GAMES FOR HEALTH JOURNAL: Research, Development, and Clinical Applications
Volume 6, Number 1, 2017

DOI: 10.1089/g4h.2016.0074

Physiological and Perceived Responses in Different Levels of Exergames in Elite Athletes

Louisa Ming Yan Chung, RNutr, DHSc,[1] Feng Hua Sun, PhD,[1] and Chris Tsz Man Cheng, BHE[2]

Abstract

Objective: Exergames have been suggested to increase the public's physical activity and to benefit cardiovascular health, particularly among the youth. However, not many studies compared the physiological and perceived responses between exergames and the authentic sports especially for elite athletes. This study aimed to investigate the physiological and perceived responses in different levels of Nintendo® Wii Fit™ U rowing exergames in one group of elite rowing athletes.

Materials and Methods: All participants were asked to perform the authentic rowing on the indoor rowing machine on the first day and to play the rowing exergames on the second day, in three levels with 1 hour rest between levels. Oxygen consumption (VO_2), lactate concentration, heart rate (HR), rating of perceived exertion (RPE), and muscle soreness scale (MSS) of the elite athletes were measured in three levels of rowing exergames and were compared with those measured in indoor rowing.

Results: Percentages of HR ranged from 57% to 64% and from 67% to 82% of peak HR in males and females, respectively. Percentages of RPE and MSS obtained from the three levels of rowing exergames ranged from 34% to 55% and from 2% to 33% of the peak RPE and the peak MSS, respectively, in authentic rowing.

Conclusion: Physiological and perceived responses of elite rowing athletes could not reach their highest response in authentic rowing even for the hard level of exergames. This study contributed direct data on the physiological benefits of exergames against authentic rowing.

Keywords: Exergames, Elite athletes, Rowing

Introduction

Insufficient physical activity is one of the top problems across different age groups. Increased screen time is one reason that occupies people's time and prevents them from doing exercises.[1] As videogames are becoming more mobile, cheaper, and more popular, videogaming behavior is predicted to grow.[2] Exergaming is defined as technology-driven videogames with physical activities.[3] Unlike the videogames that players use simple hand and finger movements, exergaming requires participants to apply part of or full body motion to play virtual sports and perform fitness exercises or physical activities. These interactive gameplays make such a motion different from traditional sedentary games in their advancement of game controllers. Examples are censored pads, hand-held haptic, sensor-based remotes, light and motion sensors, and motion pads.[4–7] The application of exergames draws escalating interest in translating real sports to virtual sports, as the body movements in exergaming can increase the levels of physical activity or sports participation.[4]

Exergames are especially popular among youth, and research continues confirming the health and fitness benefits obtained from exergaming.[8] High heart rate (HR) and energy expenditure were found in children during playing Kinect Sports—200 m hurdles and ten pin bowling.[8] Energy expenditure in adolescents playing Wii™ Sports such as bowling, tennis, and boxing was also found to be significantly higher than those playing sedentary games.[9] A recent survey revealed that around 25% of adolescents exergamed and 73% of them exergamed at a moderate or vigorous intensity.[10] This indicated the potential of exergaming in helping adolescents to achieve physical activity recommendation. In general, exergames are believed to provide benefits in youth's health, including physiological, psychological, and social outcomes.[2]

Exergames may also benefit other populations such as the elderly.[11] Recently, exergames have also been suggested to provide new tools for elite athletes in coaching or training.[12] However, debates are also found in the skill translational accuracy in movement proficiency and movement patterns

[1]Department of Health and Physical Education, The Education University of Hong Kong, Tai Po, Hong Kong.
[2]Hong Kong Sports Institute, Shatin, Hong Kong.

that are exerted in authentic sports and exergaming.[6,13] There are also opponents in exergaming as a substitute for physical activity.[9,14] In general, most of the previous studies focus on the comparisons of health benefits between exergaming and sedentary status especially in youth, and limited studies were found to compare these between exergaming and authentic sports in elite athletes.

To the authors' knowledge, limited criterion validations have been conducted to verify the quantity and quality of a specific exergames against authentic sports. Therefore, it is critical to provide some evidence-based data to support the potential application of exergames for both health and training purposes, so as to help develop the new generation exergames. The sport of rowing is popular in aerobic training and is usually available in indoor gymnastics and school settings. In addition, the players' experience in the sports and games also made for variation in movement patterns, thus there are different results in terms of the quality of the physical outcomes.[6]

Therefore, the purpose of this study was to investigate the physiological and perceived responses in different levels of Nintendo® Wii Fit™ U rowing exergames in one group of elite rowing athletes in Hong Kong. We hypothesized that the participants' physiological and perceived responses in rowing exergames were correlated with the levels of exergames, which were different from those of authentic rowing.

Materials and Methods

Participants

Five male (mean ± SD: age, 24.4 ± 6.8 yr; body weight, 73.6 ± 3.9 kg; body height, 175.6 ± 7.0 cm; body mass index [BMI], 23.9 ± 1.0 kg/m^2) and five female (age, 20.6 ± 3.2 yr; body weight, 55.2 ± 3.7 kg; body height, 162.0 ± 2.1 cm; BMI, 21.1 ± 1.6 kg/m^2) elite athletes in Hong Kong rowing sports team were recruited by snowball sampling. The inclusion criteria included ages 16–35 years with current status as full-time elite athletes in a rowing sports team. They received regular rowing training during the past 1 year. Exclusion criteria were those who got injuries in recent 3 months, got sick or took any medicine 1 week before, received surgery within 3 months, or having a mental illness that may affect responses during the assessment.

The study protocol was approved by the research ethics committee of The Education University of Hong Kong. Each participant was given an information sheet describing the purpose and procedures of this study. Participants agreed to participate in this study and signed the consent forms before the study.

Procedure and protocol

A briefing section on the instructions of using the indoor rowing machine and playing rowing exergames in three different levels was held before the study. All participants were asked to perform the authentic rowing on the indoor rowing machine (Concept 2, Model D 2006, Morrisville, VT) on the first day. During the authentic rowing test, one graded exercise test was conducted with gradually increased power output (W) in every stage.[15]

In each stage, participants were required to maintain the power output for 2 minutes. A 30-second rest was allowed between the two stages. For males, the starting power output was 180 W, and 30 W was increased for each stage. For females, the starting power output was 150 W, followed by a 25 W increase in each later stage. The authentic rowing test was stopped when participants were unable to maintain 2 minutes for that stage. All males completed seven stages and all females completed six stages. The oxygen consumption (VO_2) during the test was continuously measured by a metabolic cart system (COSMED K4 b2, Italy).

The HR was measured by a HR monitor (V800 GPS sports watch; Polar Electro, Inc., Lake Success, NY) throughout the test. Capillary blood samples were collected, and the rate of perceived exertion (RPE) and muscle soreness scale (MSS) were recorded at the end of each stage. The blood samples were used to determine the lactate concentration (Accutrend plus System; Roche, Indianapolis, IN). The RPE was recorded using a validated psychophysiological scale ranging from 6 to 20 scale, with 6 indicating ''no exertion at all'' and 20 indicating ''maximal exertion.''[16] Local muscle soreness and systemic fatigue were assessed using an 11-point scale, ranging from no pain (0) to the worst pain ever experienced (10).[17]

After 24 hours rest, all participants were asked to come back to the laboratory and play the Wii Fit U rowing exergames at easy, normal, and hard modes, with 1 hour rest between any two modes. The participants were instructed to complete the exergames with their best in each mode. The estimated duration was 1.5 minutes for the easy level, 2.5 minutes for normal level, and 3.5 minutes for hard level. The VO_2 and HR were measured continuously during the tests. The lactate concentration, RPE, and MSS were collected at resting and at the end of each level of exergames.

Data analysis

Data were analyzed using SPSS for statistical analyses version 21. Descriptive statistics were analyzed for demographic data, physical parameters, and responses in all testing items. Two-way repeated measures ANOVA (gender × levels) was used to compare the physiological responses between genders and among different levels (including peak physiological responses). Statistical significances were set at $P < 0.05$. Percentages of physiological responses of rowing at different levels of exergames were calculated with reference to those achieved with indoor rowing machine [(responses obtained from exergames/responses obtained from indoor rowing machine) × 100%].

Results

The physiological responses during different levels of exergames and peak responses during indoor rowing test are listed in Table 1. The only gender difference observed was in HR, with higher HR responses in females than in males at all levels of exergames. Regarding the VO_2, HR, RPE, and MSS, significant differences were found among the three levels of exergames in both genders. The values of these indicators during exergames were lower than the peak values. For the blood lactate concentrations, there were no differences among the three levels of exergames in both genders. However, the values during exergames were lower than the peak values in both males and females.

Percentages of testing responses achieved by rowing exergames at three different levels against those achieved by

Table 1. Physiological and Perceived Responses in Wii Fit U Rowing Exergames and Authentic Rowing Test ($N=10$)

Indicators	Male ($n=5$), mean ± SD (% of peak value)				Female ($n=5$), mean ± SD (% of peak value)			
	Exergames			*Authentic rowing*	*Exergames*			*Authentic rowing*
	Easy	*Normal*	*Hard*	*Peak*	*Easy*	*Normal*	*Hard*	*Peak*
LA, mmol/L	1.2 ± 0.3 (14)	1.1 ± 0.4 (13)	1.1 ± 0.3 (13)	8.5 ± 2.8^{a,b,c}	1.5 ± 0.4 (15)	1.4 ± 0.7 (14)	1.8 ± 1.2 (18)	10.1 ± 3.3^{a,b,c}
VO_2, mL/(min·kg)	18.1 ± 4.9 (29)	20.2 ± 6.3^a (33)	24.7 ± 11.1^{a,b} (40)	62.2 ± 8.6^{a,b,c}	18.5 ± 3.7 (31)	20.4 ± 3.8^a (34)	23.8 ± 2.5^{a,b} (40)	59.4 ± 6.2^{a,b,c}
HR, bpm^d	104 ± 16 (57)	103 ± 16^a (56)	118 ± 31^{a,b} (64)	184 ± 11^{a,b,c}	132 ± 12 (67)	145 ± 13^a (74)	162 ± 21^{a,b} (82)	197 ± 13^{a,b,c}
RPE, 6–20	6.6 ± 0.9 (35)	7.8 ± 2.2^a (41)	9.4 ± 2.5^{a,b} (50)	19.0 ± 1.2^{a,b,c}	6.2 ± 0.4 (34)	7.2 ± 1.6^a (40)	10.0 ± 2.6^{a,b} (55)	18.2 ± 0.8^{a,b,c}
MSS, 0–10	0.2 ± 0.4 (2)	0.8 ± 1.1^a (8)	2.0 ± 2.5^{a,b} (21)	9.6 ± 0.9^{a,b,c}	0.2 ± 0.4 (3)	1.4 ± 0.5^a (18)	2.6 ± 1.1^{a,b} (33)	8.0 ± 1.4^{a,b,c}

[a] $P < 0.05$, versus easy.
[b] $P < 0.05$, versus normal.
[c] $P < 0.05$, versus hard.
[d] Significant differences were found between males and females, $P < 0.05$;
HR, heart rate; LA, blood lactate concentration; MSS, muscle soreness scale; RPE, rate of perceived exertion; VO_2, oxygen consumption.

authentic rowing were calculated. Percentages of lactate obtained at all three difficulties were all less than 20% of peak lactate obtained in authentic rowing. Percentages of VO_2 obtained from the three difficulties were in the range of 29%–40% of peak VO_2 obtained from authentic rowing. Percentages of HR obtained from the three levels of rowing exergames ranged from 57% to 64% of peak HR obtained from authentic rowing in males, whereas they ranged from 67% to 82% of peak HR in females. Percentages of RPE obtained from the three levels of rowing exergames ranged from 34% to 55% of the peak RPE in authentic rowing. Percentages of MSS obtained from the three levels of rowing exergames ranged from 2% to 33% of the peak MSS in authentic rowing, showing distinct differences among the three levels.

Discussion

The major finding of this study was that VO_2 during three different levels represented around 30%–40% of peak VO_2 in authentic rowing. In addition, our results showed clearly that physiological responses were different for different levels of exergames. Our finding added to the current data by offering the first evidence in true comparison of exergaming in rowing with authentic rowing in elite athletes. Our study was consistent with one recent study, in which active gaming increased adolescents' energy expenditure as compared that with sedentary games, but the level of such increase cannot match to the same extent as physical sports.[9] In fact, the health-related physical benefits of physical activities cover a wide range of physical parameters. We argued that measurements of energy expenditure alone would not reflect the physical benefits brought by the active gaming in a comprehensive perspective. The high percentages of HR reflected in rowing exergames can represent around 60%–80% of peak HR during authentic rowing, supporting the potential benefits in improving cardiovascular health with exergames. The percentage of lactate, however, represented less than 20% of the peak values during authentic rowing, which may be caused by the short duration of each exergames (1.5–3.5 minutes).

One strength of this study was that it was the first to recruit elite rowing athletes to participate in the exergames, which may lower any inconsistency in rowing movements between the two types of rowing exercise. With its rising popularity and wide applications, exergaming was worthy to be recommended as a complementary physical activity for all. Furthermore, previous studies have shown that for those youth who seldom take exercise in their daily life, exergaming is effective in getting them to start to move.[8] It was still not known to what extent the exergaming benefited our physical fitness and health. To promote active gaming, direct data on exergaming such as energy expenditure and HR response should be ready in supporting such an endeavor.

One limitation of this study was that the sample size was small and it may not have enough power to reveal the real gender differences. In addition, the long-term effects of playing exergames on physiological responses still need further clarification to provide more valuable information in promoting physical activity and health.

Conclusion

Physiological and perceived responses were enhanced after the increase of difficulty in Wii Fit U rowing exergames in

elite rowing athletes. However, these responses could not reach their highest responses as they performed in real authentic rowing, even for the hard levels of exergames. Further studies are needed to investigate the long-term physiological adaptations of playing exergames in elite athletes.

Acknowledgments

The authors would like to thank all the participants for their hard work in this study.

Author Disclosure Statement

No competing financial interests exist.

References

1. Hamilton MT, Healy GN, Dunstan DW, et al. Too little exercise and too much sitting: Inactivity physiology and the need for new recommendations on sedentary behavior. Curr Cardiovasc Risk Rep 2008; 2:292–298.
2. Staiano AE, Calvert SL. Exergames for physical education courses: Physical, social, and cognitive benefits. Child Dev Perspect 2011; 5:93–98.
3. Oh Y, Yang S. Defining exergames and exergaming. Proc Meaningful Play 2010; 1–17.
4. Deutsch JE, Brettler A, Smith C, et al. Nintendo Wii Sports and Wii Fit game analysis, validation, and application to stroke rehabilitation. Top Stroke Rehabil 2011; 18:701–719.
5. Lieberman DA, Chamberlin B, Medina E, et al. The power of play: Innovations in getting active summit 2011: A science panel proceedings report from the American Heart Association. Circulation 2011; 123:2507–2516.
6. Levac D, Pierrynowski MR, Canestraro M, et al. Exploring children's movement characteristics during virtual reality video game play. Hum Mov Sci 2010; 29:1023–1038.
7. Mears D, Hansen L. Technology in physical education article #5 in a 6-part series active gaming: Definitions, options and implementation. Strat J Phys Sport Educ 2009; 23:1–40.
8. Mills A, Rosenberg M, Stratton G, et al. The effect of exergaming on vascular function in children. J Pediatr 2013; 163:806–810.
9. Graves L, Stratton G, Ridgers ND, et al. Energy expenditure in adolescents playing new generation computer games. Br J Sports Med 2008; 42:592–594.
10. O'Loughlin EK, Dugas EN, Sabiston CM, et al. Prevalence and correlates of exergaming in youth. Pediatrics 2012; 130:806–814.
11. Lamoth CJ, Caljouw SR, Postema K. Active video gaming to improve balance in the elderly. Stud Health Technol Inform 2011; 167:159–164.
12. Nurkkala VM, Kalermo J, Jarvilehto T. Development of exergaming simulator for gym training, exercise testing and rehabilitation. J Commun Comp 2014; 11:403–411.
13. Pasch M, Bianchi-Berthouze N, van Dijk B, et al. Movement-based sports video games: Investigating motivation and gaming experience. Entertain Comput 2009; 1:49–61.
14. Daley AJ. Can exergaming contribute to improving physical activity levels and health outcomes in children? Pediatrics 2009; 124:763–771.
15. Huntsman HD, Dipietro L, Drury DG, et al. Development of a rowing-specific VO2max field test. J Strength Cond Res 2011; 25:1774–1779.
16. Borg G. *An Introduction to Borg's RPE-Scale*. Ithaca, NY: Mouvement Publications; 1985.
17. Lee J, Goldfarb AH, Rescino MH, et al. Eccentric exercise effect on blood oxidative-stress markers and delayed onset of muscle soreness. Med Sci Sports Exerc 2002; 34:443–448.

Address correspondence to:
Feng Hua Sun, PhD
Department of Health and Physical Education
The Education University of Hong Kong
10 Lo Ping Road
Tai Po
Hong Kong

E-mail: fhsun@eduhk.hk