ORIGINAL ARTICLE

Activity and Energy Expenditure in Older People Playing Active Video Games

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ABSTRACT. Taylor LM, Maddison R, Pfaeffli LA, Rawstorn JC, Gant N, Kerse NM. Activity and energy expenditure in older people playing active video games. Arch Phys Med Rehabil 2012;93:2281-6.

Objectives: To quantify energy expenditure in older adults playing interactive video games while standing and seated, and secondarily to determine whether participants' balance status influenced the energy cost associated with active video game play.

Design: Cross-sectional study.

Setting: University research center.

Participants: Community-dwelling adults (N=19) aged 70.7±6.4 years.

Intervention: Participants played 9 active video games, each for 5 minutes, in random order. Two games (boxing and bowling) were played in both seated and standing positions.

Main Outcome Measures: Energy expenditure was assessed using indirect calorimetry while at rest and during game play. Energy expenditure was expressed in kilojoules per minute and metabolic equivalents (METs). Balance was assessed using the mini-BESTest, the Activities-specific Balance Confidence Scale, and the Timed Up and Go (TUG).

Results: Mean ± SD energy expenditure was significantly greater for all game conditions compared with rest (all $P \leq .01$) and ranged from 1.46±.41 METs to 2.97±1.16 METs. There was no significant difference in energy expenditure, activity counts, or perceived exertion between equivalent games played while standing and seated. No significant correlations were observed between energy expenditure or activity counts and balance status.

Conclusions: Active video games provide light-intensity exercise in community-dwelling older people, whether played while seated or standing. People who are unable to stand may derive equivalent benefits from active video games played while seated. Further research is required to determine whether sustained use of active video games alters physical activity levels in community settings for this population.

Key Words: Aged; Rehabilitation; Video games.

PHYSICAL ACTIVITY PARTICIPATION in people older than 65 years can maintain and improve cardiovascular, musculoskeletal, and psychosocial function.[1-4] Even light activity is associated with improved function and a reduction in mortality rates of 30% in those 70 years and older.[5,6] However, there are barriers to participation in activity in this age group, including strength and mobility limitations, lack of enjoyment in the activity, and cognitive impairments.[7-9] Therefore, the challenge is finding enjoyable physical activities that can accommodate older adults including those with limited mobility and balance.

Commercially available interactive video games may overcome these barriers and therefore offer an attractive alternative to traditional exercise programs. Platforms such as Nintendo Wii[a] and Xbox 360 Kinect[b] provide a range of familiar sports and fitness activities such as tennis, boxing, 10-pin bowling, and Tai Chi that can be played in the home environment.

Pilot studies using Nintendo Wii have illustrated the potential of active video games as a rehabilitation tool in older people. An observational study[10] of older adults with subsyndromal depression showed that a 12-week program of Wii Sports improved symptoms of depression and mental health–related quality-of-life measures. A recent controlled study[11] in adult stroke patients compared a 2-week program of nonactive leisure activities with 2 weeks of Nintendo Wii activities. Participants using Wii had a significant improvement in their upper limb motor function when compared with the recreational therapy group. Finally, balance measures were assessed after a 6-week program of Wii fitness exercises in 6 community-dwelling older adult participants. Four of the 6 participants demonstrated a clinically relevant improvement in Berg Balance Scale measures after the Wii fitness program.[12]

The mechanisms underlying improvements in rehabilitation outcomes after the use of interactive video games are unclear. It is possible that the games are sufficiently stimulating to enhance cognitive engagement without any demonstrable change in cardiorespiratory function or musculoskeletal activity.

In summary, current evidence suggests interactive video games may be a useful adjunct to rehabilitation in older people.

List of Abbreviations

ABC	Activities-specific Balance Confidence
EE	energy expenditure
MET	metabolic equivalent
RPE	rating of perceived exertion
TUG	Timed Up and Go
$\dot{V}O_2$	oxygen consumption per unit time

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However, there is a dearth of research evidence to determine whether these games are of sufficient intensity to improve cardiorespiratory fitness levels and encourage physical activity participation in this age group.

Changes in energy expenditure (EE), heart rate, and perceived exertion associated with active video games have been reported in children and adolescents[13,14] and in young to middle-aged adults.[15-17] In children and young and middle-aged adults, playing active video games generates 2 to 4 times the EE compared with rest or sedentary activities such as television viewing.[15,18-20] Depending on the game played, this EE approximates light- to moderate-intensity activity.

However, the strength, mobility, and balance limitations associated with advancing age may reduce the energy expended by older people playing these same active video games. No studies to date have investigated the physiologic demands of these games in a cohort of adults 65 years and older. Further, balance or strength impairments in this age group may affect the ability to stand for any length of time, so activities may need to be performed from a seated position. This essentially limits exercise to upper body movement alone. It is unknown whether playing video games in a seated position can provide an appreciable change in EE.

Therefore, the primary aim of this study was to quantify the energy cost associated with playing active video games while standing and seated. We also sought to determine whether a participant's balance status affected their EE during game play. The final aim was to quantify perceived exertion and body movement while playing the games. We hypothesized that the energy cost associated with playing active video games would be greater than rest, at a level of light to moderate activity.

METHODS

Participants

Eligible participants were 65 years or older, able to stand unaided or with a walking aid, English speaking, and able to provide informed consent. Participants who were unable to perform exercise for medical reasons or were taking β-blocker medication were excluded. Participants were recruited via direct contact within a community retirement village, with community notices, or by word of mouth. Written informed consent was obtained from each participant. Ethical approval for this study was obtained from the New Zealand Health and Disability Ethics Committee (NTY/10/10/077).

Anthropometric and Physiologic Measurements

Height and body mass were measured by 1 investigator (L.A.P.) using standardized procedures.[21] Respiratory gas exchange was measured by the same investigator in each instance (J.C.R.) using an indirect calorimeter expired air gas analysis system[c] with facemask.[d] A 2-point calibration procedure was conducted before each testing session according to the manufacturer's guidelines. Gas exchange was averaged over 10-second epochs.

To quantify movement, participants were instrumented with 2 dual-axial accelerometers (Actigraph Model ActiGraph GT1M[e]) worn on the right hip and dominant wrist. Positioning accelerometers on the wrist as well as the waist allowed differentiation between activity generated from upper limb movement and that of whole-body movement.[20]

We measured self-perceived exercise intensity using the Ratings of Perceived Exertion (RPEs) Scale.[22] The scale ranges from 6 (no exertion at all) to 20 (maximal exertion).

Active Video Games

The game consoles used were Nintendo Wii and Xbox 360 Kinect. The playing area was 4×4m, and the television used was a standard 32-inch flat screen. Games played while standing were Wii Sport bowling, boxing, and tennis, and Xbox 360 Kinect "Your Shape Fitness Evolved" Tai Chi, Kinect Sports bowling, boxing, and table tennis. Additionally, participants played Wii bowling and Wii boxing while seated.

Balance Measures

Balance ability of all participants was assessed by the same investigator (L.M.T.) using the mini-BESTest,[23-25] the Activities-specific Balance Confidence (ABC) Scale,[26-28] and the Timed Up and Go (TUG).[29-31] The mini-BESTest consists of 14 balance tasks. Each item is scored from 0 to 2 using preset criteria, a summed total out of 31. The ABC Scale is a self-report measure of balance that asks participants to rate their balance confidence at performing 16 different activities, on a scale from 0 to 100. The score is the average sum of all 16 items. The TUG is used to predict falls as well as provide information on function.[32] Persons are timed as they rise from a chair, walk 3m at their usual pace, turn, walk back, and sit down. The score is taken as the time taken to complete the task.

Procedures

Participants each attended 1 session at the university research center. Before testing commencement, anthropometric measures were completed followed by a 20-minute familiarization session to practice the games. A researcher supervised and provided instruction on how to play each game. After familiarization, resting oxygen consumption per unit time ($\dot{V}O_2$) was measured while participants rested quietly, positioned supine for 10 minutes. Then in a randomized order, participants played each video game for 5-minute periods interleaved with 5 minutes of seated rest. Consistent with previous research, a 5-minute duration was chosen to achieve a steady state for $\dot{V}O_2$.[19] This period has also been shown to be sufficient to demonstrate a steady state in adults.[33,34] Immediately after each game, participants were asked to rate their perceived exertion during game play by pointing to the relevant number on a copy of the Borg scale.

Metabolic data including relative $\dot{V}O_2$, minute ventilation, and respiratory exchange ratio and heart rate were measured throughout game play and rest breaks, and for a further 10 minutes after completion of gaming. After game play, the balance tests were completed.

For all activities, participants began on the easiest skill level of competition. Participants used whatever movement strategies they wanted to play the games. If a game was completed within 5 minutes, the event was restarted to complete any remaining time to produce 5 minutes of game play. Cumulative video game playing time for each participant was 45 minutes. Because periods of video game play were interspersed with equal periods of rest, we considered the physical burden of testing manageable, even for those with limited mobility.

Data Analysis

The mean values of metabolic data recorded during the final minute of uninterrupted game play were used for analyses. EE was calculated using mean $\dot{V}O_2$ and carbon dioxide consumption ($mL \cdot kg^{-1} \cdot min^{-1}$) to determine rates of fat and carbohydrate oxidation, and subsequent application of the appropriate Atwater factors. Metabolic equivalent values (METs) were calculated by dividing $\dot{V}O_2$ for each game by 1 MET (3.5 $mL \cdot kg^{-1} \cdot min^{-1}$).[35] Intensity data were classified as light, mod-

Table 1: Physiologic Characteristics and Functional Ability Scores (n=19)

Characteristic	Values
Age (y)	70.7±6.4 (65–87)
BMI (kg/m²)	27.6±6.1 (21.6–46.7)
Resting heart rate (bpm)	74.7±9.0 (60–93)
ABC score (/100)	89.1±10.8 (55.6–99.1)
Mini-BESTest (/32)	28.3±3.3 (19–32)
TUG score (s)	10.2±1.8 (8–14)

NOTE. Values are mean ± SD (range).
Abbreviations: BMI, body mass index; bpm, beats per minute.

erate, or vigorous intensity according to American College of Sports Medicine intensity categories for older adults (light, ≤3 METs; moderate, 3–6 METs; vigorous, >6 METs).[36]

Accelerometer data were uploaded using ActiLife software, version 5.[e] A 10-second epoch was used and summed to give a per minute activity count rate. Activity counts from each axis of the accelerometer were combined into a single vector.

Repeated-measurement analysis of variance and Bonferroni-corrected pairwise comparisons were conducted to assess between-game differences in mean $\dot{V}O_2$, EE, METs, wrist activity counts, hip activity counts, and RPE. Data violating the assumption of sphericity were adjusted using the Greenhouse-Geisser correction.[37] Two-tailed paired *t* tests were performed to compare between-console mean $\dot{V}O_2$, EE, METs, wrist activity counts, hip activity counts, and RPE for separate pairs of equivalent bowling, tennis, and boxing games. Paired *t* tests were also conducted to compare differences between the seated and standing video game conditions.

Pearson product-moment correlation coefficients were calculated to examine the relationships between balance test scores and EE, wrist activity counts, and hip activity counts across all game conditions, as well as EE, wrist activity counts, and hip activity counts pooled across sitting and standing game conditions. Results are expressed as mean ± SD. SPSS 19.0[f] was used for analyses.

RESULTS

Twenty community-dwelling older adults volunteered for the study. Data from 1 participant were omitted from the analysis because of a technical malfunction with the calorimeter. Fifteen women and 4 men completed the study. The participant characteristics are summarized in table 1.

$\dot{V}O_2$ was highest during boxing and tennis games, and lowest during bowling and Tai Chi games on both consoles (table 2). There was a significant effect of game condition on $\dot{V}O_2$ ($F_{4.3,77.2}=19.5$, $P<.001$), with all games resulting in greater $\dot{V}O_2$ than rest (all $P<.01$, see table 2). Similarly EE was highest during boxing and tennis games, and lowest during bowling and Tai Chi games on both consoles (see table 2). There was a significant effect of game condition on EE ($F_{4.1,74.1}=18.5$, $P<.001$), with all games resulting in greater EE than rest (all $P<.01$, see table 2). There was no significant difference in EE for the equivalent games played in a standing position compared with a seated position (see table 2).

MET values ranged from 1.5 to 3.0 (see table 2), indicating that all games were equivalent to light-intensity physical activity.[36] There was a significant effect of game condition on METs ($F_{4.2,10.3}=13.8$, $P<.001$), with all games resulting in higher METs than rest (all $P<.01$, see table 2).

With the use of the 6-to-20 RPE scale,[22] perceived exertion was rated as "light" for bowling games (10.33±1.97) to "somewhat hard" for boxing games (12.57±1.70) (see table 2). A comparison of RPE scores between games showed a significant effect of game condition on RPE ($F_{8,144}=3.6$, $P=.001$). There were no significant differences in RPE between equivalent sitting and standing games (see table 2).

Wrist and hip activity counts were highest during boxing and tennis games, and lowest during Tai Chi and bowling games on both consoles (see table 2). There was a significant effect of game condition on both wrist ($F_{4.7,85.0}=19.3$, $P<.001$) and hip ($F_{2.5,45.4}=5.9$, $P=.003$) activity counts. Wrist activity counts were higher than rest during all games (all $P<.001$, table 2). Hip activity counts were higher than rest during all games (all $P<.01$) except Xbox 360 Kinect Tai Chi ($P=.02$), table tennis ($P=.10$), boxing ($P=.02$), and Nintendo Wii boxing in a seated position ($P=.08$). There were no differences in wrist or hip activity counts between equivalent games played sitting and standing (see table 2).

There were no between-console differences in EE for equivalent bowling ($t_{18}=-.69$, $P=.65$), tennis ($t_{18}=-.46$, $P=.36$), or boxing games ($t_{18}=-.94$, $P=.50$). No between-console differences in wrist or hip activity counts were found for equivalent bowling (wrist: $t_{18}=-.67$, $P=.51$; hip: $t_{18}=-.81$, $P=.43$), tennis (wrist: $t_{18}=-2.32$, $P=.03$; hip: $t_{18}=-1.95$, $P=.07$), or boxing games (wrist: $t_{18}=.05$, $P=.96$; hip: $t_{18}=-.68$, $P=.50$). There were no between-console differences

Table 2: $\dot{V}O_2$, EE, METs, Activity Counts, and RPE for Each Game Condition (n=19)

Condition	$\dot{V}O_2$ (mL·kg^{-1}·min^{-1})	EE (kJ·min^{-1})	METs	Wrist AC (cpm)	Hip AC (cpm)	RPE
Rest	3.42±0.71	5.19±1.07	0.98±0.20	0	0	NR
Kinect Tai Chi (Zen)	7.54±2.36*	11.22±3.58*	2.16±0.67*	4027±1477*	271±209	10.16±2.27
Wii bowling sitting	5.11±1.42*†	7.73±2.12*†	1.46±0.41*†	6105±3329*†	564±511*†	9.63±2.06†
Wii bowling standing	6.64±2.84*	9.89±4.31*	1.90±0.81*	6010±3195*	580±413*	10.37±3.17
Kinect bowling	6.88±2.12*	10.14±3.22*	1.97±0.61*	6452±3592*	681±603*	9.89±2.73
Wii tennis	8.46±3.34*	12.61±5.23*	2.42±0.95*	8907±4403*	880±656*	11.26±1.76
Kinect table tennis	8.83±3.44*	13.18±5.12*	2.52±0.98*	11,111±5270*	1798±2201	11.58±1.07
Wii boxing sitting	7.91±3.72*‡	13.04±5.98*‡	2.26±1.06*‡	10,557±6696*‡	917±1086‡	10.74±4.19‡
Wii boxing standing	9.76±4.44*	15.28±6.85*	2.79±1.27*	11,260±6613*	831±749*	12.05±3.44
Kinect boxing	10.40±4.05*	16.44±7.42*	2.97±1.16*	11,184±5258*	1018±1014	12.95±1.22

NOTE. Values are mean ± SD.
Abbreviations: AC, activity counts; cpm, counts per minute; NR, not rated.
*Significantly different to rest (*P*≤.01).
†Not significantly different to Wii bowling standing (*P*>.01).
‡Not significantly different to Wii boxing standing (*P*>.01).

Table 3: Relationships Between Balance Test Scores and Mean EE, Wrist Activity Counts, and Hip Activity Counts Across All Game Conditions (n=19)

Variable	ABC	Mini-BESTest	TUG
EE			
Pooled	.25	.10	.07
Sitting	.36	.11	.20
Standing	.20	.09	.03
Wrist AC			
Pooled	.21	.41	−.19
Sitting	.35	.30	−.05
Standing	.13	.43	−.24
Hip AC			
Pooled	.25	.44	−.30
Sitting	.24	.15	−.13
Standing	.22	.49	−.32

NOTE. Values are *r* (Pearson product-moment correlation coefficient).
Abbreviation: AC, activity counts.

in RPE for equivalent bowling (t_{18}=.51, P=.62), tennis (t_{18}=−.69, P=.50), or boxing games (t_{18}=−1.03, P=.32).

As can be seen in table 3, correlation coefficients ranged from −.32 to .49, although none reached statistical significance. This may have been because of the small sample size and lack of statistical power. The strongest correlations (r=.40–.49) were between balance scores and activity counts.

DISCUSSION

This study sought to quantify the energy cost of seated and standing active video game play in older adults, and to determine whether balance status affected game play EE. To our knowledge, this is the first study to describe the energy cost of active video games in a cohort 65 years and older. Across all conditions, active video game play resulted in 1.5- to 3-fold increases in EE compared with rest. This suggests that such games could be used to promote light physical activity in older people.

Physical activity guidelines for older adults recommend higher intensity levels (≥3 METs) than those reported in this study; however, these guidelines also emphasize that any amount of physical activity incurs health benefits.[3,38] Indeed, recent evidence suggests that any activity EE lowers mortality risks[6] and mobility limitation in older people.[39] For the reduction of falls, the demonstrated benefit of exercise appears to be dependent on the exercise frequency and duration of the program rather than on the intensity of the exercise.[40] Therefore, in the frail elderly, where higher intensity exercise may not be achievable, low-moderate intensity exercise may be the best option.[4,7]

There was no difference in EE between Nintendo Wii and Xbox 360 Kinect game consoles, indicating that either platform can be used. The potential benefit of the Xbox 360 Kinect system is that it does not require a handheld controller and can be played by people with impaired hand function. The advantage of Nintendo Wii is that it can be played seated, which is not currently possible with the Xbox 360 Kinect system.

We also measured EE, activity counts, and perceived exertion for boxing and bowling games played while sitting. Interestingly, there were no significant differences in EE or any other parameter whether the games were played seated or in standing, suggesting that this form of activity might be equally efficacious for increasing activity and EE in those who are unable to stand. This has particular relevance to the frail elderly as well as others with physical impairments,[11,41] where limited balance and mobility are barriers to activity.[8]

All games were characterized by high wrist activity compared with hip movements, which indicates that the games chosen imposed relatively small lower limb movement demands. For the age group we tested, we deliberately chose games that avoided high bone-loading impact activities such as jumping or running, so our choice of activities did favor upper limb movement. The apparent lack of lower limb movement during these games may also explain the absence of differences in EE and RPE between equivalent sitting and standing games.

The METs we reported for bowling in standing (2.0 METs), tennis (2.4 METs), and boxing in standing (3.0 METs) in older adults are comparable to those reported for adolescents playing the same Nintendo Wii active video games.[20] Other studies[17,18] that have compared the energy expended while playing active video games across age groups have demonstrated slightly lower EE levels in adults when compared with children and adolescents. In contrast, higher METs have been reported for games played by young adult men (bowling, 2.7 METs; tennis, 3.0 METs; boxing, 4.2 METs).[16] These higher values may be the result of the more dynamic game play of younger adult men.

Since balance deficits and fear of falling can impair a person's mobility,[40,42] an additional aim of our study was to determine whether participants with reduced balance would expend less energy when playing these games. No significant differences were found in energy cost according to balance status. However, the balance scores reported indicate that this group of community-dwelling older adults fell within the normative ranges of balance ability. For example, the TUG scores achieved by our sample (8–14s) are within the normative range for community-dwelling people in this age group.[32,43-45] The normative score for the ABC Scale, which measures fear of falling, is 80.9% among healthy, active older adults,[28] suggesting that our group was normal to high functioning. Therefore, our findings show that older community-dwelling adults within a normative range of ability can use off-the-shelf active video games for light to moderate exercise. Future studies that assess the use of active video games in older people with more limited balance and physical function would be useful.

Study Limitations

Our participants were all novices to active video games, and also, we allowed them to use whatever strategies they wished to play the games. The range of game play techniques and physical engagement used by individuals may have contributed to the variability in EE, thereby obscuring possible differences between the energy demands of seated and standing postures. Further, EE and movement strategies used to play the games may change with repeated play. Others have shown that EE was increased in adolescents who were skilled at performing active video games when compared with those who were not.[46]

Finally, this was a laboratory-based study that did not replicate the home environment. However, we noted that participants quickly became immersed in the games, so we do not think engagement and energy responses would be significantly different in a home environment.

CONCLUSIONS

Both Nintendo Wii and Xbox 360 Kinect active video games significantly increased EE and activity levels in older people when compared with rest. This activity equates to light-intensity exercise. Furthermore, the chosen games played while sitting have a similarly beneficial effect on EE levels as while standing.

Future research is needed to determine the continued effect of playing active video games for sustained periods to determine their potential contribution to overall physical activity levels in this population. In addition, exploring individual preferences for specific games and enjoyment would be helpful in ensuring continued participation with these activities.

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Suppliers

a. Nintendo of America Inc, 4600 150th Ave Northeast, Redmond, WA 98052.
b. Microsoft Corp, 1 Microsoft Way Campus Arcade, Redmond, WA 98052.
c. Metalyser II; Cortex, Biophysik, Walter-Köhn-Str. 2d 04356 Leipzig, Germany.
d. Hans Rudolph, Inc, 8325 Cole Pkwy, Shawnee, KS 66227.
e. Actigraph, 49 E Chase St, Pensacola, FL 32502.
f. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.