**Measurements of Heart Rate and Accelerometry in Boys Playing Paintball.**

Michelle Jarvi1\*, Gregory A Brown1‡, Brandon S. Shaw2‡, and Ina Shaw2,3‡.

1Human Performance Laboratory, Department of Health, Physical Education, Recreation, and Leisure Studies, University of Nebraska Kearney, Kearney, NE 68849

2Tshwane University of Technology, Department of Sport, Rehabilitation and Dental Sciences, Private Bag X680, Pretoria, Gauteng, 0001, Republic of South Africa

3 Office of the Deputy Pro Vice-Chancellor: Research, Monash South Africa, Ruimsig, Republic of South Africa

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Correspondence: Gregory A Brown, Ph.D.

1410 w 26th st

HPERLS Dept

University of Nebraska at Kearney

Kearney, NE 68849

(308) 865 – 8333

brownga@unk.edu

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Running Head: Paintball as exercise

**CONFLICT OF INTEREST NOTIFICATION:**

The authors do not have any relationships, financial or otherwise, with or support from the manufacturers of the products tested. Hence, there are no conflicts of interest for this research.

**Abstract**

Paintball is a popular recreational sport played by 3.655 million Americans and may be sufficient physical activity to promote health. Paintball has been played as an organized sport since the 1980’s and is essentially a game of tag, except instead of touching an opponent by hand opponents are tagged by shooting them with a paintball that leaves a mark indicating who has been eliminated. A previous evaluation of paintball as physical activity had 13 subjects undergo a VO2max test to develop a heart rate (HR) /oxygen consumption relationship, and it was observed that heart rates during paintball were 68-73% of the measured maximal HR. The present study used accelerometry and HR monitors to evaluate the quantity and intensity of physical activity in boys playing paintball. Eleven boys (12.7 ± 1.0 y, 51.5 ± 11.3 kg, 161.8 ± 10.1 cm) engaged in a VO2max test to develop a HR/oxygen consumption correlation. On a separate day the boys played 7 games of outdoor paintball while wearing a HR monitor and accelerometer. The boys played paintball for a total of 80.6 ± 10.0 minutes with an average game play 11.5 ± 6.2 minutes. Average HR during paintball play was 129.6 ± 6.6 beats/min, representing 39.9 ± 12.9% VO2max. Based on accelerometry, the boys accumulated 63.2 ± 15.6 minutes of moderate intensity activity and 2.6 ± 2.8 minutes of vigorous activity during paintball. These data suggest that playing paintball may be considered as physical activity that is > 3 METs, and thus health promoting.

**Key Words:** Oxygen uptake, physical exertion, games, outdoor activity.

Paintball is a sport that is played essentially as a game of tag, except instead of touching an opponent with your hand, you mark your opponents by shooting them with a paintball. When a paintball hits an object (such as your opponent) and breaks open, it leaves a tell-tale paint mark indicating who has been eliminated. Paintball has been played as an organized sport since the 1980’s, when paintball guns first became readily available (13). Since the development of paintball as an organized sport, millions of people worldwide are reported to have played paintball and paintball has spread worldwide with paintball games being played for fun and competition in countries such as Brazil, South Africa, Russia, France, Thailand, and the United States of America (U.S.A.) (13). The Sporting Good Manufacturer’s Association annual survey of sports participation in the U.S.A. (22) indicates that 3.655 million Americans played paintball in 2010, which compares favorably with Ice Hockey (2.145 million participants), Lacrosse (1.648 million participants), Rugby (1.130 million participants), and Fast Pitch Softball (2.389 Million participants). While most paintball players play for fun, competitive paintball is played at the professional level (14) and as a club sport at colleges, universities, and high schools (15) and the popularity of paintball is evidenced by the video games NPPL Championship Paintball 2009 (16) and Greg Hastings Paintball 2 (17).

Vast research has been conducted on the various health consequences in playing paintball. In this regard, paintball can induce contusions of the skin known as “paintball purpura” due to being hit with a paintball (1; 4; 9) and eye injuries due to failure to use appropriate protective equipment when playing paintball (3; 5; 7; 8; 10). However, the intensity and duration of physical activity when playing paintball has not been well documented.

When playing paintball, players must run, jog, walk, and crawl to move around the playing area while trying to shoot opponents without being shot. A paintball game may last from a few minutes to several hours, depending on the format of the game being played and the rules for ending the game. For instance, most tournament games and games played on tournament style fields last only a few minutes since the size of the playing field is relatively small (roughly the size of a baseball infield), so game play requires short sprints and fast reflexes. In tournament style games, once a player is hit they immediately leave the playing area until the next game. On the other end of the spectrum, there are some scenario games that last for 24 hours and the playing field is several hundred acres. In a long scenario game, players work to achieve specific objectives and hit players can return to game play after meeting some type of conditions (such as 10 minutes in the “hospital” or by being tagged back in by the “medic”). In a large field scenario game, players will run, walk, jog, and crawl during game play and may stay in play for many hours. The study of Porcari et al. (11) evaluated heart rate (HR) while the participants played paintball and the HR was then used to estimate oxygen consumption (VO2) during paintball play based upon a previously determined HR/VO2 relationship from a graded exercise test. Although Porcari et al. (11) observed an average HR of 68-73% of measured maximal HR while playing paintball, and this HR corresponds to exercise at 56-64% of VO2max, these authors acknowledged that it was not possible to discern between increases in HR due to excitement, nervousness, and increases in metabolism which can increase HR without a concomitant increase in oxygen consumption (2), thereby yielding the findings of Porcari et al. (11) questionable. Furthermore, the amount of time spent in active game play, as compared with time waiting for the next game to begin after being marked out, or talking between games, has not been reported.

Based upon the foregoning, the purpose of this study was to use accelerometry and HR measurements to quantify the level of physical activity while playing paintball.

**Methods**

Overview: In order to assess the amount of intensity of physical activity during paintball, eleven healthy boys with paintball playing experience were recruited as study participants. The participants were first evaluated for aerobic fitness and body composition for subject descriptive data, and to develop a HR / VO2 regression for each subject. On a separate occasion, the subjects engaged in a day of paintball play while wearing a heart rate monitor and accelerometer to measure the level and intensity of physical activity while playing paintball.

*Initial Screening.* After an initial discussion between the investigator(s) and potential participant and the participant’s parents in which the goals, purposes, and expectations of the research study were covered, participants still willing to participate signed a document of assent and the parents completed a document of informed consent. The participant’s, in conjunction with their parents also completed a Physical Activity Readiness Questionnaire (PAR-Q) for the participant. As the participants were known to be physically active, a PAR-Q was considered to be sufficient screening for the proposed research (18). Participants then reported to the Human Performance Laboratory on another date for assessment of body composition for descriptive purposes and maximal oxygen consumption (VO2max) as a measure of cardiorespiratory fitness as well as to develop a HR/VO2 regression equation. All fitness testing occurred in the between 3:30 and 5:00 PM after the particpants had finished school for the day. Participants were instructed to eat lunch but no other food for three hours before fitness testing, to avoid strenuous physical activity between waking and exercise testing and to schedule the test on a day that did not include a Physical Education class. Particpants were also instructed to consume no caffeine for six hours prior to the exercise test, drink frequently during the day of the test and also to drink a 20 oz bottle of water between leaving school and reporting for fitness testing, and to get at least 8 h of sleep the night before the exercise test. Upon reporting for testing, subjects and their parents were verbally questioned for compliance with these pre testing instructions. Thisstudy was approved by the Institutional Review Board at the University of the Nebraska Kearney.

*Body Composition Assessment.*  Body mass was measured to the nearest 0.1 kilogram (kg) using a digital scale (PS 6600ST, Befour Inc, Saukville, WI) and height was measured to the nearest 0.5 centimeters (cm) using a stadiometer (Model 707, Seca, Hamburg, Germany). Body composition was then measured using Dual-Energy X-Ray Absorptiometry (DEXA; DPX-IQ, Lunar Corp, Madison, WI). Subject descriptive data can be found in table 1. The subjects were asked to wear comfortable clothing with minimal metal snaps, buttons, or zippers and to remove all jewelry in order to enhance the safety and accuracy of the DEXA measurement.

*Aerobic Fitness Assessment.* The participants underwent a Bruce Ramp Protocol (21) VO2max test on a treadmill. First, the participants put on a HR monitor (E600, Polar Electro, Oy, Finland) and then sat for 5 minutes in order to record resting HR. Participants were then connected to the metabolic cart (True One 2400, Parvomedics, Sandy, UT) using a facemask (NRB1, Hans Rudolph Inc., Kansas City, MO) and began by walking on the treadmill (425C, Trackmaster Treadmills, Newton, KS) at 1.7 mph with a 10% grade. The treadmill speed and grade gradually increased in small increments every 30 seconds so that every three minutes the speed had increased by 0.8 mph and the grade by 2%. Data for VO2 and heart rate were measured continuously and then averaged over 20 second intervals. The VO2max test was terminated when at least 2 of the following criteria were met: VO2 or HR decreased or remained unchanged in response to increases in workload, a respiratory exchange ratio value of 1.14 and/or a rating of perceived exertion of 20 was reached (18). If the subject did not meet 2 of the termination criteria but instead requested to stop the test, a subsequent test was performed on a separate day (and this was only necessary for 1 subject who was experiencing a minor upper repsirtaory illness on the day of the intial test)..

*Accelerometry:* Research participants wore physical activity monitors (AM7164, Actigraph Inc, Pensacola, FL) while participating in the paintball game play. The accelerometers were initialized to begin recording data 1 hour before game play began, and were set to record 15 second epochs. The cut-points for the categorization of the physically activity by the accelerometers as either sedentary, moderate, or vigorous used in this study were based on the guidelines established by Freedson (20), and Actilife software (v 6.0, Actigraph Inc, Pensacola, FL) was used for analysis of the accelerometry data.

*Paintball Game Play:* On a different day from the fitness assessment, all of the participants gathered at the paintball playing location for a typical day of playing paintball. The paintball playing area for this group is private land owned by one of the participant’s family. The game play occurred on a “Woodsball” field (13), consisting of mostly trees, shrubs, and grass, with a few small wooden “bunkers” built to provide hiding places, all within an area that is 70 m X 135 m. Prior to game play, the paintball guns used by the participants were measured to ensure that the muzzle velocity was 260-290 feet per second (fps; Prochrono Digital, Competition Electronics, Rockford, IL), which is below the generally accepted safety standard of 300 fps (3). The eye and face protection worn by the players were visually inspected to ensure that they were of a type approved for paintball use and were free from defect, and players were instructed to keep their protective gear on at all times while on the playing field.

The games to be played had a set time limit of 20 minutes. However, if a player was hit during game play, they were eliminated and immediately left the playing area. The participants played 2 games of capture the flag, in which the goal was to start at your team’s base, get to the other team’s base, capture their flag and return it to your base while eliminating your opponents without getting eliminated. The participants then played two games of “zombie” in which three players hid on the field as the zombies and the remaining players were hunters. If a zombie is marked, they are eliminated from game play, whereas if a hunter is marked, they then become a zombie and run away from the hunters for a count of ten and then begin trying to mark the remaining hunters. The participants then played 2 games of “center flag”, in which a single flag is positioned in the middle of the field, and the goal is to capture the flag, and then take it to the opposing team’s flag station. The final game was elimination, in which the goal is to eliminate all of the players on the opposing team. Throughout the game play, the participants were randomly organized into teams before each game.

Prior to the beginning of the first game, each subject put on a heart rate monitor (E600, Polar Electro, Oy, Finland). Each subject also wore an accelerometer on a belt at the waistline aligned above the right knee. The researchers recorded the time of day each game of paintball began and ended and the amount of time each player was “alive” during each game using a handheld watch with the information being written in a notebook. During game play, all researchers collecting on-field data wore protective goggles and facemasks approved for use in paintball, and also wore orange safety vests to distinguish them from the players. After the day of paintball, the data from the accelerometers and heart rate monitors were downloaded to a computer and the time stamp from the accelerometers and heart rate monitors were synchronized with the written time records of game play. In this way, the researchers were able to determine heart rate and accelerometry counts during game play and also between games.

*Calculations and Statistics:* All statistical analyses were performed using statistical software (SigmaStat 4.0, Systat Software Inc, Chicago, IL, USA). Heart rate and oxygen consumption from each 20 second averaging interval of the aerobic fitness assessment were used to develop an individual HR / VO2 regression equation for each subject (11) using simple linear correlation This HR/VO2 regression equation was then used to estimate oxygen consumption based upon the recorded average heart rate during each game of paintball. Using the resting and maximal heart rate values obtained during the aerobic fitness assessment, the average heart rates during paintball play, and the Karvonen equation (18), percentage of heart rate reserve (HRR) during paintball was calculated. The average heart rates from each game of paintball for all subjects, as well as the correpdonding VO2 and HRR, were used to cacluate the overall means and standard deviations used throughout this manuscript. Accelerometry counts per minute and heart rate were used to develop a measurement of individual physical activity intensity (19). These measurements of physical activity and intensity were used to calculate mean and standard deviations for heart rate, accelerometry counts per minute, and estimated oxygen consumption for paintball game play and time between game play. The total minutes of low, moderate, and vigorous physical activity (from accelerometry) were also determined for each subject with overall means and standard deviations being calculated. Throughout this manuscript, data are reported as means ± standard deviation.

**Results.**

*Paintball Game Play:* Over the course of 4.5 h of data collection, the participants played seven games of paintball. Each game had a 20 minute time limit, but players were eliminated from play if they were hit before the time limit. Furthermore, if the game objective was attained (e.g. eliminating all players on the opposing team) the game ended before the time limit expired. The participants were engaged in paintball game play for 80.6 ± 10.0 minutes during the 4.5 h of data collection. The average time of game play for the participants was 11.5 ± 1.4 minutes per game.

*Accelerometry Based Physical Activity*: Over the course of 4.5 h, the participants accrued 141.80 ± 24.29 minutes of moderate intensity and 6.10 ± 4.58 minutes of vigorous intensity physical activity. During the 80.6 ± 10.0 minutes of game time, participants accrued 63.2 ± 15.6 minutes of moderate intensity and 2.6 ± 2.8 minutes of vigorous intensity physical activity.

*Heart Rate Based Physical Activity*: The individual HR/VO2 regression equations developed from to VO2max testing resulted in correlation coeffeicents of 0.96 ± 0.03. Heart rates during paintball game play were 129.60 ± 6.60 beats●min-1, which correspond to 67.9 ± 6.8% of the laboratory measured maximal heart rates and 47.1 ± 9.3% of heart rate reserve (HRR). These heart rates equated to an oxygen consumption of 18.18 ± 5.02 ml●kg-1●min-1, or 39.9 ± 12.9% of the VO2max measured in the laboratory.

**Discussion.**

The primary finding from this study was that during paintball game play, the participants met the accelerometry criteria for moderate intensity physical activity (20) ~78% of the time. There was also considerable moderate to vigorous physical activity during the time between games. These accelerometry data suggest that paintball may be considered a form of health promoting physical activity. However, the heart rate data indicate that playing paintball elicited only ~ 40% of VO2max, which is below the guidelines indicating that exercise needs to elicit at least 50% of VO2max to enhance health (18). In contrast, the heart rate data indicate that playing paintball elicited VO2 of ~5.2 metabolic equivalents of task (METs), which meets the criteria for moderate intensity health promoting physical activity (23). Thus, playing paintball could meet the criteria for moderate intensity physical activity depending upon which criteria are used for assessing exercise intensity.

Generally speaking, health promoting physical activity is that which is considered to be of moderate intensity, roughly 3-6 METs (23). Using the accelerometer cut-points developed by Freedson (20), playing paintball over the course of seven, 20 minute games in 4.5 hours resulted in ~140 minutes of moderate intensity physical activity in the present study. Approximately 80 minutes of the moderate intensity physical activity occurred during game play, while the remaining 60 minutes occurred as the participants entered and exited the playing field before and after games, or while waiting in the staging area between games. These data suggest that playing paintball can be considered as a health promoting physical activity.

In the boys playing paintball in the present study the average heart rates were ~68% of the maximal heart rate attained during a graded treadmill exercise test. Porcari et al. (11) evaluated 13 participants for heart rate response to playing paintball, and observed average heart rates of ~68-73% of measured maximal heart rate. As these data appear in an abstracted form from a conference presentation, further details on the participants and detailed methodology are unavailable for further comparison to the present investigation. However, based on percentage of maximal heart rate, it appears that playing paintball meets the guidelines for health promoting physical activity (23).

In contrast to the evaluation of percentage of maximal heart rate while playing paintball, when evaluating heart rate as a percentage of HRR (18) the heart rates in the boys playing paintball in the present study were only ~48% of HRR, which is insufficient to meet the guidelines for health promoting physical activity (23). Although using a heart rate to monitor exercise intensity is considered to be reliable, it is not a flawless technique. The difference in physical activity intensity between the percentage of maximal heart rate and percentage of HRR observed in the present study highlight some of the challenges with using heart rate to evaluate exercise intensity (2, 18). For instance, the challenges of using heart rate to monitor exercise intensity are exacerbated during a discontinuous physical activity (2) such as paintball, in which the participants may sprint for a short distance, then crouch, crawl, walk, jog, or be still until the next burst of activity. Furthermore, heart rate can be influenced by the heightened cardiac responsiveness of competition or being in an unpredictable situation (24), such as while playing paintball. Additionally, it has been observed that a laboratory measurement of maximal heart rate may not represent the maximal heart rate that can be attained during competition, or even rigorous training (25).

The present data contrast considerably with those of Porcari et al. (11) with regards to the VO2 elicited by playing paintball. In the present evaluation of the heart rate–VO2 relationship, playing paintball elicited a VO2 of ~40% of VO2max, which is lower than the standard of 50% of VO2max necessary to be considered moderate intensity physical activity (18). Porcari et al. (11) observed that playing paintball elicited a VO2 of ~56-64% of VO2max, which exceed the minimum threshold of 50% VO2max to be considered moderate intensity physical activity. The limited information available in Porcrari et al. (11), does not include any subject descriptive data, details on the size of playing area, duration of game play, and so on, thus a thorough evaluation of the reasons for discrepancy between those previous findings and the present study is not possible. However, the myriad of factors that influence the individual response to an exercise stmuls (e.g. age, gender, level of fitness, and so on) could be responsible for the discrepancy in percentage of VO2max between the present study and Porcrari et al. (11). Furthermore, the heart rate–VO2 relationship can result in values that deviate from the correct measurement of VO2 by up to 20% (2). Overall, the data from the measurement of heart rate while playing paintball present discrepant information as to whether paintball can be considered moderate intensity physical activity.

Moderately intense physical activity can be defined as notable increases in heart rate (23), which did occur while playing paintball in the present study. Moderately intense physical activity can also be defined as physical activity of 3-6 METs (20, 23). Based on the heart rate-VO2 relationship in the present study, playing paintball resulted in an intensity level of ~5.2 METs. The accelerometry data also indicated that a considerable amount of time playing paintball meets the cut-point (20) criteria for moderate intensity physical activity. Therefore, the present data indicate that playing paintball can be part of an overall active lifestyle, and the physical activity during playing paintball could count towards the necessary physical activity to promote health.

**Table 1.** Subject descriptive data for 11 boys who wore heart rate monitors and accelerometers to measure the level of physical activity while playing paintball.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | | | |
| Age (y) | 12.64 | ± | 1.03 |
| Body Height (cm) | 161.77 | ± | 10.77 |
| Body Mass (kg) | 51.52 | ± | 11.31 |
| Body Fat (%) | 36.67 | ± | 8.74 |
| VO2max (ml/kg/min) | 46.83 | ± | 7.69 |

Values represent Means ± standard deviation

**References**

1. Aboutalebi S and Stetson CL. Paintball purpura. J Am Acad Dermatol 53: 901-902, 2005.

2. Achten J and Jeukendrup AE. Heart rate monitoring: applications and limitations. Sports Med 33: 517-538, 2003.

3. Alliman KJ, Smiddy WE, Banta J, Qureshi Y, Miller DM and Schiffman JC. Ocular trauma and visual outcome secondary to paintball projectiles. Am J Ophthalmol 147: 239-242, 2009.

4. Ambay AR and Stratman EJ. Paintball: dermatologic injuries. Cutis 80: 49-50, 2007.

5. Banitt MR, Malta JB, Mian SI and Soong HK. Rupture of anterior lens capsule from blunt ocular injury. J Cataract Refract Surg 35: 943-945, 2009.

6. Conn JM, Annest JL, Gilchrist J and Ryan GW. Injuries from paintball game related activities in the United States, 1997-2001. Inj Prev 10: 139-143, 2004.

7. Kay CN, Saunders TS and Pavan PR. Ocular injuries sustained in paintball trauma. Graefes Arch Clin Exp Ophthalmol 248: 331-332, 2010.

8. Kennedy EA, Stitzel JD and Duma SM. Matched experimental and computational simulations of paintball eye impacts. Biomed Sci Instrum 44: 243-248, 2008.

9. Levsky ME and Crowe M. What is your diagnosis? Paintball purpura. Cutis 75: 148, 157-148, 158, 2005.

10. Pahk PJ and Adelman RA. Ocular trauma resulting from paintball injury. Graefes Arch Clin Exp Ophthalmol 247: 469-475, 2009.

11. Porcari JP, Kammel T, Doberstein S, Fater D, Foster C. Physiological Responses to Paintball. Med Sci Sports Exerci 36(5): S248, 2004.

12. Kennan E. How Safe is Paintball? http://extremesports.suite101.com/article.cfm/how\_safe\_is\_paintball. Published Sept 9, 2007. Accessed August 22, 2012.

13. World and Regional Paintball Information Guide. http://www.warpig.com/paintball/newbie/newbie.shtml Accessed August 22, 2012.

14. National Professional Paintball League, http://www.nppl.com/, Accessed August 22, 2012.

15. National Collegiate Paintball Association, http://ncpapaintball.com/collegepb/, accessed August 22, 2012.

16. Amazon.com, http://www.amazon.com/NPPL-Championship-Paintball-2009-Xbox-360/dp/B001CDL6U2, Accessed August 22, 2012.

17. http://www.amazon.com/Greg-Hastings-Paintball-2-Nintendo-Wii/dp/B0038N9WWI, Accessed August 22, 2012.

18. ACSM's Guidelines for Exercise Testing and Prescription. Philadelphia: Lippincott, Williams, & Wilkins, 2000.

19. Fudge BW, Wilson J, Easton C, Irwin L, Clark J, Haddow O, Kayser B and Pitsiladis YP. Estimation of oxygen uptake during fast running using accelerometry and heart rate. Med Sci Sports Exerc 39: 192-198, 2007.

20 Freedson PS, Pober D, Janz KF. Calibration of accelerometer output for children. Med Sci Sports Exerc.;37(11 suppl): S523–30, 2005.

22. Will PM and Walter JD. Exercise testing: improving performance with a ramped Bruce protocol. Am Heart J 138: 1033-1037, 1999.

22. 2011 SGMA Topline Report www.aahperd.org/naspe/advocacy/governmentRelations/upload/2011-SGMA-Participation-Topline-Report.pdf; accessed May 3, 2012.

23. Haskell WL, Lee IM, Pate RR et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007;39:1423-34.

24. Johnston, D.W., Anastasiades, P. and Wood, C. The relationship between cardiovascular responses in the laboratory and in the field. Psychophysiology 27(1), 34-44, 1990.

25. Semin, K., A.C. Stahlnecker, K.A. Heelan, G.A. Brown, B.S. Shaw, and I. Shaw. Discrepancy between Training, Competition and Laboratory Measures of Maximum Heart Rate in NCAA Division 2 Distance Runners. J Sports Sci & Med 7 (4), 455-460, 2008.