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Interactive Video Games and Physical Activity: A Review of the Literature and Future Directions

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ABSTRACT

Background Physical activity has been associated with many health benefits for both adults and children; however, over half of the Canadian population is not active enough to experience these benefits. Thus, there is a need to implement innovative physical activity interventions.

Purpose The purpose of this paper was to review the available literature regarding interactive exercise video games as a potential physical activity intervention.

Methods The literature search was performed using online databases yielding 19 articles.

Results Research suggested that interactive gaming provided increased energy expenditure, increased oxygen uptake, and heart rate over traditional video games or sedentary activities, as well as increased adherence and affective attitude.

Conclusions Future research in this area is recommended to better understand the benefits of interactive gaming for physical activity interventions. **Health & Fitness Journal of Canada 2008;1(1):14-24.**
Keywords: Interactive Video Games, Physical Activity, Review, Future Direction

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INTRODUCTION

Physical activity (PA) has been linked to the prevention of numerous chronic diseases and conditions; however, 48% of men and 54% of women in Canada are considered inactive (Warburton et al. 2007b) and 57% of children and youth between the ages of five and 17 do not participate in enough levels of PA to achieve optimal health benefits (Craig et al. 2001).

The importance of PA is well-established. As a result, improving activity levels has become a public health priority through the development of interventions. Most interventions are self-regulatory, employing techniques such as goal setting and self-monitoring, and are based on the persuasive ability of the health benefits of PA (Kahn et al. 2002). While many similar interventions aim to improve participation, they have only had a modest effect (Foster et al. 2005; Rhodes and Pfaeffli in press). Affective attitude, concerned with feeling states and emotional judgments about a behaviour, is reliably linked to PA (Rhodes et al. in press). Indeed, research concerning affective beliefs shows it to be a better predictor of both intention and behaviour than instrumental beliefs such as those concerning health and appearance (French et al. 2005; Lowe et al. 2002; Rhodes et al. in press). Limited intervention research, however, has focused on the affective properties of exercise.

The incorporation of video games with exercise as a PA initiative seems a promising avenue for interventions due to the high affective properties of these games and the prior established gaming experiences of many sedentary adults and children/adolescents. Still, the literature on this topic is limited and needs to be appraised critically and united in order to establish future directions and provide recommendations for health promoters. This paper examines the literature surrounding interactive gaming and provides direction for future research in this area.

Methods

Articles were retrieved through database searching of Academic Search Premier, Alt Health Watch, Biomedical Reference Collection Comprehensive, Business Source Premier, CINAHL with Full Text, Computer Science Index, ERIC, Film and Television Literature Index, Health Source: Nursing/Academic Edition and Consumer Edition, Medline, MLA Directory, MLA International, Primary Search, PsycARTICLES, PsycCRITIQUES, PsycINFO, SPORTDiscus, Web of Science, and PubMed.

Search terms used were combinations of interactive games, interactive video games and video games paired with PA and exercise. To be included, articles needed to be English, peer-reviewed studies and include interactive technology paired with PA. Studies were excluded if they pertained to skill development and motor learning, did not include PA, or did not have an interactive component (e.g., computer games).

Initial searches yielded 673 articles: 33% were eliminated as duplicates; 51% were eliminated because they did not involve PA and/or an interactive component; 4% were eliminated because they involved rehabilitation populations focusing on motor skills and skill development; and 5% were eliminated because they involved only computers and had no PA component. After these eliminations and manually checking bibliographies, 18 articles remained. Studies were grouped based on subtopic: physiological outcomes, behavioural outcomes, and psychological outcomes and mediators.

Results

Study Characteristics

Of the 18 studies, 11 were cross-sectional and seven were randomized control trials. Four of these studies used interactive type exercise equipment, and 14 used interactive video games that are exercise-based. Participant ages ranged from seven to 60. See Table 1 for a summary of the studies included in this review.

Physiological Outcomes

Eleven studies examined whether interactive games could affect physiological outcomes through energy expenditure (EE), oxygen uptake (VO_2) and heart rate (HR). Energy expenditure during interactive games was compared to EE at rest, or while playing sedentary video games, and illustrated significantly higher EE during active video games than traditional and sedentary activities (Graves et al. 2007; Graves et al. 2008; Lanningham-Foster et al. 2006; Maddison et al. 2007; Ridley and Olds, 2001; Sell et al. 2008; Wang and Perry, 2006). Heart rate was significantly greater for active gaming conditions in four studies (Graves et al. 2008; Maddison et al. 2007; Sell et al. 2008; Wang and Perry, 2006) and produced significantly lower maximal heart rates after a six week intervention among participants using an interactive game bike (Warburton et al. 2007a). Oxygen consumption was significantly higher in active games compared to sedentary (Ridley and Olds, 2001) and intervention participants using an interactive game bike had significant increases in VO_{2max} (Warburton et al. 2007a). Overall, interactive gaming has illustrated positive physiological outcomes including increased EE, HR and VO_2 over traditional video games and sedentary activities.

Behavioural Outcomes

Six studies measured behavioural outcomes such as usage, adherence and attendance. Three studies measured usage of active games at home and found no significant differences between intervention and control groups (regular video games) for minutes of

Table 1: Literature Used in Review.

Researchers	Year	Sample	Design	Measures	Statistical Results
Annesi & Mazas	1997	N=39 21-60 years old	Randomized Controlled Trial: -Upright bicycle group -Recumbent exercise bicycle group -Virtual reality-enhanced exercise bicycle group 14 weeks, suggestion 3 or more sessions of 20-30min	Exercise-induced Feeling Inventory -record before and after at 6 points during program Self-motivation Inventory -Week 1 and Week 14 Tracking calendars -attendance -adherence (considered adherer if did not miss 2 full weeks)	13 drop-outs VR group: 83.33% adherers Recumbent: 61.54% adherers Upright: 57.14% adherers -virtual reality better adherence (sig difference, $F_{2,36}$ = 4.61 p<.02) -self motivation not significant predictor of attendance
Chin A Paw, Jacaobs, Vaes-sen, Titze & van Mechelen	2008	N=27 9-12 year olds 11 dropped out	Randomized Controlled Trial -Home group (n=14) given interactive dance simulation video game to use at home whenever they liked, told to track all uses -Multiplayer group (n=13) multiplayer group received same instruction as home group but were invited to a weekly 60 minute multiplayer session	Aerobic fitness: shuttle run test Body weight and height Skinfolds (triceps, biceps, subscapular, and anterior suprailiac) Physical activity recalled through self-report Competence of sport measured using CBSK-M All measurements performed at baseline, after 6 weeks, after 12 weeks	15% dropout in multiplayer group compared to 64% in home group (p=.02) Multiplayer group played 901 min over 12 weeks, where home group played 376 min (results not significant)
Graves, Ridgers & Stratton	2008	N=13 (6 female, 7 male) 11-17 years old	Cross-sectional	-tennis, boxing, bowling (Wii) -XBOX 360 -heart rate -accelerometer -VO_2	Non-dominant upper limb activity, EE and HR significantly greater during Wii sports boxing than tennis or bowling (p<.044) M=267.2 kg^{-1} min^{-1} (SD=115.8); M=136.7 bpm Hip activity best predicted EE $R2$ > .53
Graves, Stratton, Ridgers, & Cable	2007	N=11 (6 male, 5 female) 13-15 year olds	Cross-sectional	-energy expenditure across 4 games: XBOX 360 (sedentary), wii bowling, wii tennis, wii boxing -energy expenditure measured using intelligent device for energy expenditure and activity (IDEEA)	All active games significantly greater energy expenditure than resting (p<0.001) Boys energy expenditure greater than girls for wii tennis (p=0.013) Wii greater energy expenditure than XBOX 360 (p<0.001), energy expenditure at least 51% greater (equivalent to approximately 250 kJ or 60 kcal per hour)
Lanningham-Foster, Jensen, Foster, Redmond & Walker	2006	N=25 (12 boys, 13 girls) 15 lean, 10 overweight	Cross-sectional	Energy expenditure measured using indirect calorimeter built specifically for use with children 1 seated video game:	Seated television watching: increases of 50 +/- 29 kJ/hr (p<.0001) over resting energy expenditure

				Disney's Extreme Skate Adventure on Playstation 2 2 active video games: first used USB camera to place participant in the game for interactivity (Eye Toy), second was Dance Dance Revolution Energy expenditure measured at rest, while playing sedentary game, while walking on the treadmill at 1.5 miles/hr, and during the 2 active games	Seated video gaming: increases of 55 +/- 29 kJ/hr (*p*<.0001) over resting energy expenditure Walking while watching TV: increases of 353 +/- 118 kJ/hour (*p*<.00001) over resting energy expenditure Walking while watching TV: increases of 302 +/- 105 kJ/hour (*p*<.00001) over sitting and watching TV Eye Toy (active game #1): increases of 273 +/- 101 kJ/hour (*p*<.00001) over resting energy expenditure Dance Dance Revolution: increases of 382 +/- 181 kJ/hour (*p*<.00001) over resting energy expenditure No significant differences based on age and gender
Maddison, Mhurchu, Jull, Jiang, Prapavessis, & Rodgers	2007	N=21 10-14 years old	Cross-sectional	Heart rate using Polar Accurex monitor Physical activity levels using Actigraph Accelerometer Oxygen uptake measured using indirect calorimetry gas-exchange analysis system Measurements taken at rest, playing inactive video game, playing active video gaemes (Eye Toy Knockout- boxing, Homerun- baseball, Groove- dancing upper body, AntiGrav- hover board, PlayStation 2 Dance UK- dance pad)	Energy expenditure significantly greater (*p*<.001) in active video games (range = 2.9 +/- 0.7 kcal/min to 6.5 +/- 1.7 kcal/min) compared with rest (1.3 +/ 0.2 kcal/min), and non active video games (1.6 +/- 0.2 kcal/min) Active games resulted in significantly higher heart rate and activity counts compared with nonactive games and rest (*p*<.001) No gender differences across conditions
Madsen, Yen, Wlasiuk, Newman, & Lustig	2007	N=30 (data for 26 participants at 3 months and 21 participants at 6 month) 9-18 year olds BMI above 95th percentile	Cross-sectional	Used Dance Dance Revolution, instructed to use 30 min/day, 5 days/ week and record diary on a video card that estimates energy expenditure per day Semi-structured phone interviews bi-weekly for 2 months, then monthly thereafter Measured height and weight for BMI at baseline, 3 months and 6 months	12 participants used DDR at least twice a week in first 3 months 2 of 21 participants used DDR twice a week or more for months 3 to 6 No changed in BMI at 3 and 6 months Phone interviews described stressors inhibiting use, and 13 participants reported DDR to be boring within 4

					weeks
McDougall, & Duncan	2008	N=12 (7 female, 5 male) 8-11 years old	Cross-sectional	Participants played EyeToy (active video game) during lunch breaks during one week Focus groups to discuss beliefs on video game playing Heart rate measured using Polar Advantage Heart Rate Monitor during lunch hours Pedometry measured using New Lifestyles Pedometer during lunch periods	Focus groups: Children understand excessive gaming can have negative health impacts, most owned game consoles at home Step count: Boys: *M*=1503 (*SD*= 453.3) Girls: *M*=1303 (*SD*= 230.1) Heart rate: Boys: *M*=145 (*SD*= 6.5) Girls: *M*=151 (*SD*= 19) Minutes MVPA: Boys: *M*=10 (*SD*= 1) Girls: *M*=12.6 (*SD*= 5.1) Post interviews: All listed EyeToy as favourite game, said they would continue playing afterwards and thought children not enthusiastic about PA should engage in this game
Ni Mhurchu, Maddison, Jiang, Jull, Prapavessis, & Rodgers,	2008	N=20 (8 female, 12 male) 12-14 year olds	Randomized controlled trial Intervention group: Received EyeToy active video game and dance mat Control group: Already owned sedentary PlayStation 2	Physical activity measures: Actigraph accelerometer (objective) Physical Activity Questionnaire for Children (PAQ-C) (subjective) Daily activity log kept Height, weight, waist circumference	Total video game playing: intervention group 54 min/day, control group 98 min/day = difference -44 minutes/day 95% CI [-92,2]. *p*= .06 Active video game playing: intervention group 41 min/day, control group 27 min/day = difference 14 minutes/day 95% CI [-15,43]. *p*= .3 Inactive video game playing: intervention group 47 min/day, control group 99 min/day = difference -52 minutes/day 95% CI [-101,-2]. *p*= .04 PA counts for all participants *M*=12.1 hours/day (*SD*=1.4) Counts higher for intervention group: 6 weeks: mean difference= 194 counts/min 95% CI [32,310]. *p*= .04 12 weeks: mean difference= 48 counts/min 95% CI [-153,187]. *p*= .6 No significant differences between moderate and vigorous intensity or PAQ-C scores Boys significantly more

					active than girls p<.05
Pettitt, Wollitzer, & Jovanovic	2005	N=20 (15 girls, 5 boys) 13-17 year olds All obese (BMI between 26.3 and 62.8)	Randomized controlled trial Intervention group: Spent 1 hour of session playing Dance Dance Revolution Control group: Spent 1 hour of session engaging in vigorous exercise	Program was 3 days/week, 3 hours/day Other 2 hours spent by both groups learning about nutrition, active PA, motivational training on self-esteem	No significant difference between groups for weight loss after 8 week session
Rhodes, Warburton & Coble	2008	N=27	Randomized Control trial Experimental condition (n=16): Interactive video game (Game bike linked to Sony Playstation) Control condition (n=11): Stationary cycling Moderate intensity activity 60-75% HR reserve, 3 days/wk for 30min for 6 weeks	Questionnaires using the theory of planned behaviour	Results in favour of intervention: Affective attitude (d=1.2) Intention (d=.67) Adherence (d=.71) Partial mediation of game bike on adherence via intention and affective attitude
Ridley & Olds	2001	Observation phase: N=134 10-12 year olds Measurement phase: N=10 (5 male, 5 female)	Cross-sectional (observational)	Observation phase: Measured behaviours at video game centre over 1770 minutes Measurement phase: Height and weight Polar Accurex Heart Rate Monitors Caltrac accelerometers 5 conditions: -resting -playing Daytona (a simulated driving game) -Air Hockey (table hockey) -Final Furlong (simulated horse-racing game with whole body movement) -Mini Dunxx (mini-basketball shooting game) Measured: VO2 Minute ventilation Respiratory exchange ratio	Rest: VO_2 (ml·kg^{-1}·min^{-1}) M= 4.3 (SD=0.8) EE (kJ·kg^{-1}·min^{-1}) M=0.09 (SD=0.02) HR (beats per min) M=103 (SD=13) Daytona: VO_2 (ml·kg^{-1}·min^{-1}) M= 7.6 (SD=1.5) EE (kJ·kg^{-1}·min^{-1}) M=0.16 (SD=0.03) HR (beats per min) M=112 (SD=13) Caltrac Accelerometer (counts per minute) M=0.1 Mini Dunxx: VO_2 (ml·kg^{-1}·min^{-1}) M= 13.1 (SD=1.6) EE (kJ·kg^{-1}·min^{-1}) M=0.27 (SD=0.03) HR (beats per min) M=139 (SD=16) Caltrac Accelerometer (counts per minute) M=0 Air Hockey: VO_2 (ml·kg^{-1}·min^{-1}) M= 14.9 (SD=3.6) EE (kJ·kg^{-1}·min^{-1}) M=0.31 (SD=0.08) HR (beats per min) M=131 (SD=13) Caltrac Accelerometer (counts per minute) M=0.1 Final Furlong:

					VO_2 (ml·kg^{-1}·min^{-1}) *M*= 26.5 (*SD*=7.5) EE (kJ·kg^{-1}·min^{-1}) *M*=0.57 (*SD*=0.16) HR (beats per min) *M*=169 (*SD*=15) Caltrac Accelerometer (counts per minute) *M*=1.3 Significant differences across mean VO_2 for 5 conditions (F=58.5, $p \leq .0001$)
Russell & Newton	2008	N=168 College-aged students	Randomized control intervention Treatment 1: Interactive video game cycle ergometer exercise Treatment 2: Regular cycle ergometer exercise Control Condition: Video game only control condition	Mood states measured immediately before, after and 10 minutes after -positive affect and negative affect schedule -marlowe-crowne social desirability scale -attentional grid (immediately before and after) -RPE (every 5 min)	-video game control had more post-session NA than interactive condition and exercise control in immediate post and 10-min post Exercise condition higher positive mood than video game control No significant differences for RPE based on condition
Sell, Lillie & Taylor	2008	N=19 (male) college students 12 experienced in playing Dance Dance Revolution, 7 inexperienced	Cross-sectional	Rest: Oxygen uptake (VO_2), respiratory exchange ratio (RER), heart rate (HR) Graded exercise test on treadmill to determine VO_{2max} -measured perceived exertion, RER, HR Video Game testing: 30 minutes of continuous play Same measurements as at rest Total energy expenditure Total steps taken Subjective rating of overall enjoyment	-no significant differences between experienced and inexperienced groups for VO_{2max} Signficant differences in baseline HR p<.05 -experienced *M*=73.2 bpm (*SD*=8.4) -inexperienced *M*=64.5 bpm, (*SD*=5.3) -experienced groups had significantly higher (p<.05) levels of enjoyment,, steps per minute, total steps in 30 minutes, total energy expenditure, average energy expenditure per minute, relative energy expenditure when controlling for body weight, and significantly lower time to expend 150 kcal, and steps required to expend 150 kcal
Tan, Aziz, Chua & The	2002	N= 40 (21 male, 19 female) Mean age = 17.5 years	Cross-sectional	Heart rate and oxygen consumption measured during graded treadmill test and dance simulation game	Heart rate during dance: 137 beats per min +/- 22 VO_2 during dance 24.6 ml/kg/min +/- 4.7 Meets requirements of ACSM for developing and maintaining cardiorespiratory fitness (60% heart rate max)
Unnithan, Houser &	2006	N=22 (16 boys, 6 girls)	Cross-sectional	Modified Bar-Or physical activity questionnaire to	-no significant differences between groups for VO_2

Fernhall		11-17 years old 10 overweight, 12 non-overweight		recall PA over last week and last 6 months -height and weight for BMI -ventilation (V_E), energy cost (VO_2), respiratory exchange ratio (RER) -Heart rate -modified walking treadmill test to determine VO_{2peak} -Dance Dance Revolution played for approximately 12 minutes -all physiological measures taken while playing, to determine caloric expenditure	prior to treadmill and DDR -absolute peak VO_2 and peak V_E significantly higher in overweight group during treadmill test ($p \leq 0.05$) -absolute VO_2 and V_E (average and peak) significantly higher in overweight group during treadmill test ($p \leq 0.05$) -no significant differences in VO_2 between groups when adjusting for body mass -overweight expend significantly more calories per minute when playing DR than non-overweight ($p \leq 0.05$) -caloric expenditure had no significant differences between groups when adjusting for fat free mass -no significant differences between groups for VO_2 and HR sustained during DDR -percentages of HRmax sustained by both groups during DDR were in the range for increasing cardiovascular fitness according to ACSM
Wang & Perry	2006	N=21 (all male) 7-10 years old	Cross-sectional	Blood pressure blood glucose, blood lactate, VO2, energy expenditure, respiratory quotient all measured prior to, during and after video game play Game was Tekken 3 by Sony Playstation	Significant increases from baseline: Heart rate: 18.8% ($p<0.001$), Cohen d =1.41 Systolic BP: 22.3% ($p<0.001$), Cohen d =1.00 Diastolic BP: 5.8% ($p<0.006$), Cohen d =0.67 Ventilation: 51.9% ($p<0.001$), Cohen d =1.59 Respiratory rate: 54.8% ($p<0.001$), Cohen d =2.16 Oxygen consumption: 49.0% ($p<0.001$), Cohen d =1.52 Energy expenditure: 52.9% ($p<0.001$), Cohen d =1.49
Warburton, Bredin, Horita, Zbogar, Scott, Esch, & Rho-des	2007	N=14 (all male) 18-25 years old	Randomized controlled trial Experimental condition (n=7): Interactive video game (Game bike linked to Sony Playstation) Control condition (n=7):	Adherence to exercise: -Attendance evaluated when participants attended sessions Anthropometry and body composition: -Body mass and height -Body composition using	Attendance: Participants in interactive video game group attended 30% more sessions than control (experimental: M=78% (SD=18), control: M=48% (SD=29), $p<0.05$)

	Stationary cycling Recommended exercise regime: moderate intensity exercise 3 days per week for 30 minutes per day for 6 weeks	bioelectrical impedance Aerobic and musculoskeletal fitness: -Maximal aerobic power during incremental maximal exercise test on electronically braked cycle ergometer -Muscular strength using hand-held dynamometer -Dynamic leg power using vertical jump test -Flexibility using flexometer Resting blood pressure Perceptions of effort on the exercise ergometers: -30 minute session on each bike (video interface not hooked up) with matched heart rate to compare design, anticipated level of discomfort, and actual level of discomfort during session on each type of ergometer All measurements at baseline and at 6 weeks	Body composition: No significant changes in body mass, BMI, or body composition for both groups Aerobic fitness: Significant change in VO_{2max} for experimental group (M=11.0% (SD=5.1) $p<0.05$), no significant change for control group, 69% of variance in VO_{2max} due to attendance Cardiorespiratory response to exercise: -No significant change to respiratory exchange ratio for either group -significant improvement in maximal power output in experimental group ($p<0.05$) -maximal heart rate significantly reduced ($p<0.05$) in experimental group -oxygen pulse significantly increased ($p<0.05$) after experimental training Musculoskeletal fitness: -no significant changes to grip strength and flexibility for both groups -significant increase in vertical jump in experimental group ($p<0.05$), 44% of variance in vertical jump explained by attendance Resting blood pressure: -no significant changes for both groups Perceived effort on two ergometers: -Monark control bike stated as smoother and more comfortable

game play (Chin et al. 2008; Madsen et al. 2007; Ni et al. 2008). This should be viewed as a positive finding because it illustrates that active games were used as much as passive games. Two studies found significantly higher adherence rates for interactive gaming conditions compared to regular exercise (Annessi and Mazas, 1997; Rhodes et al. 2008; Warburton et al. 2007a). These studies show that interactive gaming provides higher levels of both adherence and attendance.

Psychological Outcomes and Mediators

Psychological outcomes and mediators such as affect and feeling states and rate of perceived exertion were assessed in five studies. Interactive gaming was associated with significantly higher levels of affective attitude than non-interactive conditions (Annessi and Mazas, 1997; Rhodes et al. 2008). Negative affect was significantly higher in a sedentary video game control in comparison to an exercise intervention (both non-interactive exercise and interactive exercise) (Russell and Newton, 2008). Rate of perceived exertion was not found to be significant between the interactive condition and the control (Russell and Newton 2008) despite Warburton and colleagues (2007a) finding that the control cycle ergometer was smoother and easier to handle than the gamebike in the intervention.

Discussion and Future Directions

This paper aimed to review and discuss the state of research of interactive gaming and PA. While the physiological outcomes of interactive games are encouraging for health promotion, illustrating significantly higher EE, VO_2 and HR, little research has examined psychological determinants and behavioural adherence outcomes from interactive gaming. Still, the minimal research studying psychological factors yielded positive results with high levels of reported affect (Rhodes et al. 2008; Russell and Newton, 2008), and adherence rates (Annessi and Mazas, 1997; Rhodes et al. 2008; Warburton et al. 2007a). As well, of all the types of equipment, Dance Dance Revolution and Gamebike have been shown to achieve the American College of Sports Medicine's recommendations for developing, maintaining and improving cardiovascular fitness (Tan et al. 2002; Unnithan et al. 2006; Warburton et al. 2007a). This suggests that interactive games have potential as an effective exercise intervention.

While interactive gaming combined with PA illustrates significant benefit, future research is required to extend both sample generalizability and the data collection setting. The studies using interactive games targeted children, adolescents and young adults, and only one study had participants over 25, who are shown to be at risk for low PA participation rates (Allender et al. 2008). As a result, it is not possible to compare the different types of equipment because of the limited populations used. All studies using exercise equipment with enhanced interactivity (e.g., interactive cycling) were focused on college-aged participants, whereas all studies using interactive games (e.g., Wii) were performed with child, youth and adolescent participants. In terms of setting, most research is laboratory- or facility-based and therefore lacks ecological validity at present. Also, little research explains potential mechanisms for making these games successful, whether it be through distraction from the exercise task itself, or through the interactive engagement nature of the game.

CONCLUSIONS

In summary, the current research on interactive gaming and PA is promising with examples of increased energy expenditure and health-related fitness improvements. Evidence of better adherence compared to control groups is also encouraging; however, the long-term behavioural adherence, comparisons to other forms of activity, generalizability to adult populations, and ecological validity of its effectiveness is currently unknown. Further research is needed to apply this extant knowledge to the general populace and inform health promotion recommendations.

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