space. Although the initial cost of exergames may be a barrier to cash-strapped fitness programs, the cost is comparable with exercise equipment like stationary bicycles or rowing machines (Yang et al., 2008). *In the Groove* or a two-person DDR setup costs less than $200 and requires little space (Chamberlin & Gallagher, 2008). Current exergames include varied sports activities such as bicycling, dancing, aerobics, kickboxing, and martial arts (Lieberman, 2006). Hispanic and African American 8- to 18-year-old youth play video games more than white youth (Rideout et al., 2010). Whether or not exergames are a good investment for school systems depends on whether they are a sustainable physical activity over time.

To maximize effectiveness in schools, exergames could integrate physiological measures (Smith, 2005). A physical education course could adopt the following exergame routine to optimize health: a warm-up period of 5–10 min of low-intensity exercise, 20 min at 77%–90% of maximal heart rate, and a cool-down period of 5 min of low-intensity exercise to return heart rate to resting levels, performed at least 3 days per week (Sinclair, Hingston, & Masek, 2007). Such a routine could be taught in school during physical education classes and exported to children's homes.

To sustain interest, Sweetser and Wyeth (2005) suggest that exergames require concentration, challenge, skill development, deep but effortless immersion, and opportunities for social interaction. Games should include appropriate feedback and clear goals. Interactivity, behavior change goals, and first-person control make video games effective health behavior promoters (Baranowski et al., 2008). Incorporating these elements into exergames could provide similar benefits.

CONCLUSION

Current research, though limited, links exergame play to weight loss, physical and mental fitness, and improved health. Exergames are enjoyable tools that increase energy expenditure during play, motivate players to become more physically active, promote social interaction, and enhance cognitive performance. Incorporating exergames into schools, health clubs, and homes can promote healthy youth development and combat the childhood obesity crisis. Indeed, playing exergames could become one of the most popular, engaging, and health-promoting homework assignments of the twenty-first century.

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