

## Measurements of Heart Rate and Accelerometry to Determine the Physical Activity Level in Boys Playing Paintball

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### ABSTRACT

*International Journal of Exercise Science* 6(3) : 199-207, 2013. 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 VO<sub>2</sub>max 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 VO<sub>2</sub>max 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 11.5 ± 6.2 minutes/game for a total of 80.6 ± 10.0 minutes of game play. Average HR during paintball play was 129.6 ± 6.6 beats/min, representing 39.9 ± 12.9% VO<sub>2</sub>max. 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, adolescent

### INTRODUCTION

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 (25). 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.) (25). The Sporting Good Manufacturer's Association annual survey of sports participation in the U.S.A. (23) 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 (19) and as a club sport at colleges, universities, and high schools (18) and the popularity of paintball is evidenced by the video games NPPL Championship Paintball 2009 (6) and Greg Hastings Paintball 2 (5).

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, 7, 17) and eye injuries due to failure to use appropriate protective equipment when playing paintball (4, 8, 14, 16, 20). 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. (21) evaluated heart rate (HR) while the participants played paintball and the HR was then used to estimate oxygen consumption ( $VO_2$ ) during paintball play based upon a previously determined HR/ $VO_2$  relationship from a graded exercise test. Although Porcari et al. (21) observed an average HR of 68-73% of measured maximal HR while playing paintball, and this HR corresponds to exercise at 56-64% of  $VO_{2max}$ , 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. (21) 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 foregoing, the purpose of this study was to use accelerometry and HR measurements to quantify the level of physical activity while playing paintball.

## METHODS

### *Participants*

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 / VO<sub>2</sub> 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.

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 by the Institutional Review Board to be sufficient health 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 (VO<sub>2max</sub>) as a measure of cardiorespiratory fitness as well as to develop a HR/VO<sub>2</sub> regression equation. All fitness testing occurred in the between 3:30 and 5:00 PM after the participants 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. Participants 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. This study was approved by the Institutional Review Board at the University of the Nebraska Kearney.

### *Protocol*

**Body Composition Assessment:** Body weight was measured and recorded 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.

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	Measure
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
VO <sub>2</sub> max (ml/kg/min)	46.83 ± 7.69

Values represent Means ± standard deviation.

**Aerobic Fitness Assessment:** The participants underwent a Bruce Ramp Protocol (24) VO<sub>2</sub>max 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 VO<sub>2</sub> and heart rate were measured continuously and then averaged over 20 second intervals. The VO<sub>2</sub>max test was terminated when at least 2 of the following criteria were met: VO<sub>2</sub> 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 (3). 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 respiratory illness on the day of the initial test).

**Accelerometry:** Research participants wore physical activity monitors (AM7164, Actigraph Inc, Pensacola, FL) on a belt positioned on the hip at the level of the superior iliac crest and aligned above the right knee 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 (10), 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 (25), 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 (4). 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.

#### *Statistical Analysis*

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 / VO<sub>2</sub> regression equation for each subject (11) using simple linear correlation. This HR/VO<sub>2</sub> 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 (3), 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 corresponding VO<sub>2</sub> and HRR, were used to calculate 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 (11). 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  $\pm$  standard deviation.

## RESULTS

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 by a paintball before the time limit. Furthermore, if the game objective was attained (e.g. eliminating all players on the opposing team or capturing the opposing team's flag and returning it to your base) the game ended before the time limit expired. The time of game play for the participants was  $11.5 \pm 1.4$  minutes per game and the games lasted  $13.4 \pm 6.4$  minutes, with the longest game taking the full 20 minutes and the shortest game lasting only 5 minutes. The participants were engaged in paintball game play for a total of  $80.6 \pm 10.0$  minutes during the 4.5 h of data collection.

Over the course of 4.5 h, the participants accrued  $141.80 \pm 24.29$  minutes of moderate intensity and  $6.10 \pm 4.58$  minutes of vigorous intensity physical activity. Approximately 78% of the time during game play was moderate intensity physical activity, and ~3% of the time during game play was vigorous intensity physical activity (Table 2).

Table 2. Summary of time spent playing paintball, accelerometry data, and heart rates in 11 boys who played recreational paintball on an outdoor field for 7 games over the course of 270 minutes.

Game Play Time (minutes)	$80.6 \pm 10.0$
Moderate Physical Activity during game play (minutes)	$63.2 \pm 15.6$
Vigorous Physical Activity during game play (minutes)	$2.6 \pm 2.8$
Heart Rate during Game Play (beats / minute)	$129.60 \pm 6.60$

Data are Means  $\pm$  standard deviation. Moderate Physical Activity = accelerometer counts of 3-6 METs. Vigorous Physical Activity = accelerometer counts  $> 6$  METs.

The individual HR/ $VO_2$  regression equations developed from to  $VO_{2max}$  testing resulted in correlation coefficients of  $0.96 \pm 0.03$ . Heart rates during paintball game play corresponded to  $67.9 \pm 6.8\%$  of the laboratory measured maximal heart rates and  $47.1 \pm 9.3\%$  of heart rate reserve (HRR; table 2). Based on the HR/ $VO_2$  regression equations, these heart rates equated to an oxygen consumption of  $18.18 \pm 5.02$  ml·kg<sup>-1</sup>·min<sup>-1</sup>, or  $39.9 \pm 12.9\%$  of the  $VO_{2max}$  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 (10 ~63 out of 80 minutes of the game playing time. There was also ~76 additional minutes of moderate to vigorous physical activity during the 189 minutes between games (~40% of the non-game playing time). These accelerometry data for intensity and duration of physical activity suggest that paintball may be considered a form of health promoting physical activity. However, the HR/ $VO_2$  regression equation data indicate that playing paintball elicited only ~ 40% of  $VO_{2max}$ , which is below the

guidelines indicating that exercise needs to elicit at least 50% of  $VO_2$ max to enhance health (3). In contrast, the HR/ $VO_2$  regression equation data indicate that playing paintball elicited  $VO_2$  of ~5.2 metabolic equivalents of task (METs), which meets the criteria for moderate intensity health promoting physical activity (12). Thus, based on the HR/ $VO_2$  regression equation data, playing paintball could meet the criteria for moderate intensity physical activity when using METs, but not percent  $VO_2$ max, as a guideline.

Generally speaking, health promoting physical activity is that which is considered to be of moderate intensity, roughly 3-6 METs (12). Using the accelerometer cut-points developed by Freedson et al. (10), 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 63 minutes of the moderate intensity physical activity occurred during game play, while the remaining 76 minutes of moderate intensity physical activity occurred as the participants entered and exited the playing field before and after games, or while waiting in the staging area between games. Thus, the present accelerometry data suggest that playing 7 games of paintball over the course of 270 minutes elicits sufficient quantities and intensities of physical activity to 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. Similar to the present study, Porcari et al. (21)

evaluated 13 participants for heart rate response to playing paintball, and observed average heart rates of ~68-73% of measured maximal heart rate. As the data for Porcari et al. (21) 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 the percentage of maximal heart rate in the present data and those of Porcari et al. (21), it appears that playing paintball meets the intensity guidelines for health promoting physical activity (12).

In contrast to the evaluation of percentage of maximal heart rate while playing paintball, when evaluating heart rate as a percentage of HRR (3) the heart rates in the boys playing paintball in the present study were only ~40% of HRR, which is insufficient to meet the intensity guidelines for health promoting physical activity (12). 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, 3). 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 (13), 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 (22).

The present data contrast considerably with those of Porcari et al. (21) with regards to the  $VO_2$  elicited by playing paintball. In the present evaluation of the heart rate- $VO_2$  relationship, playing paintball elicited a  $VO_2$  of ~40% of  $VO_{2max}$ , which is lower than the standard of 50% of  $VO_{2max}$  necessary to be considered moderate intensity physical activity (3). Porcari et al. (21) observed that playing paintball elicited a  $VO_2$  of ~56-64% of  $VO_{2max}$ , which exceeds the minimum threshold of 50%  $VO_{2max}$  to be considered moderate intensity physical activity. The limited information available in Porcari et al. (21), 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 stimulus (e.g. age, gender, level of fitness, and so on) could be responsible for the discrepancy in percentage of  $VO_{2max}$  between the present study and Porcari et al. (21). Furthermore, the heart rate- $VO_2$  relationship can result in values that deviate from the correct measurement of  $VO_2$  by up to 20% (2). Overall, the data from the measurement of heart rate while playing paintball in the present investigation and of Porcari et al. (21) represent 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 occurred while playing paintball in the present study. Moderately intense physical activity can also be defined as physical activity of 3-6 METs (10, 12). Based on the heart rate- $VO_2$  relationship in the present study, playing paintball resulted in an intensity level of ~5.2 METs. The accelerometry data also indicated that ~78% amount of time playing paintball meets the cut-point (10) criteria for moderate intensity physical activity. Therefore, the present data indicate that playing paintball can be part of an overall active lifestyle for boys, and the physical activity during playing paintball could count towards the necessary physical activity to promote health. Further evaluations of physical activity while playing paintball in adults and females, as well as different playing conditions and scenarios, are necessary to obtain a more complete understanding of if and how playing paintball can be part of an overall physically active and healthy lifestyle.

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