Summer 1-1-2012

Heart Rate and Accelerometry during Singles Footbag Net Play

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Heart Rate and Accelerometry during Footbag Net Singles Play

by

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A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Health Studies

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Abstract

This investigation examined the heart rate responses and movement characteristics of experienced footbag net players during singles play. Footbag net is a net/court sport similar to volleyball, but it is played with a footbag (e.g., Hacky-Sack™) using only the feet. In singles footbag net, players are allowed either one or two kicks to propel the footbag over the net. Subjects were 15 males and 1 female, ranging in age from 18- 60 years, with a mean age of 33.6 years. Subjects played two games of singles footbag net using two different scoring systems: "sideout" scoring and "rally" scoring. Mean heart rates were 149.4 bpm for games played under the sideout scoring system and 148.7 bpm for games played under the rally scoring system. Sideout games were 1.2 minutes (~11%) longer than rally games. The mean heart rate responses to competitive play using sideout scoring and rally scoring were not significantly different ($p>0.05$). For play under both scoring systems, the average exercise intensity—expressed as a percentage of age-predicted maximum heart rate (MHR_{est})—was 80-81% MHR_{est}. Accelerometer counts accumulated during play were similar for both scoring systems. It is recommended that additional research be conducted to evaluate the extent to which accelerometry may contribute to physiological and metabolic measurements of footbag net competition.

Acknowledgments

This research was developed and completed with the guidance and assistance of my graduate advisor, Gary Brodowicz, Ph.D. I wish to thank all the staff and students of Portland State University for a fine education and enjoyable college experience. I should also note that the completion of my entire graduate program was greatly enabled by the Beaverton School District's Tuition Reimbursement program. I thank the school district for supporting the professional advancement of its employees in this way. Finally, none of my personal accomplishments would be possible without my lovely wife Beth. Her love and support make great things happen.

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Glossary

Accelerometer: A device that measures the acceleration of a system (Oxford University Press, 2007).

Epoch Length: A specific point in time or the interval between two such points, but not as such a measure of time (Oxford University Press, 2007).

Exercise Intensity: A specific level of muscular activity that can be quantified, for example, in terms of power output (work done or energy expended per unit time), forces resisted (e.g., free weights lifted per unit time), the magnitude and duration an isometric force is sustained, or the velocity of progression (Oxford University Press, 2007).

Footbag: 1) A small round beanbag designed primarily for kicking and bumping with various body parts; 2) The generic name for the sport associated with kicking these small round beanbags. Footbag is commonly known by the brand name Hacky-Sack™ in the United States.

Footbag Net: A kicking sport played in singles or doubles on a 44' long x 20' wide court using only the feet to propel a small round beanbag (footbag) over the net.

Maximal Heart Rate (HR_{max}): The highest heart rate attainable during an all-out effort to the point of exhaustion (i.e., during maximal exercise). Maximal heart rate is often used to calculate training heart rates. It can be determined directly during maximal exercise, but this is not always a safe or practical procedure. Therefore, it is generally estimated based on an individual's age, since HR_{max} has been shown to decline with age. The most common formula for age-predicted maximal heart rate (MHR_{est}) is "220- age". Another formula developed by Tanaka et al. (2000) is "208- 0.7(age)." These estimations may be subject to errors of 10% or more (Oxford University Press, 2007).

Maximal Oxygen Uptake (VO_{2max}): The maximum amount of oxygen that a person can extract from the atmosphere and transport for use in tissues. Maximal oxygen uptake is estimated as the maximum volume of oxygen voluntarily consumed per unit time, during a large muscle group activity of progressively increasing intensity that is continued until exhaustion. It is often called VO_{2max}, and expressed as the absolute (L/min) or relative (mL/kg/min) rate of oxygen consumed. The average VO_{2max} for 20 year-old females and males is between 32-38 mL/kg/min and 36-44 mL/kg/min, respectively. Endurance athletes generally have a higher VO_{2max} than athletes involved in strength/power activities. Aerobic training may improve VO_{2max} by 15–20% or more. (Oxford University Press, 2007).

Metabolic Equivalent (MET): A unitless measure used to estimate the metabolic cost (energy expenditure as reflected by oxygen consumption) of physical activity. One MET equals the resting metabolic rate, which is an oxygen uptake of approximately 3.5 mL/kg/min. METs are used to compare the energy costs of different activities (Oxford University Press, 2007).

Introduction

Background

Footbag is a kicking sport that is named after the small, round, hand-sewn beanbags (footbags) that comprise the object of the sport. Footbag is but one of a wide spectrum kicking games played throughout the world for hundreds, if not thousands, of years. Soccer is certainly the most popular kicking sport on Earth (although like most "kicking" sports it is not purely a kicking game, making use of all parts the body at times, depending upon the role of the player). The common goal of these games is to propel some type of an object through the air or across the ground using mainly the feet and legs. Footbag is a uniquely American creation with its own history, rules, infrastructure, and popularity. Footbag is often called Hacky-Sack™, a reference to the brand name of the first American footbag company (now owned by Mattel Sports), and the first footbag brand to gain widespread popularity. In the United States, footbag is overwhelmingly known as Hacky-Sack™ by the general public, but this is not necessarily the case in other countries.

Recreational footbag play most often involves an informal collection of players gathering together in a circle to kick, bump, and "stall" the footbag. The goal is generally simple: keep the footbag aloft, using various parts of the body, but mainly by kicking it with the feet. Competitive sport footbag is essentially the evolution of this circle kicking game into a sport played at a high level worldwide. This study attempts to describe some of the physiological responses of playing one type of sport footbag: singles footbag net.

Footbag net is a court and net sport similar to volleyball, but it is played using only the feet, with footbags that are firmer than those typically encountered. The footbags used for the net sport are hand-sewn beanbags slightly smaller than a tennis ball and filled with plastic pellets, creating a bouncy sphere that looks and plays similar to a miniature soccer ball. Like the sport of tennis, footbag net can be played in singles or doubles. In singles footbag net, players may use either one or two kicks to propel the footbag over the net. In doubles footbag net players alternate up to three kicks, much like beach volleyball. The footbag net court has the same dimensions as a badminton court, with a five-foot high net separating the sides.

Significance

There has been limited research investigating the physiological responses and exercise intensity of footbag net. Only one study, conducted at the University of Utah (Graetzer & Chen, 1990), could be located. The current study adds to the body of knowledge about the physiological responses of footbag net competition.

Purpose

The purpose of this study was to investigate the intensity of singles footbag net play in experienced players by measuring heart rate responses and accelerometer counts during competition under two scoring conditions: rally scoring and sideout scoring.

Research questions

- Among experienced footbag players, what is the heart rate response to singles footbag net competition?
- Is the heart rate response during singles footbag net competition dependent upon the scoring system used (i.e., "sideout" scoring vs. "rally" scoring)?

- What information does accelerometry provide about the intensity of singles footbag net competition?

Hypotheses

- H_1: The mean heart rate mean of experienced footbag players during singles footbag net competition will be approximately 80% of predicted maximal heart rate.
- H_2: The mean heart rate response during “sideout” scoring will be greater than the mean heart rate response during “rally” scoring.
- H_3: Accelerometry count data will provide information about the intensity of singles footbag net competition that is similar to heart rate data.

Assumptions

This investigation makes certain assumptions regarding exercise physiology, sports competition, and study methods. It is assumed that heart rate is a valid measure of exercise intensity during footbag net competition. It is also assumed that each subject made every effort to win each point and each game. Additionally, it is assumed that the data collection process and instrumentation did not interfere with the effort or skill of each subject.

Review of Literature

Footbag

There has been limited published research related to recreational or sport footbag. Further, it appears that none of the previous research that could be located was published in peer-reviewed journals.

In 1987 an article entitled, "Footbagging: Helpful Activity for Athletes?" appeared in The Physician and Sportsmedicine (Murphy, 1987). This appears to be the first reference of the sport in a professional journal. In this article, a sports physician and a kinesiologist each speculated on the use of footbag for cardiovascular benefits, agility/coordination, and rehabilitation. They specifically postulated on the possible benefits of the stretching and strengthening acquired by playing the game. This article referenced a proposed study at the University of Colorado – Boulder that was funded by Wham-O (owner of the Hacky-Sack™ brand). However, no other records of the aforementioned proposed study could be located.

The first exercise physiology study of footbag was performed at the University of Utah (Graetzer & Chen,1990). It appears this study was never published in a professional peer-reviewed journal, but study results were disseminated in two issues of the sport magazine "Footbag World". Ten male and three female "elite" competitive footbag players completed a series of tests designed to measure maximal heart rate, heart rate while engaged in various forms of footbag play/competition, maximal oxygen uptake (VO_{2max}), oxygen uptake while footbagging, and body composition via underwater weighing. The metabolic data collection took place using several different footbag skill-related protocols where subjects performed various tasks designed to mimic common footbag activities: “Unlimited Consecutive”, “5 Minute Consecutive”, “Doubles Distance One Pass”, “2 Minute Singles Freestyle”, “Singles Net”, and “Doubles Net”. Most pertinent to the present study, they found that during singles footbag net the subjects' mean heart rate was 152.2 bpm, and subjects worked at an intensity of approximately 83% of maximal heart rate.

James Harley authored perhaps the most comprehensive chronicle of the history and development of footbag in his 2001 doctoral dissertation “Performing Sport: Footbag Freestyle from Circle to Stage” (Harley, 2001). Harley's focus was on the evolution of one popular type of footbag play (freestyle) from recreational to performance sport. His lengthy account of the origin and history of footbag utilized careful analysis of early written/photographic records and personal interviews with founders and innovators to describe the evolution of the game from basic ideas to demonstrations to tournaments. Although he addressed footbag net only briefly, his compilation of the early types of footbag play included the evolution of specialization and diverging styles of play in the sport, and is required reading for a thorough understanding of the development of game.

Footbag History

According to the International Footbag Players' Association (2012), footbag was invented by Mike Marshall in 1972 in Oregon City, Oregon. Marshall sewed a homemade beanbag and began kicking and bumping the object into the air using most parts of his body, similar to soccer. Shortly thereafter, Marshall met John Stalberger at an outdoor festival and introduced him to the game. Stalberger, an experienced athlete, was recovering from a knee injury and found the kicking motions of the new game to be therapeutic for his knees. During practice and development they came to call the activity "hacking the sack." Later, they applied for a patent for their "Hacky Sack" invention. During the application process, Marshall unexpectedly died in his sleep from a heart attack at the age of 28. Stalberger continued on as co-inventor and primary promoter of the new sport.

Over time Stalberger placed more emphasis on the exclusive use of the lower body to keep the footbag aloft. He espoused proper kicking techniques (the "five basic kicks"), and the use of the upper body strictly for counter-balancing the kicks of the lower body (Harley, 2001). Stalberger felt that by stressing equal use of both sides of the body and restricting the touching to only the feet and knees the game could be used as an athletic or physical training tool. Later he began using the generic term "footbag" for the game in part to emphasize to the public the idea of using mainly the feet to play the game, and to distinguish footbag as an American creation with unique rules compared to other foot sports of the world (Harley, 2001).

Stalberger eventually started a footbag manufacturing company called "The National Hacky Sack Company". This was the first company to start organizing and teaching the footbag game to schools. In 1977 the first player's association for the sport was founded, dubbed "The National Hacky Sack Association". Fittingly, the first official footbag tournament was held in the birthplace of the game - Oregon City, Oregon.

Footbag continues to be a growing sport now played all over the world, with the most popular competitive footbag sports being footbag net and freestyle. The website www.footbag.org (published by the International Footbag Players' Association) currently lists 460 footbag clubs spread among 48 countries. International Footbag Players' Association, Inc. (IFPA) is a non-profit corporation whose mission is to promote footbag as an amateur competitive sport. The rules of footbag sports are published by the International Footbag Committee division of the IFPA. The World Footbag Championships tournament has existed for nearly 30 years, and has been hosted by numerous cities across North America and Europe, including San Francisco, Chicago, Montreal, Berlin, Helsinki, and Prague. The 2012 World Footbag Championships will take place in Warsaw, Poland.

Footbag net was one of the earliest forms of competitive footbag developed by Stalberger (Harley, 2001). It was presented as part of public demonstrations of the game, on a court and net closer to volleyball-sized than the current badminton-sized court used in competition. The regulation footbag net court is now 44 feet long (divided in half by the net) and 20 feet wide, with the middle of the net 5 feet above the ground. Unlike other net sports like badminton and tennis, the court dimensions remain the same for both singles and doubles play. Each 22 x 20 foot side is further divided in half by a center line (used only for the serve), making a total of four equal serving quadrants. For each side, the right hand serving quadrant (when facing the net) is considered the "even" side, and the left hand serving quadrant is considered the "odd" side. The current score of the server determines from which side the next serve will originate. Serves are kicked cross-court from behind the baseline.

To be used in competition, footbags must conform to certain requirements

(International Footbag Committee, 2010): be approximately spherical in shape; have a soft, pliable covering; contain loose filling of any material; and be subject to certain size and weight restrictions. The only legal body contact surfaces in footbag net are those “below the knee.” This makes kicking with the feet the most common and accurate choice for footbag net players. Touching any part of the net equipment during play is a foul, as is touching the opponent on their side of the net. However, a footbag net player can jump up and kick (“spike”) the footbag on their opponent's side of the net as long as the leg is pulled back quickly enough to avoid contacting the net or opponent. This is called “breaking the plane.” If two players attempt to kick the footbag simultaneously it is known as a “joust.” See Appendix A for more detailed rules of footbag net.

Figure 1.   Example of a Footbag Net "Spike" and “Joust”

Scoring Systems

In recent years the scoring system used in some popular net sports (e.g., volleyball) has changed. This newer scoring system is known by various names including “rally” scoring and “straight” scoring. The new approach counts every point played as a point for the winning player/team, rather than either a point or a simple loss of serve as was the case historically with "sideout" scoring. One proposed benefit of the "rally" scoring system is that it attempts to control the number of total points available to play and thus the total amount of possible time of a match.

The idea of controlling the total possible time of a sports match received great attention in 2010 at the Wimbledon Tennis Championships in a match that came to be known as "The Match That Would Not End". The match lasted for a record 11 hours, 5 minutes spread over three days. John Isner won the longest match in tennis history over Nicolas Mahut by the score of at 70-68 in the fifth set. This was a first round match, and the extreme length of this match was unexpected and disrupted the timing of other matches in the tournament schedule (Associated Press, 2010).

Shortly thereafter, the World Footbag Championships took place in Oakland, California. The finals match in open doubles net pitted the three-time defending champions from Germany against the top team from Montreal, Quebec. The match was a closely contested three-game match using sideout scoring that lasted about 2.5 hours (anecdotally considered record length for a footbag match). This made for a match that many in attendance declared one of the finest quality World Championship finals ever played. However, this also marked at least the temporary end of the use sideout scoring at the World Footbag Championships. Perhaps in response to the length of the record-setting Wimbledon and Oakland matches of the previous summer, the 2011 World Championships in Helsinki, Finland employed rally scoring exclusively (in a publicized effort to plan a predictable match schedule). The 2012 World Championships in

Warsaw, Poland have also announced a plan to use only rally scoring (International Footbag Players' Association, 2012).

In terms of its effects on determining game outcomes, rally scoring is a significant change from classic sideout scoring for at least three reasons:

1. A player/team can lose the game while serving. Not possible under sideout scoring.

2. A player/team can win the game by executing a sideout play (winning return of service). Also not possible under sideout scoring.

3. A player/team can win a game or match when leading by only 1 point, if the score is “capped” at a given number (e.g., 15, 21, 25) and the winning player/team is the first to reach the cap. This restriction is sometimes eliminated for important matches to force the winning player/team to win by 2 points, historically the criterion required to win.

The footbag net rules and definitions for the two most common scoring systems are briefly described below (International Footbag Committee, 2010). See Appendix A for more detailed rules of footbag net.

A. Classic Scoring: With classic scoring, points are only awarded when the serving team wins a rally. A rally is the sequence of playing actions from the moment the service is hit by the server until the footbag is ruled "dead". The serve (but no point) is awarded to a receiving team who wins a rally, also referred to as a "side out".

1. Point: A point is awarded to the serving team only. A point is awarded when the receiving player or team fails to return the footbag over the net and in-bounds in the allotted number of kicks (2 for singles, 3 alternating kicks in doubles) or commits a

foul.

2. Side Out: Service shifts to the other player or team (a side out) when the serving player or team fails to serve into the proper service court, subsequently fails to return the footbag over the net and in-bounds in the allotted number of kicks, or commits a foul.

3. Game: A game is the first player or team to score 15 points. At the tournament director's discretion, preliminary games may be to 11 points. Players must win by 2 points.

4. Match: A match is the winner of two out of three possible games, except in consolation rounds or losers' bracket in double elimination tournaments when one game to 15 points makes a match.

B. Rally Scoring: In rally scoring, a point is awarded to the winner of each rally, regardless of who serves. The serve and a point are awarded to a receiving team who wins a rally.

1. Point: A point is awarded after every rally to the player/team winning the rally, whether they served or received the rally. A point is awarded when a player/team fails to return the footbag over the net and in-bounds in the allotted number of kicks (2 for singles, 3 alternating kicks in doubles) or commits a foul.

2. Side Out: Service shifts to the other player or team (a side out) when the serving player or team fails to serve into the proper service court, subsequently fails to return the footbag over the net and in-bounds in the allotted number of kicks, or commits a foul.

3. Game: A game is the first player or team to score 21 points. If the score reaches 20 points each, then the game will be decided on a difference of two points, up to a ceiling of 25 points. At the tournament director's discretion, preliminary games may be to 15 points with a ceiling of 17 points, and consolation games may be to 11 points with a ceiling of 13 points.

4. Match: A match is the winner of two out of three possible games, except in consolation rounds or losers' bracket in double elimination tournaments when one game to 21 points makes a match. At the tournament director's discretion, consolation rounds may be played as two out of three possible games to 11 points, up to a ceiling of 13 points.

Heart Rate, VO_{2max}, and Exercise Intensity

Heart rate measurements are a useful tool for assessing exercise intensity and measuring cardiovascular fitness. Cardiovascular fitness is typically determined by measuring maximal oxygen uptake (VO_{2max}), which is the ability of the cardiovascular system to take in, transport, and utilize oxygen at the cellular level. Exercise physiologists have long noted a linear relationship between heart rate and oxygen uptake for the majority of activity levels. Freedson and Miller (2000) found that heart rate and VO_2 were closely related and exhibited a linear relationship, particularly between the heart rates of 110 and 150 bpm. They concluded that the use of heart rate as a physiological marker of VO_2 is a reasonable approach to assess physical activity.

Strath et al. (2000) studied the correlation between heart rate and VO_2 and energy expenditure during a variety of moderate intensity physical activities. Sixty-one adults wore a portable indirect calorimetry system that directly measured expired carbon dioxide and also measured heart rate. A modestly linear correlation (r=0.68) was found between HR and VO_2. Energy expenditure was also predicted by incorporating measured heart rate data into the Jackson et al. (1990) heart rate reserve model equation. This model incorporates measured heart rate, age-predicted HR_{max}, resting heart rate, gender, percent body fat, and physical activity level. The investigators then compared the indirect calorimetry results with the prediction equation and found a strong correlation (r=0.87).

Equations for estimating VO_{2max} have also been developed. The most common field test methods for estimating VO_{2max} use walking and jogging protocols. The results of these tests (e.g., time, heart rate) are entered into equations in order to estimate VO_{2max}. Submaximal fitness tests are a way to estimate VO_{2max} without the use of costly equipment and the risk of physically overtaxing the subjects. Other ways to estimate VO_{2max} in the field include non-exercise prediction equations. These equations typically use variables such as age, gender, BMI, body fat percentage, and self-reported physical activity measures (e.g., questionnaires, Borg scale) to estimate VO_{2max}.

Besson, Brage, Jakes, Ekelund, & Wareham (2010) found that questionnaires can provide a high correlation between self-reported and objectively measured vigorous physical activity. Redha (2001) found the correlation between heart rate and rating of perceived exertion to be 0.62 – 0.85 among Division I tennis players. However, Frost (1994) found that subjects required as many as eight exercise sessions with immediate heart rate feedback to achieve "mastery" of matching self-report ratings to actual heart rate measurements. Besson et al. (2010) also noted that the accuracy of questionnaires diminishes with lower levels of physical activity, and the main benefit of questionnaires is their use in large-scale epidemiological studies.

Prediction equations, submaximal fitness testing, and/or questionnaires are alternative means of estimating heart rate and energy expenditure, but are inherently inferior to direct measurements. There are limitations, however, in using heart rate to estimate the quantity and quality of physical activity and energy expenditure. These can include the effects of ambient temperature, emotional state, hydration status, type of muscular contraction, and size of muscle mass involvement (Strath et al., 2000).

Motion Sensors and Physical Activity

Accelerometry utilizes motion sensors to track movement in one or more planes. A pedometer is an example of a motion sensor that records movement in a vertical plane. Accelerometry data are typically presented in the form of "steps" or "counts". Most research has focused on instrument validity and reliability, and the development of methods to classify various intensities of physical activity or energy expenditure.

The Actiheart motion sensor/heart rate monitor was tested for reliability and validity by Brage, Brage, Franks, Ekelund, & Wareham (2005). The Actiheart monitor was compared with electrocardiographic (ECG) data, and the Actiheart was found to be accurate within 1 bpm at heart rates above 25 bpm. In terms of technical validity, the accelerometer output from the Actiheart was significantly related to average acceleration in a linear fashion. Measures of movement and heart rate generally agreed with measures of acceleration and heart rate, and provided relatively precise estimates of physical activity during walking and running. Inter-instrument reliability of the Actigraph accelerometer was investigated by McClain, Sisson, & Tudor-Locke (2007). Their study of free-living adults used pairs of accelerometers on each subject and revealed high inter-instrument reliability across a range of activity levels, including moderate-to-vigorous physical activity. Other studies of accelerometers have also found that these tools have good validity. Hendrick et al. (2010) found reasonable validity and stability during treadmill and ground level walking using the RT3 accelerometer.

Edwardson and Gorely (2010) studied the relationship between epoch length and physical activity intensity. Their study of children and adolescents collected physical activity data in epochs of 5 seconds, and then the data were reconfigured into 15, 30, and 60 second epochs. Their research suggested that 5-second epochs would be the most appropriate epoch length to detect short periods of intense physical activity, and even shorter epoch lengths of 1 or 2 seconds may be more appropriate. They concluded that the total volume of activity accumulated is not affected by epoch length. The epoch length only becomes an issue when physical activity intensity is the outcome of interest.

Hendelman, Miller, Bagget, Debold, & Freedson (2000) noted that laboratory investigations have established a linear relationship between the counts recorded using accelerometry and energy expenditure during locomotion. This has led to the development of various equations to predict MET level or intensity classification from accelerometer recordings. Relationships between counts and METs have been stronger for walking. Golf and household activities were underestimated by 30-60% based on the equations derived from level walking. The count-MET relationship for accelerometry was found to be dependent on the type of activity performed, which may be due to the inability of accelerometers to detect increased energy cost from upper body movement, load carriage, or changes in surface or terrain.

Three Actigraph energy expenditure equations were found to have different predictive validity in children and adolescents, depending upon the type of physical activity performed by the subjects (Trost, Way, & Okely, 2006). The mean energy expenditure of slow walking was best predicted by the Puyau equation. The mean energy expenditure of slow running was best predicted by the Trost equation. The mean energy expenditure of fast running was best predicted by the Freedson equation. They concluded that each of the equations may be useful for estimating participation in moderate and vigorous activity (see Appendix B for full detail of these equations).

Some researchers have further investigated the possible use of mathematical equations to estimate energy expenditure from the combination of accelerometer and heart rate data. Brage et al. (2003) explained that the limitations of heart rate monitoring (e.g., biological variance) and the limitations of accelerometry (e.g., biomechanical variance) are not positively correlated, and thus an equation combining the two measures would theoretically be a more accurate measure of exercise intensity. Later research (Brage et al., 2007) demonstrated the importance of the individual calibration of heart rate-physical activity intensity and accelerometry-physical activity intensity for the most accurate estimates of intensity. They suggested the pre-testing of subjects using laboratory or field tests.

The idea of combining accelerometry with heart rate measurement for assessing physical activity was also studied by De Bock et al. (2010). They found that devices that combined heart rate and accelerometry data yielded an accurate classification of moderate-to-vigorous physical activity in preschoolers. They also wrote that recent research in older children has shown that the accuracy of physical activity measurement increases if accelerometry is combined with other physiological measures, such as heart rate. Freedson and Miller (2000) further noted that, while neither motion sensors nor heart rate monitors are perfect markers of physical activity, they do eliminate subjectivity in obtaining physical activity information. They concluded that providing simultaneous heart rate data with motion counts is recommended to further verify that elevated heart rate can accurately represent physical activity intensity.

Methods

Subjects

Given that the population of interest for this study was defined as "footbag net players", subjects were not chosen randomly. Rather, subjects recruited for this study were volunteers that met certain criteria. The first criterion was that potential subjects were "experienced footbag net players." An experienced footbag net player was defined as an adult over age 18 years with at least one year of experience playing footbag net and participation in at least one organized footbag net tournament. Volunteers not meeting this definition were excluded because it was felt they may have lacked familiarity with game rules and also may not have been skilled enough to successfully participate in the study. Subjects under 18 years of age were excluded because the focus was on the physiological responses in adults.

All subjects were also required to be free of known health risks. Any participation in exercise, sports, or athletic competition brings with it an increased likelihood of injury or death. All subjects were adult experienced athletes, apparently healthy, free of known injuries and cardiovascular conditions, and presumably able to engage in study protocols without excessive risk. A short, validated health screening protocol (Physical Activity Readiness Questionnaire - "PAR-Q") was used to evaluate the need for physician approval prior to participation in the study. Subjects with known health conditions or injuries that may have been aggravated by engaging in sports participation and maximal exercise testing would have been excluded for their own health and safety. As part of participation in this study subjects were asked to perform a maximal exercise test that involved heart rate measurement during several maximal-effort sprints.

Subjects were recruited via emails, phone calls, website forums, and social networking websites. It was anticipated that subjects would be 18-50 years of age, with no gender or ethnic restrictions. All subject participation was voluntary, based upon verbal agreement and written informed consent. Approximately 23 potential subjects agreed verbally or via email to participate in the study. Of this pool of potential subjects, 16 completed all parts of the protocol and provided complete data. Of the remaining potential subjects, one became injured and required surgery (incident unrelated to this investigation), one withdrew for fear of getting injured, and others simply stopped returning phone calls/emails/messages without any indication that they no longer wished to participate in the study.

Procedures

All testing took place on grass playing fields in outdoor parks in the Portland, Oregon metropolitan area. Five different parks were used in an effort to make the locations convenient for the volunteers. Data collection took place from August to December, 2011. It was originally anticipated that it would take about two hours to complete each data collection session (i.e., submit required forms, be fitted with equipment, warm-up, play two games of singles footbag net, complete the running field test, and cool-down). Most of the data collection sessions required only 1.0 to 1.5 hours.

Subjects agreed upon the date, time, and location of each data collection session via phone calls and emails. Subjects were also given reminder calls the morning of the study. There were zero “no shows” at data collection sessions. When subjects arrived at the park they were provided with the Informed Consent and PAR-Q forms. None of the PAR-Q forms revealed contraindications to physical activity/exercise, so each subject then signed two copies of the Informed Consent; one copy was returned to the investigator and one copy was given to the subject.

Several safeguards were in place throughout subject testing. These included: 1) CPR training of the principal investigator; 2) a first-aid kit on site; 3) two cell phones available in case of emergencies; and 4) free access to cool water, shade, and sunblock.

Age, height, and weight data were obtained separately for each subject by the principal investigator. Age was recorded in years (defined as most recent completed birthday). Height was measured to the nearest half-inch without shoes using a Stanley FatMax retractable measuring tape. The tape measure was previously validated against two different engineering rulers. Weight was measured to the nearest one-tenth kilogram using a Taylor Instruments 7553 Glass Lithium Electronic scale. This scale was chosen for its quality and portability, and was previously validated against an electronic veterinary scale. Each subject was then fitted with an Actitrainer accelerometer/heart rate monitor with waist belt and a heart rate monitor chest strap. Each Actitrainer was checked several times before and during data collection to ensure that heart rate data were being recorded properly. Actitrainer heart rate measurements were also compared with palpated radial pulse counts to validate accuracy during testing.

After the descriptive data were recorded and subjects were fitted with the recording gear, they performed a warm-up (light stretching and kicking) for at least 10 minutes before game data collection began. Subjects then played two games of singles footbag net: one game was played using sideout scoring and one game was played using rally scoring (in random order). Sideout games were played to 15 points, and rally games were played to 21 points. A coin toss was used to decide the scoring system for the first game. An additional coin toss determined which player served first (the loser of the coin toss served first in the second game). Subjects were allowed three minutes of rest between games and were encouraged to drink water to stay cool and replace sweat loss. After the second footbag net game, subjects rested for three minutes in preparation for the sprint tests.

In an effort to determine maximal heart rate, a series of 60-90 yard sprints were performed by each subject (the distance varied based upon safe running spaces). After each sprint, heart rate was measured and subjects were provided with a brief rest before repeating the sprint. All subjects completed at least two maximal-effort sprints.

When subjects completed the sprint tests, they were instructed to spend several minutes walking slowly to actively recover from the exertion and allow time for heart rate recovery. Subjects were monitored during this time to ensure that recovery was proceeding normally before the heart rate monitor chest strap and Actitrainer belt were removed. The chest and belt straps were then disinfected with Lysol™ disinfectant spray and allowed to dry before storage.

Equipment

Bodyweight was measured with a Taylor Instruments 7553 Glass Lithium Electronic Scale. Height was measured with a Stanley FatMax measuring tape. Heart rate and accelerometer data were obtained with an Actigraph Dual Axis Actitrainer activity monitor with heart rate monitor chest strap. Data were uploaded to ActiLife Software version 5.10.0. Time was measured with a digital watch (Tech4O Accelerator HRM). Footbag net equipment included net footbags, a regulation net, and court lines. Miscellaneous equipment included data collection forms, water, sunblock, a first-aid kit, cell phones, and disinfectant spray.

Data Analysis

Within 10 hours of each session, data were uploaded from the accelerometers to a software-licensed desktop computer using ActiLife Software version 5.10.0. Accelerometry data were recorded minute-by-minute, with an epoch length of one second. Each minute displayed was therefore the average of 60 epochs. All subject data were then copied to OpenOffice.org version 3.3.0 spreadsheet software. Basic descriptive statistics (mean, standard deviation, minimum, maximum) were calculated for each variable. A paired-samples t-test was used to compare the mean heart rate of sideout scoring system play and rally scoring system play. Additionally, a paired-samples t-test was conducted to compare the mean horizontal accelerometer counts with the mean vertical accelerometer counts.

Results

Table 1 presents the subject descriptive data. Subjects included 15 males and 1 female ranging in age from 18-60 years, with a mean of 33.6 years.

Table 1. Subject Descriptive Data

Subject	Age (yrs)	Gender	Mass (kg)	Ht (m)	BMI
1	34	M	56.9	1.74	18.8
2	44	M	79.0	1.74	26.1
3	60	M	82.4	1.73	27.5
4	53	M	101.4	1.96	26.4
5	45	M	78.6	1.84	23.2
6	41	M	66.5	1.75	21.7
7	32	M	111.6	1.85	32.6
8	18	M	61.0	1.78	19.3
9	30	M	72.7	1.73	24.3
10	21	M	81.8	1.83	24.4
11	19	M	59.6	1.60	23.3
12	24	M	105.8	1.78	33.4
13	25	M	88.5	1.93	23.8
14	44	F	55.8	1.59	22.1
15	24	M	92.0	1.77	29.4
16	24	M	100.3	1.73	33.5
mean	33.6		80.9	1.8	25.6
sd	12.8		18.0	0.1	4.6
min	18		55.8	1.59	18.8
max	60		111.6	1.96	33.5

The highest heart rate achieved by each subject during the maximal-effort sprint protocol is presented in Table 2. The maximal-effort sprint heart rate (HR_{sprint}) is compared with an age-predicted maximal heart rate estimate using 220 - age. The mean heart rate of all subjects during the running protocol was 169.3 bpm. Two subjects (#2 and #15) suffered muscular injuries while performing the maximal-effort sprint running protocol, and this may have adversely affected their HR_{sprint} results.

Table 2. Peak Heart Rate During Maximal-Effort Sprint Tests

Subject	HR_{sprint} (bpm)	220-age (bpm)
1	172	186
2*	154	176
3	143	160
4	151	167
5	163	175
6	165	179
7	177	188
8	182	202
9	183	190
10	182	199
11	177	201
12	183	196
13	180	195
14	171	176
15*	148	196
16	177	196
mean	169.3	186.4
sd	13.6	12.8
min	143	160
max	183	202

(*injured during sprint protocol)

Figure 2 depicts the typical heart rate response of one subject (subject #9) during sideout scoring and rally scoring games. This subject's data were typical of the heart rate responses of subjects during the footbag games.

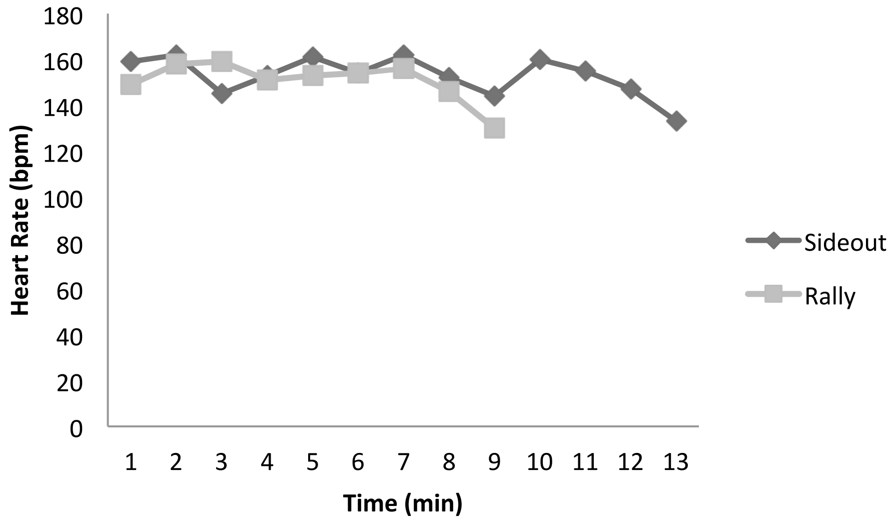

Figure 2. Typical Heart Rate Response to Footbag Net Competition Under Sideout and Rally Scoring

Table 3 presents subject heart rates during the footbag net competition. The $HR_{sideout}$ and HR_{rally} are the mean heart rates of each subject during singles footbag net competition using sideout scoring and rally scoring, respectively. The mean heart rates of all subjects by scoring system were 149.4 bpm for games with sideout scoring and 148.7 bpm for games with rally scoring. Figure 3 displays the heart rate data graphically.

Table 3. Mean Heart Rate During Footbag Net Competition Under Sideout and Rally Scoring

Subject	$HR_{sideout}$ (bpm)	HR_{rally} (bpm)
1	164	156
2	140	129
3	132	127
4	135	132
5	146	157
6	163	177
7	180	181
8	115	119
9	153	151
10	142	147
11	145	147
12	175	171
13	167	146
14	154	160
15	146	139
16	133	140
mean	149.4	148.7
sd	17.3	17.9
min	115	119
max	180	181

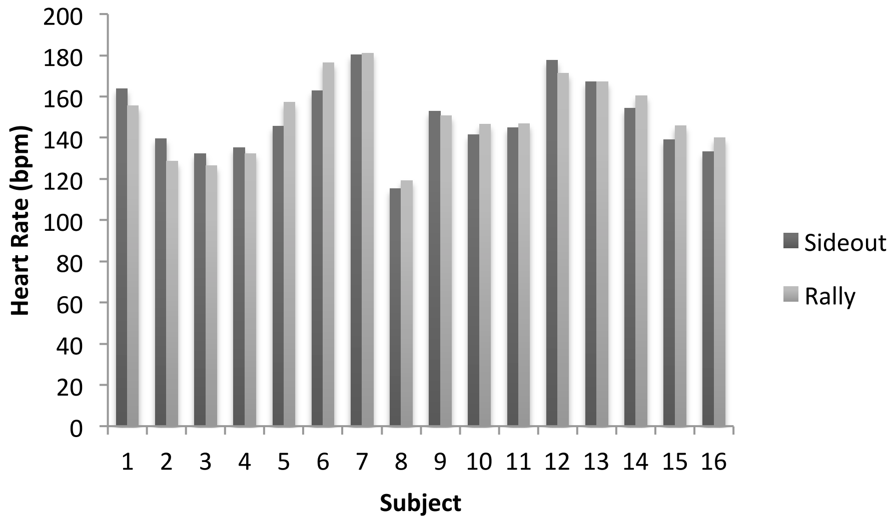

Figure 3. Mean Heart Rate During Footbag Net Competition Under Sideout and Rally Scoring

Table 4 presents the duration of each game played by subject and scoring system. Sideout games averaged 1.2 minutes (~11%) longer than rally games. Rally games had less variation in length, with a standard deviation of 1.7 minutes (versus 4.0 minutes in sideout games).

Table 4. Game Duration of Footbag Net Competition Under Sideout and Rally Scoring.

Subject	**Sideout (min)**	**Rally (min)**
1	18	9
2	18	9
3	17	12
4	17	12
5	7	11
6	7	11
7	12	12
8	13	9
9	13	9
10	7	10
11	7	10
12	11	10
13	11	10
14	16	13
15	10	14
16	10	14
mean	12.2	10.9
sd	4.0	1.7
min	7	9
max	18	14

Table 5 presents the average heart rates of each subject by scoring system as a percentage of the common age-predicted maximal heart rate formula 220 – age, and the Tanaka, Monahan, & Seals (2000) formula 208 – (0.7 x age). Average heart rates were 80% of 220 – age and 81% of 208 – (0.7 x age).

Table 5. Mean Relative Heart Rate During Footbag Net Competition Under Sideout and Rally Scoring

Subject	220-age (bpm)	sideout (%)	rally (%)	208-(0.7*age) (bpm)	sideout (%)	rally (%)
1	186	88	84	184	89	85
2	176	80	73	177	79	73
3	160	83	79	166	80	77
4	167	81	79	171	79	77
5	175	83	90	177	83	89
6	179	91	99	179	91	99
7	188	96	96	186	97	98
8	202	57	59	195	59	61
9	190	81	79	187	82	81
10	199	71	74	193	73	76
11	201	72	73	195	74	76
12	196	89	87	191	92	89
13	195	86	75	191	88	77
14	176	88	91	177	87	90
15	196	74	71	191	76	73
16	196	68	71	191	70	73
mean	186.4	80	80	184.5	81	81
sd	12.8	10	11	9.0	10	10
min	160	57	59	166	59	61
max	202	96	99	195	97	99

A paired-samples t-test was performed to compare the mean accelerometer counts for axis 1 (vertical) and axis 2 (horizontal). The t-statistic ($t=1.21$) was not statistically significant ($p>0.05$), indicating that the mean accelerometer counts in these movement planes were not different. Therefore, accelerometer count data for each subject are the sum of axis 1 and axis 2 values. Mean accelerometer counts during footbag net competition under sideout and rally scoring are presented in Table 6 and depicted graphically in Figure 4.

Table 6. Mean Accelerometer Counts During Footbag Net Competition Under Sideout and Rally Scoring

Subject	Sideout	Rally
1	5833	6577
2	5952	5504
3	4512	4628
4	6934	7649
5	5921	6797
6	6827	7185
7	6826	6391
8	7148	8888
9	6360	6965
10	6919	7691
11	7195	7486
12	5888	5397
13	5146	5092
14	5913	5778
15	5403	6680
16	4810	5597
mean	6099	6519
sd	840	1133
min	4512	4628
max	7195	8888

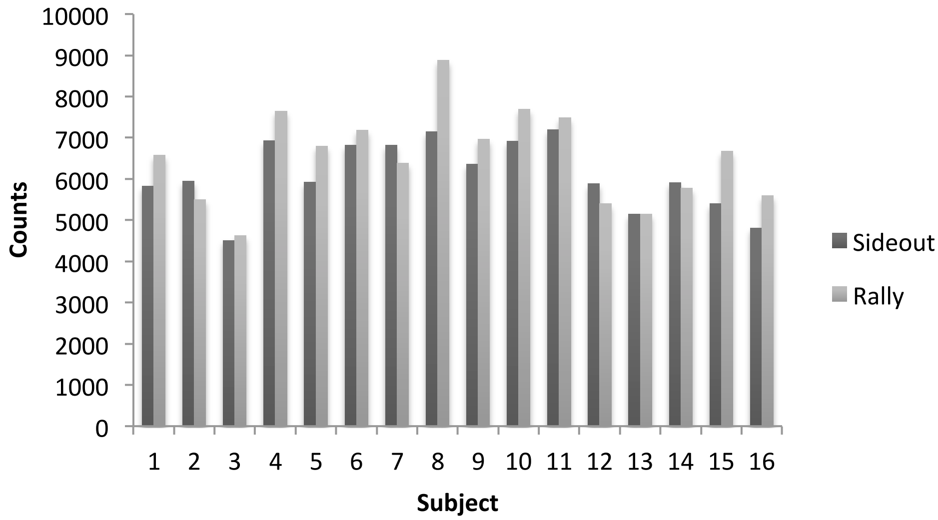

Figure 4. Mean Accelerometer Counts During Footbag Net Competition Under Sideout and Rally Scoring

A paired-samples t-test was performed to compare the mean heart rate under sideout scoring with the mean heart rate under rally scoring. The t-statistic (t=0.31) was not statistically significant (p>0.05), indicating that the heart rate responses under the two scoring systems were similar.

Discussion

Maximal Heart Rate Measurement

In this investigation, heart rate responses to singles footbag net competition were measured and recorded using accelerometer/heart rate monitors. Heart rate measurements are commonly used to describe the relative intensity of physical activity (i.e., activity heart rate relative to maximal heart rate). Heart rate responses to physical activity can therefore be described in terms of a percentage of each individual's maximal heart rate, and the physiological demand of activities can be quantified and compared. Ideally, the maximal heart rate is directly measured during the performance of a graded maximal exercise test in a laboratory under the supervision of a physician or exercise physiologist. For this investigation, however, a field test protocol involving repeated running sprints (HR_{sprint}) was selected as the most efficacious method for determining maximal heart rates. However, we believe the sprint running protocol failed to elicit maximal heart rates. For every subject the HR_{sprint} measurements were lower than their age-predicted maximum heart rate, and were at least 11 bpm lower in 14 subjects using the 220 – age formula and 12 subjects using the 208 – (0.7 x age) formula. Further, two subjects had HR_{sprint} measurements that were lower than peak heart rates obtained during singles footbag net competition. Given these results, the validity of the sprint running protocol used in this investigation is questionable.

Maximal Heart Rate Estimation

While 220 - age is a common and convenient method used to estimate an individual's maximal heart rate, some research has developed alternative equations. Tanaka, Monahan, & Seals (2000) found that maximal heart rate is predicted to a large extent by age alone, and is independent of gender and physical activity level. Their research concluded that the commonly used 220 – age equation underestimates maximum heart rate in older adults. This would have the effect of overestimating the true level of physical stress imposed during exercise and could result in inappropriate exercise prescriptions. They developed an alternative equation (208 - (0.7 × age)) to predict maximal heart rate in healthy adults to address these concerns.

Table 3 shows the mean heart rate responses during singles footbag net competition under sideout scoring and rally scoring. The individual heart rates for each scoring system are also presented in Table 5 as a percentage of estimated maximal heart rate using both age-predicted maximal heart rate formulae (i.e., 220 - age and 208 – (0.7 x age)). As noted above, the Tanaka et al. equation generally results in maximal heart rate estimates that are slightly lower for younger individuals and slightly higher for older individuals. When the mean heart rates under each scoring system are expressed as a percentage of estimated maximal heart rate, these age-related differences are even smaller. The percentage of maximal heart rate during sideout scoring and percentage of maximal heart rate during rally scoring differ by only 1-3% for each subject when the 220 - age and 208 - (0.7 x age) are compared.

The heart rate data in this investigation can be directly compared with the results of Graetzer and Chen (1990). They found that during singles footbag net the mean heart rate of their subjects was 152.2 bpm, which represented 82.8% of maximal heart rate.

Though the scoring system they used was not indicated, it is likely that they used the classic sideout scoring system, since the study was conducted over twenty years ago. In the present study, the mean heart rate during sideout scoring was 149.4 bpm, or about 3 bpm lower than that reported by Graetzer and Chen (1990). Graetzer and Chen (1990) also directly measured maximal oxygen uptake (VO_{2max}) as well as oxygen uptake while performing various footbag skills. Thus, their claim that subjects worked at 82.8% of maximal heart rate appears valid. As noted above, the present study is limited by the apparent inaccuracy of the maximal heart rate field test protocol. It is therefore not possible to more precisely describe the subjects' exercise intensity in relation to maximal heart rate. However, the estimated maximal heart rates (Table 5) suggest that during sideout scoring subjects achieved between 80% (220 – age) and 81% (208 – 0.7 x age) of maximal heart rate, and these results are consistent with Graetzer and Chen (1990).

Accelerometry

The accelerometry data collected in this study provided an additional method for describing the physical activity associated with the game of footbag net. When the accelerometer counts during competition are compared visually with the heart rate data, the shapes of the plots are similar, indicating a close relationship between movement and heart rate for most subjects. One notable exception is subject #8, who displayed some of the highest accelerometer counts coincident with some of the lowest heart rates. This illustrates a limitation of accelerometry in accurately measuring exercise intensity, as well as a limitation of heart rate in accurately measuring physical activity. An analysis of axis 1 and axis 2 counts during footbag net competition revealed no significant difference between movement counts in the horizontal and vertical planes. This suggests that the movements during competitive singles footbag net take place in both planes to a similar extent. The accelerometer data may be limited by the placement of the instrument on the subject's body. Accelerometers were positioned at the subjects' hips, which may not be the most appropriate location for footbag net competition.

Environmental Effects

As noted earlier, data collection took place from August to December, 2011, and all testing was conducted outdoors. Ambient temperature and relative humidity were not measured, but the environmental conditions varied from hot summer days to cool days in late fall. Given this variability in the weather, heart rate responses during competition may have been confounded by the environmental conditions. Freedson and Miller (2000) noted that factors such as high ambient temperature and high humidity can cause an increase in heart rate, which would overestimate the intensity of exercise.

Other studies have found conflicting evidence. Morante and Brotherhood (2007) studied the physiological responses of tennis players in relation to air temperature. Their sample of 25 tennis players was tested in air temperatures ranging from 14.5 to 38.4 degrees Celsius (58.1 – 101.1 degrees Fahrenheit). Skin temperature and sweat rate were positively correlated with air temperature. However, they found no association between heart rate and air temperature. Molloy (2003) studied the effects of exercise intensity and age in a hot, humid environment. He found that highly fit older and younger males can have similar heat tolerance capabilities if they followed high intensity exercise heat acclimation protocols.

Hamstring Injuries

Two of the sixteen subjects (12.5%) experienced muscle injuries during the maximal heart rate sprint running protocol. Both injured subjects appear to have suffered hamstring strains. Brockett, Morgan, and Proske (2004) studied hamstring strain injuries in elite athletes. They cited a variety of risk factors that have been studied that presumably increase the risk of muscle strains, including inadequate warm-up, fatigue, muscle weakness, inflexibility, poor lumbar posture, low hamstrings-to-quadriceps peak torque, and eccentric contractions. They noted that the athletes most at risk of a hamstring strain are those with a previous history of such injuries. Strain injuries are known to occur during eccentric contractions, so they recommended that anyone considered at risk of a strain injury take part in an eccentric exercise training program.

Conclusion

The physiological response and movement of experienced footbag net players during singles competition was described in this investigation by examining heart rate and accelerometer data. This study and previous research suggest that typical singles footbag net competition results in heart rates of approximately 150 bpm. The relative intensity of the exercise performed by the players in this study was approximately 80% of age-predicted maximal heart rate. The accelerometry results in this study generally supported previous research suggesting that heart rate and physical activity as measured by accelerometer counts are positively related.

Limitations

The limited subject population and the lack of random sampling used in this investigation limits external validity; conclusions are applicable only to experienced footbag net players and should not be considered generalizable to other populations.

The principal investigator has been a competitive footbag net player since 1993, and has considerable national/international competitive experience. This experience and familiarity with the sport could presumably bias data collection efforts. However, the principal investigator made every effort to eliminate bias during both the data collection and data analysis phases of the project. These efforts included testing only volunteer subjects who provided written, informed consent; collecting data only on subjects who competed against one another (as opposed to the principal investigator or other non-subject); and ensuring that the protocol and game rules were consistently followed. Although subjects were paired for competition for convenience of testing (and also paired by age and footbag net experience in an effort to avoid lop-sided matches), it is unlikely that this had a significant effect on performance during competition. All subjects were encouraged to try their best during all parts of the data collection protocol.

This study was undertaken strictly for scientific inquiry in partial fulfillment of the requirements for the degree of Master of Science in Health Studies at Portland State University. No other recognition or compensation of any kind has been or will be received by the study investigator from any individual or group associated with the study, including those involved in recreational or competitive footbag.

Future Research

The accelerometers used for this investigation measured only two planes of movement (horizontal and vertical) and were positioned at subjects' hips. Positioning tri-axial accelerometers at other locations (e.g., ankles) on the subjects during footbag net competition may provide additional data that more accurately measures the intensity of movement. Because the feet are used most often during footbag net, placement of accelerometers at the hip may not be the most adequate measure of activity during play. Further research should also investigate the effects of actual tournament play on heart rate during footbag net competition. The mental and physical demands of tournament play are presumably greater than the demands experienced during the staged games that have been used in studies to date. Finally, future research that uses a sprint-running protocol for the determination of maximal heart rate should use longer sprint distances with less frequent and/or shorter recovery intervals. It is also recommended that future studies screen participants more thoroughly for previous muscle strain injuries in order to alert them to the risk of re-injury and to provide guidelines for prevention.

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Appendices

Appendix A: Rules of Footbag Sports

This section contains an abbreviated version of the rules of footbag sports, focusing on those rules most pertinent to footbag net and this investigation (International Footbag Committee, 2010). See http://www.footbag.org/rules/ for complete rules.

107.01. Footbag Specifications
To be used in competition, footbags must:
A. Be approximately spherical in shape;
B. Have a soft, pliable covering; they cannot be rigid balls;
C. Contain loose filling of any material; and
D. Be subject to the following size and weight restrictions:
  1. Diameter of footbag: Minimum: 2.54cm (1.0 inches); Maximum: 6.35cm (2.5 inches)
  2. Weight of footbag: Minimum: 20g (0.71 ounces); Maximum: 70g (2.47 ounces)

302.01. Court Dimensions
The footbag net court dimensions are the same for both singles and doubles play. The court dimensions are 20 feet in width divided in half by the center line and 44 feet in length divided in half by the net, making four equal serving quadrants. For each side, the right hand serving quadrant will be considered the "even" side, and the left hand serving quadrant will be considered the "odd" side.

302.02. Net Height and Stanchion Placement
The net height is five feet and is measured at center court. Net stanchions should be as close as possible, but just outside the net court boundaries; net stanchions are out of bounds.

302.05. Footbag Net Equipment
Touching any part of the net equipment such as the net, stanchion and guy wires constitutes a foul, unless the bag is driven into the net with such force that the footbag's trajectory causes the net to contact a player on the other side (See Foul Definitions, 303.09-C).

303.02. General
A. Live Footbag: The footbag is considered "live" beginning with the moment of contact by the server's foot, and is considered "dead" as soon as the footbag touches the ground, net stanchions, anything beyond the court perimeter, drops below the net without going over it after a player or team has used the maximum allowable number of kicks, or a foul occurs, whichever comes first. Note: A Net Equipment Foul supersedes all other fouls, and may occur after the footbag would otherwise be declared dead (see 303.09-C), unless

a net plane foul (see 303.09-D) causes a net equipment foul, in which case the contact foul supersedes the net equipment foul, or unless the footbag is driven into the net with such force that the footbag's trajectory causes the net to contact a player on the other side of the net.
B. Legal Kicks: A kick is legal when the footbag is contacted with one continuous striking motion by a legal kicking surface. This includes double hits, rolls, and pushes, as long as a striking motion is used and the delay, double hit, or roll is clearly accidental.

303.09. Fouls
If a foul is committed by the receiving team, the result is a point for the serving team. If the serving team committed the foul, the result is either a side out or a point, depending on which scoring system is used. Except for “delay of game” or “unsportsmanlike conduct”, a foul may only occur while the footbag is still "live" (see 303.02-A Live Footbag).
A. Consecutive Foul: In singles net, when a player contacts the footbag more than two consecutive kicks. In doubles net, when a player contacts the footbag twice in a row.
B. Delay Foul: When the footbag is delayed or stalled on the foot.
C. Net Equipment Foul: When any part of a player's body or clothing, attached or unattached, touches the net, the guy wires of the stanchions, or the stanchions themselves without stated equipment being propelled by a footbag driven into the net with such force that the footbag's trajectory causes the net to contact a player on the other side of the net. For the purposes of a Net Equipment Foul, a point lasts 3 seconds after the footbag has been declared dead (see 303.02-A Live Footbag). Net fouls supersede all other fouls, unless a net plane foul (see 303.09-D) resulted in a net foul, in which case the plane contact foul supersedes the net equipment foul.
D. Net Plane Foul: When a player touches the opponent while breaking the plane of the net (above or below the net).
E. Receiving Foul: In doubles net, when a player receives the serve out-of-order, a point is awarded to the serving team.
F. Service Line Foul: When the support foot of the server touches the service line or beyond before contacting the footbag on the serve, and when the support foot is outside the sideline or center line extension.
G. Total Kick Foul: In singles net, when the footbag is contacted more than twice or in doubles net when the footbag is contacted more than three times before it is returned over the net.
H. Upper Body Foul: When the footbag comes in contact with any part of the upper body or clothing. Upper body is defined as the kneecap and above.
I. Delay of Game Foul: When a time-out exceeds its allotted time (see 303.07 Time-Outs and Breaks Between Games).
J. Interference Under Net Foul: When player contacts the footbag under the net on the opponent's side of the net before the footbag has been declared dead (303.02-A).
K. Unsportsmanlike Conduct Foul: Scorekeepers and tournament officials are allowed to assess unsportsmanlike conduct fouls (see 107). "Silent" foul cards or verbal warnings will be used to communicate the assessment of foul to players. Yellow cards will signify

warnings, and red cards will signify ejection from the game. Players/teams are generally allowed 2 yellow cards before being presented with a red ejection card, but these limits may be modified by tournament officials.
L. Line Rope Boundary Foul: When rope based line equipment is used, significantly altering the position of the line is considered a boundary foul.

Glossary
Center Line: Divides the length of the playing court in half to create the four equal quadrants.
Coin Toss: A coin toss at the beginning of the 1st and 3rd games to decide serve and side.
Fault: An error incurred while serving: A. When serve does not land in proper receiving court. B. When two let serves occur successively. C. When player commits service-line foul.
Let Serve: A serve which hits the net and lands in the proper receiving quadrant. Server is allowed one more serve.
Quadrant: One of four 10 ft. X 22 ft. areas into which the footbag net court is divided.
Receiving Player or Team: The player or team that is on the receiving end of the serve. In doubles net, there must be a player in each quadrant and the team must receive serve in this order until side out.
Receiving Rotation: In doubles net, after the service rotation has been established, each receiving team member must be in the quadrant they were in during their team's last serve to receive the opposing team's serve.
Screening: Blocking an opponent's vision in doubles net with the upper body. May also apply in blocking service (although screening the serve is a foul).
Seeding: The arrangement of the draw for footbag net events, so that the better players do not play against each other in early rounds.
Serve: Used to begin play. The server kicks the footbag from behind the service line into the receiving quadrant.
Service Ace: Occurs when receiving team fails to make contact with footbag landing inside the proper receiving quadrant.
Service Line: The back line from where the serve is initiated.
Serving Player or Team: The player or team initiating play with a serve.
Side Line: The side boundary lines of the playing court.
Side Out: When the serving player or team fails to return the footbag over the net during play, creates a foul or fails to get a good serve into play. The opposing team becomes the serving team:

a) when a serve does not land in the proper receiving court,
b) when two "let" serves occur successively, or
c) when a serving player commits a service-line foul.

Appendix B: Actigraph Energy Expenditure Equations

Trost et al.:

kcal x min [sup-1] = -2.23 + 0.0008 (counts per minute) + 0.08 (body mass kg)

Freedson child:

METs = 2.757 + (0.0015 x counts per minute) – (0.08957 x age yr) – (0.000038 x counts per minute x age yr)

Puyau et al.:

AEE (kcal x kg [sup-1] x min [sup-1] = 0.0183 + 0.00001 (counts per minute)

Appendix C: Participant Information and Informed Consent

You are invited to participate in an exercise science study about the sport of Footbag Net (a.k.a. Hacky-Sack, Kick-Volley). This study is called “Heart Rate and Accelerometry During Footbag Net Singles Play”. It is a thesis project being conducted by Christopher M. Siebert in partial fulfillment of requirements for a Master’s Degree in Health Studies (Portland State University School of Community Health; Advisor - Gary Brodowicz, Ph.D.). The purpose of this study is to investigate the intensity of singles footbag net play in experienced players by measuring heart rate and accelerometer counts during competition.

Interested subjects will be volunteers willing to engage in vigorous exercise, and share health information for safety reasons. Volunteers may withdraw from the study at any time for any reason. Volunteers should be experienced footbag net players over age 18 who have at least one year experience playing footbag net and who have participated in at least one organized footbag net tournament.

Methods: Participants will wear heart rate monitors and accelerometers to measure heart rates and movement during footbag net play. Participants will play two games of singles footbag net: one using “sideout scoring” and one using “straight scoring” (in random order). Following a brief rest period after the games, subjects will complete a short, running field test designed to measure maximal heart rate. The study will take place in an outdoor park or indoor gymnasium in a convenient location for volunteers. It is anticipated that it will take about two hours to complete the entire data collection session (i.e. submit required forms, warm-up, be fitted with equipment, play two games of singles footbag net, and complete the field test).

Benefits: Participants in this study will get the benefit of learning about their intensity of play during footbag net competition, including heart rate and accelerometer counts. Additionally, they will learn how their maximal heart rate compares with a commonly used formula for age-based maximal heart rate estimation. Finally, they will also have the satisfaction of knowing that they have helped add to the body of knowledge about footbag net play.

Risks and Safeguards: Any participation in exercise, sports, or athletic competitions brings with it an increased likelihood of injury or death. As part of participation in this study subjects will be asked to perform a maximal exercise test that involves measuring heart rate during maximal effort exercise. This requires strenuous exertion through vigorous physical activity. Several safeguards will be in place throughout subject testing, including: 1) CPR trained investigator, 2) first-aid kit on site, 3) at least 2 cell phones available for emergencies, and 4) access to cool water, shade, and sunblock as needed.

You agree that your participation in this study represents your own voluntary decision to participate in an exercise physiology study. Further, you understand that any participation in sports or athletic competitions brings with it an increased risk of INJURY or even DEATH. You understand that as part of your participation in this study you will be asked to perform a maximal exercise test that involves measuring your heart rate at maximum effort exercise. This requires strenuous exertion through vigorous physical activity.

You proclaim that you are in good health and free of medical concerns which would increase your risk for injury or death. All potential participants will be required to fill out a Physical Activity Readiness Questionnaire (PAR-Q) to discern any health risks. Subjects should be experienced athletes, apparently healthy, free of known injuries and cardiovascular conditions, and able to engage in study procedures without excessive risk. Subjects with known health conditions that may be aggravated by engaging in sports participation and maximal exercise testing will be excluded for their own health and safety.

All efforts will be made to maintain confidentiality of all information provided by study volunteers. Names of study participants will not be published in any form. Descriptive characteristics of subjects (height, weight, age, etc.) will be described in the study but never with any names or other identifying information. Original data will be kept only by Christopher M. Siebert.

Your signature below certifies that you are over eighteen years of age, you understand the information presented in this Participant Information and Consent form, you are of sound mind, and sign of your own free will. All study participants will receive copies of this Participant Information and Consent form.

Signature: ____________________________________ Date: _______________

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Appendix D: Subject Data Sheet

Research Data Sheet
Christopher M. Siebert, Lead Researcher
Date:____________

Subject Descriptive Data

Player 1 (code:__________) Actitrainer #________ Polar #________

Time data collection begin:__________ Time data collection end:__________

Age (yrs):__________ Weight (kg/lb):____________Height (m/ft):____________

Heart Rate begin:__________ HR max:__________ HR end:__________

Player 2 (code:__________) Actitrainer #________ Polar #________

Time data collection begin:__________ Time data collection end:__________

Age (yrs):__________Weight (kg/lb):____________Height (m/ft):____________

Heart Rate begin:__________ HR max:__________ HR end:__________

Game Data

Game #1 Scoring Format: sideout straight/rally

Time begin:____________ Time stop:____________ Time total:____________

Player 1 (code:_______) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Player 2 (code:_______) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Game #2 Scoring Format: sideout straight/rally

Time begin:__________ Time stop:____________ Time total:____________

Player 1 (code:_______) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Player 2 (code:_______) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Time begin:____________ Time stop:____________ Time total:____________

Voluntary Heart Rate max Time begin:___________ Time stop:___________

Player 1 (code:_______) HR begin:__________HR max:__________HR end:__________ Total Field Lengths:__________

Player 2 (code:_______) HR begin:__________HR max:__________HR end:__________ Total Field Lengths:__________

Appendix E: PAR-Q

PAR-Q & YOU
(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before starting to become much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES **NO**

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by your doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

	YES to one or more questions
If you answered	Talk to your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES. ▪ You may able to any activity you want – as long as you start slowly

and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.

- Find out which community programs are safe and helpful to you.

NO to all questions	**DELAY BECOMING MUCH MORE ACTIVE**:
If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can: ▪ start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go. ▪ Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.	▪ If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or ▪ If you are or may be pregnant – talk to your doctor before you start becoming more active. **PLEASE NOTE:** If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed use of the PAR-Q:</u> The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.
No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE __________________________________DATE_______________

SIGNATURE OF PARENT________________________WITNESS____________
Or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Appendix F: Paired-Samples t-Test on Heart Rate

	Sideout	***Rally***
Mean	149.38	148.69
Variance	298.78	319.96
Observations	16	16
Pearson Correlation	0.87	
Hypothesized Mean Difference	0	
df	15	
t Stat	**0.31**	not sig
P(T<=t) one-tail	0.38	
t Critical one-tail	1.75	
P(T<=t) two-tail	0.76	
t Critical two-tail	2.13	

Appendix G: Paired-Samples t-Test on Accelerometer Counts

	Axis 1	*Axis 2*
Mean	3156.09	3110.44
Variance	1374928.06	1010425.87
Observations	369	369
Pearson Correlation	0.79	
Hypothesized Mean Difference	0	
df	368	
t Stat	**1.21**	not sig
P(T<=t) one-tail	0.11	
t Critical one-tail	1.65	
P(T<=t) two-tail	0.23	
t Critical two-tail	1.97	