

# The health benefits of interactive video game exercise

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**Abstract:** The purpose of this study was to evaluate the effectiveness of interactive video games (combined with stationary cycling) on health-related physical fitness and exercise adherence in comparison with traditional aerobic training (stationary cycling alone). College-aged males were stratified (aerobic fitness and body mass) and then assigned randomly to experimental ( $n = 7$ ) or control ( $n = 7$ ) conditions. Program attendance, health-related physical fitness (including maximal aerobic power ( $VO_{2\text{ max}}$ ), body composition, muscular strength, muscular power, and flexibility), and resting blood pressure were measured before and after training (60%–75% heart rate reserve, 3 d/week for 30 min/d for 6 weeks). There was a significant difference in the attendance of the interactive video game and traditional training groups ( $78\% \pm 18\%$  vs.  $48\% \pm 29\%$ , respectively).  $VO_{2\text{ max}}$  was significantly increased after interactive video game ( $11\% \pm 5\%$ ) but not traditional ( $3\% \pm 6\%$ ) training. There was a significantly greater reduction in resting systolic blood pressure after interactive video game ( $132 \pm 6$  vs.  $123 \pm 6$  mmHg) than traditional ( $131 \pm 7$  vs.  $128 \pm 8$  mmHg) training. There were no significant changes in body composition after either training program. Attendance mediated the relationships between condition and changes in health outcomes (including  $VO_{2\text{ max}}$ , vertical jump, and systolic blood pressure). The present investigation indicates that a training program that links interactive video games to cycle exercise results in greater improvements in health-related physical fitness than that seen after traditional cycle exercise training. It appears that greater attendance, and thus a higher volume of physical activity, is the mechanism for the differences in health-related physical fitness.

*Key words:* chronic disease, aerobic training, virtual reality.

**Résumé :** Analyser l'influence des jeux vidéo interactifs combinés à une séance d'exercice sur un vélo stationnaire sur la condition physique santé et sur la persévérance en matière de pratique d'activité physique comparativement à une simple séance d'effort sur un vélo stationnaire dans un contexte classique d'entraînement aérobie. Nous répartissons aléatoirement de jeunes hommes selon leur capacité aérobie et leur masse corporelle dans deux groupes, l'un expérimental ( $n = 7$ ) et l'autre, témoin ( $n = 7$ ). Au début et à la fin du programme d'entraînement (60%–75% de la fréquence cardiaque de réserve, 3 jours par semaine à raison de 30 min par jour durant 6 semaines), nous évaluons le taux de participation, la pression sanguine au repos et la condition physique santé incluant les tests suivants : la puissance aérobie maximale ou  $VO_{2\text{ max}}$ , la composition corporelle, la force musculaire, la puissance musculaire et la flexibilité. On observe une différence significative du taux de participation dans les séances d'entraînement sur vélo stationnaire agrémentées de jeux vidéo interactifs comparativement aux séances classiques d'entraînement sur vélo stationnaire ( $78\% \pm 18\%$  et  $48\% \pm 29\%$ , respectivement). On observe aussi une augmentation significative du  $VO_{2\text{ max}}$  dans le groupe expérimental ( $11\% \pm 5\%$ ) mais pas dans le groupe témoin ( $3\% \pm 6\%$ ). De plus, on observe une plus grande diminution de la pression sanguine au repos dans le groupe expérimental (de  $132 \pm 6$  à  $123 \pm 6$  mmHg) que dans le groupe témoin (de  $131 \pm 7$  à  $128 \pm 8$  mmHg). On n'observe pas de différence de composition corporelle entre les deux groupes. Le taux de participation est associé à la condition expérimentale et aux variations des valeurs des indicateurs de santé :  $VO_{2\text{ max}}$ , hauteur de saut vertical et pression sanguine. D'après nos observations, un programme d'entraînement combinant des exercices physiques et des jeux vidéo interactifs suscite de plus grandes améliorations de la condition physique santé que ne le fait un programme d'entraînement classique sur vélo stationnaire. Il semble que le taux de participation soit l'élément-clé pour accroître la pratique de l'activité physique et améliorer la condition physique santé.

*Mots-clés :* maladie chronique, entraînement aérobie, monde virtuel.

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## Introduction

There is extensive literature indicating that physical activity is an effective preventive strategy against cardiovascular disease, obesity, stroke, hypertension, type 2 diabetes, colon cancer, breast cancer, osteoporosis, and several psychological disorders (see review by Warburton et al. (2006a)). Health promotion programs have publicized widely the beneficial effects of physical activity on health status. Despite this information, the majority of North American adults do not meet the minimal requirements for physical activity wherein health benefits are thought to occur (Warburton et al. 2006a, 2006b). In fact, many North Americans are at an increased risk for chronic disease as a result of physical inactivity. Clearly, the burden of physical inactivity on society is substantial (Warburton et al. 2006a, 2006b).

The steepest decline in physical activity occurs between high school and young adulthood (Canadian Fitness and Lifestyle Research Institute 2001). In addition, approximately 40%–65% of individuals who initiate a traditional physical activity program withdraw within 3–6 months (Annesi 2001; Dishman and Buckworth 1996). Furthermore, we know that prior behaviour patterns are consistently the best predictor of future behaviour (Rhodes et al. 2004), suggesting that curbing this activity decline from adolescence to young adulthood may substantively help promote lifelong physical activity behaviour and, in turn, markedly improve health status. Some success has been achieved with behaviour interventions aimed to improve the level of physical activity (Dishman and Buckworth 1996), but the need for better intervention efforts has been advocated (Sallis 2001).

Based on the high prevalence of television and video game activities, some researchers have evaluated using these behaviours as contingency management strategies for exercise in young people (Epstein and Roemmich 2001). In fact, recent work indicates that reinforcing physical activity with sedentary behaviour is a simple and effective means of increasing physical activity participation and improving indicators of health status (Goldfield et al. 2006; Roemmich et al. 2004). Thus, it appears that contingent access to television and (or) video games may be effective in improving physical activity.

Limited research has evaluated interactive video game/virtual reality exercise. The integration of these behaviours seems a reasonable premise for promoting physical activity and removes the discipline required to initiate and maintain a contingency management plan. Indeed, preliminary evidence has tested interactive video bike technology and shown increased attendance (in male and female adults) compared with a control condition (Annesi and Mazas 1997), and these types of exercise equipment are beginning to become readily available to the general public. Unfortunately, no investigation has examined the effects of interactive computer games on physical activity behaviour and (or) risk factors for future disease in young adults. This research is warranted to determine and quantify the physiological benefits that can be derived from this technology. This information would be particularly useful in the development and implementation of intervention protocols that utilize this technology.

Accordingly, the primary objective of this investigation was to determine whether an interactive video game played during stationary cycling results in significantly greater improvements in multiple risk factors for chronic disease (i.e., aerobic fitness, body composition, blood pressure, and musculoskeletal fitness) in comparison with standard stationary cycling (control condition). We also sought to evaluate whether or not interactive video game exercise would lead to different exercise attendance rates than traditional cycle exercise. We hypothesized that participants in the experimental condition (interactive video game) would experience significantly greater reductions in the risk for chronic disease. Furthermore, based on previous research (Annesi and Mazas 1997), we hypothesized that the interactive video game exercise training program would result in greater attendance rates, leading to concomitantly greater changes in health-related physical fitness.

## Materials and methods

### Experimental design

We conducted a 6 week, prospective, randomized, controlled interactive video game intervention trial among college-aged males (Table 1). Participants ( $n = 14$ ) were stratified (by baseline aerobic fitness and body mass) and then randomly assigned to either the experimental (interactive video game;  $n = 7$ ) or control (stationary cycling;  $n = 7$ ) conditions. Program attendance was monitored throughout the 6 week program. We also assessed body mass and composition, resting blood pressure, and cardiovascular and musculoskeletal fitness at baseline and after 6 weeks of aerobic training. The measurement team was blind to the treatment conditions of the participants.

### Participants

We invited 14 low-active young males (18–25 y) (Table 1) to participate in the investigation, who were engaging in physical activity below Health Canada's recommended threshold (4 times/week for at least 30 min at a moderate intensity) over the last 3 months. Participants were screened for physical activity inclusion via self-report. Additional exclusion criteria included individuals who (i) were engaged in a regimented endurance training program within the previous 6 months, (ii) had participated in another research investigation within 30 d, (iii) exhibited abnormal blood pressure responses at rest (i.e., systolic blood pressure  $\geq 140$  mmHg and (or) diastolic blood pressure  $\geq 90$  mmHg) and (or) during exercise testing, and (iv) had known cardiopulmonary disease. All participants were recruited using advertisements containing a description of the inclusion and exclusion criteria for this investigation. Two participants were excluded from engaging in this investigation owing to being physically active on a daily basis. None of the 14 participants that met the inclusion criteria from the screening procedures withdrew from the investigation; however, as discussed later, some individuals participated in limited training sessions. All 14 participants were retained in the data analyses. The protocol was reviewed and approved by the Clinical Screening Committee for Research and Other Studies Involving Human Subjects of the University of British Columbia. Each participant provided

**Table 1.** Health-related physical fitness measures before and after a 6 week training program.

Variable	Traditional		Video	
	Pre	Post	Pre	Post
Age (y)	22±2	—	23±5	—
Height (cm)	176±10	—	177±6	—
Weight (kg)	85±18	85±18	84±13	82±14
Body mass index (kg·m <sup>-2</sup> )	28±6	27±6	27±6	27±6
Fat mass (kg)	17±8	17±9	18±9	17±10
Lean body mass (kg)	68±11	68±12	66±5	66±5
Maximal respiratory exchange ratio	1.20±0.06	1.25±0.09	1.21±0.05	1.19±0.06
Maximal heart rate (beats·min <sup>-1</sup> )	189±9	185±11	194±12	183±12*
Maximal power output (W)	307±43	296±9	272±36	307±43*
Maximal oxygen pulse (mL·beat <sup>-1</sup> )	19±4	20±4	17±3	20±3*
Grip strength (kg)	98±15	102±20	101±15	103±10
Flexibility (cm)	27±7	29±9	29±8	31±8
Leg power (W)	5089±801	5132±946	4858±724	5237±652*
Vertical jump (cm)	54±8	55±8	52±5	58±6*
Resting systolic blood pressure (mmHg)	131±7	128±8	131±7	123±6*
Resting diastolic blood pressure (mmHg)	68±5	67±9	69±7	67±6

\*Significant change after interactive video game training ( $p < 0.05$ ).

written informed consent and the investigation was conducted according to the Declaration of Helsinki.

## Experimental conditions

### Intervention group

Participants were required to exercise on a GameBike<sup>®</sup> (Cat Eye Electronics Ltd., Boulder, Col.) interactive video gaming system that was linked to a Sony Playstation 2<sup>®</sup> (Sony Computer Entertainment America Inc., Foster City, Calif.) and a television monitor. The GameBike<sup>®</sup> system reads the participant's speed (measured by cycling cadence) and steering, which in combination with a full function handlebar-mounted game controller allows each participant the opportunity to play a variety of Sony Playstation 2<sup>®</sup> video games. Participants were allowed to select a video game from a variety of Sony Playstation 2<sup>®</sup> video games (including Smuggler's Run, ATV Offroad Fury, Gran Turismo 3, NASCAR Heat, and Need for Speed). They were instructed to exercise at a moderate intensity (as described below) by manually adjusting the cycle ergometer resistance during each training session. However, participants were provided complete freedom to exercise at an intensity and duration that they desired. During each exercise session, participants could monitor their heart rate continuously by a Polar<sup>™</sup> heart rate monitor (Polar S-510, Polar Electro Oy, Kempele, Finland) to allow for the self-evaluation of exercise intensity.

### Control group

Each participant exercised on a standard bicycle (Monark Ergonomic 828E, Sweden) at an intensity and duration that they desired. Identical to the intervention group, participants were provided a recommended exercise prescription (as described below). Participants could monitor their heart rate continuously by a heart rate monitor (Polar S-510) to allow for the self-evaluation of exercise intensity. The duration on the bike per session was recorded.

### Recommended training regime

The recommended exercise training regime consisted of moderate intensity exercise (i.e., 60%–75% of heart rate reserve), 3 d/week for 30 min/d for 6 weeks. Participants were also provided with instructions on the perceptions of exertion (RPE) associated with the recommended training intensity. Each training session began with a standardized warm-up and cool-down period consisting of light stretching and 5 min of submaximal cycling at a low intensity (i.e., approximately 30% of heart rate reserve). Participants were permitted to engage in exercise during the weekdays (Monday–Friday) between 7 am and 7 pm. They also wore heart rate monitors on each training day and were provided individualized training heart rate zones. Although all participants were provided the same recommendations regarding exercise intensity and frequency of training, individuals were allowed complete freedom to choose exercise intensity and the frequency with which they participated in training. This was done to increase the ecological validity (real-world transferability) of the training program.

## Measurements

### Adherence to exercise

Exercise adherence was measured by taking attendance during the 6 week protocol. Each participant was provided with a recommendation to exercise 3 d/week (as discussed above). Attendance was evaluated as the actual number of sessions attended, divided by the recommended number of sessions. Given the fact that participants were free to attend as many exercise sessions per week (up to a maximum of 5), the weekly and total attendance could in theory be above 100%. However, previous research has indicated that an increase in weekly attendance above 100% is rare (0.5%) (Annesi 1999). Mean attendance was recorded for the 6 weeks of the investigation. A research assistant was present during all scheduled exercise times, assisted with the heart rate monitoring, and recorded the attendance of all participants.

### **Anthropometry and body composition**

Body mass (kg) and standing height (cm) were measured according to standard procedures. Body composition was assessed using bioelectrical impedance (Tanita 305, Tokyo, Japan) early in the morning (within 3 h of waking) and at the same time for each participant at each testing period. For the bioelectrical impedance measures, participants were asked to avoid alcohol consumption (within 48 h), intense exercise (12 h prior), diuretics such as coffee, tea, and caffeinated soda (12 h prior), and eating or drinking (4 h prior). Participants were also asked to empty their bladder within 30 min of the test.

### **Aerobic and musculoskeletal fitness**

Maximal aerobic power was assessed during an incremental (25 W·min<sup>-1</sup>) to maximal exercise test on an electronically braked cycle ergometer (Ergoline GmbH, Germany). Expired gas and ventilatory parameters were acquired and averaged every 15 seconds using a metabolic cart (Ergocard, Medisoft, Dinant, Belgium). Heart rate was monitored continuously by electrocardiography.

Musculoskeletal fitness (i.e., muscular strength, muscular power, and flexibility) was assessed according to the guidelines established by the *Canadian Physical Activity Fitness and Lifestyle Approach* (Canadian Society for Exercise Physiology 1996). Muscular strength was assessed using a hand-held dynamometer adjusted individually to hand size. The dynamometer was held in line with the forearm at the level of the thigh, away from the body. Participants performed 2 trials, alternating with both the dominant and non-dominant hand. The highest score was recorded and the combined score for both hands was calculated.

Dynamic muscular leg power was assessed using a vertical jump test (Vertec™ device; Sports Imports, Columbus, Ohio). Participants were required to pause in the semisquat position before jumping as high as possible to touch the Vertec™ device. No run-up or prejump was permitted. Participants performed 3 trials, with the highest score being recorded. Leg power was calculated using a standardized formula (Sayers et al. 1999).

Flexibility was measured using a flexometer (Modified Wells and Dillon, Warburton Flexometer, Ascent Lifestyle Management Inc., Vancouver, B.C.). Participants warmed up for this test by performing a modified hurdle stretch (held for 20 s) twice on each leg. With the knees fully extended, the participants were required to bend and reach forward as far as possible. Participants performed 2 trials, with the highest score being recorded.

### **Resting blood pressure**

Resting blood pressure in the supine position was measured at rest (in duplicate) using an automated blood pressure device (Pulse Wave™ CR-3000, Hypertension Diagnostics Inc., Eagan, Minn.). The lower of the two recordings was taken as the measure at each time point. The device was calibrated daily. Participants were allowed to rest for 10 min in the supine position before the first measurement of blood pressure.

### **Perceptions of effort on the exercise ergometers**

In this investigation, we sought to compare the interactive

video game system with an exercise bike that is commonly found in exercise facilities and that is used in considerable research investigations. Thus, we have tried to optimize the ecological validity of the present investigation. To ensure that the internal validity of this study was not limited, we ran a protocol study in 15 college-aged males (not involved in the training portion of this study), comparing the 2 bikes under matched heart rate conditions over a 30 min period to test whether or not there were preferences between bikes (order randomly assigned). Both bikes were not interfaced with interactive video game media during this portion of the trial. Participants were asked to compare the 2 ergometers with respect to design quality, the anticipated level of discomfort while exercising, and the actual level of discomfort while exercising over a 30 min period of submaximal exercise.

### **Statistical analyses**

All tabular values are reported as the mean ± standard deviation (SD). Data contained in figures are reported as the mean ± standard error of the mean (SEM). An independent *t* test was used to evaluate the differences in program attendance between groups. The physiological training data were evaluated using a mixed model analysis of variance (ANOVA). Post-hoc comparisons (Tukey) were conducted if a main effect for training and (or) group was found. The level of significance was set a priori at  $p < 0.05$ . Hierarchical OLS regressions (mediator analyses) were conducted (Baron and Kenny 1986). These analyses evaluated whether attendance mediated the relationships between condition (interactive video and traditional cycling; independent variables) and changes in health outcomes (e.g.,  $VO_{2\max}$ , vertical jump, and systolic blood pressure).

## **Results**

There were no significant differences in any of the demographic or physiological parameters of interest between groups at baseline (Table 1).

### **Attendance**

There was a significant difference in the attendance of the interactive video game and traditional training groups (Fig. 1). Participants in the interactive video game intervention attended approximately 30% more frequently than participants in the traditional training group ( $78 \pm 18$  vs.  $48 \pm 29\%$ , respectively). The attrition in the intervention group appeared to occur at random throughout the study period. In comparison, there was a progressive decline in participation rates in the traditional training group with time.

### **Health-related physical fitness**

#### **Body composition**

There was no significant change in body mass, body mass index, fat mass, or lean body mass after interactive video game and traditional training (Table 1).

#### **Aerobic fitness**

There was a significant change in  $VO_{2\max}$  in the interactive video game group (Fig. 2;  $11.0 \pm 5.1\%$ ). There was no significant improvement in  $VO_{2\max}$  after traditional training

( $3.4 \pm 5.6\%$ ). Approximately 69% of the variance in the change in  $\text{VO}_2\text{max}$  with training was explained by attendance levels (Fig. 3).

### Cardiorespiratory response to exercise

There was no significant change in the maximal respiratory exchange ratio after either training program. There was a significant improvement in maximal power output in the interactive video game training group, but no significant change after traditional training (Table 1). Maximal heart rate was significantly reduced in the interactive video game group, and slightly (but not significantly) reduced after traditional training (Table 1). Oxygen pulse was significantly increased after interactive video game training (Table 1).

### Musculoskeletal fitness

There was no significant change in grip strength or flexibility in either training group (Table 1). There was a significant change in vertical jump and leg power in the interactive video game training group (Table 1; Fig. 4). There was no significant change in vertical jump and leg power in the traditional training group (Table 1; Fig. 4). Approximately 44% of the variance in the change in vertical jump with training was explained by attendance levels (Fig. 4).

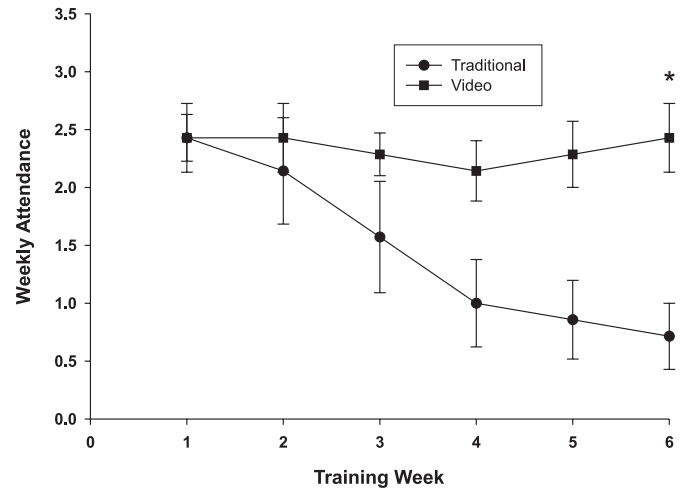
### Resting blood pressure

There was a significant reduction in resting systolic blood pressure in both training groups. However, the magnitude of change in systolic blood pressure was significantly greater after interactive video game training in comparison with traditional training (Table 1). Approximately 91% of the variance in the change in systolic blood pressure with training was explained by attendance levels. There was no significant change in diastolic blood pressure with training in interactive video game training.

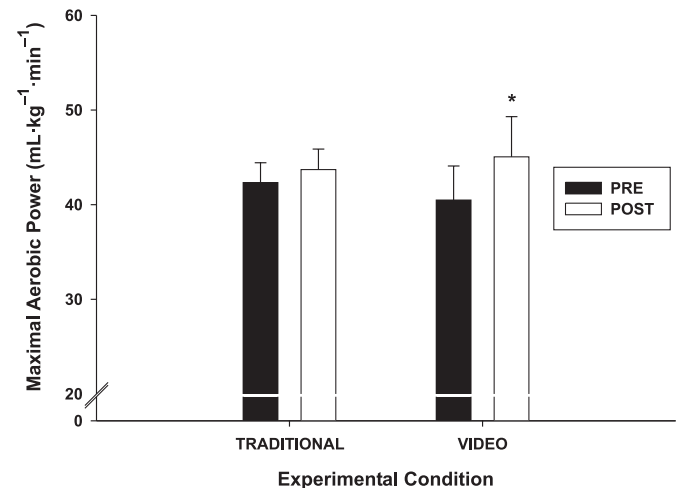
### Mediator analyses

The mediator analyses revealed that attendance coordinated/mediated the relationships between condition and changes in health outcomes (including changes in  $\text{VO}_2\text{max}$ , vertical jump, and systolic blood pressure). In each instance, the entry of attendance as an independent variable in the hierarchical OLS regression reduced the beta of the condition to nonsignificant, demonstrating mediation. For instance, the dependent variable of changes in vertical jump was reduced in the regression equation from a significant standardized beta of 0.60 ( $p < 0.05$ ) to a nonsignificant beta of 0.35 ( $p = 0.19$ ), suggesting full mediation. Similarly, the dependent variable of changes in  $\text{VO}_2\text{max}$  was reduced in the regression equation from a significant standardized beta of 0.61 ( $p < 0.05$ ) to a nonsignificant beta of 0.22 ( $p = 0.28$ ), suggesting full mediation. With respect to changes in resting systolic blood pressure, there was also a reduction in the regression from a significant standardized beta of  $-0.55$  ( $p < 0.05$ ) to a nonsignificant beta of  $-0.04$  ( $p = 0.75$ ) when attendance was entered as an independent variable in the hierarchical regression analyses. These analyses reveal that the shared variance between condition and health outcome changes is coordinated by the variance shared with attendance.

**Fig. 1.** Weekly program attendance in interactive video game and traditional cycle training groups (mean  $\pm$  SEM). Asterisk (\*) indicates significant difference between interactive video game and traditional training groups ( $p < 0.05$ ).



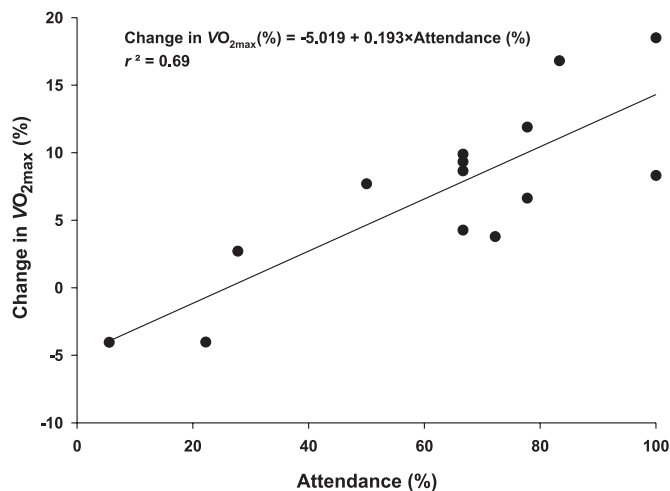
**Fig. 2.** Change in aerobic fitness with interactive video game and traditional training (mean  $\pm$  SEM). Asterisk (\*) indicates significant change after interactive video game training ( $p < 0.05$ ).



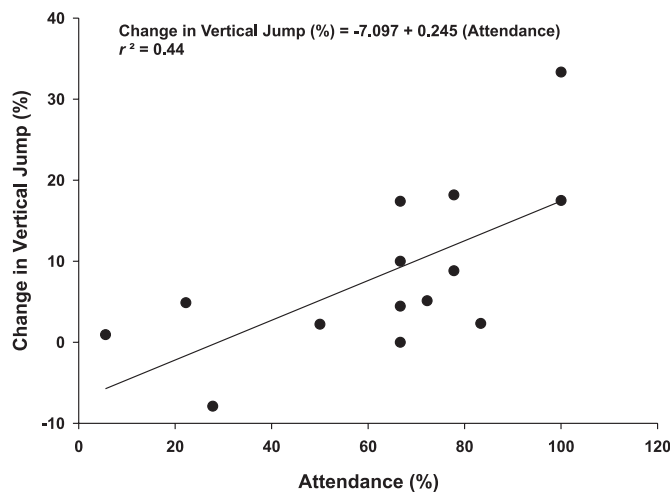
### Perceived effort on the two ergometers

In a separate protocol study with 15 males not involved in the training portion of this study, we revealed that the participants perceived the Monark control bike as smoother and more comfortable during exercise compared with the video exercise bike (with no interface with the interactive video media). Thus, the exercise bike linked to the interactive video media did not appear to be a preferred ergometer over the traditional Monark cycle ergometer. Thus, the health benefits associated with the intervention appear to be the result of the specific effects of the enjoyment and pleasure associated with the interactive video games and not the comfort of the exercise ergometer itself. This strengthens greatly the internal validity of the present investigation. It is important to note that the manufacturers of the interactive video game ergometers have recently designed a commercial ergometer (GameBike Pro, Cat Eye Electronics, Source Distributors Inc., Dallas, Tex.) designed for use in health clubs and schools.

**Fig. 3.** Relationship between change in maximal aerobic power and attendance.



**Fig. 4.** Relationship between change in vertical jump and attendance.



## Discussion

To our knowledge, the present investigation is the first to examine the effects of interactive video games on objective physiological indicators of health status. Consistent with our original hypotheses, we revealed that interactive video game training leads to significant improvements in several markers of health status. Importantly, the health benefits appear to be greater than that observed in individuals who are provided free and open access to traditional exercise training. Commensurate with Annesi and Mazas (1997), we also showed that a training program that links interactive video games to cycle exercise results in greater program adherence than that observed after traditional cycle exercise training (in the setting wherein participants are free to choose the amount of exercise they perform).

### Health-related physical fitness

Changes in aerobic fitness of approximately 8%–20% are common after supervised aerobic training programs in asymptomatic (Warburton et al. 2004a, 2004b) and clinical (Warburton et al. 2004b, 2005) populations. For instance,

we previously revealed a 13% improvement in  $VO_{2\max}$  after continuous (traditional) and interval training in college-aged males (Warburton et al. 2004a). In our earlier work, participants were required to attend each day and cycle from 30–48 min daily, 3 d/week at approximately 65% of  $VO_{2\max}$ . By the study design, participants were required to attend all training sessions and exercise at a closely monitored intensity and duration. In the present investigation, participants were permitted to attend as many or as few exercise sessions as they wanted. In addition, participants could exercise at a self-selected pace and duration. As such, the onus to engage in physical activity was solely on the participants, with no encouragement for attendance being provided to either training group. Although the training program and exercise intensity were identical to that used in the present investigation, there were markedly greater changes in aerobic fitness (13%) in our previous study in comparison with the changes observed in the traditional stationary training group (3%) in the present investigation. The most plausible explanation is the differences in attendance and associated differences in training volume between investigations. Interestingly, the relative change in  $VO_{2\max}$  after the interactive video game training program was very similar to that observed in our earlier, more regimented trial that required full attendance. Therefore, in our experience, it appears that interactive training resulted in comparable changes in cardiovascular fitness to that seen after regimented research investigations. More importantly, the interactive video game training program resulted in significantly greater changes in  $VO_{2\max}$  than that observed after traditional cycle exercise training in college-aged males who were provided the choice to exercise. It appears that, when given the choice to exercise in a traditional manner, many college-aged males will not adhere to the recommended exercise prescription and, in turn, not reap the health benefits of aerobic training.

In the present investigation, we also observed a significant reduction in resting SBP after both traditional and interactive video game exercise training. The reduction in blood pressure, however, was significantly greater in the interactive video game group (9 vs. 3 mmHg, respectively). Although our investigation precluded individuals with established hypertension (i.e., SBP  $\geq 140$  mmHg and (or) DBP  $\geq 90$  mmHg) from participating in this investigation, the majority had resting blood pressures that would classify them as “pre-hypertensive” (i.e., SBP 120–139 mmHg or DBP 80–89 mmHg) (Pescatello et al. 2004). Two main factors may account for this: (i) the participants were all sedentary, which is an established risk factor for elevated blood pressure; (ii) it is common for blood pressure to be elevated upon the initial assessment, owing to anxiousness surrounding the measurement of blood pressure (e.g., the “white coat syndrome”). However, we took every effort to ensure that the participants were as relaxed as possible when taking resting blood pressure measurements. We also only recorded the lower of the two measurements of blood pressure.

The reduction in resting blood pressure is comparable to that observed in other trials (as reviewed in the ACSM position statement (Pescatello et al. 2004)). The fact that the interactive video game training program resulted in an approximate 9 mmHg reduction in systolic blood pressure is of great significance from a health-related perspective. For

instance, a 2 mmHg reduction in SBP has been associated with a 14% and 9% reduction in the risk of stroke and coronary artery disease, respectively (Pescatello et al. 2004).

Unique to the present investigation, we also revealed that a training program that involved interactive video games resulted in significant improvements in musculoskeletal fitness (in particular, leg power). There is mounting evidence that enhanced musculoskeletal fitness is associated with an improvement in overall health status and a reduction in the risk for chronic disease and (or) disability (Warburton et al. 2001a, 2001b). Accordingly, there has been an increased focus on the evaluation of the health benefits of activities that tax the musculoskeletal system (Warburton et al. 2006a, 2006b). An improvement in muscular power is thought to be of great importance for functional status and the ability to perform activities of daily living (particularly in the elderly). The participants in the present investigation were young and healthy with no apparent physical limitations. Moreover, their musculoskeletal fitness levels were not at a level that would be associated with an elevated risk for functional impairments. Nonetheless, the fact that muscular power was improved after interactive video games indicates that this form of exercise can improve indicators of health status other than traditional cardiovascular markers (e.g.,  $VO_2 \text{ max}$ ). It remains to be determined whether or not this form of training would be of benefit to populations (e.g., the frail elderly) that are at risk for functional limitations owing to their low musculoskeletal fitness levels.

This research is the first to reveal that interactive video games results in greater improvements in health-related physical fitness than traditional cycling (when performed in an environment of open choice to exercise). The changes in health-related physical fitness (namely, cardiovascular and musculoskeletal fitness) and resting systolic blood pressure were directly associated with the attendance levels. Furthermore, we revealed that the shared variance between condition and health outcome changes is coordinated by the variance shared with attendance. That is, attendance mediates the condition versus change in health-outcome relationships. A greater attendance necessitates a greater volume of exercise. This highlights the importance of the total volume of exercise for the derivation of health benefits in the participants of the present investigation. This supports previous work that indicates that the volume of exercise is of key importance for the physiological adaptations and health benefits arising from exercise interventions (Warburton et al. 2004a, 2006a, 2006b). We must however acknowledge that the intensity of exercise was not measured throughout the intervention and, as such, the intensity of exercise may have also contributed to the observed health benefits.

### Exercise adherence

Limited research has examined the utility of video games as a health behaviour intervention. Video games have been promoted as useful tools for learning (Emes 1997) and health education (Lieberman 1997), but only 1 published study investigated the effects of interactive computer games on behaviour (Annesi and Mazas 1997). Thus, the present investigation adds to this limited literature evaluating the effects of interactive video game exercise on exercise behaviour (i.e., adherence) and health status.

Previous research using behavioural economic theory revealed that people are often reinforced by sedentary behaviours (e.g., television, video games) in comparison with physical activity (Epstein et al. 1999; Saelens and Epstein 1999), and that contingency management of sedentary behaviours with physical activity has been a successful promotion strategy (Epstein et al. 1995; Faith et al. 2001; Saelens and Epstein 1998). Specifically, the pioneering work of Epstein and colleagues (Goldfield et al. 2000; Saelens and Epstein 1998, 1999) revealed the potential reinforcing effects of video games and (or) television for physical activity. This work provided support for the rationale of the present investigation. The results of these studies were encouraging, but a major problem with this contingency strategy is in the real-world "transfer" or ecological validity. That is, many people will skip the contingency plan (e.g., exercise) and engage directly in the desired sedentary behaviour when left unsupervised (as done in the previous studies). As male adolescents and young adults frequently play video games during their leisure time, we hypothesized that trying to integrate the attractive properties of sedentary activities into the physical activity experience may result in better adherence to a physical activity training program. This moves beyond a contingency management strategy, as the reinforcing stimulus is the physical activity experience itself.

Our exercise adherence data support our hypotheses, indicating that the combination of video games and physical activity leads to greater exercise adherence than traditional aerobic training in college-aged males. In the present investigation, individuals assigned to the traditional cycling training program participated in less than 50% of the recommended exercise classes. This low exercise adherence rate occurred despite the fact that the participants were provided free, open access to advanced training expertise, facilities, and equipment. The temporal changes in attendance rates are suggestive that the participants may have become bored or disinterested with the traditional training program. Thus, given the choice, many young adult males will not participate routinely in physical activity programs that involve traditional cycling exercise. In contrast, the individuals assigned to the interactive video game training program participated in close to 80% of the recommended exercise classes, and the level of attendance remained relatively constant throughout the intervention. Thus, it appears that interactive video game exercise is a good medium by which to improve exercise adherence rates in college-aged males. These findings also have significant implications for the long-term adherence to exercise. It stands to reason that a program that combines physical activity with a preferred leisure-time activity is more likely than traditional exercise intervention programs to lead to greater exercise adherence and associated health benefits (as illustrated in the present investigation). Whether these findings are transferable to other populations remains to be determined. For instance, it is unclear whether females (who are less likely to play video games) would see as great of health benefits from an intervention of this nature.

### Conclusions

We have shown that interactive video game exercise is ef-

fective in enhancing exercise adherence, and several markers of health status in sedentary college-aged males. It is important to note that, based on the BMI data, this sample of young males would be considered to be overweight. Thus, these findings also have implications for the secondary prevention of obesity. Given the mass appeal of video games among school-aged children, adolescents, and young adults, it stands to reason that this form of training may be useful in the battle against physical inactivity and associated health complications. This training program is a relatively low-cost intervention, especially given the already established base of Sony Playstation 2<sup>®</sup> video game machines in many private dwellings. Further research is therefore warranted that evaluates this form of training on a larger scale in schools, recreation/community centers, and the home environment, and over an extended time frame, with participants from both genders and varied backgrounds.

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