Can persons with paraplegia obtain training heart rates when boxing on the Nintendo Wii?

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ABSTRACT

The objective of this study was to determine whether playing the boxing game on the Nintendo Wii™ could produce heart rates within 50 to 80% of the estimated heart rate reserve in people with paraplegia. Two participants engaged in three gaming sessions on the Nintendo Wii over a two week period. A ten minute warm up was done using the cycling programme on the Wii, followed by ten minutes of boxing. During the warm up participants were instructed to cycle at a comfortable pace. For the boxing, they competed against an able bodied player and were encouraged to give maximal effort. Heart rate was recorded at one minute intervals. Participant 1 was a 19 year old male who was classified as AIS A, neurological level T_{11}. Participant 2 was a 23 year old male who was classified as AIS A, neurological level T_7. During boxing participant 1 demonstrated values ranging from 33 to 55.7% of his estimated heart rate reserve. Participant 2 showed values ranging from 56 to 83.5% of his estimated heart rate reserve. The results indicate that persons with low level paraplegia can achieve training heart rates on the Nintendo Wii. Further studies are required however using a larger and more varied sample.

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INTRODUCTION

The incidence of traumatic spinal cord injuries for Western Europe, Australia and North America has been found to range from 15 to 39 per million (Cripps et al 2011). The incidence of spinal cord injury in Jamaica is somewhere within this range. The head of the physical therapy department at the major treatment facility on the island (population size approximately 2.71 million) indicated that they see on average 50 patients per year with a spinal cord injury (Henry, 2012 personal communication).

A significant risk for persons who have sustained a spinal cord injury is the development of cardiopulmonary problems (Bauman and Spungen 2008, Myers et al 2007, Phillips et al 1998). In the past respiratory and renal complications were leading contributors to mortality in this population; however, in recent years cardiovascular disease has been shown to be the leading cause of mortality in persons with chronic spinal cord injuries (Garshick et al 2005). A review of studies investigating physical capacity in wheelchair dependent persons shows that low values for maximal oxygen consumption (VO_{2max}) and peak power output were a common finding across studies (Hasima et al 2006). On an arm ergometer test, nearly one in four healthy persons with paraplegia fail to achieve VO_2 levels required to perform many of the essential activities of daily living (Noreau et al 1993).

Regular exercise has been shown to be beneficial in partially reversing some of the negative metabolic and musculoskeletal changes that occur following a spinal cord injury (Myers et al 2007). Common modes of accomplishing cardiopulmonary conditioning in this population include arm ergometry, wheelchair propulsion or swimming. For many, these activities can become quite monotonous resulting in decreased effort and low adherence. For others lack of resources may prohibit exercise participation. In the North American population, lack of motivation, lack of energy, not knowing where to exercise and lack of interest were the main barriers to exercise participation in persons with spinal cord injuries (Scelza et al 2005). In Jamaica, economic cost, lack of transportation and inadequate facilities were identified as the main barriers to exercise in persons with spinal cord injuries (Roopchand-Martin et al 2013). The use of virtual reality, in particular activity based video games, may be one approach that could potentially address several of these barriers.

Studies investigating the use of virtual reality training in adult and pediatric neurological conditions have shown significant improvement in physical outcomes including posture, balance, locomotion and upper and lower extremity function (Braynton et al 2006, Brüsch et al 2010, Chen et al 2007, Jack et al 2001, Merians et al 2002, Reid and Campbell 2006, Saposnik et al 2010, Sveistrup et al 2003, Viau et al 2004, You et al 2005). Researchers have also begun to explore the use of virtual exercise environments to augment traditional treadmill and ergometer exercises in order to improve cardiac and pulmonary function in persons with spinal cord injury (Widman et al 2006, Burns et al 2012).

Eight adolescents with spina bifida participated in a study which attempted to integrate a computer gaming programme into an

arm ergometer activity. After sixteen weeks of training there was significant improvement in all cardiopulmonary variables investigated. All participants indicated that the use of the game made the task more enjoyable and provided greater motivation to exercise than cycling without the gaming system (Widman et al 2006). Heart rate values greater than 50% of the heart rate reserve were reported by Burns et al (2012) for nine persons with chronic spinal cord injury during a bout of exercise with the Nintendo Gamecube controlled by a custom arm ergometer and a session of game play with the XaviX Tennis System.

The Nintendo Wii® (Nintendo, Redmond, Washington) is a commercial off the shelf gaming system which is fairly easy to set up. A range of activities are available which can be used by both able bodied individuals as well as those with physical disabilities. Studies in sedentary young and older adults have shown that games on the Nintendo Wii can be used as an effective activity for promoting physical health (Bosch et al 2012, Douris et al 2012, Guderian et al 2010, Worely et al 2011). A comparison of Wii Fit aerobics with traditional aerobics in twenty-one healthy sedentary college students has shown that the Nintendo Wii Fit, Free Run programme could act as an alternative to traditional moderate intensity exercise in fulfilling the American College of Sports Medicine (ACSM) requirements for physical activity (Douris et al 2012). Thirty minutes of boxing using the Wii Sports programme was shown to provide a moderate to vigorous aerobic response in healthy young adults (Bosch et al 2012).

Very little research has been done to date regarding the energy expenditure associated with active videogaming in persons with disability. Hurkmans et al explored the energy expenditure associated with playing tennis and boxing on the Wii Sports disc in adults with cerebral palsy (Hurkmans et al 2010) and patients with chronic stroke (Hurkmans et al 2011). In both studies participants played each game for fifteen minutes and energy expenditure, which was reported in metabolic equivalents, was found to be consistent with the requirements for moderate intensity exercise stipulated by the American College of Sports Medicine.

While observing persons with paraplegia engaged in a balance training programme on the Nintendo Wii this team of researchers noted that they appeared to be working at levels that could potentially result in cardiopulmonary benefits; however, no data were identified at the time that explored the use of the Nintendo Wii for cardiopulmonary training in this population. The optimal exercise intensity for improving cardiovascular fitness in persons with spinal cord injuries still needs to established, however, based on research to date, a range of 50 to 80% of the heart rate reserve (HRR) has been recommended, with the higher training intensities (70 – 80% HRR) showing greater improvements in cardiovascular function (Wharburton et al 2012). This study sought to determine whether the boxing game on the Nintendo Wii could produce heart rates anywhere within 50 to 80% of the estimated HRR in persons with paraplegia when competing against another player.

METHODS

An observational study was conducted at the Sir John Golding Rehabilitation Centre in Jamaica after ethical approval was obtained from the ethics committee of the University of the West Indies, Mona Campus and the regional health authority for the centre.

PARTICIPANTS

Two persons were recruited into the study from the in-patient population at the Sir John Golding Rehabilitation Centre. They were included on the basis that they had a traumatic spinal cord injury resulting in paraplegia, were medically stable, had been attending physical therapy for at least eight weeks, and signed an informed consent form for participation in the study. Persons with orthopedic impairments that could hinder their participation in the game were excluded.

Participant 1 was an 18 year old male patient who had sustained a gunshot injury to the spine. At the time of the study he was seven months post injury and his neurological level was T_{11} on the American Spinal Injury Association (ASIA) International Standards for Neurological Classification for Spinal Cord Injury Scale (ISCOS). Participant 2 was a 23 year old male, who sustained a gunshot injury resulting in fractures of the T_6 and T_7 vertebrae and a haemopneumothorax. At the time of the study he was six months post injury and his neurological level of injury was T_8. Both participants were classified as AIS A on the ASIA Impairment Scale, which indicates complete injury with no preservation of sensory or motor function in the sacral segments. Prior to the injury both participants were healthy and had no previous history of chronic or systemic medical problems. At the time of the study both participants were engaged in some strength training activities but were not involved in any form of structured cardiovascular training activity.

PROCEDURE

Training was conducted in a gym setting with participants seated in their wheelchairs. The Nintendo Wii system was connected to a television which was placed 1.2m in front of the participant. The boxing game on the Wii Sports disc was used for training and the game was set for two players, allowing the research participant to compete against an able bodied physical therapy student. The student played from a seated position in a stable chair. A space of approximately 1m was left between the two players to ensure that there was no physical contact with one another while playing.

Heart rate values were obtained during the gaming activity using a Polar heart rate monitor which consisted of a chest strap and a wristband. The wristband was positioned on a stable surface close to the participant to allow for the heart rate values to be read off with no disruption to the game. Heart rate values were documented at one minute intervals, for a total of ten minutes, by another physical therapy student. A total of three gaming sessions were conducted with a two day gap between each session.

Immediately prior to the boxing session each participant did a ten minute warm using the cycling programme on the Nintendo Wii Sports Resort disc. This required the participant to hold the Wii remote in one hand and the Wii nunchuck in the other. By pumping the arms up and down both participants were able to navigate the virtual bicycle through a virtual path, while remaining seated in their wheelchairs. During this time they

played alone and were instructed to play at a comfortable pace. For the boxing they competed against the able bodied physical therapy student and were instructed to give maximal effort. During the gaming activity participants were constantly encouraged to maintain good technique and not just flick the remote with their wrist.

The training heart rate range was estimated using the Karvonen formula (American College of Sports Medicine, 2006). The maximal heart rate was determined from the age predicted maximum values. The heart rate values obtained during training were compared with the estimated target values to see whether participants were working in the range required to obtain cardiovascular benefits.

RESULTS

Participant 1 had an average resting heart rate of 95 beats per minute and his age predicted maximal heart rate was 202 beats per minute. The training heart rate range representing 50 to 80% of his estimated heart rate reserve was 148 to 180 beats per minute. Participant 2 had an average resting heart rate of 109 beats per minute and his age predicted maximal heart rate was 197 beats per minute. The training heart rate range for him was 153 (50%) to 179 (80%) beats per minute.

During the boxing game the mean heart rate values achieved by participant 1 over the three trials fell within 33 to 55.7% of the heart rate reserve. For participant 2 the values ranged from 56 to 83.5% of the heart rate reserve (Table 1).

however, that the values obtained varied widely between the two participants, with participant 1 maintaining heart rate levels between 50 to 60% HRR for most of the ten minute period whilst participant 2 was 70% and above.

The higher heart rate values obtained in this study were similar to that of Bosch et al (2012) who showed a mean heart rate response of 77.5% of heart rate maximum in healthy adults age 23 – 27 years during 30 minutes of Nintendo Wii boxing. The lower values obtained were similar to that of Donovan and Hussey (2012) who showed a mean heart rate response of 58% of heart rate maximum in healthy males aged 19 – 27 years with 15 minutes of Nintendo Wii boxing. Findings were also comparable to that obtained by Burns et al (2012) who reported heart rate values averaging > 50% heart rate maximum in persons with paraplegia during exergaming cycling.

Both participants were given the same instructions, which included giving their maximal effort; however, the heart rate responses were different. Factors such as upper body muscle strength and endurance would have had an impact on maximal performance levels; however, these were not assessed prior to the trials. It is possible that participant 2 may have had better conditioned upper body muscles. This could have possibly allowed him to sustain a higher rate of punching during the boxing game as compared to participant 1 resulting in higher heart rate values. Further studies exploring the use of Wii games in this population should take into consideration upper body endurance and the possible impact on performance on the games.

Table 1: Heart rate values obtained over three trials of boxing for participant 1

Time into the boxing programme (minutes)	HR Trial 1	HR Trial 2	HR Trial 3	Mean HR (beats/ minute)	Mean % HRR
0 (HR at the end of warm up)	105	106	106	106	10
1	130	130	129	130	33.0
2	140	136	144	140	42.5
3	166	136	152	151	52.8
4	166	146	138	150	51.9
5	162	138	145	148	50.0
6	163	125	135	141	43.4
7	157	146	152	152	53.8
8	149	149	148	149	50.9
9	167	153	141	154	55.7
10	156	150	140	149	50.9
Mean and SD values obtained over the 10 minute period	156 SD 12	141 SD 9	142 SD 7	146 SD 7	48 SD 7
Resting HR = 95, Age predicted maximal HR = 202					
50% HRR = [(202-95) x 0.5] + 95 = 148			80% HRR = [(202-95) x 0.8] + 95 = 180		

DISCUSSION

The results of the study indicate that males with low level paraplegia can obtain between 50 to 80% of the heart rate reserve during 10 minutes of boxing on the Nintendo Wii when preceded by a 10 minute cycling warm up. It was noted

Both participants in this study were instructed to give maximal effort; however, apart from looking at the heart rate values, no other method was used to evaluate effort. It would have been useful in this study to ask the participants to rate their levels of perceived exertion during the activity to ensure that they were in fact giving maximal effort. Persons with spinal cord injuries below the level of T_6 generally have elevated resting heart rates and therefore changes in heart rate

Table 2: Heart rate values obtained over three trials of boxing for participant 2

Time into the boxing programme (minutes)	HR Trial 1	HR Trial 2	HR Trial 3	Mean HR (beats/ minute)	Mean % HRR
0 (HR at the end of warm up)	134	131	137	134	28.4
1	141	172	162	158	56
2	177	179	173	176	77
3	176	176	160	171	70
4	176	179	170	175	75
5	169	183	180	177	78
6	175	181	169	175	75
7	169	169	169	169	68
8	185	186	179	183	84
9	171	174	174	173	73
10	179	179	174	177	78
Mean and SD values obtained over the 10 minute period	172 SD 12	178 SD 5	171 SD 6	174 SD 7	73 SD 8
Resting HR = 109, Age predicted maximal HR = 197					
50% HRR = [(197-109) x 0.5] + 109 = 153			80% HRR = [(197-109) x 0.8] + 109 = 179		

may not necessarily be the best measure of effort during an exercise activity. Future studies should consider measuring exertion levels in addition to heart rate when exploring the use of the Wii boxing game in persons with spinal cord injury.

In this study there were only two participants and both were AIS A and had low levels of paraplegia. In addition to the upper extremity muscles being intact they also had almost fully intact abdominal muscles which would have allowed their participation in the game to differ from persons with higher levels of paraplegia. The results of this study therefore are not applicable to full spectrum of persons with spinal cord injuries. Further studies need to be conducted with a larger sample of persons with spinal cord injury including wider age ranges, varying degrees of impairment and of both sexes. This study also indicates that it would be useful to conduct studies exploring cardiopulmonary conditioning with the Nintendo Wii in this population.

CONCLUSION

This study showed that males with low levels of paraplegia can obtain heart rate values that are within the zone required for cardiopulmonary benefits when competing in boxing against another player on the Nintendo Wii. Further studies are required however using a larger and more varied sample of persons with spinal cord injury.

KEYPOINT

- Boxing on the Nintendo Wii can elicit training heart rate values in persons with paraplegia.

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PERMISSIONS

Ethics – Ethical approval for this study was granted by the University of the West Indies Ethics Committee (ECP 28,11/12) and the South East Regional Health Authority.

DISCLOSURES

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There is no conflict of interest (financial, professional or personal) associated with the conduct of this study or the writing of this paper.

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