

Citation for published version: Mackintosh, KA, Standage, M, Staiano, AE, Lester, L & McNarry, MA 2016, 'Investigating the Physiological and Psychosocial Responses of Single- and Dual-Player Exergaming in Young Adults', Games for Health Journal, vol. 5, no. 6, pp. 375-381. https://doi.org/10.1089/g4h.2016.0015

DOI: 10.1089/g4h.2016.0015

Publication date: 2016

Document Version Peer reviewed version

Link to publication

Final publication is available from Mary Ann Liebert, Inc., publishers http://dx.doi.org/10.1089/g4h.2016.0015 Copyright©2016 Mary Ann Liebert, Inc. publishers.

University of Bath

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

1	Running Title: Single- and Dual-player exergaming in adults
2	
3	
4	
5	Investigating the Physiological and Psychosocial Responses of Single- and Dual-Player
6	Exergaming in Young Adults
7	
8	Kelly Mackintosh, ¹ Martyn Standage, ² Amanda E. Staiano, ³ Leanne Lester, ⁴ Melitta McNarry ¹
9	¹ College of Engineering, Swansea University, Wales, UK, ² Department for Health, University of
10	Bath, England, UK, ³ Pennington Biomedical Research Center, ⁴ School of Sport Science, Exercise
11	and Health, University of Western Australia
12	
13	Corresponding Author: Kelly Mackintosh
14	
15	

Abstract

2 *Objective:*

3 This study investigated the effect of acute exergaming on the physiological and psychosocial responses
4 of young adults and the modulatory effect of a single- or dual-player game play situation.

5 *Materials and Methods:*

Thirty six participants (19 male; 21.7 ± 3.8 years; 23.65 ± 3.17 kg·m⁻²) each completed two 30-minute
exergame sessions in a randomised order (single- and dual-player) whilst wearing an Actiheart[®] to
estimate energy expenditure. Positive and negative affect, subjective vitality and indices of intrinsic
motivation were assessed directly after each gaming bout.

10 *Results:*

There was no significant difference in energy expenditure or psychosocial outcomes between 11 12 conditions. Although males expended more energy than females in both single- (z=-2.124, p=0.033)and dual-player situations (z=-2.679, p=0.007), females reported significantly greater vitality (z=-2.219, 13 p=0.026) and effort/importance than males (z=-2.001, p=0.045). Conversely, males reported greater 14 negative affect (z=-2.872, p=0.004) and pressure/tension (z=-3.295, p=0.001)). A linear mixed effects 15 16 model revealed that energy expenditure during exergaming was a significant predictor of interest and enjoyment (P=0.001) and effort and importance (P=0.001). This relationship between energy 17 18 expenditure and psychosocial variables was not modulated by sex or order of game play (single or dual-19 player first).

20 *Conclusion:*

The present results suggest that females have a more positive psychosocial response to exergaming relative to males, highlighting exergames such as Wii boxing as a potential avenue for future interventions seeking to address the low physical activity levels that characterise the young adult population.

25

26

Introduction

Regular participation in physical activity is associated with numerous physiological and psychological health benefits.¹⁻³ Accordingly, a physically active lifestyle is considered a choice that can profoundly and positively influence health and longevity.⁴ Despite World Health Organisation guidelines that adults should engage in at least 150 minutes of moderate-to-vigorous physical activity (MVPA) throughout the week,⁵ 23% of adults globally are not sufficiently active to accrue health benefits.⁶

Whilst physical activity levels appear to decline progressively with age,⁷ this decline is 8 especially pronounced in young, university-aged adults for whom physical activity is evidenced to 9 decrease by 24% during the transition from high school to college.⁸ This decrease is further 10 compounded by an increase in sedentary behaviours;⁹ in addition to time spent sitting in lectures and 11 12 studying, recent studies have suggested that a significant proportion of students' time is spent playing video games.¹⁰ Indeed, Wack and Tantleff-Dunn¹⁰ reported that, on average, students spent 10 hours 13 per week playing video games, with 8.5% of students spending up to 35 hours per week. Similarly, 14 studies have shown the mean time spent playing video games to be 8.5 ± 12.2 hours per week, with 15 39% of students playing more than 2 hours per week.^{11, 12} The popularity of game play has led to the 16 17 development of games that aim to combine video game playing with physical activity in an effort to 18 counteract the negative consequences associated with conventional, sedentary game playing without necessitating people to relinquish highly-valued behaviours.¹³ 19

Active video games, often referred to as exergames, have been shown to significantly increase energy expenditure relative to rest or traditional sedentary video games.¹⁴⁻¹⁸ However, methodological issues, including a reliance on small sample sizes, a predominant focus on children and adolescents and limited ecological validity largely constrain the interpretation of previous studies. Specifically, Miyachi et al.¹⁵ suggested that previous studies may have underestimated the energy expenditure associated with exergames due to indirect calorimetry restricting natural play patterns.

With many contemporary video games incorporating a multi-player element, the predominant utilisation of a "single-player" mode in previous studies is unlikely to be representative of typical game play; preadolescents generally choose a multi-player dance exergame over traditional solitary physical

activities,¹⁹ with the primary reason cited for playing such games being social interaction.²⁰ Indeed, 1 2 exergames have recently been highlighted as a mechanism to build social relationships and skills.²¹ A 3 key issue with the utilisation of single-player modes is a failure to account for the influence of 4 competition on energy expenditure and enjoyment, which have been shown to be substantially higher when a competitive element was incorporated within video games.²² Indeed, competition has been 5 shown to engender greater gains when measuring performance-based outcomes, a notion supported by 6 7 findings in children showing a higher energy expenditure during exergames played against a peer than against a virtual character.²³ The applicability of these findings to adults is presently unclear; Peng and 8 Crouse²⁴ reported a greater energy expenditure during single-player gaming whilst Bonetti et al.¹⁴ found 9 10 no difference between single and multi-player modes. Whilst it is important to recognise that "singleplayer" games typically involve a virtual peer and are thus not true "single-player" modalities, these 11 12 discrepancies may additionally be attributable to the utilisation of non-randomised, short duration (5 minutes or less) exergame play. Furthermore, inter-study comparisons are limited by the use of 13 accelerometry-based assessments of exercise intensity, which are reliant on arbitrary cut-points²⁵ and 14 are renowned for over- or under-estimating energy expenditure dependent on the location and activity.²⁶ 15 16 It has been suggested that the combination of synchronised accelerometry and heart rate data demonstrate greater validity and reliability for the estimation of free-living energy expenditure.^{27, 28} 17

A key barrier to participation in physical activity and exercise is the widespread view that 18 exercise is not enjoyable.²⁹ However, it has been suggested that exergames may be perceived as being 19 20 less strenuous and more enjoyable than traditional programmes, even when total energy expenditure is 21 similar.³⁰ Although recent research has acknowledged the potential relationship between energy 22 expenditure and psychosocial variables with regards to mediating the influence of an exergame-based weight loss programme,³¹ further research is required to elucidate the basis for such a relationship. 23 24 Indeed, the influence of acute bouts of exergaming on psychosocial responses is presently unclear and requires resolution before our understanding of long-term relationships may be advanced. 25

Therefore, the purpose of the present study was to investigate the effect of an aerobic-based exergame on the physiological and psychosocial responses of young adults and the modulatory effect of single- or dual-player games on these responses.

2

Materials and Methods

3 Sample Population

A total of 36 university students (19 male; 21.7 ± 3.8 years; 23.65 ± 3.17 kg·m⁻²) were recruited
and provided written informed consent to take part in this study, which was approved by the local Ethics
Committee.

7 Experimental procedures

Stature and sitting stature to the nearest 0.1 cm (Seca Ltd. Birmingham, UK) and body mass to 8 9 the nearest 0.1 kg (Seca Ltd. Birmingham, UK) were measured using standard techniques [29] and subsequently used to initialise the Actiheart to estimate energy expenditure. Body mass index was 10 calculated (body mass (kg)/stature² (m²)). Waist circumference was measured to the nearest 0.1 cm 11 12 using a non-elastic anthropometric tape and measurements were taken at the narrowest point between 13 the bottom of the ribs and the iliac crest. All measurements were undertaken by the same trained 14 researchers with the participants barefoot and wearing minimal clothing. During this initial session, the 15 participants were familiarised with the Wii Boxing exergame to be utilised in the study through a 16 practice single player session; 23 participants reported previous experience of playing the specific 17 exergame. The exergame is inherently competitive in both single and dual player modes with a possible 18 win/lose/draw outcome in both conditions.

One week later, participants were asked to return to the laboratory in a hydrated state, having avoided caffeine and alcohol for the previous 24 hours. Participants were randomly assigned to a gaming order (single- or dual-player first), and all instructions were provided by pre-recordings to ensure consistency between participants. Each game condition was played for 30 minutes with a 12 minute rest between conditions to allow heart rate to return to baseline values. All dual-player gaming situations were performed with randomly-selected same-sex participants, which has been shown to create a non-threatening environment.³²

26 *Experimental Measures*

During the each exergaming bout, heart rate and uni-axial accelerometery data were
simultaneously recorded at a 1 minute epoch using the Actiheart[®] monitor (CamnTech, UK). Following

skin preparation, the monitor was attached to the chest at V1 or V2 (4th intercostal) and 10 cm laterally
at V4 or V5³³ using two 3M electrodes. The ActiHeart[®], which was calibrated for each participant's
age, body mass and stature, has been reported to provide valid and reliable measures of free-living
physical activity levels.^{33, 34}

5 Immediately after each exergaming condition, participants were asked to complete a series of 6 questionnaires to assess the psychological responses to that exergame. Specifically, to assess subjective vitality, four items of the State Level Subjective Vitality Scale ³⁵ were used with responses rated on a 7 seven-point scale ranging from 1 (not at all true) to 7 (very true). The mean of the four components was 8 9 taken. To assess positive and negative affect, the participants responded to nine adjectives identified by Diener and Emmons.³⁶ This scale consists of four positive affect adjectives (joyful, happy, pleased, 10 enjoying/having fun) and five negative affect adjectives (depressed, worried/anxious, frustrated, 11 12 angry/hostile, unhappy). Participants were requested to rate each adjective using the precursory stem, "What extent did you experience the following emotions during the experimental task?". Responses 13 were made as to the degree that each emotion was experienced during the experiment on a 7-point scale 14 15 ranging from 1 (not at all) to 7 (extremely). The mean of the components was calculated for positive 16 and negative affect. Finally, to assess intrinsic motivation, items from the interest/enjoyment, perceived competence, effort/importance, pressure/tension and perceived choice subscales of the Intrinsic 17 Motivation Inventory (IMI)³⁷ were used. Participants were requested to rate how true each statement 18 19 was for them on a 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree).

20 Data Analysis

To analyse the Actiheart recordings, a branched equation model based on accelerometry and heart rate data was utlised to estimate energy expenditure.³⁸ These methods have previously been reported to be valid and reliable.^{27, 28} To assess the influence of order, sex and condition on energy expenditure, a mixed repeated measures ANOVA was conducted.

A total of 72 data points were available for analysis (36 participants x 2 conditions). To address the within subject correlation between repeated measures, linear mixed models were used to determine whether energy expenditure was a significant predictor of psychosocial variables. For each model, covariates sex, BMI, condition (1 vs 2 player), order (1 player first vs 2 player first) and an interaction

between sex and energy expenditure, sex, order and condition and condition and order were tested. As 1 2 all interactions were insignificant, they were excluded from the final models. A separate analysis was 3 conducted to investigate the influence of order and condition on energy expenditure. To account for the 4 multiple comparisons, a Bonferroni correction was applied to adjust confidence intervals and 5 significance values. Effect sizes (ES) were calculated using Cohen's d formula and interpreted according to published guidelines.³⁹ All statistical analyses were conducted using PASW Statistics 21 6 7 (SPSS, Chicago, II). All data are presented as means \pm standard deviation. Statistical significance was 8 set at $P \leq 0.05$.

9

Results

10 Descriptive characteristics of the study sample are reported in Table 1. There was no significant 11 difference in age, BMI or waist circumference between those who completed single-player vs. dualplayer first. Energy expenditure as a function of sex and order of play (single-player first vs. dual-player 12 first) is presented in Figure 1. Energy expenditure did not significantly differ during single and dual 13 player conditions $(297.9 \pm 132.0 \text{ vs. } 292.3 \pm 142.4 \text{ J}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}, \text{ respectively; } F(1,32) = 0.20, p = 0.71,$ 14 15 ES = 0.04); however, males expended more energy than females for both conditions (single-player: 363.6 ± 151.0 vs. 250.4 ± 100.6 J·kg⁻¹·min⁻¹, F(1,32) = 7.59, p = 0.033, ES = 0.88; dual-player: $332.0 \pm$ 16 137.0 vs. 222.1 \pm 102.9 J·kg⁻¹·min⁻¹, F(1,32) = 8.36, p = 0.007, ES = 0.92). The energy expenditure 17 18 during the single-player condition was not significantly dependent on the order of play (F(1,32) = 0.50,p = 0.181, ES = 0.60). However, those who engaged in a dual-player situation first expended 19 20 significantly more energy during the dual-player condition than those who participated in a singleplayer situation first (F(1,32) = 8.51, p = 0.006, ES = 1.11). 21

Females reported significantly greater vitality (t(70) = -2.2, p = 0.030) and choice than males (t(70) = -3.1, p = 0.003), whereas males reported significantly greater negative affect (t(70) = 2.4, p = 0.021) and pressure/tension (t(70) = 3.9, p = 0.000) (Table 2). There were no significant differences between sex with respect to positive affect, perceived competence, effort and importance or interest/enjoyment. Furthermore, there was no influence of condition on any of the psychosocial variables (Table 3). The linear mixed model revealed that energy expenditure was a significant predictor of interest and enjoyment and effort and importance and that this relationship was not dependent on order, condition or sex. Specifically, as energy expenditure increased, as did interest and enjoyment (t(65) =2.7, p = 0.001) and effort and importance (t(65) = 3.6, p = 0.001). There were no significant interactions between order, condition or sex in determining the relationship between energy expenditure and psychosocial variables.

7

Discussion

The purpose of this randomized, crossover design study was to compare the physiological and 8 9 psychological responses of young adults during single- and dual-player exergame play. Contrary to our hypothesis, there was no significant difference in overall energy expenditure or any psychosocial 10 11 variables between conditions. Nonetheless, energy expenditure was a significant predictor of participant's perceptions of effort and importance and interest and enjoyment. Interestingly, whilst 12 males demonstrated significantly greater energy expenditure than females, irrespective of condition, no 13 interaction was evident between sex, energy expenditure and psychosocial factors. However, females 14 15 reported significantly higher vitality and perceived choice, whereas males perceived significantly greater pressure/tension and negative affect following game-play. Given these positive findings with 16 17 regards to the psychosocial responses of female participants following exergaming, the present results 18 highlight the potential utility of exergames in enhancing energy expenditure in females.

19 The present findings are in agreement with previous studies reporting no significant difference in energy expended between conditions.¹⁴ However, it is pertinent to note the contradictory findings of 20 Peng et al.²⁴, who reported a greater energy expenditure during single player, and Staiano et al.²³, who 21 reported the converse. Such discrepancies could be attributed to the use of substantially shorter bout 22 durations $(5-\text{minutes})^{24}$, although the reliance on accelerometry to estimate energy expenditure in both 23 of these studies limits inter-study comparisons due to the potential confounding effect of different 24 energy expenditure prediction algorithms.^{23, 40} Furthermore, the equivocal findings may be related to 25 the games employed and, specifically, whether the single-player mode was truly single-player⁴⁰ or 26 rather involved competing against a computer-generated opponent.²³ Indeed, with regards to the latter, 27

it could be postulated that participants in the present study never really experienced a non-competitive
 gaming experience. Nonetheless, earlier work reported higher energy expenditures for children playing
 against peers rather than virtual characters.²³

4 This study examined how different game-play modes affected not only energy expenditure but 5 indices of intrinsic motivation. It is hypothesised that the young adults who participated in the present 6 study may have created a different social context and indeed pressures in comparison to previously 7 studied adolescents. This is demonstrated in the present study by the greater degree of pressure/tension and negative affect reported by the males. Players may be differentially motivated based on comparing 8 themselves to their opponents' competence, thereby affecting their own effort and energy 9 expenditure.^{41, 42} However, it is not clear the extent to which the players were competing against or 10 cooperating with each other, which may differentially influence energy expenditure.⁴³ 11

The linear mixed-model revealed that young adults playing an exergame alone are likely to expend more energy if they play against someone first. It is therefore possible that dual-play is more beneficial over the longer-term. Specifically, a 12-week exergaming study of children aged 9 to 12 years observed less drop-out and higher engagement among those assigned to a dual-player condition (15% attrition; 901 minutes) vs. a solitary in-home condition (64% attrition; 376 minutes).⁴⁴ However, the intensity level of play between conditions was unknown, as is the transferability of findings in children to adults.

19 The linear mixed-effects model revealed that effort/importance increased as energy expenditure 20 increased. It is perhaps unsurprising that as participants' energy expenditure increased, so did their 21 associated perceptions of effort and importance. Interestingly, energy expenditure during exergaming 22 was not a predictor of perceived competence. Such a finding is contrary to expectation as perceived 23 competence may indicate mastery of gaming, which would be anticipated to be associated with a greater 24 exercise economy due to a higher proficiency and efficiency of the necessary movements and thus decreased energy expenditure. This may be attributable to the relative gaming experience of the 25 participants, with more experienced gamers demonstrating a depressed response due to a greater state 26 of "training" or a reduced emotional response.^{45, 46} The familiarisation provided prior to the start of the 27

present study may have negated a potential relationship between energy expenditure and perceived
 competence.

Interestingly, although enjoyment has been shown to be higher in dual- vs. single-player 3 gaming,²⁴ there was no influence of condition on the relationship between energy expenditure and 4 5 interest and enjoyment in the present study. It is interesting to note that enjoyment was highly rated in both conditions and comparable to a study in similar-aged participants.⁴⁷ Such high values contradict 6 7 previous research identifying that exergames associated with greater energy expenditures are less enjoyable than more sedentary games,¹⁷ although it is pertinent to note the potential influence of 8 9 different social interaction elements across the games in this previous study which may confound the attribution of the decreased enjoyment to an increased energy expenditure per se. The findings in the 10 11 present study infer positive health implications, especially as research has identified that university students enjoy physical activity more in a group setting rather than on their own.⁴⁸ With the frequently 12 reported increased energy expenditure and enjoyment associated with exergaming,²⁹ enjoyment could 13 be more critical for long-term adherence and sustainability rather than energy expenditure associated 14 15 with acute exergaming bouts.

While some researchers suggest that exergames are perceived as more enjoyable compared to 16 traditional aerobic exercise modalities,²⁹ others report decreases in positive well-being.⁴⁹ Individual 17 factors may contribute to differential effects on energy expenditure and psychosocial variables, such as 18 19 sex and game-play preference (i.e., competitive vs. solitary gaming). Specifically, energy expenditure 20 during exergaming was dependent on sex, with males expending significantly more energy, irrespective of condition. Evidence from both biology and evolutionary psychology supports the notion of a 21 heightened male competitive tendency.⁵⁰⁻⁵² Therefore, given that both conditions were competitive 22 against another player (virtual or real), it seems plausible that male participants worked harder because 23 they may be more competitive. Despite this, males reported significantly more pressure/tension and 24 25 negative affect, whereas females reported greater vitality, choice and effort/importance. Nonetheless, there were no significant differences between sexes for positive affect, competence and 26 27 interest/enjoyment. In a study of adolescents, boys reported enjoying dual-play in competitive contexts

such as boxing, whereas girls enjoyed dual-play in co-operative contexts such as dance-based games.⁵³
In one study participants who self-rated as highly competitive reported higher levels of enjoyment and
positive mood during a competitive gaming context, whereas participants self-rated as low in
competitiveness reported higher enjoyment and motivation when placed in a non-competitive gaming
context.⁵⁴ Future research should better characterize the individual factors that contribute to differential
responses in energy expenditure during exergaming and how interventions can be tailored to elicit
higher intensity activity.

In accord with previous research,^{55, 56} and indeed UK government guidelines, the present study 8 9 found that both conditions elicited an energy expenditure conducive of moderate-intensity physical activity (i.e., 3.0 to 6.0 METs; single-player: 4.3 ± 1.9 METs; dual-player: 4.2 ± 2.0 METs). Conversely, 10 numerous studies have reported values significantly below this threshold.⁵⁷⁻⁶⁰ It is postulated that the 11 type, duration and context of game played, as well as further psychosocial variables underpinning game 12 play, may explain these equivocal findings. Furthermore, in agreement with a recent meta-analysis,⁴⁰ 13 the game utilised in the present study could incorporate whole body movements and potentially explain 14 15 higher energy expenditure values. Specifically, 19.4% of participants met energy expenditure levels commensurate of vigorous-intensity physical activity (6.0 METs) and there was a wide range of METs 16 17 during game play (1.3 to 9.5 METs).

18 The present study was associated with numerous strengths, such as the utilisation of the ActiHeart[®] which facilitates a more ecologically valid environment to determine energy expenditure 19 20 and does not prohibit movement in the same manner as indirect calorimetry. Furthermore, the present study is the first to account for the potential influence of energy expenditure in determining the 21 psychosocial responses associated with exergames in young adults, as well as an inclusion of a dual-22 player social context, strengthening external validity. The incorporation of a 30-minute gaming duration 23 advances other studies, which have used as little as 5-minute bouts. It is unlikely that a 5-minute bout 24 25 will be representative of a sustained period of exergaming. It is postulated that a 30-minute gaming period is more typical of actual gaming._Whilst the methodological design allowed additional 26 27 comparisons through the randomisation of game-play order, the potential influence of the opponents'

1 relative skill level was not controlled for, a question that may be worth addressing in future research. It 2 is also important to note that many exergames, including the one used in the present study, involve 3 competing against a virtual character in the single player mode. Given the evidence that suggests that humans readily anthropomorphize virtual entities⁶¹ and that participants will treat virtual exergame 4 players as real people (i.e., the psychological dynamics of human groups apply),⁶² such modes should 5 not be considered single-player in the true sense. Furthermore, it is important to note that the present 6 7 study only considered the potential influence of competition on the relationship between energy expenditure and psychosocial variables. Future studies should seek to investigate the influence of other 8 group dynamics on the relationship, such as social facilitation or the Kohler effect. Nevertheless, it is 9 possible that a laboratory environment or a potential novelty effect may have artificially enhanced, or 10 reduced, the energy expended in the current study. A further limitation worthy of consideration is the 11 12 utilisation of single exergaming bouts. Whilst the sex-effect in the model accounts for the same-sex dyads, future research should seek to investigate the specific influence of sex within dual-player 13 14 situations. Indeed, evidence regarding motivational gains in collective work contexts suggests that 15 males show greater motivation when paired with a more capable female, whilst females efforts were more variable when paired with a male counterpart.⁶³ Although the present findings extend our 16 17 knowledge surrounding the relationship between energy expenditure, psychosocial variables, sex and 18 condition associated with exergames, caution must therefore be taken when extrapolating such findings 19 to a more sustained game playing environment. Further research is warranted to ascertain the mediatory 20 effect; that is, whether the game-play context per se, or indeed the specific energy expenditure during 21 game-play, affected the psychosocial variables.

In summary, the present study showed no significant difference between the energy expended or the psychosocial experience in either a single- or dual-player condition. Energy expenditure was an important factor in effort and importance and interest and enjoyment following exergaming. Both conditions elicited energy expenditures commensurate with national physical activity recommendations. The current findings extend our understanding of the mediators of psychosocial variables, suggesting that exergames should be considered as a potential avenue for future interventions 1 seeking to address the low physical activity levels that characterise the young adult population,

2 especially in females given their more positive psychosocial response to exergaming.

- 3
- 4

5 Acknowledgements

6 AES is supported in part by 1 U54 GM104940 from the National Institute of General Medical Sciences

7 of the National Institutes of Health, which funds the Louisiana Clinical and Translational Science

8 Center.

9

10 Author Disclosure Statement

- 11 No competing financial interests to disclose.
- 12

13 Corresponding Author

- 14 Dr. K.A. Mackintosh
- 15 College of Engineering, Swansea University
- 16 Bay Campus
- 17 Swansea, SA1 8EN
- 18 Tel 01792 295075
- 19 Fax 01792 295676
- 20 Email: k.mackintosh@swansea.ac.uk
- 21

1		References
2 3 4	1.	Lioret S, Maire B, Volatier JL, et al. Child overweight in France and its relationship with physical activity, sedentary behaviour and socioeconomic status. Eur J Clin Nutr. 2007;61:509-516.
5 6	2.	Loucaides C, Jago R, Theophanous M. Physical activity and sedentary behaviours in Greek-Cypriot children and adolescents: a cross-sectional study. Int J Behav Nutr Phys Act. 2011;8:90.
7 8	3.	Janssen I, LeBlanc A. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010;7:40.
9 10	4.	Paffenbarger RS, Hyde R, Wing AL, et al. Physical Activity, All-Cause Mortality, and
10	5.	Longevity of College Alumni. N Engl J Med. 1986;314:605-613. World Health Organisation. Global recommendations on physical activity for health. 2010.
12	6.	World Health Organisation. Physical Activity: Factsheet N°385. 2015.
13	7.	Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by
14		accelerometer. Med Sci Sports Exerc. 2008;40:181-188.
15	8.	Kwan MY, Cairney J, Faulkner GE, et al. Physical Activity and Other Health-Risk Behaviors
16		During the Transition Into Early Adulthood. Am J Prev Med. 2012;42:14-20.
17	9.	Pullman AW, Masters RC, Zalot LC, et al. Effect of the transition from high school to university
18		on anthropometric and lifestyle variables in males. Presented in part at the Canadian Society
19		for Nutritional Sciences, Canadian Nutrition Congress, held in Winnipeg, Manitoba, from 18-
20		21 June 2007. Appl Physiol Nutr Metab. 2009;34:162-171.
21	10.	Wack ER, Tantleff-Dunn S. Cyber sexy: Electronic game play and perceptions of attractiveness
22		among college-aged men. Body Image. 2008;5:365-374.
23	11.	Lucas K, Sherry JL. Sex Differences in Video Game Play: A Communication-Based
24		Explanation. Commun Res. 2004;31:499-523.
25	12.	Ogletree S, Drake R. College Students' Video Game Participation and Perceptions: Gender
26	10	Differences and Implications. Sex Roles. 2007;56:537-542.
27 28	13.	Faith MS, Berman N, Heo M, et al. Effects of Contingent Television on Physical Activity and Television Viewing in Obese Children. Pediatr. 2001;107:1043-1048.
29	14.	Bonetti A, Drury D, Danoff J, et al. Comparison of Acute Exercise Responses Between
30		Conventional Video Gaming and Isometric Resistance Exergaming. J Strength Cond Res.
31	1.5	2010;24:1799-1803.
32	15.	Miyachi M, Yamamoto K, Ohkawara K, et al. METs in Adults While Playing Active Video
33	16	Games: A Metabolic Chamber Study. Med Sci Sport Exerc. 2010;42:1149-1153.
34 35	16.	Stroud LC, Amonette WE, Dupler TL. Metabolic responses of upper-body accelerometer- controlled video games in adults. Appl Physiol Nutr Metab. 2010;35:643-649.
36	17.	Lyons E, Tate D, Ward D, et al. Energy Expenditure and Enjoyment during Video Game Play:
37	17.	Differences by Game Type. Med Sci Sport Exerc. 2011;43:1987-1993.
38	18.	Howe CA, Barr MW, Winner BC, et al. Energy Expenditure and Enjoyment during Video
39		Game Play: Differences by Game Type. J Phys Act Health. 2015;12:171-177.
40	19.	Chin A Paw MJM, Jacobs WM, Vaessen EPG, et al. The motivation of children to play an
41		active video game. J Sci Med Sport. 2008;11:163-166.
42	20.	Liebermann DA. Dance Games and Other Exergames: What the Research Says. Santa Barbara:
43		University of California; 2006.
44	21.	Lieberman DA, Chamberlin B, Medina E, et al. The Power of Play: Innovations in Getting
45		Active Summit 2011. A Science Panel Proceedings Report From the American Heart
46		Association. 2011;123:2507-2516.
47	22.	Vorderer P, Hartmann T, Klimmt C. Explaining the enjoyment of playing video games: the role
48		of competition. 2nd International Conference on Entertainment Computing. Pittsburgh2003.
49	23.	Staiano AE, Calvert SL. Wii Tennis Play for Low-Income African American Adolescents'
50	. .	Energy Expenditure. Cyberpsychol. 2011;5:4.
51	24.	Peng W, Crouse J. Playing in parallel: the effects of multiplayer modes in active video game
52		on motivation and physical exertion. Cyberpsychol Behav Soc Netw. 2013;16:423-427.

- Aadland E, Steene-Johannessen J. The use of individual cut points from treadmill walking to assess free-living moderate to vigorous physical activity in obese subjects by accelerometry: is it useful? BMC Med Res Methodol. 2012;12:172.
- 4 26. Crouter S, Churilla J, Bassett D, Jr. Estimating energy expenditure using accelerometers. Eur J
 5 Appl Physiol. 2006;98:601-612.
- Barreira TV, Kang M, Caputo JL, et al. Validation of the Actiheart Monitor for the
 Measurement of Physical Activity. Int J Exerc Sci. 2009;2:60-71.
- 8 28. Brage S, Brage N, Franks PW, et al. Reliability and validity of the combined heart rate and movement sensor Actiheart. Eur J Clin Nutr. 2005;59:561-570.
- 29. Vernadakis N, Kouli O, Tsitskari E, et al. University students' ability-expectancy beliefs and subjective task values for exergames. Comp Educ. 2014;75:149-161.
- Brumels KA, Blasius T, Cortright T, et al. Comparison of efficacy between traditional and video game based balance programs Clin Kinesiol. 2008;62:26-31.
- Staiano AE, Abraham AA, Calvert SL. Adolescent Exergame Play for Weight Loss and
 Psychosocial Improvement: A Controlled Physical Activity Intervention. Obesity.
 2013;21:598-601.
- 17 32. Derry JA. Single-sex and coeducation physical education: perspective of adolescent girls and female physical education teachers. Melpomene J. 2002;22:17-28.
- Brage S, Brage N, Ekelund U, et al. Effect of combined movement and heart rate monitor
 placement on physical activity estimates during treadmill locomotion and free-living. Eur J
 Appl Physiol. 2006;96:517-524.
- 34. Thompson D, Batterham AM, Bock S, et al. Assessment of Low-to-Moderate Intensity Physical
 Activity Thermogenesis in Young Adults Using Synchronized Heart Rate and Accelerometry
 with Branched-Equation Modeling. J Nutr. 2006;136:1037-1042.
- Ryan RM, Frederick C. On energy, personality, and health: Subjective vitality as a dynamic reflection of well-being. J Pers. 1997;65:529-565.
- 27 36. Diener E, Emmons RA. The independence of positive and negative affect. J Pers Soc Psychol.
 28 1984;47:1105-1117.
- 37. McAuley E, Duncan T, Tammen VV. Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. Res Q Exerc Sport.
 31 1989;60:48-58.
- 32 38. Brage S, Brage N, Franks PW, et al. Branched equation modeling of simultaneous
 33 accelerometry and heart rate monitoring improves estimate of directly measured physical
 34 activity energy expenditure. J Appl Physiol. 2004;96:343-351.
- 35 39. Cohen J. *Statistical power analysis for the behavioural sciences*. Hillsdale, NJ: Erlbaum; 1988.
- 40. Peng W, Lin J-H, Crouse J. Is Playing Exergames Really Exercising? A Meta-Analysis of
 Energy Expenditure in Active Video Games. Cyberpsychol Behav Soc Netw. 2011;14:681688.
- Feltz DL, Forlenza ST, Winn B, et al. Cyber Buddy Is Better than No Buddy: A Test of the
 Köhler Motivation Effect in Exergames. Games Health J. 2014;3:98-105.
- 41 42. Ryan RM. Control and information in the intrapersonal sphere: An extension of cognitive evaluation theory. J Pers Soc Psychol. 1982;43:450-461.
- 43 43. Marker AM, Staiano AE. Better Together: Outcomes of Cooperation Versus Competition in
 44 Social Exergaming. Games Health J. 2015;4:25-30.
- 45 44. Paw CA, Marijke J, Jacobs WM, et al. The motivation of children to play an active video game.
 46 J Sci Med Sport. 2008;11:163-166.
- 47 45. Livingstone MB, Robson PJ, Totton M. Energy expenditure by heart rate in children: an evaluation of calibration techniques. Med Sci Sport Exerc. 2000;32:1513-1519.
- 49 46. Graves LE, Ridgers ND, Stratton G. The contribution of upper limb and total body movement
 50 to adolescents' energy expenditure whilst playing Nintendo Wii. Eur J Appl Physiol.
 51 2008;104:617-623.
- 52 47. Duncan MJ, Dick S. Energy expenditure and enjoyment of exergaming: a comparison of the
 53 Nintendo Wii and the gamercize power stepper in young adults. Med Sport. 2012;16:92-98.
- 54 48. Burke SM, Carron AV, Eys MA. Physical activity context: Preferences of university students.
 55 Psych Sport Exerc Sci. 2006;7:1-13.

- 49. Douris P, McDonald B, Vespi F, et al. Comparison Between Nintendo Wii Fit Aerobics and Traditional Aerobic Exercise in Sedentary Young Adults. J Strength Cond Res. 2012;26:1052-1057.
- Buunk AP, Massar K. Intrasexual competition among males: Competitive towards men,
 prosocial towards women. Pers Individ Dif. 2012;52:818-821.
- 6 51. Cashdan E. Are men more competitive than women? Br J Soc Psychol. 1998;37:213-229.
- 7 52. Niederle M, Vesterlund L. Do Women Shy Away from Competition? Do Men Compete Too
 8 Much? Q J Econ. 2007;122:1067-1101.
- 9 53. Bailey BW, McInnis K. Energy cost of exergaming: a comparison of the energy cost of 6 forms of exergaming. Arch Pediatr Adolesc Med. 2011;165:597-602.
- Song H, Kim J, Tenzek KE, et al. The effects of competition and competitiveness upon intrinsic motivation in exergames. Comput Human Behav. 2013;29:1702-1708.
- 13 55. Maddison R, Mhurchu CN, Jull A, et al. Energy Expended Playing Video Console Games: An
 Opportunity to Increase Children's Physical Activity? Ped Exerc Sci. 2007;19:334-343.
- 15 56. Tan B, Aziz AR, Chua K, et al. Aerobic Demands of the Dance Simulation Game. Int J Sports
 16 Med. 2002;23:125-129.
- 17 57. O'Donovan C, Hirsch E, Holohan E, et al. Energy expended playing Xbox KinectTM and
 18 WiiTM games: a preliminary study comparing single and multiplayer modes. Physiother.
 19 2012;98:224-229.
- 58. O'Donovan C, Roche EF, Hussey J. The energy cost of playing active video games in children
 with obesity and children of a healthy weight. Pediatr Obes. 2014;9:310-317.
- Solution of the contribution of upper limb and total body movement to adolescents' energy expenditure whilst playing Nintendo Wii. Eur J Appl Physiol. 2008;104:617-623.
- 25 60. Unnithan VB, Houser W, Fernhall B. Evaluation of the Energy Cost of Playing a Dance
 26 Simulation Video Game in Overweight and Non-Overweight Children and Adolescents. Int J
 27 Sports Med. 2006;27:804-809.
- 28 61. Reeves B, Naas C. The media equation: How people treat computers, television, and new media
 29 like real people and places. *Stanford*. CA: CSLI Publications; 1996.
- Feltz DL, Forlenza ST, Winn B, et al. Cyber Buddy Is Better than No Buddy: A Test of the
 Köhler Motivation Effect in Exergames. Games for Health Journal. 2014;3:98-105.
- 32 63. Lount RB, Messé LA, Kerr NL. Trying Harder for Different Reasons. Z Soc Psychol.
 33 2000;31:221-230.

1 Table 1. Participant descriptive characteristics

	Total	Males	Females
N	36	19	17
Age (years)	22.0 ± 4.2	22.5 ± 5.5	21.5 ± 2.3
Stature (m)	1.7 ± 0.1	1.8 ± 0.1	$1.7\pm0.1^*$
Body mass (kg)	69.3 ± 13.5	77.4 ± 12.0	$60.4 \pm 8.6^{*}$
BMI (kg·m ⁻²)	23.3 ± 3.5	24.5 ± 4.0	$21.8 \pm 2.4^{*}$
Waist circumference (m)	0.8 ± 0.1	0.8 ± 0.1	$0.7\pm0.1^{*}$

2 Note. Mean \pm SD. *P < 0.05

- 1 Table 2. Descriptive characteristics of psychosocial variables determined immediately following each
- 2 exergame by sex.

	Male	Female	Effect size
	(<i>n</i> = 38)	(<i>n</i> = 34)	(Cohens d)
Vitality	5.1 ± 1.1	$5.7 \pm 1.0^{*}$	0.52
Positive affect	5.7 ± 0.7	5.9 ± 0.9	0.32
Negative affect	2.3 ± 0.8	$1.8 \pm 1.0^{**}$	0.54
Pressure or tension	2.5 ± 1.1	$1.7 \pm 0.7^{**}$	0.87
Competence	5.3 ± 0.9	4.8 ± 1.2	0.47
Choice	5.7 ± 1.0	$6.3 \pm 0.6^{**}$	0.73
Effort and importance	5.0 ± 1.1	$5.5 \pm 1.1^{*}$	0.45
Interest and enjoyment	5.4 ± 1.1	5.5 ± 1.2	0.09

3 *Note*. Means \pm SD. All parameters determined from a 7-point scale. n = number of participants * 2

4 conditions. Significant influence of sex: *p<0.05, **p<0.001

1 Table 3. Descriptive characteristics of psychosocial variables by condition.
--

	Single-Player	Dual-Player	Total	Effect size
	(n = 36)	(<i>n</i> = 36)	(<i>n</i> = 72)	(Cohens's d)
Vitality	21.4 ± 4.2	21.5 ± 4.5	21.5 ± 4.3	0.02
Positive affect	23.1 ± 3.0	23.1 ± 3.8	23.1 ± 3.4	0.00
Negative affect	10.2 ± 4.2	10.2 ± 5.0	10.2 ± 4.6	0.00
Pressure or tension	2.2 ± 1.0	2.1 ± 1.0	2.1 ± 1.0	0.10
Competence	4.9 ± 1.1	5.2 ± 1.1	5.1 ± 1.1	0.29
Choice	6.0 ± 0.9	6.1 ± 0.9	6.0 ± 0.9	0.11
Effort and importance	5.2 ± 1.2	5.3 ± 1.1	5.2 ± 1.1	0.09
Interest and enjoyment	5.4 ± 1.0	5.5 ± 1.2	5.5 ± 1.1	0.09

Note. Means \pm SD. All parameters determined from a 7-point scale. n = 36 participants * 2 conditions.

1 Table 4. Linear mixed model of psychosocial predictors of exercise intensity.

	β	95% LCI	95% UCI	p value
Condition – first game-play session	0.06	-0.02	0.14	0.136
Order – single-player first	-0.30	-0.53	-0.06	0.016*
Vitality	-0.01	-0.03	0.01	0.446
Positive Affect	0.02	-0.02	0.05	0.334
Negative Affect	0.00	-0.01	0.02	0.807
Pressure or Tension	-0.07	-0.16	0.01	0.082
Perceived Competence	-0.07	-0.14	0.00	0.042*
Perceived Choice	0.01	-0.08	0.10	0.826
Effort and Importance	0.11	0.03	0.19	0.007**
Interest and Enjoyment	0.04	-0.06	0.15	0.382
Male x Single-Player	0.74	0.40	1.09	<0.001**
Male x Dual-Player	0.70	0.36	1.05	<0.001**
Female x Single-Player	0.16	0.05	0.26	0.006**

2 *Note*. *p<0.05, **p<0.001. Dependent variable – log of energy expenditure. Reference category:

3 Condition – second game-play; Order – dual-player first; Sex x Condition – female, dual-player. LCI =

4 Lower confidence interval. UCI=Upper confidence interval.