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1 **Running Title:** Single- and Dual-player exergaming in adults

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5 **Investigating the Physiological and Psychosocial Responses of Single- and Dual-Player**
6 **Exergaming in Young Adults**

7

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Abstract

Objective:

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

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.

Results:

There was no significant difference in energy expenditure or psychosocial outcomes between 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 ($z=-2.219$, $p=0.026$) and effort/importance than males ($z=-2.001$, $p=0.045$). Conversely, males reported greater negative affect ($z=-2.872$, $p=0.004$) and pressure/tension ($z=-3.295$, $p=0.001$). A linear mixed effects 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 expenditure and psychosocial variables was not modulated by sex or order of game play (single or dual-player first).

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.

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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 especially pronounced in young, university-aged adults for whom physical activity is evidenced to decrease by 24% during the transition from high school to college.⁸ This decrease is further compounded by an increase in sedentary behaviours;⁹ in addition to time spent sitting in lectures and 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 per week playing video games, with 8.5% of students spending up to 35 hours per week. Similarly, studies have shown the mean time spent playing video games to be 8.5 ± 12.2 hours per week, with 39% of students playing more than 2 hours per week.^{11, 12} The popularity of game play has led to the development of games that aim to combine video game playing with physical activity in an effort to counteract the negative consequences associated with conventional, sedentary game playing without necessitating people to relinquish highly-valued behaviours.¹³

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

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

5 **Materials and Methods**

6 *Sample Population*

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

10 *Experimental procedures*

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

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

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1 *Experimental Measures*

2 During the each exergaming bout, heart rate and uni-axial accelerometry data were
3 simultaneously recorded at a 1 minute epoch using the Actiheart® monitor (CamnTech, UK).
4 Following skin preparation, the monitor was attached to the chest at V1 or V2 (4th intercostal) and 10
5 cm laterally at V4 or V5³³ using two 3M electrodes. The ActiHeart®, which was calibrated for each
6 participant's age, body mass and stature, has been reported to provide valid and reliable measures of
7 free-living physical activity levels.^{33, 34}

8 Immediately after each exergaming condition, participants were asked to complete a series of
9 questionnaires to assess the psychological responses to that exergame. Specifically, to assess
10 subjective vitality, four items of the State Level Subjective Vitality Scale³⁵ were used with responses
11 rated on a seven-point scale ranging from 1 (not at all true) to 7 (very true). The mean of the four
12 components was taken. To assess positive and negative affect, the participants responded to nine
13 adjectives identified by Diener and Emmons.³⁶ This scale consists of four positive affect adjectives
14 (joyful, happy, pleased, enjoying/having fun) and five negative affect adjectives (depressed,
15 worried/anxious, frustrated, angry/hostile, unhappy). Participants were requested to rate each
16 adjective using the precursory stem, "What extent did you experience the following emotions during
17 the experimental task?". Responses were made as to the degree that each emotion was experienced
18 during the experiment on a 7-point scale ranging from 1 (not at all) to 7 (extremely). The mean of the
19 components was calculated for positive and negative affect. Finally, to assess intrinsic motivation,
20 items from the interest/enjoyment, perceived competence, effort/importance, pressure/tension and
21 perceived choice subscales of the Intrinsic Motivation Inventory (IMI)³⁷ were used. Participants were
22 requested to rate how true each statement was for them on a 7-point scale ranging from 1 (strongly
23 disagree) to 7 (strongly agree).

24 *Data Analysis*

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

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1 A total of 72 data points were available for analysis (36 participants x 2 conditions). To
2 address the within subject correlation between repeated measures, linear mixed models were used to
3 determine whether energy expenditure was a significant predictor of psychosocial variables. For each
4 model, covariates sex, BMI, condition (1 vs 2 player), order (1 player first vs 2 player first) and an
5 interaction between sex and energy expenditure, sex, order and condition and condition and order
6 were tested. As all interactions were insignificant, they were excluded from the final models. A
7 separate analysis was conducted to investigate the influence of order and condition on energy
8 expenditure. To account for the multiple comparisons, a Bonferroni correction was applied to adjust
9 confidence intervals and significance values. Effect sizes (ES) were calculated using Cohen's d
10 formula and interpreted according to published guidelines.³⁹ All statistical analyses were conducted
11 using PASW Statistics 21 (SPSS, Chicago, IL). All data are presented as means ± standard deviation.
12 Statistical significance was set at $P \leq 0.05$.

13 Results

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

26 Females reported significantly greater vitality ($t(70) = -2.2$, $p = 0.030$) and choice than males
27 ($t(70) = -3.1$, $p = 0.003$), whereas males reported significantly greater negative affect ($t(70) = 2.4$, $p =$

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1 0.021) and pressure/tension ($t(70) = 3.9, p = 0.000$) (Table 2). There were no significant differences
2 between sex with respect to positive affect, perceived competence, effort and importance or
3 interest/enjoyment. Furthermore, there was no influence of condition on any of the psychosocial
4 variables (Table 3).

5 The linear mixed model revealed that energy expenditure was a significant predictor of
6 interest and enjoyment and effort and importance and that this relationship was not dependent on
7 order, condition or sex. Specifically, as energy expenditure increased, as did interest and enjoyment
8 ($t(65) = 2.7, p = 0.001$) and effort and importance ($t(65) = 3.6, p = 0.001$). There were no significant
9 interactions between order, condition or sex in determining the relationship between energy
10 expenditure and psychosocial variables.

11 Discussion

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

24 The present findings are in agreement with previous studies reporting no significant
25 difference in energy expended between conditions.¹⁴ However, it is pertinent to note the contradictory
26 findings of Peng et al.²⁴, who reported a greater energy expenditure during single player, and Staiano
27 et al.²³, who reported the converse. Such discrepancies could be attributed to the use of substantially

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1 shorter bout durations (5-minutes)²⁴, although the reliance on accelerometry to estimate energy
2 expenditure in both of these studies limits inter-study comparisons due to the potential confounding
3 effect of different energy expenditure prediction algorithms.^{23, 40} Furthermore, the equivocal findings
4 may be related to the games employed and, specifically, whether the single-player mode was truly
5 single-player⁴⁰ or rather involved competing against a computer-generated opponent.²³ Indeed, with
6 regards to the latter, it could be postulated that participants in the present study never really
7 experienced a non-competitive gaming experience. Nonetheless, earlier work reported higher energy
8 expenditures for children playing against peers rather than virtual characters.²³

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

17 The linear mixed-model revealed that young adults playing an exergame alone are likely to
18 expend more energy if they play against someone first. It is therefore possible that dual-play is more
19 beneficial over the longer-term. Specifically, a 12-week exergaming study of children aged 9 to 12
20 years observed less drop-out and higher engagement among those assigned to a dual-player condition
21 (15% attrition; 901 minutes) vs. a solitary in-home condition (64% attrition; 376 minutes).⁴⁴ However,
22 the intensity level of play between conditions was unknown, as is the transferability of findings in
23 children to adults.

24 The linear mixed-effects model revealed that effort/importance increased as energy
25 expenditure increased. It is perhaps unsurprising that as participants' energy expenditure increased, so
26 did their associated perceptions of effort and importance. Interestingly, energy expenditure during
27 exergaming was not a predictor of perceived competence. Such a finding is contrary to expectation as
28 perceived competence may indicate mastery of gaming, which would be anticipated to be associated

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1 with a greater exercise economy due to a higher proficiency and efficiency of the necessary
2 movements and thus decreased energy expenditure. This may be attributable to the relative gaming
3 experience of the participants, with more experienced gamers demonstrating a depressed response due
4 to a greater state of “training” or a reduced emotional response.^{45,46} The familiarisation provided prior
5 to the start of the present study may have negated a potential relationship between energy expenditure
6 and perceived competence.

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

20 While some researchers suggest that exergames are perceived as more enjoyable compared to
21 traditional aerobic exercise modalities,²⁹ others report decreases in positive well-being.⁴⁹ Individual
22 factors may contribute to differential effects on energy expenditure and psychosocial variables, such
23 as sex and game-play preference (i.e., competitive vs. solitary gaming). Specifically, energy
24 expenditure during exergaming was dependent on sex, with males expending significantly more
25 energy, irrespective of condition. Evidence from both biology and evolutionary psychology supports
26 the notion of a heightened male competitive tendency.⁵⁰⁻⁵² Therefore, given that both conditions were
27 competitive against another player (virtual or real), it seems plausible that male participants worked

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1 harder because they may be more competitive. Despite this, males reported significantly more
2 pressure/tension and negative affect, whereas females reported greater vitality, choice and
3 effort/importance. Nonetheless, there were no significant differences between sexes for positive
4 affect, competence and interest/enjoyment. In a study of adolescents, boys reported enjoying dual-
5 play in competitive contexts such as boxing, whereas girls enjoyed dual-play in co-operative contexts
6 such as dance-based games.⁵³ In one study participants who self-rated as highly competitive reported
7 higher levels of enjoyment and positive mood during a competitive gaming context, whereas
8 participants self-rated as low in competitiveness reported higher enjoyment and motivation when
9 placed in a non-competitive gaming context.⁵⁴ Future research should better characterize the
10 individual factors that contribute to differential responses in energy expenditure during exergaming
11 and how interventions can be tailored to elicit higher intensity activity.

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

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22 The present study was associated with numerous strengths, such as the utilisation of the
23 ActiHeart® which facilitates a more ecologically valid environment to determine energy expenditure
24 and does not prohibit movement in the same manner as indirect calorimetry. Furthermore, the present
25 study is the first to account for the potential influence of energy expenditure in determining the
26 psychosocial responses associated with exergames in young adults, as well as an inclusion of a dual-
27 player social context, strengthening external validity. The incorporation of a 30-minute gaming

1 duration advances other studies, which have used as little as 5-minute bouts. It is unlikely that a 5-
2 minute bout will be representative of a sustained period of exergaming. It is postulated that a 30-
3 minute gaming period is more typical of actual gaming. Whilst the methodological design allowed
4 additional comparisons through the randomisation of game-play order, the potential influence of the
5 opponents' relative skill level was not controlled for, a question that may be worth addressing in
6 future research. It is also important to note that many exergames, including the one used in the present
7 study, involve competing against a virtual character in the single player mode. Given the evidence that
8 suggests that humans readily anthropomorphize virtual entities⁶¹ and that participants will treat virtual
9 exergame players as real people (i.e., the psychological dynamics of human groups apply),⁶² such
10 modes should not be considered single-player in the true sense. Furthermore, it is important to note
11 that the present study only considered the potential influence of competition on the relationship
12 between energy expenditure and psychosocial variables. Future studies should seek to investigate the
13 influence of other group dynamics on the relationship, such as social facilitation or the Kohler effect.
14 Nevertheless, it is possible that a laboratory environment or a potential novelty effect may have
15 artificially enhanced, or reduced, the energy expended in the current study. A further limitation
16 worthy of consideration is the utilisation of single exergaming bouts. Whilst the sex-effect in the
17 model accounts for the same-sex dyads, future research should seek to investigate the specific
18 influence of sex within dual-player situations. Indeed, evidence regarding motivational gains in
19 collective work contexts suggests that males show greater motivation when paired with a more
20 capable female, whilst females efforts were more variable when paired with a male counterpart.⁶³
21 Although the present findings extend our knowledge surrounding the relationship between energy
22 expenditure, psychosocial variables, sex and condition associated with exergames, caution must
23 therefore be taken when extrapolating such findings to a more sustained game playing environment.
24 Further research is warranted to ascertain the mediatory effect; that is, whether the game-play context
25 per se, or indeed the specific energy expenditure during game-play, affected the psychosocial
26 variables.

27 In summary, the present study showed no significant difference between the energy expended
28 or the psychosocial experience in either a single- or dual-player condition. Energy expenditure was an

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1 important factor in effort and importance and interest and enjoyment following exergaming. Both
2 conditions elicited energy expenditures commensurate with national physical activity
3 recommendations. The current findings extend our understanding of the mediators of psychosocial
4 variables, suggesting that exergames should be considered as a potential avenue for future
5 interventions seeking to address the low physical activity levels that characterise the young adult
6 population, especially in females given their more positive psychosocial response to exergaming.

7

8

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13

14 **Author Disclosure Statement**

15 No competing financial interests to disclose.

16

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References

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

Field Code Changed

- 1 25. Aadland E, Steene-Johannessen J. The use of individual cut points from treadmill walking to
2 assess free-living moderate to vigorous physical activity in obese subjects by accelerometry:
3 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*
5 *J Appl Physiol.* 2006;98:601-612.
- 6 27. Barreira TV, Kang M, Caputo JL, et al. Validation of the Actiheart Monitor for the
7 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
9 movement sensor Actiheart. *Eur J Clin Nutr.* 2005;59:561-570.
- 10 29. Vernadakis N, Kouli O, Tsitskari E, et al. University students' ability-expectancy beliefs and
11 subjective task values for exergames. *Comp Educ.* 2014;75:149-161.
- 12 30. Brumels KA, Blasius T, Cortright T, et al. Comparison of efficacy between traditional and
13 video game based balance programs *Clin Kinesiol.* 2008;62:26-31.
- 14 31. Staiano AE, Abraham AA, Calvert SL. Adolescent Exergame Play for Weight Loss and
15 Psychosocial Improvement: A Controlled Physical Activity Intervention. *Obesity.*
16 2013;21:598-601.
- 17 32. Derry JA. Single-sex and coeducation physical education: perspective of adolescent girls and
18 female physical education teachers. *Melpomene J.* 2002;22:17-28.
- 19 33. Brage S, Brage N, Ekelund U, et al. Effect of combined movement and heart rate monitor
20 placement on physical activity estimates during treadmill locomotion and free-living. *Eur J*
21 *Appl Physiol.* 2006;96:517-524.
- 22 34. Thompson D, Batterham AM, Bock S, et al. Assessment of Low-to-Moderate Intensity
23 Physical Activity Thermogenesis in Young Adults Using Synchronized Heart Rate and
24 Accelerometry with Branched-Equation Modeling. *J Nutr.* 2006;136:1037-1042.
- 25 35. Ryan RM, Frederick C. On energy, personality, and health: Subjective vitality as a dynamic
26 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.
- 29 37. McAuley E, Duncan T, Tammen VV. Psychometric Properties of the Intrinsic Motivation
30 Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. *Res Q Exerc*
31 *Sport.* 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;
36 1988.
- 37 40. Peng W, Lin J-H, Crouse J. Is Playing Exergames Really Exercising? A Meta-Analysis of
38 Energy Expenditure in Active Video Games. *Cyberpsychol Behav Soc Netw.* 2011;14:681-
39 688.
- 40 41. Feltz DL, Forlenza ST, Winn B, et al. Cyber Buddy Is Better than No Buddy: A Test of the
41 Köhler Motivation Effect in Exergames. *Games Health J.* 2014;3:98-105.
- 42 42. Ryan RM. Control and information in the intrapersonal sphere: An extension of cognitive
43 evaluation theory. *J Pers Soc Psychol.* 1982;43:450-461.
- 44 43. Marker AM, Staiano AE. Better Together: Outcomes of Cooperation Versus Competition in
45 Social Exergaming. *Games Health J.* 2015;4:25-30.
- 46 44. Paw CA, Marijke J, Jacobs WM, et al. The motivation of children to play an active video
47 game. *J Sci Med Sport.* 2008;11:163-166.
- 48 45. Livingstone MB, Robson PJ, Totton M. Energy expenditure by heart rate in children: an
49 evaluation of calibration techniques. *Med Sci Sport Exerc.* 2000;32:1513-1519.
- 50 46. Graves LE, Ridgers ND, Stratton G. The contribution of upper limb and total body movement
51 to adolescents' energy expenditure whilst playing Nintendo Wii. *Eur J Appl Physiol.*
52 2008;104:617-623.
- 53 47. Duncan MJ, Dick S. Energy expenditure and enjoyment of exergaming: a comparison of the
54 Nintendo Wii and the gamercize power stepper in young adults. *Med Sport.* 2012;16:92-98.

- 1 48. Burke SM, Carron AV, Eys MA. Physical activity context: Preferences of university students.
2 Psych Sport Exerc Sci. 2006;7:1-13.
- 3 49. Douris P, McDonald B, Vespi F, et al. Comparison Between Nintendo Wii Fit Aerobics and
4 Traditional Aerobic Exercise in Sedentary Young Adults. J Strength Cond Res.
5 2012;26:1052-1057.
- 6 50. Buunk AP, Massar K. Intrasexual competition among males: Competitive towards men,
7 prosocial towards women. Pers Individ Dif. 2012;52:818-821.
- 8 51. Cashdan E. Are men more competitive than women? Br J Soc Psychol. 1998;37:213-229.
- 9 52. Niederle M, Vesterlund L. Do Women Shy Away from Competition? Do Men Compete Too
10 Much? Q J Econ. 2007;122:1067-1101.
- 11 53. Bailey BW, McInnis K. Energy cost of exergaming: a comparison of the energy cost of 6
12 forms of exergaming. Arch Pediatr Adolesc Med. 2011;165:597-602.
- 13 54. Song H, Kim J, Tenzek KE, et al. The effects of competition and competitiveness upon
14 intrinsic motivation in exergames. Comput Human Behav. 2013;29:1702-1708.
- 15 55. Maddison R, Mhurchu CN, Jull A, et al. Energy Expended Playing Video Console Games:
16 An Opportunity to Increase Children's Physical Activity? Ped Exerc Sci. 2007;19:334-343.
- 17 56. Tan B, Aziz AR, Chua K, et al. Aerobic Demands of the Dance Simulation Game. Int J Sports
18 Med. 2002;23:125-129.
- 19 57. O'Donovan C, Hirsch E, Holohan E, et al. Energy expended playing Xbox Kinect™ and
20 Wii™ games: a preliminary study comparing single and multiplayer modes. Physiother.
21 2012;98:224-229.
- 22 58. O'Donovan C, Roche EF, Hussey J. The energy cost of playing active video games in children
23 with obesity and children of a healthy weight. Pediatr Obes. 2014;9:310-317.
- 24 59. Graves LF, Ridgers N, Stratton G. The contribution of upper limb and total body movement
25 to adolescents' energy expenditure whilst playing Nintendo Wii. Eur J Appl Physiol.
26 2008;104:617-623.
- 27 60. Unnithan VB, Houser W, Fernhall B. Evaluation of the Energy Cost of Playing a Dance
28 Simulation Video Game in Overweight and Non-Overweight Children and Adolescents. Int J
29 Sports Med. 2006;27:804-809.
- 30 61. Reeves B, Naas C. The media equation: How people treat computers, television, and new
31 media like real people and places. Stanford. CA: CSLI Publications; 1996.
- 32 62. Feltz DL, Forlenza ST, Winn B, et al. Cyber Buddy Is Better than No Buddy: A Test of the
33 Köhler Motivation Effect in Exergames. Games for Health Journal. 2014;3:98-105.
- 34 63. Lount RB, Messé LA, Kerr NL. Trying Harder for Different Reasons. Z Soc Psychol.
35 2000;31:221-230.