Small Sided Games: Physical Activity, Heart Rate, and Skill Outcomes in Club-level, Adolescent Girls Soccer

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Dedication

I dedicate this dissertation to my loving and caring wife Holly, without whom I could never have navigated this course. Thank you.

Abstract

The United States is in the midst of a physical activity (PA) crisis. Children across the country struggle to achieve the recommended dosage of daily PA. Sport is one mechanism for the accrual of PA in children. Soccer is one sport that has demonstrated efficacy in generating PA at a level commensurate with increases in health. With soccer, the use of small sided game training (SSG) has become an effective method for the development of match related performance outcomes in soccer players, the same outcomes associated with improved health. Much of the research has focused on elite male performers. However, there is minimal research investigating the effects of SSG training on youth, specifically club-level youth. In addition, the preponderance of research is focused on this mode of training for males, creating a gap in the literature detailing outcomes experienced by females. Previous research exploring the physiologic, time and motion, and skill outcomes associated with SSG training have been generally positive in both performance measures and health outcomes. There are questions as to the effectiveness of generalizing results to individuals who come from geographic regions where soccer is not a leading professional sport (e.g. United States). The potential for a difference in outcomes could exist with less cultural demand for performance in the sport. When this is juxtaposed against the poor results of children to receive the recommended dose of physical activity, there is a call for increased knowledge centered on SSG training, a popular training method. This research attempts to address the void in the literature using observational approaches. The results in indicate that SSG training produces greater time in moderate to vigorous physical activity (MVPA) than at intensities below this threshold (p = .05). This effect was moderated by competition level (CL), with Premier (P) players generating greater values than Classic 1 (C1) players and Classic 3 (C3) players. Classic 1 players in turn

generated greater values than Classic 3 players. Heart rate response, indicates that when measuring two unique heart rate thresholds, 70% HR_{max} and 85% HR_{max}, SSG training is efficacious in producing exercise intensities above these commonly used intensities (p value). With the use of a performance metric, positive possession (PosP), to delineate between CL in SSG training, significant results were found when stratifying PosP by CL *(p* = .05). This investigation adds to the existing body of knowledge describing the utility of this training modality. The effect of CL on these outcomes, along with descriptions of the moderating effect of time and player position, is described in this underrepresented population, club-level adolescent females. This works aligns previous research while laying the foundation for larger more comprehensive trials.

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CHAPTER 1: Introduction

1.1 Background

For youth (ages 2–19 yr.), the petition to get a daily dose of physical activity (PA) is pronounced (White House Office of the First Lady, 2010). The connection between sedentary behavior and negative health outcomes, including increased risk for premature death, heart disease, diabetes, colon cancer and high blood pressure is established (Physical Activity Guidelines Advisory Committee, 2008). In addition, the associations between overweight and obese individuals and increased risk for debilitating diseases have also been well documented. These include the development of diabetes, high blood pressure, high cholesterol, asthma, arthritis, and overall poor health status (Daniels et al., 2005; Dietz & Robinson, 2005). While a concern to public health advocates there are methods for mitigating these negative outcomes. One such approach, the accrual of moderate to vigorous physical activity (MVPA), has been shown to have a positive effect in combating these harmful results (Gutin, 2008; Physical Activity Guidelines Advisory Committee, 2008).

Youth can receive a substantial dose of PA through youth sport (P. T. Katzmarzyk & Molina, 1998). This is particularly relevant in the United States where youth sports occupy a position high in the consciousness of Americans. It is estimated that total registrants for youth sport sits somewhere between 40 and 60 million (63% male, 37% female). In conjunction with a multi-registrant rate of 27%, the positive impact of youth sports on the accrual of PA is evident and potentially powerful (National Council on Youth Sports, 2008; Seefeldt & Ewing, 1997). However, while contributing significantly to the daily accrual of MVPA, as well as a concurrent reduction of sedentary behaviors, participation in youth sport practice or games does not appear to meet the daily recommendation for MVPA (Leek et al., 2011; Sacheck et al., 2011; Wickel & Eisenmann, 2007).

Soccer is a sport that has shown promise as a source of MVPA (Leek et al., 2011). Much research has been at an elite level of competition done on small sided games (SSG) used in soccer training. Training factors have been identified that have effect on selected training outcomes, both physiologic and skill related (S. V. Hill-Haas, Rowsell, Dawson, & Coutts, 2009; S. V. Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Participation in SSG has also been shown to have positive health outcomes in untrained, deconditioned adults (Krustrup, Dvorak, Junge, & Bangsbo, 2010). While a comprehensive understanding of moderating factors for physiologic and skill outcomes has been established, there are gaps in the literature surrounding youth, especially females, an underrepresented group. This research will address the following gaps in the literature:

1. No published study has examined the moderating effect of competition level (CL) on the accrual of MVPA. While data exists describing the accrual of MVPA during sport competition in youth stratified by age and sport, nothing to date has sought to control the practice environment to examine the effect of a participant's level of competition. Included in this exploration is a description of the relative contribution to MVPA from SSG participation during scrimmage play and passive rest (instructional time). This serves as a beginning to developing research describing the unique effects of sport training on MVPA, a priority in PA research (Pate & O'Neill, 2011).
2. In the research surrounding SSG training for soccer competition, nothing was found that examined the effect of SSG on physiologic outcomes (Heart Rate [HR]) in club-level, adolescent female players. The amount of information available demonstrating the efficacy of SSG training in generating exercise intensities resulting in performance gains is substantial, however the

representation within the research is biased in the direction of both elite and male participants exists. This research will examine time spent above two exercise intensities (EI) associated with performance increases, <70% HR maximum (HR_{max}) and <85% HR_{max}, during SSG training in club-level adolescent females, an underrepresented population. Within the context of these outcomes, the potential for moderation from both time (T) and CL will be explored. Description of HR outcomes, stratified by intensity level, will also be included in the results

3. This research will also inspect the effect of CL on skill outcomes in club-level, adolescent females during SSG training. This will be the first trial seeking to use video cataloging of skill events in this population and CL. The popularity of SSG training and the use within this population require the documentation of factors that may create differences in both training outcomes and team selection processes. This will be the first trial of its kind to combine these unique methods, with this population for the purpose of informing the coaching community with such metrics. Identification of a metric, Positive Possession (PosP), will be described for the first time. Description of shooting, passing, and possession outcomes will also be given.
4. Finally, continuing the theme of representative research, of the literature in existence surrounding SSG training in soccer, none was found specific to this population of interest, club-level, adolescent girls. This is interesting to note understanding the trend of decreasing PA in females as they reach adolescence (Andersen, 2011; Centers for Disease Contol and Prevention, February 2, 2010; Kerner, Kurrant, & Kalinski, 2004) and the increased PA derived from soccer training when compared to other sports ((Leek et al., 2011). With the increasing participation of youth sport, the popularity of soccer in the United States, and the

previously mentioned opportunity for positive impact, more data is required to better understand the implication on the health of today's youth (Federation of International Football Associations, 2012; National Council on Youth Sports, 2008; National Sporting Goods Association, 2011; Pate & O'Neill, 2011; Seefeldt & Ewing, 1997)

1.2 Dissertation Aims

This research aims to investigate PA, HR, and skill outcomes accrued in SSG's (4v4, free-play) during club-level adolescent female soccer training. Examination of moderators will be included. These are:

- Time – changes across game conditions, from Game 1 to Game 2 to Game 3
- Competition Level – changes across level of play, operationalized as Premier (high school), Classic 1, and Classic 3(municipal recreation)
- Player Position – changes across positional assignment, the predominate position assigned the player during the current season

Three papers have been written to meet this goal. The first describes the relative proportion of MVPA attained during SSG training. Results have been stratified into five categories (sedentary, light, moderate, vigorous, and very vigorous). The second paper explores differences in the relative proportion of time spent above two EI's associated with physiologic performance, <70% HR_{max} and <85% HR_{max}. Descriptions of EI, stratified into five categories (<70% HR_{max}, 70-85% HR_{max}, 85-90% HR_{max}, 90-95% HR_{max}, and >95% HR_{max}), are included. The third paper describes the relative differences in skill outcomes, (Positive Possession [PosP]), moderated by T and CL, found during SSG training. Descriptions of skills outcomes performed during training follow. The following are the Specific Aims and Hypotheses for each manuscript:

Specific Aim 1: To descriptively quantify the accrual of MVPA during repeated SSG's in club-level adolescent female soccer players. The effect of CL and PP on the amount of MVPA accrued will be examined. These hypotheses will be tested:

Hypothesis 1: During SSG training, players will spend significantly more time in MVPA than sedentary physical activity (SPA) or light physical activity (LPA).

Hypothesis 2: Competition level will demonstrate a significant effect on MVPA, demonstrating differences in SSG's games in club-level adolescent females. MVPA demonstrate the following significant differences when stratified by CL, Premier (P) > Classic 1 (C1) > Classic 3 (C3).

Hypothesis 3: Player position will demonstrate a significant effect on MVPA, demonstrating differences in SSG's games in club-level adolescent females. MVPA will demonstrate the following significant differences when stratified by PP, Midfielders (M) > Forwards (F) > Defenders (D).

Specific Aim 2: To examine Exercise Intensity (EI), operationalized as a percentage of HR_{max}, recorded during SSG training in club-level adolescent female soccer players. Comparison of the time spent above and below 85% HR_{max} will be analyzed. Two moderating effects will be further explored. The effect of T (repeated games) and CL will be described. These hypotheses will be tested:

Hypothesis 1: Time (sec) spent >70% HR_{max} will be significantly greater than time spent <70% HR_{max} for G1, G2, and G3.

Hypothesis 2: Time (sec) spent >85% HR_{max} will be significantly greater than time spent <85% HR_{max} for G1, G2, and G3.

Hypothesis 3: Time will demonstrate a significant effect on EI, demonstrating differences accrued during repeated SSG's in club-level adolescent females.

Time spent >70%HR_{max} and >85% HR_{max} will significantly increase from G1 to G2 to G3.

Hypothesis 4: Competition level will demonstrate a significant effect on EI, demonstrating differences accrued during repeated SSG's in club-level adolescent females, stratified by CL. Time spent at >70% HR_{max} and >85% HR_{max} will be significantly greater for P than for C1 than for C3 players.

Specific Aim 3: To describe the ability of PosP to delineate between CL. Examination of CL as a moderator of PosP could lead to the establishment of a logistically feasible metric to quantify 4v4 skill outcomes. This could facilitate the stratification of players into appropriate CL. Secondarily, to quantify skill outcomes (shooting, passing, and ball possession) accrued during SSG's in club-level adolescent female soccer players.

Hypothesis 1: Time will demonstrate a significant effect on PosP during repeated SSG training. Increases will exist in PosP across all game conditions.

Hypothesis 2: Competition Level will reveal a significant effect on PosP demonstrated during SSG's in club-level adolescent females. PosP scores will significantly increase from C3 to C1 to P.

1.3 Definitions

For a complete list of abbreviations, see Appendix 2, page 138. The following are common abbreviations and their definitions:

- MVPA – Moderate to vigorous physical activity, three to six METS
- HR_{max} – Heart Rate maximum, a measure of maximal exercise intensity
- PosP – Positive possession – completed passes + shots on goal
- CL – Competitive level, the developmental level of the player
- PP - Player position, the field position predominantly played

CHAPTER 2: Literature Review

CHAPTER 2: Literature review

2.1 Introduction

This literature review will start with a review of PA in children. Detail on the role of sport in the acquisition of MVPA will be described. SSG's in soccer training will then be examined. Nested in this review, factors that affect physiologic and technical (skill) outcomes are outlined. Finally, a review of instruments to be used in data acquisition will complete the literature review.

2.2 Physical Activity and Children

The development of national guidelines for PA has been an important step in the process of empowering American citizens to lead healthier lifestyles (U. S. Department of Health & Human Services, 2008). Their primary goal is to offer guidance to Americans on the importance of activity and healthy as a way to improve quality of life and reduce the risk of chronic disease. Establishing parameters, a minimum of 60 minutes of MVPA daily, for children and adolescents was an objective of the authoring committee (Table 1). Stratification of PA by outcomes (Cardiovascular, muscle, and bone strengthening) was further outlined.

Table 2.1. *Physical Activity recommendations for children and adolescents*

Daily Recommendation	**Children and adolescents should do 1 hour of PA daily**	
Physical Activity Type	***Definition***	***Recommendation***
Aerobic	Rhythmic movement of large muscle groups. Activities designed to increase cardiorespiratory fitness (running, dancing, bicycling, etc.)	60 minutes daily of moderate to vigorous activity, vigorous activity no less than three days per week
Muscle Strengthening	Unstructured (u) or structured (s) work that seeks to overload major muscle groups increasing their ability to generate force (Climbing trees (u), jumping (u), weight training (s), etc.)	Included within the 60 minutes of movement daily, no less than three distinct times per week
Bone Strengthening	Higher impact type movements that stimulate increase in bone density and strength (Running, jumping, sport play, etc.)	Included within the 60 minutes of movement daily, no less than three distinct times per week

Currently, the performance of American children in meeting PA recommendation is mixed (U. Ekelund, Tomkinson, & Armstrong, 2011; Li, Treuth, & Wang, 2010). Data from the Youth Risk Behavioral Surveillance System (YRBSS) database indicates that alarming trends continue to appear on the national landscape (Centers for Disease Control and Prevention, 2010). Physical activity in children and adolescents drops as kid's age. As children become adolescents in high school 23% will report no daily activity of any kind. Juxtaposed against those meeting the minimum requirement of 60 minutes daily, 18% of high school students, the number is a sobering. Less than 1 in 5 high school students meet the daily requirement of PA, while 1 in 4 do nothing active at all (Centers for Disease Control and Prevention, 2010).

2.3 Youth Sport Participation

Sport participation has long been a process by which American children receive PA. Due to the robust movement signature inherent in sport, opportunities exist to acquire PA in all three domains described by the committee. The sheer volume of participants creates a unique opportunity to provide PA for children and adolescents. In 2008, the National Council on Youth Sports (NCYS) estimated that 44 million youths participate in sport annually. When including duplicate registrations, the estimate climbs to 60.3 million participants. Stratification by sex indicates that boys register at a 2:1 ratio to girls. The average length of time in a given program is five years (National Council on Youth Sports, 2008). According to trend data, while sex representation has remained relatively consistent, the number of participants has risen from 32 million in 1997. While the data reported is market research, produced from participating organizations, the high level of participation is obvious. This level of participation is supported, having been previously documented by the United States Department of Education. Estimations from the National Center for Educational Statistics (1995) place youth sport participation at 48.3 million (Seefeldt & Ewing, 1997).

To further grasp the impact of youth sport, 2010 National Sporting Goods Association (NSGA) categorical data estimates the number of overall participants in specific types of sporting activity from individual to team based sport. Currently basketball is the leading team sport with 26.9 million, followed by soccer with 13.5 million, and baseball with 12.5 million to round out the top three team sports by participation (National Sporting Goods Association, 2011). The 2006 Federation of Football Associations (FIFA) census, *Big Count*, places U.S. association soccer participation at 3.9 million registered and over 20 million unregistered participants (Federation of International Football Associations, 2012).

In should be noted that gauging overall participation numbers for sport is difficult (Hedstrom & Gould, 2004). Much of the data available for use in establishing current prevalence estimates is generated through sports agencies. This calls into question measurement and selection biases. Opposing this bias, an argument for the validity of this data is the connection between market analysis and the prediction models used to facilitate financial success for stakeholders, large corporate retailers and entertainment providers. In effect this creates a reasonable “check and balance” on the accuracy of agency data.

2.4 Physical Activity in Youth Sport

Sport has been shown to have a beneficial effect on the accrual of PA in youth. Factors that have been investigated are reviewed below.

Sport days vs. non-sport days.

Wickel and Eisenmann (2007) examined the contribution of sport participation to daily PA. Further analysis was completed in documenting the percentage of daily PA attributable to recess and physical education. Using accelerometry, the researchers sampled boys between the ages of 6–12 years (n=119). The subjects were all recreational youth sport participants in basketball, flag football, and soccer. A nested group (n=36) were then randomly selected for an additional 24-hour assessment of non-sport days. Stratification into four levels of PA occurred. They were sedentary (PA_S), light (PA_L), moderate (PA_M) and vigorous (PA_V). Results indicated that on days with sport participation, significant increases (p<.05) in PA_M, PA_V, and MVPA occurred. Furthermore, on sport days, significantly less time was spent in PA_S than on non-sport days. Sport provided a more robust environment for activity while also limiting time being sedentary. Differences were also present between sports. Soccer (HIITS) provided

greater amounts of PA_V than flag football (non-HIITS). Basketball (HIITS) provided more PA_M than soccer and more PA_L than flag football.

Between Sports.

Differences exist between sports ((Wickel & Eisenmann, 2007); Katzmarzyk, Walker and Malina,(2001). Katzmarzyk, Walker and Malina (2001) sought to document the amount and quality of PA through direct notational observation of youth sports activities in recreational athletes, boys and girls ages 11–14 years. They found that there were no significant sex differences ($p<.05$) in the quantity and quality of PA during their participation based on sex. Conversely, differences between sports did appear. Outdoor soccer appeared to present the most robust activity opportunity, providing less sitting time than in-line hockey and ice hockey. Indoor soccer provided less sitting time than basketball, in-line hockey, and ice hockey ($p<.05$). Outdoor soccer also had the greatest time spent jogging and sprinting. This is in support of previously mentioned trials, indicating soccer's efficacy to produce MVPA. The relative time spent in PA_S and PA_L was noteworthy, 52% of the time being spent in sedentary or light activity.

Leek et al. (2011) examined the PA patterns and intensities at youth sports practice, comparing youth soccer and baseball/softball practices. As hypothesized, soccer practice contributed to more MVPA than either baseball or softball, 17 minutes of PA_V. In terms of absolute contribution to national guidelines, less than 25% of all participants received the daily recommendation of MVPA during their practice session. Additionally, as players aged, their MVPA minutes decreased. Suggestions for this reduction included increased time on skill development tasks that require less movement than other, more active practice scenarios (Leek et al., 2011).

The selection of these two sports were based in the participation rates in the U.S. as well as the hypothesized difference in MVPA values the two sports would generate,

soccer being higher. Using a cross sectional design of participants in community sport leagues in San Diego County, California, accelerometer data was taken to quantify activity patterns in both sports. Participants included both boys and girls, ages 7–14 years. Twenty-nine teams in total were examined, 14 soccer and 15 baseball/softball. These were further stratified into two groups, 7–10 and 11–14 year olds. Population matching occurred in sex distribution and socio-economic status. As is the case in all field work, there are uncontrollable factors. These included the relative length of season (10/11 months – soccer, 5 months – baseball/softball) and cost to participate ($500 – soccer, $70 - $85 – baseball/softball). Description of these fees were not provided, leaving open the possibility of additional team fees that may skew sample recruitment by increasing total cost to the participant. Accelerometer data was stratified into four intensities, PA_S, PA_L, PA_M, PA_V. The outcome variable of interest was total minutes spent in each category. Results indicated the following:

- Fewer than 25% of the youth examined received the federal guideline of 60 minutes MVPA
- Soccer provided an additional 17 minutes of PA_V
- Soccer participants ages 7–10 were the most active
- Twenty-four percent of 7–10 year old soccer players net the 60-minute guideline, that number drops to less than 10% in the 11 – 14 year old category

Within youth soccer games.

Sacheck et al. (2011) sought to document the percentage of daily PA that participation in a recreational soccer league provided during game play. Included in this analysis was a look at the role of BMI, comparing normal weight (5th–85th percentile) against overweight (85th–95th percentile) and obese (>95th percentile) participants. Consistent with other findings the recommended daily dose of MVPA is only partially

accounted for through sport participation, approximately 25%. Alarming within this data is the amount of time spent in sedentary activity when compared to the other activity levels (Table 4). Sex did not have an effect, except in PA_M, where girls spent more time than boys.

Table 2.2. *Physical Activity levels by sex, 50min youth soccer match*

	Males		**Females**	
	Time		**Time**	
Intensity	*Min*	*%*	*Min*	*%*
PA_S	25.9 (4.5)	50.0 (8.6)	25.1 (6.2)	48.4 (11.1)
PA_L	10.2 (3.7)	19.7 (6.6)	9.2 (2.6)	17.8 (5.1)
PA_M	11.9 (3.0)*	23.0 (5.6)**	13.7 (3.7)	26.6 (7.4)
PA_V	3.9 (2.7)	7.4 (5.0)	3.7 (2.3)	7.2 (4.5)
MVPA	15.8 (4.4)	30.4 (8.0)	17.5 (4.7)	33.8 (9.5)

Note: Adapted from Sacheck et al. (2011)*; Means (SD);* $p < 0.05$, ** $p < 0.01$, vs. females*

A child's weight status also significantly impacted the time spent in each level. Overweight and obese participants spent more time being sedentary (PA_S), with less PA_M, PA_V and MVPA (p<.05). Based on the already limited time spent in MVPA through the sporting activity, this result is provocative. While the absolute amount of MVPA experienced by normal weight children was 3.0 minutes (mean). In a 50-minute match, this represents 6% less time than normal weight participants. This is further compounded by the same relationship with PA_S, where overweight / obese kids spent 6.2% more time.

Table 2.3. *Physical Activity levels by BMI, 50-min youth soccer match*

	Normal Weight	**Overweight or Obese**
Intensity	*Min*	*Min*
PA_S	24.7 (5.9)	27.8 (4.3)*
PA_L	9.5 (3.2)	9.7 (2.4)
PA_M	13.5 (3.7)	11.8 (2.6)*
PA_V	4.1 (2.6)	2.8 (1.4)**
MVPA	17.6 (4.8)	14.6 (3.1)**

Note: Adapted from Sacheck et al. (2011)*; Means (SD);* $p < 0.05$, ** $p < 0.01$, vs. normal weight*

Strengths and Limitations.

As with any cross sectional approach, causal factors are challenging to determine. The use of youth programs is a move away from sport performance paradigms, placing an emphasis on sport as a PA intervention. Sacheck et al. (2011) included comparisons of energy intake (snacks) and EE estimates above basal metabolic rate (effect of game). This is a provocative, especially in light of cultural patterns of snacking after youth sports (Stovitz, 2010). Leek et al. (2011) addressed an important question in comparing two popular sports played in the U.S. Historically speaking, the initial approach taken to documenting PA quantity and quality by Katzmarzyk, Walker and Malina (2001) was novel in its attempt to compare multiple youth sports by PA patterns.

In this era of technological advancement, the lack of more sophisticated measurement tools is a limitation. The use of accelerometers to directly measure movement is accepted practice. Accelerometry though lacks the ability to measure physiologic outcomes associated with PA. More sophisticated time and motion tracking

systems, such as advanced video recording / tracking systems, are available but may lack feasibility due to equipment requirements and cost. Finding cost effective methods to integrate these technologies into PA field research is the next step in increasing methodological accuracy. While Katzmarzyk, Walker and Malina (2001) did address a novel question; the approach to data collection, observational notation, may lack reliability with high levels of inter-tester variability possible. Leek et al. (2011) also provided a novel approach to addressing the question of youth sport and PA quantity and quality.

Sport creates different PA patterns depending on the movement characteristics inherent to the sport. As a whole, sport seems to provide only a partial dose of daily recommendations for PA; however, the lack of sport significantly decreases the level of MVPA found in a child's day, replacing it with PA_S. This is demonstrative of the important role sport participation can play in the accumulation of MVPA in children. A child's current weight status and sex may mediate the relationship, although sex seems to play a less important role (Leek et al., 2011).

Research in the future should include a more detailed account of the quantity and quality of PA in youth sport practice. Factors that either increase or decrease PA during a training session need to be identified. Stratification of practice time using time on task analysis captured with time and motion technology (Motion Analysis TM), would offer insight into the relationship between instructional techniques and PA outcomes. Continued analysis of factors that may increase or decrease PA in a sport environment is necessary to further empower stakeholders to make decisions that can benefit end users.

Table 2.4. *Physical Activity quantity and quality in youth sport*

Author	Aim	Dependent Variable	Design	Subjects	Results* (All listed are minimum p<.05)
Katzmarzyk et al. (2001)	To document the amount of time spent at various levels of PA during youth sports events	Time and Levels of PA	Cross sectional Direct Observation, Notational	Boys and girls; Youth sport participants; *n*=79 (b=21, g=58) (11– 14 yrs.)	**Boys, differences between all sports** Sitting, standing, walking, jogging, sprinting
					Girls, differences between all sports Sitting, jogging, sprinting
					Total, differences between all sports Sitting, standing, walking, jogging, sprinting
Leek et al. (2011)	To document the amount of PA during organized youth soccer and baseball/softball (b/s) practice	Time and levels of PA (Sedentary, Light, Moderate, Vigorous) Contribution to daily PA recommendation	Cross sectional Accelerometer	Boys and girls; Youth sport participants, *n*=200 (14 soccer, 15 b/s team)	**MVPA, Total** Soccer > b/s; boys > girls 7–10 yrs. > 11–14 yrs.
					MVPA, Percentage of Practice Soccer > b/s; boys > girls 7–10 yrs. > 11–14 yrs.
					PA Level by Sport Soccer < b/s, light activity (percent of total) Soccer < b/s, moderate activity (percent of total) Soccer > b/s, vigorous activity (total minutes, percent of total)

Author	Aim	Dependent Variable	Design	Subjects	Results* (All listed are minimum p<.05)
Sacheck et al. (2011)	To document the amount of PA during 50-min. soccer match Estimate energy usage	Time and levels of PA (Sedentary, Light, Moderate, Vigorous) Energy expenditure	Cross sectional Accelerometer, Dietary Questionnaire	Boys and girls, Youth sport participants, *n*=111 (boys=36, girls=75) (9 yrs.)	Boys > girls, moderate activity (total minutes, percent of total) Normal weight < Overweight/Obese, sedentary Normal weight > Overweight/Obese, moderate, vigorous, MVPA
Wickel & Eisenmann (2007)	To document the contribution of organized sport to daily PA (Basketball [BB], Flag Football [FF], Soccer [S]) To document the contribution of recess (Rc) and physical education (PE) to daily PA	Time and levels of PA (Sedentary, Light, Moderate, Vigorous)	Cross sectional Accelerometer 24 hour collection on sport day, nested group additional non-sport day	Boys, youth recreational sport participants *n*=119 (6–12 yrs.), Nested group *n*=36	**Anthropometrics** Age: S<BB=FF Mass: S<BB=FF **Intensity, between sports** PA_L: BB>FF PA_M: BB>S PA_V: S>FF MVPA: BB>FF **Sport (S) vs. Non-sport (NS)** PA_S: NS>S PA_M: S>NS PA_V: S>NS MVPA S>NS

Note: *For abbreviations see Appendix 2*

2.5 SSG's in Soccer

Soccer has been demonstrated to offer greater levels PA than other sports. In soccer training, SSG's are used routinely to match game characteristics during training. These same characteristics may have a positive impact on health. SSG's in soccer have reliably demonstrated positive effects on health indices. There is evidence of the efficacious training and health effect that participation in soccer (game play) can elicit (J. Bangsbo, Mohr, & Krustrup, 2006; J. Bangsbo, 1994; J. Bangsbo et al., 2010; A. Dellal, Hill-Haas, Lago Penas, & Chamari, 2011; S. V. Hill-Haas et al., 2009; S. V. Hill-Haas, Coutts, Rowsell, & Dawson, 2009; Krustrup, Christensen et al., 2010; Owen, Wong, McKenna, & Dellal, 2011).

Exhibiting consistent steady state stress with non-linear periods of activity at high intensity, soccer provides strong stimulus for physiologic adaptation. It is this quality that suggests efficacy as a public health intervention. Physiologic and time and motion analysis of soccer training sessions support the training stimulus provided on aerobic, anaerobic, alactic, and ATP-PC systems in both adults and youth (Casamichana & Castellano, 2010; Gabbett & Mulvey, 2008; S. V. Hill-Haas et al., 2009). These effects are observed in cardiovascular fitness, metabolic fitness and musculoskeletal fitness outcomes in both intervention and observational longitudinal studies. Such outcomes are beneficial from a public health perspective. As obesity prevalence and associated comorbidities rise in the United States the isolation of efficacious interventions is of great interest to researchers and policy makers (Kranz, Mahood, & Wagstaff, 2007; Ogden & Carroll, 2010a; Ogden & Carroll, 2010b; Physical Activity Guidelines Advisory Committee, 2008; Yang, Telama, Hirvensalo, Viikari, & Raitakari, 2009).

In a recent executive summary of the health and fitness benefits of participation in SSG's Krustup, et.al (2010) concluded that the substantial health and fitness benefit

was realized following consistent play (Krustrup, Dvorak et al., 2010). Summarizing the effects of a series of randomized controlled trials conducted through the Department of Exercise and Sport Science, University of Copenhagen, Denmark, Krustup determined that SSG training provided health outcomes equal to, and often greater than steady state endurance running (E) in untrained men and women. Both modalities demonstrated significant, positive outcomes to inactive controls in eliciting physiologic and phenotypic adaptations (p<05). The strong outcomes associated with soccer participation in SSG's are a positive finding in the fight against non-communicable (NCD) and chronic disease (CD). An analysis of these trials follows with a summary of findings presented in Table 5.

Physical Performance Adaptations.

Performance adaptations were consistently recognized through the use of soccer as a fitness training modality (J. Bangsbo et al., 2010; Krustrup, Christensen et al., 2010). Compared to E, several outcomes generated through soccer training were equivalent or greater (p<05). Greater increases in peak sprint velocity, yo-yo intermittent endurance test and continuous endurance were realized. Improvements in jump height and power were also seen in women. These results were also demonstrated during a yearlong follow-up study where reductions in training volume (2.4x/wk./12wk to 1.3x/wk./52wk.) did not result in appreciable decline of performance (Randers et al., 2010). Included in the results of this trial were significant improvements (p<.05) in plantar jump force (N/kg), work (J/kg) and power (Watt/kg) outputs, balance, 30-m sprint time and counter movement jump not previously recorded

Cross-sectional research supports the positive effect of lifelong soccer participation in the rate of force development (RFD) and postural balance, finding no difference between football trained elderly men (M=69.6yrs, SEE=1.4yrs) when compared to untrained young men (M=32.4, SEE=0.9 yrs.) (Sundstrup et al., 2010). The

implication of such lifelong participation against the results of these trials is strong evidence for the continued use of this type of sport to elicit positive health outcomes across the lifespan.

Musculoskeletal Adaptations.

Muscle adaptations include the greater development of lean mass and losses in fat mass (Knoepfli-Lenzin et al., 2010; Krustrup et al., 2010). Strength was also increased in hamstring and quadriceps with a concurrent increase quadriceps cross sectional size. Muscular fiber type and distribution were affected demonstrating movement away from Type IIx (Krustrup, Christensen et al., 2010). Important in these findings was increased bone mineral density and bone mineral content in the group that maintained soccer participation for the year (Randers et al., 2010). Soccer consistently provided a stimulus that was realized in significant adaptation similar to or greater than E ($p<.05$).

Cardiovascular, Body Composition and Health Improvements.

The most compelling case for soccer may be seen in cardiovascular and body composition outcomes. Improvements in HR_{rest}, HR_{var}, HR_{pace}, VO_{2max}, relative $VO_{2max,}$ - $O_{2uptake}$, citrate synthase concentrations, body composition, and blood profiles clearly outpaced that of E (J. Bangsbo et al., 2010; Knoepfli-Lenzin et al., 2010; Krustrup et al., 2010; Randers et al., 2010). Increases in capillary profusion were also recognized.

While SSG and E did establish significant findings within-group in several of these outcomes, SSG routinely revealed significant increases between-group, indicating a increases from pre-test to post-test that were significantly greater than E ($p<.05$). This wide-ranging intensity is evidenced in differences between the two modalities found in time spent above 90% of HR_{max} (Krustrup, Christensen et al., 2010). The greater amount of time above this threshold in soccer training may indicate a greater breadth of training

stimulus. Soccer provides a greater emphasis on random, interval patterning as opposed to a steady state stimulus.

Strengths of this research include the examination of soccer as a health intervention. Previous research into soccer focuses on soccer as a performance sport. The use of randomized controlled trials (RCT) is preferable. The reliability of methods between the trials and the reproducibility in outcomes was also noteworthy.

Limitations include the sample pool and homogeneity of the sample. Soccer is culturally accepted in Northern Europe. This creates questions around the ability to generalize results to nations with less of a cultural sense of the sport. The addition of qualitative data may also be appropriate. A mixed methods approach may offer insight which positivistic, quantitative research cannot. Understanding and integrating the psychological, cultural and social factors into the model creates a more robust picture.

Table 2.5. *Soccer vs. Steady State Running, performance outcomes*

Author	Aim	Dependent Variable	Design	Subjects	Results* (All listed are sig. p<.05) (*sig. at 4/wk.)
Bangsbo (2010)	Effects of 16 wk. soccer (S) vs. running (E) vs. control (C)	Performance & Muscle Adaptations	RCT, 1hr, 2x/wk., inactive controls SSG vs. SS run	Women, untrained 19-47yrs; S=21, R=18, C=14	S: VO_{2max}, YYIET2, SV_{peak}, CS*, $Cap_{density}$ E: VO_{2max}, YYIET2, CS*
Knoepfli-Lenzin (2010)	Effects of 12 wk. soccer vs. running vs. control	Cardiovascular Risk Profile	RCT, 1hr, 2.4x/wk., inactive controls SSG vs. SS run	Men, active, mild hyper-tension, 25-45yrs, S=15, R=15, C=17	S: HR_{rest}, HR_{var}, BP, BMI, WC, W/H, FM, BF%, $CHOL_T$, $CHOL_T$/HDL, VO_{2max}, $VO_{2maxRel}$, V_{max}, YYIET2 E: HR_{rest}, HR_{var}, BP, BMI, FM, $CHOL_T$/HDL, VO_{2max}, $VO_{2maxRel}$, V_{max}, YYIET2

Author	Aim	Dependent Variable	Design	Subjects	Results* (All listed are sig. p<.05) (*sig. at 4/wk.)
P. Krustup et al. (2010)	Effects of 12 wk. soccer vs. running vs. control	Performance & Muscle Adaptations	RCT, 1hr, 2-3x/wk., inactive controls SSG vs. SS run	Men, untrained, 20-43yrs, S=14, R=13, C=11	S: CS, $Cap_{density}$, $Fiber_{mean}$, $Fiber_{dist}$, HR_{pace}, $VO2_{peak}$, $O_{2uptake}$, RER_{pace} E: $Cap_{density}$, HR_{pace}, VO_{2peak}, $O_{2uptake}$
P. Krustup (2010)	Effects of 16 wk. soccer vs. running vs. control	Cardiovascular Risk Profile	RCT, 1hr, 2x/wk. inactive controls SSG vs. SS run	Women, untrained, 19-47yrs; S=25, R=25, C=15	S: BP_{sys}, BP_{dias}, $O_{2uptake}$, FM, LDL/HDL E: BP_{sys}, $O_{2uptake}$, FM
P. Krustup et.al (2010)	Effects of 12 wk. soccer vs. running vs. control	Cardiovascular Risk Profile	RCT, 1hr, 2-3x/wk., inactive controls SSG vs. SS run	Men, untrained, 20-43yrs, S=13, R=12, C=11	S: $TrTime_{>90\%HR}$, BP_{sys}, BP_{dias}, LM, FM, LDL, $Cap_{density}$, E: $O_{2uptake}$, BP_{sys}, BP_{dias}, FM, $Cap_{density}$

Author	Aim	Dependent Variable	Design	Subjects	Results* (All listed are sig. p<.05) (*sig. at 4/wk.)
Randers et.al (2010)	Effects of 12 wk., 1yr follow-up soccer vs. control	Cardiovascular Risk Profile Performance & Muscle Adaptations 1yr follow	RCT, 1hr, 2.4x/wk./12wk.; 1.3x/wk./52wk.; inactive controls SSG vs. SS run	Men, untrained, 20-43yrs, S=13, R=12, C=7	S: FM, BF%, LM_{quad}, LM_{body}, BMD_{legs}, BMC_{legs}, $O_{2uptake}$, V_{peak}, HR_{pace}, HR_{rest}, BP_{sys}, $CHOL_T$, Gly_{mus}, CS, $Fiber_{mean}$, $Plantar_f$, $Plantar_w$, $Plantar_p$, Con_w, Bal_r, Bal_l, YYIET2, ITT, $30m_{sprint}$, CMJ

SSG's Moderating Factors

In SSG's, consideration has been given to the effect of specific factors on physiologic, technical and tactical outcomes (S. V. Hill-Haas et al., 2011). The advent of techniques to measure on-field performance (e.g. heart rate/physiologic monitors and video analysis) has led to increased interest in quantifying these training modalities. In training sessions, the unique characteristics of an SSG may include specific conditions that emphasize one component of play over another.

Comparative, cross sectional trials specific to SSG training have focused on factors that affect physiologic and skill outcomes found during training. Research into factors that affect SSG's has demonstrated that manipulation of variables of a game can impact performance and learning environments and outcomes such as shooting, passing, and dribbling (S. V. Hill-Haas et al., 2011). These manipulations create unique tactical situations while producing specific physiologic stresses explicit to match play. In terms of utility, this can provide coaches the opportunity to maximize time on task while the smaller numbers of players afford more repetitions per player than are seen in the larger, full-sized game format. This research on SSG's provides insight into variables that affect desired outcomes (Table 6).

Field Size.

Casamichana and Castellano (2010) reported differences found when altering the size of the playing surface. Changes in the relative playing area had significant effect on effective playing time, both physical and physiologic outcomes, technical actions, and the rate of perceived exertion (RPE). The increase in relative playing area increased the work rate and load on players while decreasing the technical actions, both performed and successful attempts completed.

Playing level and rule changes.

In an examination of playing level and rule changes, Dellal et al. (2011) found that professional players were different than amateur players in several outcomes of interest. These included differences in time and motion, technical actions, physiologic, and RPE outcomes. Professional players consistently demonstrated less physiologic stress, lower RPE, greater distance covered, both total and at medium / high intensity and greater technical ability. The appearances of differences were consistent through rule changes defining the number of ball contacts allowable per player.

Continuous and Interval play, Player Numbers.

Hill-Hass looked at the effect of both continuous vs. interval (S. V. Hill-Haas et al., 2009) and player numbers (S. V. Hill-Haas, Dawson, Coutts, & Rowsell, 2009) in producing differences in time and motion, physiologic and RPE outcomes. Continuous play (1x24m) was shown to elicit a greater percentage of HR_{max} ($\%HR_{max}$) while interval (4 x 6m, 1.5m passive rest) resulted in greater amounts of medium and high intensity running and number of repeated sprints. The same research group also investigated the effect of changing player numbers while maintaining the relative playing area. This also had significant effects on time and motion, physiologic, and RPE outcomes. Using 2v2, 4v4 and 6v6 formats andmore players appeared to reduce the total high intensity work, reduce the HR response and reduce the RPE. The implication of these results is important in the design of training sessions seeking specific physiologic adaptations, as well as technical and tactical mastery of the sport.

The results supported the work done by Rampinini et al. (2007). This research isolated player numbers (3v3, 4v4, 5v5, 6v6), field dimensions (small, medium and large) and coach encouragement (with and without). Increases in player numbers were shown to reduce $\%HR_{max}$, BLa, and RPE with significant differences between 3 and 4 players

and 5 and 6 players. Increasing the field dimension had the effect of increasing $\%HR_{max}$ and BLa only from medium to large while RPE was affected when moving from a small field to medium only. Coach encouragement also made a significant difference as each outcome was positively influenced.

Table 2.6. *Changes to Game Conditions, performance outcomes*

Author	Aim	Dependent Variable	Design	Subjects	Results* (All listed are minimum sig. p<.05)
Casamichana & Castellano (2010) *	To describe the effect of increasing pitch size in SSG's	Effective playing time (EP) Physical (P) Physiologic (Ph) Motor skill (Tech) Rate of Perceived Exertion (RPE)	Comparative, Cross sectional SSG at three sizes of pitch (SSG_L, SSG_M, SSG_S) with constant team size (5v5+GK) SSG_L = 272.8 m/*n* SSG_M = 175 m/*n* SSG_S = 73.6 m/*n*	Boys; youth players; *n*=10 (15 yrs.)	**EP** [b,c] **P**: $Dist_T$ [a,b,c], $Dist_{Mn}$ [a,b,c], Spd_M [b], $Dist_L$ [b], $Dist_M$ [b,c], $Dist_H$ [b], W:R [b], Spr_F [b] **Ph**: $\%HR_{max}$ [b,c], $\%HR_{mean}$ [b,c], $>90\%HR_{max}$ [b,c] **Tech:** Inter [d], Con_D [d,f], Con_S [e], Clr [d,e], $Ball_P$ [d,e] **RPE** [b,c]

Author	**Aim**	**Dependent Variable**	**Design**	**Subjects**	**Results*** **(All listed are minimum sig. p<.05)**		
Dellal et al. (2011) **	To describe the effects of playing level (professional vs. amateur) and rule changes in SSG's	Time/motion characteristics (TM) Technical actions (Tech) Physiologic (Ph) Rate of Perceived Exertion (RPE)	Comparative, Cross sectional 3 player ratios (2v2, 3v3, 4v4); 3 touch conditions (1-touch, 2-touch, free-play)	French male soccer players, *n*=40 Professional *n*=20 (27.4 yrs) Amateur, 4th division *n*=20 (26.3 yrs.)	**2v2** **TM**: $Dist_T^{abc}$ $Dist_S^{abc}$ $\%Dist_S^{abc}$ $Dist_{TH}^{abc}$ SJ^{abc} CMJ^{abc} **Tech**: $Duels^{abc}$ $Duels_M^{abc}$ $\%Pass_S^{a}$ $Balls_L^{def}$ $Balls_{LM}^{def}$ $Poss_{\#}^{def}$ **Ph**: BLa^{def} **RPE**^{def}	**3v3** **TM**: $Dist_T^{abc}$ $Dist_S^{abc}$ $\%Dist_S^{ac}$ $Dist_{TH}^{abc}$ $\%Dist_{TH}^{ac}$ SJ^{abc} CMJ^{abc} **Tech**: $Duels^{abc}$ $Duels_M^{abc}$ $\%Pass_S^{a}$ $Balls_L^{def}$ $Balls_{LM}^{def}$ $Poss_{\#}^{abc}$ **Ph**: BLa^{def} HR_{max}^{d} $\%HR_{Res}^{d}$ **RPE**^{df}	**4v4** **TM**: $Dist_T^{abc}$ $Dist_S^{abc}$ $\%Dist_S^{ab}$ $Dist_{TH}^{a}$ SJ^{abc} CMJ^{abc} **Tech**: $Duels^{ac}$ $Duels_M^{c}$ $\%Pass_S^{ac}$ $Balls_L^{def}$ $Balls_{LM}^{def}$ **Ph**: BLa^{def} **RPE**^{def}

Author	Aim	Dependent Variable	Design	Subjects	Results* (All listed are minimum sig. p<.05)	
Hill-Haas et al. (2009)	To describe the effect of continuous vs. intermittent time sequencing in SSG's	Physiologic Time/motion characteristics	Comparative, Cross sectional 24 minutes of SSG play 1 continuous bout (Con) vs. 4 x 6 min. (Int)	Boys, Youth competitive soccer players, *n*=16 (16 yrs.)	**Continuous** %HRmax RPE	**Intermittent** $Dist_M$ $Dist_H$ $Sprint_R$ $Sprint_T$ $Sprint_{Time}$
Hill-Haas et al.(2009)	To describe effect of player number in SSG's	Time/motion characteristics (TM) Physiologic (Ph) Rate of Perceived Exertion (RPE)	Comparative, Cross sectional 3 player ratios (2v2, 4v4, 6v6) Same relative pitch area per player	Boys, Youth competitive soccer players, *n*=16 (16 yrs.)	**TM**: $Dist_L^{a}$ $Sprint_{Time}^{a}$ $Sprint_{TimeMax}^{abc}$ $Sprint_D^{ab}$ $Sprint_{DMax}^{abc}$ $Sprint_{TimeB}^{a}$ **Ph**: $\%HR_{max}^{abc}$ $<75\%HR_{max}^{b}$ $75 – 84\%HR_{max}^{abc}$ $80 – 89\%HR_{max}^{ab}$ $>90\%HR_{max}^{abc}$ BLa^{ab} **RPE**^{abc}	

Author	Aim	Dependent Variable	Design	Subjects	Results* (All listed are minimum sig. p<.05)
Rampinini et al. (2007b)	To describe the effect of player number (PN), field dimension (FD) and coach encouragement (CE) in SSG's	Physiologic Rate of Perceived Exertion (RPE)	Comparative, Cross sectional 4 player ratios (3v3, 4v4, 5v5, 6v6) 3 relative playing areas (small, medium, large) With/out coach encouragement	Boys, Youth competitive soccer players, *n*=16 (16 yrs.)	**PN** HR_{max} 3>4=5>6 BLa 3>4=5>6 RPE 3>4=5>6
					FD HR_{max} S=M<L BLa S=M<L RPE S<M=L
					CE HR_{max} W>WO BLa W>WO RPE W>WO

*Note: * [a]SSG_L>SSG_M; [b]SSG_L>SSG_S; [c]SSG_M>SSG_S; [d]SSG_S>SSG_L; [e]SSG_S>SSG_M; [f]SSG_M>SSG_L*

*** [a] Pro >Amt, 1-touch; [b] Pro >Amt 2-touch; [c] Pro >Amt free; [d]Amt. >Pro. 1-touch; [e]Amt. > Pro. 2-touch; [f] Amt. >Pro free.*

 # [a]2v2>4v4, [b]2v2>6v6, [c]4v4>6v6

Strengths and Limitations.

Strengths of these trials include the wide variety of factors that have been examined. Using maximal aerobic field-tests to control for training effects seen over the season length is a strong approach reducing potential confounding created from outside training (Rampinini et al., 2007b). The reporting of effect sizes occurred only in one paper (Dellal et al., 2011). The effect sizes between professional and amateur players were often large (i.e. .5 - .7) when player numbers were small (i.e. 2v2) becoming smaller as player numbers grew (i.e. .1 - .3). Such results are indicative of the effect of playing level. As game conditions became difficult (small numbers) more skilled players handled the demand with greater ease, creating a wide gap in physiologic outcomes generated during play. The inclusion of time and motion analysis is also a strong addition to physiologic research in sport. Outcomes are a sensitive to a number of influences. The quantification of time and motion characteristics offers another level of insight into the work profile of the subject, reducing an issue in applying results derived through linear analysis of means and standard deviations. The multi-factorial design is also strength. Coaches routinely combine factors or game conditions to drive a particular result.

Limitations in any sport research setting include challenges to construct and external validity. The level of external validity in the investigation of SSG's is greater than that of laboratory testing, as are field tests (they more closely resemble the playing environment). However, field tests are limited when compared to laboratory conditions for deriving actual peak values. Also challenging in comparative research is the lack of randomization. However, the use of a single group to perform in two unique environments does create a matching approach to the methodology. Generalizing

results is also challenging from these trials. The use of professional and skilled amateurs may not generalize to club-level players, a vast majority of participants.

2.6 Instruments

In current free-living trials (i.e. sport practice), two measurement methods dominate the literature, HR monitoring and accelerometry. With the advent of motion analysis techniques, technology continues to be used to describe unique phenomena occurring in sport.

Heart Rate.

HR monitoring is often used in the evaluation on physiologic outcomes in sport (Casamichana & Castellano, 2010; Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2009; Esposito et al., 2004; Foster, 2010; Owen et al., 2011). Heart rate is considered to be an omnibus measure of physiologic systemic stress. This is true under steady state conditions of linear oxygen uptake; however, in measuring physiologic stress associated with acyclic movement, HR monitoring may have limitations. One limitation is bias introduced from extrinsic factors that may lead to the overestimation of work in non-steady state environments through increases in HR not related to oxygen uptake (LaMonte, Ainsworth, & Reis, 2006). HR values have been shown to be sensitive to several factors that may bias their accuracy in predicting intensity of movement (i.e. heat, nutrition, rest). Without individual HR–VO_2 curves, developed through gas exchange testing, accuracy in estimating work is equivocal. HR can also be sensitive to daily individual variability. With this said, HR monitoring is a feasible method of measuring physiologic stress readily accepted by both the exercise physiology and coaching communities (Esposito et al., 2004). In an effort to validate this practice, Esposito et al. (2004) compared the work output between soccer specific field tests and laboratory measures using HR as a metric to predict oxygen utilization and found significant relationships between both lab based and field based HR-VO_2 curves (r=.98

and r=.99, p<.001, respectively). Further analysis demonstrated that there was no significant difference between HR achieved during field play and laboratory measurements (p=.05*).*This finding is supportive of HR as an omnibus measure of physiologic output during soccer training, even in the acyclic environments found in match play.

Accelerometers.

PA measured through accelerometry does not demonstrate the same sensitivity to environmental factors (McClain & Tudor-Locke, 2009; Troiano et al., 2008). Accelerometry offers flexibility in the measure of PA. (LaMonte et al., 2006; Sacheck et al., 2011). Widely used in field-based research, the triaxial accelerometer has been thoroughly vetted as a valid instrument for the measurement of PA in children and adults (McClain & Tudor-Locke, 2009). Janz (1994) compared the ActiGraph 7164 to the criterion measure of HR, measured through telemetry. Validity correlation coefficients ranged from r = .50 - .74. This moderate to high value combined with reported comfort and ease of wearing the monitor support its validity and utility in field use. Further validation research comparing the 7164 to a newer version, the GT1M (employed in this trial) indicated high levels of agreement between the two units in classifying MET intensity categories (96.1%) (Kozey, Staudenmayer, Troiano, & Freedson, 2010). Differences were evident in step counts (p<.05), however, when converted to intensity levels, meaningful differences did not result.

Motion Analysis.

Video based time and motion analysis has been used extensively in notational evaluation and quantifications of movement in sport (C. Carling, Bloomfield, Nelsen, & Reilly, 2008; Casamichana & Castellano, 2010; Figueroa, 2006; Gabbett & Mulvey, 2008; Harley et al., 2010; S. V. Hill-Haas et al., 2009; S. V. Hill-Haas, Dawson et al.,

2009). In this trial, the use of video recordings allows for the notational examination of repeated skills (shooting, passing, and dribbling), increasing ecologic validity through the use of video recording devices and state of the art software (e.g. Mambo Suites and Tango Online, Match Analysis, Emeryville, CA)(C. Carling, Williams, & Reilly, 2005). The group outsourced for the cataloging of the video recording, Match Analysis™, is the provider of game cataloging for Major League Soccer, the Mexican Football Federation and several national team programs. A complete list of clients can be found on their website, www.matchanlysis.com. Similar to the use of industry driven market research, validity and reliability trials of notational cataloguing do not exist for this group, however their service to the highest level of the sport serves as a form of ecologic validity within the soccer industry.

2.7 Summary

Physical activityis a high priority within the national discourse on health (Pate & O'Neill, 2011). Researchers in public health and sport have continued efforts to examine the impact of movement gained through sporting activity. Whether it is from a sports performance paradigm or that of public health, sport participation has been shown to be an efficacious component of a preventive health approach at both group and individual levels.

Soccer participation specifically has shown promise as an intervention. The movement signature of the sport requires consistent steady state aerobic output with random, acyclic periods of high intensity. Small sided games SSG's have been shown to be equal or greater than steady state aerobic exercise in several physiologic outcomes. Soccer participation has also shown the ability to generate greater levels of movement, from low to vigorous in both youth and adults. However, the absolute effect for youth is equivocal. Research directly measuring the quantity and quality of PA in youth sport has

shown that while contributing to a child's overall daily MVPA recommendation (60-minutes MVPA daily), participation alone does not guarantee meeting this goal. There appear to be large periods of the practice session spent in either PA_S or PA_L. The question of efficacy is further clouded by questions around generalizing data generated with elite performers to club-level participants, and adults to youth. Additionally, training outcomes are modality dependent, further complicating training designs for coaches. SSG research has demonstrated that a number of factors, such as playing level, number of players, rule conditions, influence outcomes (Table 3). Regardless, SSG's have consistently demonstrated the ability to create environments that support the accrual of MVPA and elicit positive performance and health outcomes.

Further analysis is needed to describe factors that increase or decrease PA outcomes in youth sport (Pate & O'Neill, 2011). Recent research indicates that soccer participation has a positive effect on the accrual MVPA and PA_V when compared to other sports. That is an important finding when examined against the high number of participants nationally. However, there is a lack of analysis describing the unique parameters that either increase or decrease PA during a training session with club-level, adolescent players. Such analysis should start with the relationship of SSG's to the accrual of MVPA. SSG's have been shown to create a more robust training environment and is widely used in training youth athletes. In lieu of data that suggests low levels of MVPA, juxtaposed against high levels of PA_S at youth sport practice, investigation of this factor is worthy. Such research will build upon the description of the role of youth sport in the accrual of daily MVPA recommendations (P. T. Katzmarzyk et al., 2001; Leek et al., 2011; Sacheck et al., 2011).

At both an individual and group level, increasing the effectiveness of logistically feasible, high impact programs that promote PA such as youth sport is prudent. Sports

play a positive role in offering physically active environments to children. Increasing the ability to provide daily dosages of MVPA, while meeting the performance requirements of sport is worthy of investigation. A more thorough description of the relationship between SSG's and MVPA outcomes will further this effort.

Continued exploration of the club-level, adolescent player is called for due to the vast numbers they represent as both an absolute number and a percentage of participants. In support of these potential differences, Castagna (2003) found that competitive Italian high school students were able to only reach a maximal oxygen uptake of 53% in a SSG format that used small courts. This is in contrast to the results listed. Factors described that may have reduced the work rate in this trial were the small court, rules employed and low coach motivation to the group. While these findings are in alignment with those found in previous research with similar conditions, the lower work rate calls into question the application of the results to club-level, adolescent participants.

The U.S. has approximately four-million participants in association soccer, however more than 20-million are estimated to participate without any affiliation to an association (Federation of International Football Associations, 2012). Applying results generated with skilled participants to those whose goals may be more social is a central question in framing sport as a public health intervention. While the work of Krustrup et al. (2010) has demonstrated the efficacy of SSG's in reducing multiple risk factors for untrained adult men and women, little research has been done on club-level, adolescent participants.

The intensity created in soccer game play promotes positive health and physical performance gains. When combined with appropriate frequency and time on task, soccer

participation may create a dose of PA that is in alignment with recommendations from several national agencies (U. S. Department of Health & Human Services, 2008).

CHAPTER 3: Moderate to vigorous physical activity levels in repeated small sided games in adolescent female soccer players: the effect of time, competition level, and player position

Introduction

The call for increasing physical activity (PA) in children has been pronounced. Since recommendations have been has been first published, attention has been placed on this important facet of child development. The effects of an active lifestyle on health outcomes are readily recognized as beneficial for the mitigation of multiple lifestyle related pathologies (U. Ekelund et al., 2012; Malina, 2010; Physical Activity Guidelines Advisory Committee, 2008; World Health Organization, 2010). Current U.S. Department of Health and Human Services and World Health Organization recommendations call for youth to acquire 60-minutes of MVPA daily (Pate et al., 1995; U. S. Department of Health & Human Services, 2008; World Health Organization, 2010). In the U.S., this recommendation has met with only moderate success. Approximations place the prevalence of all kids receiving the recommended dose of PA at 30% -40% (U. Ekelund et al., 2011). This can be further stratified by sex and age with 27% and 22.5% of 12-15 year old males and females respectively receiving a 60-minute dose of MVPA daily from both non-school and school related activities (Fakhouri, Hughes, Burt, Fulton, & Ogden, 2014).

Youth sport is one avenue through which children receive a dose of PA, often providing an environment supportive of the accrual of Moderate to Vigorous Physical Activity (MVPA) (P. T. Katzmarzyk & Molina, 1998; Leek et al., 2011; Pate & O'Neill, 2011; Sacheck et al., 2011; Wickel & Eisenmann, 2007). In the U.S. youth sport participation is substantial, creating a possible mechanism to combat the low performance of PA. National Sporting Goods Association categorical data estimates place basketball as the leading team sport with 26.9 million participants, followed by soccer with 13.5 million, and baseball with 12.5 million to round out the top three team sports by participation (National Sporting Goods Association, 2011). The 2006

Federation of Football Associations (FIFA) census, *Big Count*, places U.S. association soccer participation at 3.9 million registered and over 20 million unregistered participants (Federation of International Football Associations, 2012). However, even with impressive rates of participation, questions exist surrounding the effectiveness of youth sport in meeting the goal of 60-minutes daily of MVPA. Measurement of PA at both sport practice and games have demonstrated high levels of time spent in both sedentary (<1.5 METS) and light activity (1.6-2.9 METS) (Leek et al., 2011; Sacheck et al., 2011). Leek et al. (2011) found that the mean percentage of time spent in Sedentary and Light intensity ranges was 46.9 % of total time at soccer practice in boys and girls ages 7-14. Sacheck et al. (2011) examined MVPA time in 50 minutes soccer games in children aged 9 years, finding that only 33% of available minutes were at or above an intensity to qualify as MVPA. Regardless of these modest results, soccer training and match play has been shown to possess movement characteristics that may foster MVPA (Gabbett & Mulvey, 2008; S. V. Hill-Haas, Dawson et al., 2009; S. V. Hill-Haas et al., 2011; T. Reilly, 2005). This is readily apparent in literature describing the use of various training modalities to elicit increases in performance in elite players, both adult and youth. One training modality that has been researched is the use of small sided games (SSG) (Gabbett, 2006; Gabbett, Jenkins, & Abernethy, 2009; S. V. Hill-Haas et al., 2011). A SSG can be identified by the following parameters:

- game conditions (e.g. defined playing surface, >1 team, competition, match like playing rules, use of special conditions)
- use of multiple players at once
- engagement of all training participants throughout activity

Research is inclusive of various moderating factors and task specific game conditions that effect physiologic, time and motion, and skill outcomes (e.g. player numbers, field

dimensions, touch limitations). Of these, competition level (CL) has demonstrated effect in the professional ranks (A. Dellal et al., 2011). Another, playing position (PP) has also shown significant effect in work rate analytics of match play (Gil, 2007; Harley et al., 2010). These moderating factors could also have a significant impact on youth play, however, the effect of such conditions on MVPA outcomes in youth sport has not been widely pursued (P. T. Katzmarzyk et al., 2014; Pate & O'Neill, 2011).

SSG training has also been found to have a positive impact on several health outcomes. Intervention trials using SSG's have shown efficacy in generating positive health outcomes in untrained, deconditioned participants (Krustrup, Dvorak et al., 2010). Researchers hypothesize that the positive health outcomes are due in large part to the acyclic, randomized physical demand created during play. These same health outcomes are clearly related to high levels of MVPA (Physical Activity Guidelines Advisory Committee, 2008).

Currently there is a void in research examining the impact of SSG's on the accrual of MVPA in youth sport practice for adolescent girls. The amount of time spent in sedentary or light activity is noteworthy, especially when juxtaposed against the impression of youth sport as a provider of the daily dose of MVPA (Leek et al., 2011; Sacheck et al., 2011). As girls are clearly at risk for the loss of MVPA as they age research into sport and PA in girls is warranted (Bengoechea, Sabiston, & Ahmed, 2010; Mathieu et al., 2009; Pate & O'Neill, 2011; Trost, Rosenkranz, & Dzewaltowski, 2008). With the large number of girls participating in youth soccer in the United States, combined with the popularity of SSG's in soccer training, describing the effect on the accrual of MVPA in soccer training is a next step in developing effective means for increasing this important facet of sport participation.

It is the aim of this trial to quantify the accrual of MVPA during SSG training in club-level adolescent female soccer players. Primary analysis will examine the effect of Time (T) across games (G1 through G3) Secondary analysis will include the examination of CL as a possible and PP as potential moderators MVPA outcomes in SSG training. We hypothesize that MVPA time will be consistent across game conditions, negating the effect of T. We also hypothesize that MVPA will be greater in Premier (P) than Classic 1 (C1) than Classic 3 (C3) players, demonstrating the effect of CL. Our final hypothesis is that Midfielders (M) will have significantly greater MVPA than Forwards (F) than Defenders (D).

Methods

Participants.

Forty-three club-level, female adolescent soccer players registered to Minnesota Youth Soccer Association (MYSA) participating member clubs (Centennial Soccer Club, North East Soccer Club, and St. Croix Soccer Club) volunteered to participate in this trial. This convenience sample was solicited through soccer clubs who had responded to an email seeking participation. Correspondence with club leadership identified teams that met the inclusion criteria: Girls team, Under-13 through Under-16 (age), C3 through P (CL). Electronic communications with coaches' followed, leading to a players-only meeting where participants were directly recruited for volunteer participation in the trial. All subjects were currently participating on one of three unique teams, one each at P, C1, and a C3 level of play. Each team finished in the upper half of group play in the year preceding the trial. The subjects were healthy, high school aged students who had no known metabolic disorders, physical limitations or medication use that would preclude them from participation. The study was approved by the Institutional Review Board at the

University of Minnesota, Twin Cities. All subjects gave written informed assent with parental consent to participate.

Game Format and Design.

Training dates were chosen based on convenience for the teams participating. Dates were affected by training availability and game schedules. At least one full rest day prior to data acquisition was required. On one date, July 11, data was captured in concurrent time slots (6p-7p; 7p – 8p). For this data collection, no players were required to participate in consecutive sessions, eliminating any fatigue effect within the group from concurrent training bouts.

Subjects from each team (P, C1, and C3) were randomized to one of two waves (Wave 1 and Wave 2), creating six unique waves of subjects (3 Teams x 2 Waves). Waves were then assigned to one of the two dates (per team) for data collection. On the selected training date the selected Wave participated in three games (G1, G2, and G3). **Figure 3.1** illustrates the flow of players. For G1, players were randomly selected to one of two teams (Red and Yellow). Between each successive game (G1 and G2, G2 and G3) random assignment was re-applied, giving the Red and Yellow rosters unique combinations for each 8-minute bout. The effect of this process created 18 unique 8-minute bouts (3 Teams x 2 waves x 3 Games) for analysis. This format (8-minute bouts) also facilitated the recording of data into 1-second epochs, increasing the sensitivity of the measure, MVPA (Edwardson & Gorely, 2010). Randomization between game conditions allowed for the analysis of data free from bias from player grouping, an important factor when attempting to generalize to the population of youth players.

The scrimmage format was a 4v4, free-play scrimmage. Conditions on play included immediate ball availability on those played out of bounds, all restarts from the ground (no throws) and free touches (no restrictions on dribbling). Each scrimmage was

separated with a 4-minute recovery (instructional time). Randomization was managed during recovery. Three scrimmages and recoveries were linked together making the entire training time 36-minutes (24 minutes play, 12 minutes recovery). A 10-minute progressive, dynamic warm-up was administered to the subjects prior to their participation. The adapted format for the scrimmages has been described elsewhere (Casamichana & Castellano, 2010; A. Dellal et al., 2011; S. V. Hill-Haas et al., 2011). Field dimensions were 30m x 20m, using “Pugg” goals (Boston, MA) on each end line, goalies were not used. Cones were equally dispersed to establish touch and end lines.

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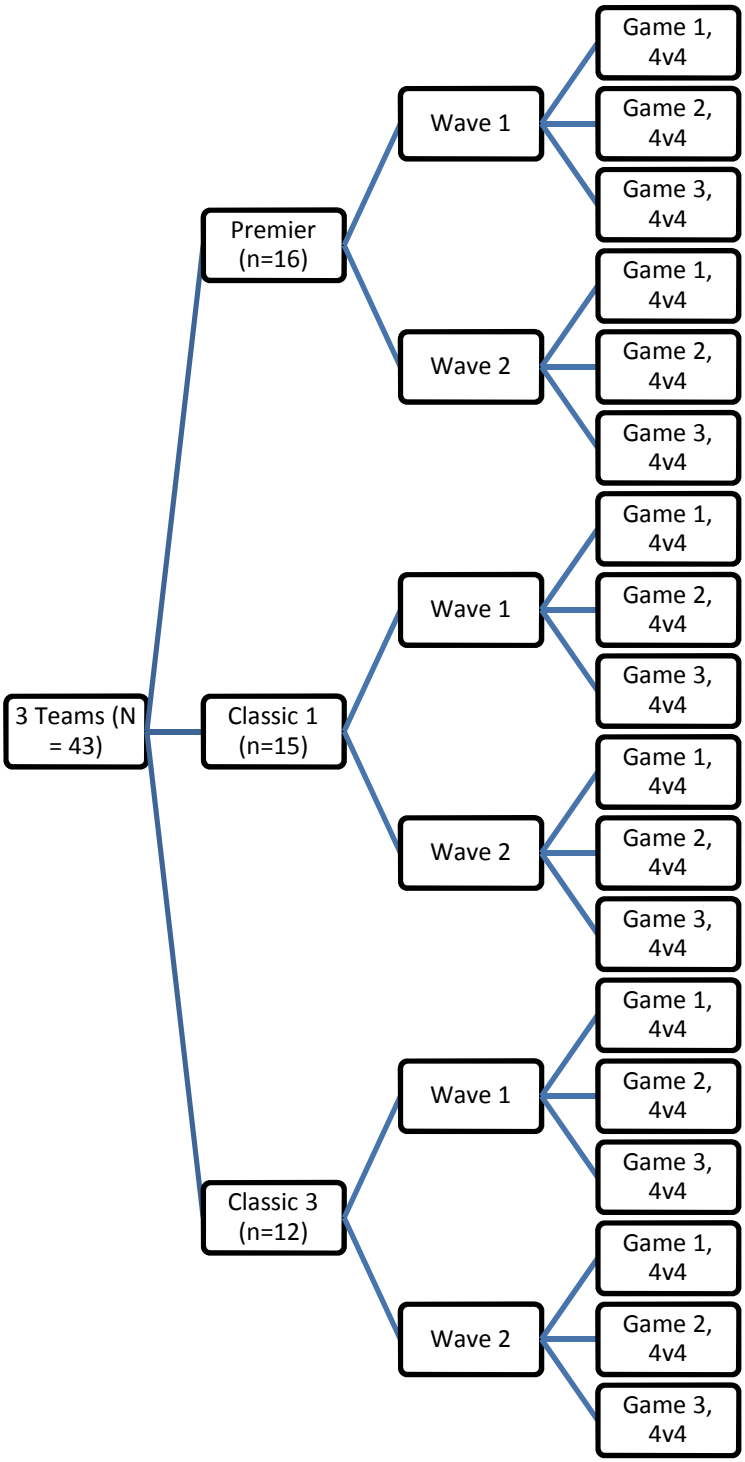


Figure 3.1 Distribution of teams by Competitive Level and Wave

Data Collection.

All training sessions took place during the traditional seasonal window during the 2013 spring MYSA soccer season (May – July). Environmental conditions for each training session are summarized (**Table 3.4**).

Subjects were required to be present 30-minutes prior to the arranged training session to fill out informed consent paperwork and for equipment set-up. Following the informed consent process, anthropometric data (self-reported) was acquired through a questionnaire. Subjects were informed that they were to come prepared with a self-recorded height and weight prior to testing. Subsequent to the survey, a direct measure of height and weight were taken (Seca 763; Chino, CA). Procedures for this measure are outlined by the Minnesota Department of Health (Minnesota Department of Health, 2011). Ultimately, self-reporting of height and weight was required for statistical analysis following an equipment failure in the stadiometer scale used for direct measurement on July 11. Prior to this, 27 of the 42 participants had completed both self-report and direct measure. This nested data was statistically analyzed (Pearson's Product-Moment Correlation) to establish the strength of association. The correlation between directly measured and self-reported Body Mass Index (BMI) was very high (r=.91, p<.01). This presents a strong case for the validation of using self-reported height and weight as a functional alternative to directly measured height and weight in this trial.

Other descriptive variables of interest were culled through the use of the pre-competition questionnaire. These included:

- Age
- Grade
- Race
- Predominate Playing Position

- Years of soccer experience
- Highest level of soccer competition (team placement)
- Outside sport participation, years of experience

Following a brief overview of the rules for play, subjects were outfitted with accelerometers (ActiGraph™ GTM1, Pensacola, Fl) secured to participants above the right hip by elastic (Leek et al., 2011; Matthews, Hagströmer, Pober, & Bowles, 2012). All three scrimmages and recovery periods were played. At the commencement of play, equipment was recovered followed by a 5-minute cool down before releasing the subjects.

Data Analysis.

Analysis of accelerometry data was completed using ActiLife software, version 5. (ActiGraph, Fort Walton Beach, FL). Cut points for the stratification of PA levels of intensity have demonstrated variability in previous trials (Strath, Pfeiffer, & Whitt-Glover, 2012). **Table 3.1** details cut points used to determine stratifications of PA intensity in this trial (approximate MET values included) (Eston, Rowlands, & Ingledew, 1998; Freedson, Pober, & Janz, 2005; Trost, Loprinzi, Moore, & Pfeiffer, 2011):

Table 3.1. PA counts stratified in Intensity Categoires

PA Intensity	GTM1 Counts	METS (1 MET = 3.5 ml/min/kg^{-1} O_2)
Sedentary (PA_S)	< 150	1.00 – 1.50
Light (PA_L)	150 - 499	1.51 – 2.99
Moderate (PA_M)	500 - 3999	3.00 – 5.99
Vigorous (PA_V)	4000 - 7599	6.00 – 8.99
Very Vigorous (PA_{VV})	>7600	>9.00

MVPA was calculated as a summation of PA_M, PA_V, and PA_{VV}. Raw data was converted to counts in 1-second epochs and downloaded to Microsoft™ Excel 2007 (Seattle, WA) for conversion into categorical data in preparation for statistical analysis.

Statistical Analysis

Statistical analysis was completed by using SPSS software (IBM, Armonk, NY), v19. Prior to statistical analysis all variables were checked for normality using both statistical (Shapiro-Wilk test) and visual examination (Histogram and Q-Q Plot). As described in the results section, normality could not be assumed, therefore non-parametric techniques were employed. Descriptive statistics are presented as medians and inter-quartile ranges (IQR). Description of median differences between time above and below MVPA thresholds was accomplished using Wilcoxon Signed Rank Tests. Examination of the analysis of variance between game conditions, G1 to G3, and MVPA was accomplished using Kruskal-Wallis test. Factor analysis of the effect of CL, PP and T followed. Evidence of significance in any moderator was explored post-hoc (difference between means) using the Mann-Whitney test. Statistical significance for all tests was set at p=.05.

Results

Normality

Normality was assessed for all analyses. The assumption of normality could not be supported through the inspection of both Histograms and Normal Q-Q plots in most cases. An example of this is found in **Figure 3.2**, the distribution of Total MVPA for Premier players. When normality was found to be supported, data was expressed with parametric statistics (e.g. Means and Standard Deviations), when not, non-

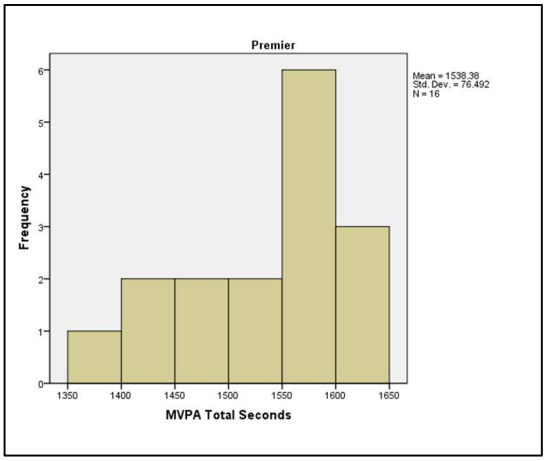


Figure 3.2 MVPA Total Seconds, Premier

parametric techniques were used (e.g. Wilcoxon Signed Ranks Test).

Participant and Environmental Descriptive.

All 43 recruited participants completed this trial. Median ages (IQR) for the sample were 15.23yrs (±1.02). Height and weight demonstrated some variability as expected in a sample of adolescents. Players were 1.68m (±.11) tall, weighing 56.29kg (±12.29). The group had substantial playing experience, with many of the participants having started soccer participation in their grade school years. The median years played was 11.00yr (±2.00). Other sport participation was mixed, with large variability coming from the P and C3 groups. Participant characteristics for the entire sample are presented in **Table 3.2**. Stratification of participants by both CL (P, *n*=16; C1, *n*=15; and C3,*n*=12) and PP (D, *n*=17; M, *n*=17; and F, *n*=9) are presented in **Table 3.3**

Table 3.2. Descriptive Statistics* - All Subjects

	All Subjects (*N*=43)
Age (yrs)	15.23 (1.02)
Heightt (m)	1.68 (.11)
Weight (kg)	56.29 (12.26)
BMI (kg/m^2)	20.99 (3.59)
Soccer Experience (yrs)	11.00 (2.00)
Other Sport Experience (yrs)	4.00 (8.00)

*Data is expressed as Median (IQR)

Table 3.3. Descriptive Statistics*			
Stratified by Competition Level	Premier (*n*=16)	Classic 1 (*n*=15)	Classic 3 (*n*=12)
Age (yrs)	15.41 (.53)	15.49 (.29)	14.06 (1.36)
Ht (m)	1.68 (.11)	1.68 (.11)	1.57 (.15)
Wt (kg)	58.57 (8.40)	54.48 (14.07)	50.62 (19.41)
BMI	21.03 (2.06)	19.64 (4.59)	20.59 (7.71)
Soccer Experience (yrs)	11.00 (1.00)	11.00 (1.00)	8.00 (4.00)
Other Sport Experience (yrs)	4.50 (8.00)	8.00 (7.00)	2.00 (4.00)
Stratified by Player Position	Defender (*n*=17)	Midfielder (*n*=17)	Forward (*n*=9)
Age (yrs)	15.23 (.99)	15.16 (1.05)	15.39 (1.54)
Ht (m)	1.68 (.13)	1.63 (.12)	1.60 (.11)
Wt (kg)	58.02 (10.44)	51.30 (9.31)	56.75 (10.61)
BMI	21.00 (3.58)	20.38 (4.23)	21.99 (3.24)
Soccer Experience (yrs)	10.00 (3.00)	11.00 (2.00)	11.00 (3.00)
Other Sport Experience (yrs)	5.00 (6.00)	3.00 (8.00)	6.00 (8.00)
*Data is expressed as Median (IQR)			

Environmental characteristics demonstrated some variability as expected over the course of the 7-week data collection window. Results are described in **Table 3.4.** Values listed were recorded at the start of the training session (www.accuweather.com). The range for temperature was recorded as 17.78℃ - 29.00 ℃ (*Mdn [IQR]* = 27.00 [4.00]), for relative humidity 37.00% - 74.00% (*Mdn [IQR]* = 46.00 [21.00]), and for wind speed 0.00kph – 25.90kph (*Mdn [IQR]* = 11.27 [9.01]). Sun and shade, as well as field conditions are also listed for review.

Table 3.4. Descriptive Statistics - Environmental Conditions					
Date, CL	Temp. (^{0}C)	Humidity	Wind (kph)	Sun	Field
7/11, P	29.0	37%	11.1	Full	Dry, Hard
7/11, P	27.0	45%	18.3	Full	Dry, Hard
6/23, C1	27.0	66%	25.9	Full	Dry, Hard
6/21, C3	25.0	74%	0.00	Overcast	Dry, Soft
6/16, C1	29.0	47%	9.3	Full	Dry, Hard
5/24, C3	17.5	46%	11.3	Overcast	Dry, Soft

Time.

Prior to exploring differences in MVPA, moderated by CL and PP, differences in Time (T) spent in MVPA (between games) was examined to determine the effect of T

across all game conditions (*N*=43). Using a Friedman Test, T did not demonstrate significant effect. Significance was not found between time spent in MVPA between G1, G2, and G3 (χ^2 (2, *n*=43) = 1.952, *p* = .377). The median time (sec) for each game was 444.00, 444.00, and 436.00 respectively. The IQR ranged from 395.00 – 463.00 across all games. **Table 3.5** summarizes results for MVPA (sec) against T in each game.

Table 3.5 – Total Means and Standard Deviations, MVPA

Time	*N*	Median (sec)	IQR
Game 1	43	444.00	405.00 – 463.00
Game 2	43	444.00	402.00 – 459.00
Game 3	43	436.00	395.00 – 454.00

MVPA

Examination of the amount of time spent (sec) above and below movement intensities equivalent to MVPA indicated significant differences. Using a Wilcoxon Signed Rank Test significant results were found, with time above MVPA significantly greater than time below MVPA. In each SSG training game, more than 91% of the time on task (*Mdn*) was spent at intensities qualifying for MVPA. Contrasted against the time spent below MVPA, 9% being the greatest, the difference is obvious. **Figure 3.3** illustrates the differences in time spent above and below MVPA. Statistical output and effect sizes are given in **Table 3.6.** Note worthy in this analysis are the associated effect sizes (Cohen, 1992). In each of the three game conditions, SSG training elicited a "Large" effect on time accrued in MVPA.

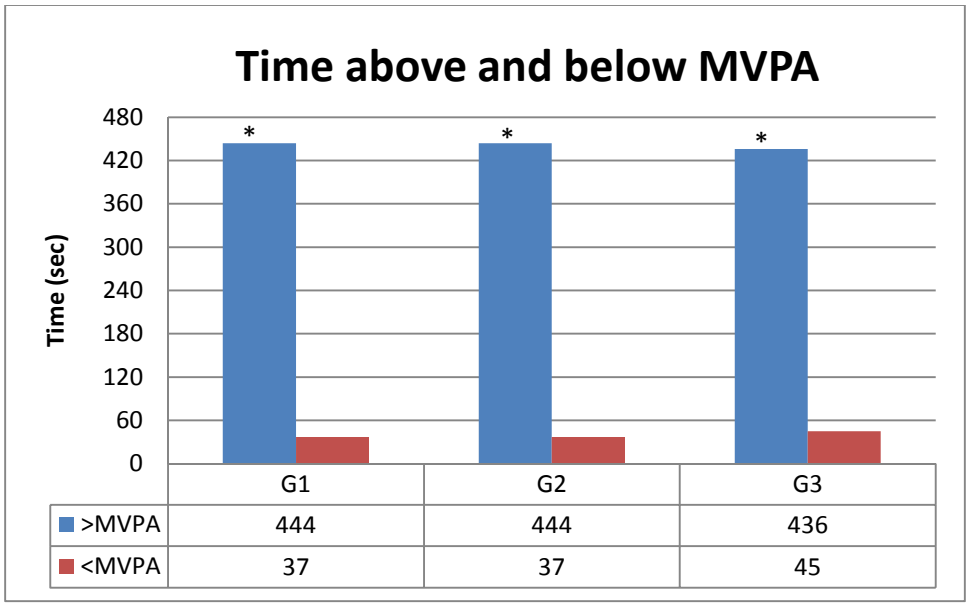


Figure 3.3 Times above and below MVPA in Game 1, Game 2, and Game 3

* Statistical Significance *p*<.05; ** Results reported as Medians

Table 3.6 – Wilcoxon Signed Ranks Test Results with Effect Size – SSG Training on MVPA

(*N*=43)	G1	G2	G3
Z	-5.712	-5.712	-5.712
p Value	*p* < .001	*p* < .001	*p* < .001
Effect Size (*r*)	Large (*r* = .62)	Large (*r* = .62)	Large (*r* = .62)
>MVPA (sec)*	444 (58)	444 (57)	436 (59)
<MVPA (sec)*	37 (58)	37 (57)	45 (59)
* Results expressed as Median (IQR)			

MVPA and Competition Level.

It was hypothesized that CL would have a significant effect on the accrual of MVPA. Results from this trial support the hypothesis that MVPA is moderated by CL in club-level adolescent females. Analysis indicates that CL does have a significant effect (*p* = .05) on the accrual of MVPA during SSG in club-level adolescent female soccer players (P > C1 > C3). A Kruskal-Wallis test revealed statistically significant differences in MVPA moderated by CL in all game conditions. Statistical results are summarized in **Table 3.7.**

Table 3.7. Kruskal-Willis Test Results – MVPA (sec) by CL			
	G1	G2	G3
χ^2 (2, *n*=43)	20.101	18.503	18.343
p Value	*p* < .001*	*p* <. 001*	*p* < .001*
*Significant Result (*p*=.05)			

Once significance was found within the sample, examination of differences between specific groups was accomplished through the use of the Mann-Whitney test to compare group medians. Results indicate that MVPA levels were highest in P than in C1 than in C3 across all game conditions. Effects sizes indicate that CL has a medium to large effect on the amount of time spent in MVPA (Cohen, 1992). Results are summarized in **Table 3.8**.

Table 3.8 – Mann-Whitney Test Results with Effect Size			
P to C1 (*n*=31)	G1	G2	G3
Z	-2.45	-2.217	-2.768
p Value	*p* = .014*	*p* = .027*	*p* = .005*
Effect Size (*r*)	Medium (*r* = .44)	Medium (*r* = .40)	Large (*r* = .50)
P to C3 (*n*=28)			
Z	-3.926	-3.717	-3.715
p Value	*p* < .001*	*p* < .001*	*p* < .001*
Effect Size (*r*)	Large (*r* = .74)	Large (*r* = .70)	Large (*r* = .70)
C1 to C3 (*n*=27)			
Z	-3.100	-3.172	-2.565
p Value	*p* = .002*	*p* = .002*	*p* = .010*
Effect Size (*r*)	Large (*r* = .60)	Large (*r* = .61)	Medium (*r* = .49)
*Significant Result (*p*<.05)			

The median time spent above MVPA in each game stratified by CL is further illustrated in **Figure 3.4**. A visual inspection of these scores demonstrates the effect of CL on the accrual of MVPA.

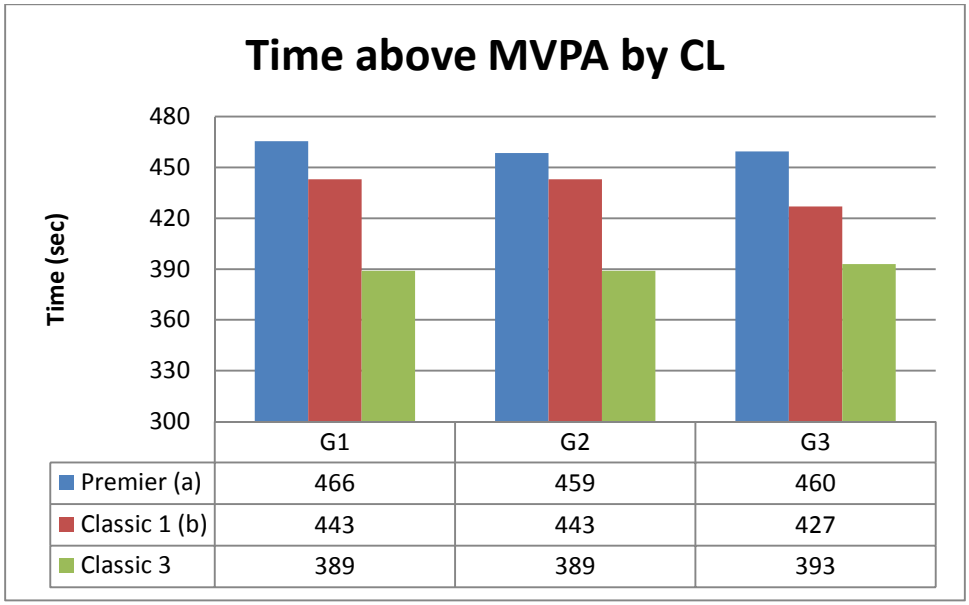


Figure 3.4 Time (sec) above MVPA stratified by CL (medians)
a = P>C1, P>C3; b = C1>C3 in all game condition; *p* <.05

Time spent in each of the PA levels is also noteworthy. For each CL, MVPA accrued during SSG was high. MVPA total time spent, based on median values, in G1 was approximately 97%, 92%, and 81% for P, C1, and C3 respectively. For G2 these percentages were 96%, 92%, and 81%. For G3 they were 96%, 89%, and 82%. **Figures 3.5, 3.6, and 3.7** illustrate the time spent in PA intensities (Sedentary, Light, Moderate, Vigorous, and Very Vigorous) during SSG play, stratified by CL, for each of the game conditions. Apparent in this inspection of the graphs is the large amount of time spent in intensities above MVPA as a percentage of the total time.

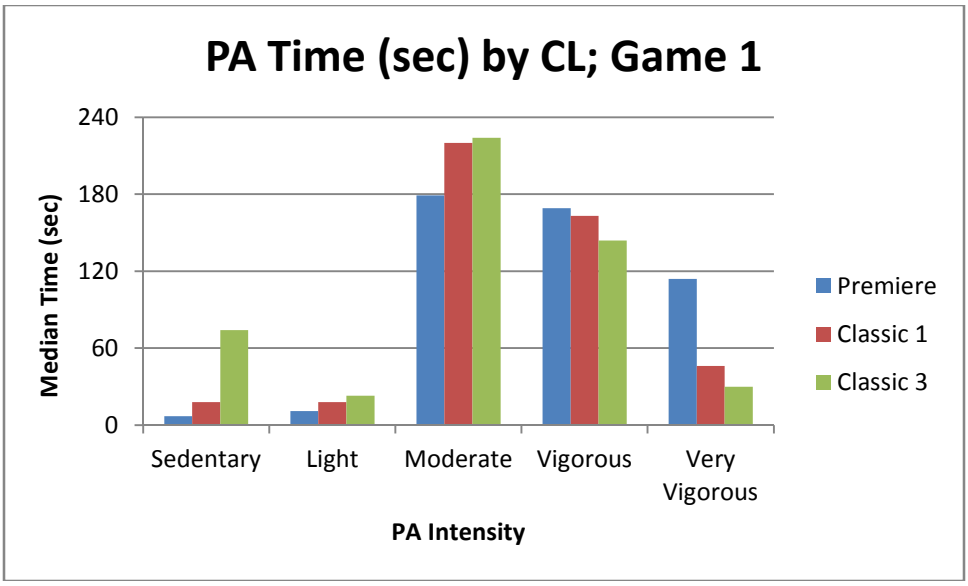


Figure 3.5 PA Level (sec) Stratified by CL, Game 1 (*Mdn*)

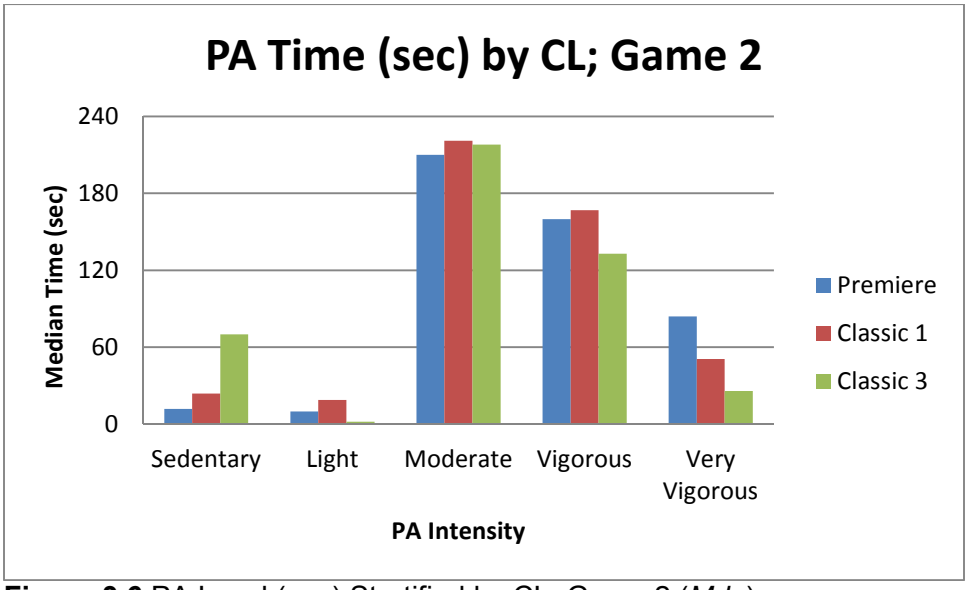


Figure 3.6 PA Level (sec) Stratified by CL, Game 2 (*Mdn*)

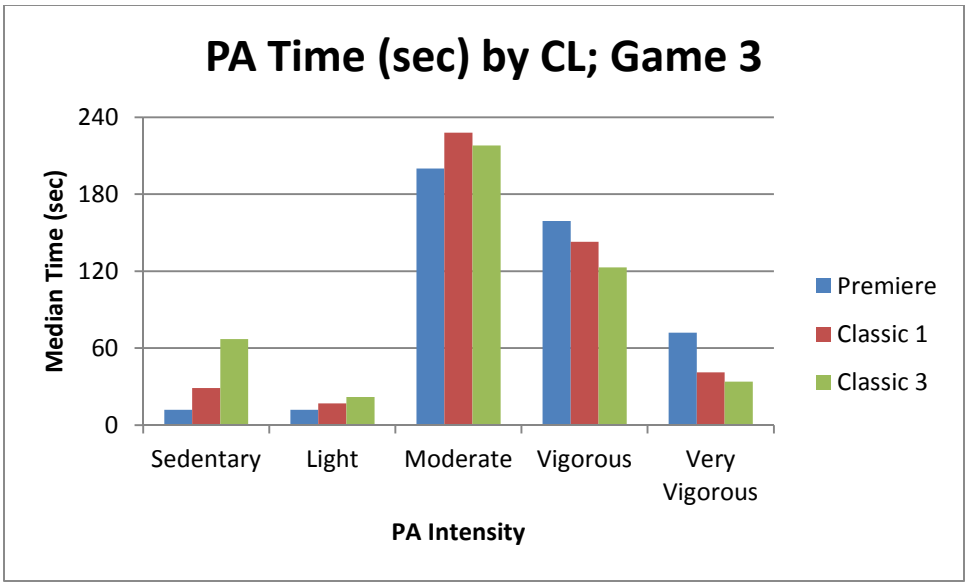


Figure 3.7 PA Level (sec) Stratified by CL, Game 3 (*Mdn*)

MVPA and Playing Position.

A secondary aim of this trial was to evaluate the moderating effect of PP on the accrual of MVPA. Results from the Kruskal-Willis Test did not demonstrate a significant difference in MVPA stratified by PP. While MVPA remained at a high overall percentage of the total SSG time, positional play did not affect the outcomes. Defenders, midfielders, and forwards all registered similar MVPA results across the game conditions. **Table 3.9** lists these results. An examination of the median scores underscores this finding. **Figure 3.8** illustrates the median MVPA times, stratified by PP, for each game condition.

Table 3.9. Kruskal-Willis Test Results – MVPA (sec) by PP

	G1	G2	G3
χ^2 (2, *n*=43)	.468	.041	.434
p Value	*p* = .791	*p* = .980	*p* = .805

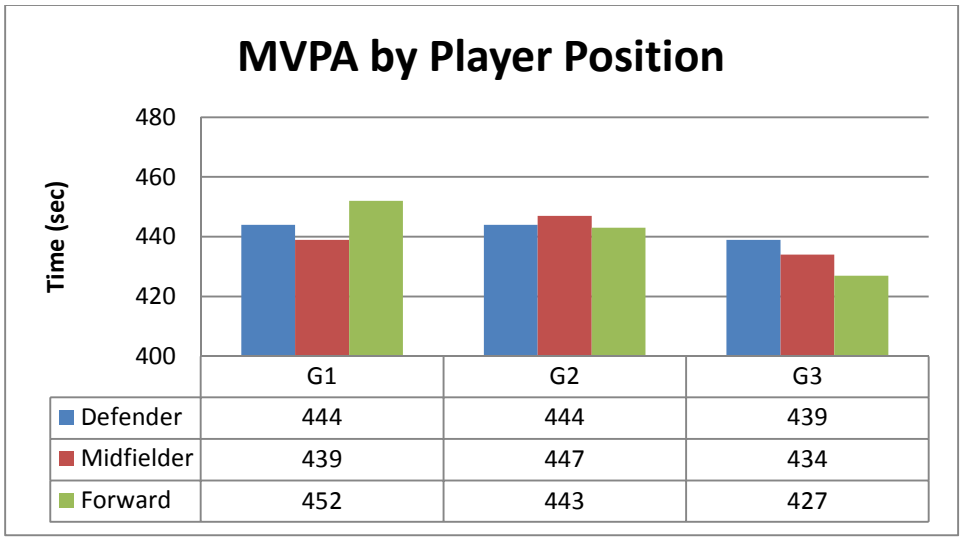


Figure 3.8 MVPA (sec) by Player Position (*Mdn*)

Discussion

The amount of MVPA accrued by children throughout the day has become a national focus (Fakhouri et al., 2014; P. T. Katzmarzyk et al., 2014; Malina, 2010; Physical Activity Guidelines Advisory Committee, 2008; World Health Organization, 2010).Sport has been shown to be one avenue through which children can receive a dose of MVPA. Furthermore, with the poor performance of adolescent females in acquiring a full dose of MVPA, across all avenues of PA, there is a immediate need to better understand MVPA as a function of youth sport (P. T. Katzmarzyk et al., 2014; Leek et al., 2011; Pate & O'Neill, 2011; Physical Activity Guidelines Advisory Committee, 2008). There have been several attempts to quantify PA through youth sport (P. T. Katzmarzyk & Molina, 1998; Leek et al., 2011; Sacheck et al., 2011; Wickel & Eisenmann, 2007). This work is the first to seek to describe a specific training modality, SSG training, on the PA and MVPA signature associated with its use. Further exploration of the moderating effect of CL and PP, two distinct components in youth sport, on the accrual of MVPA is also a first.

The application of various coaching and training methodologies, such as SSG training, has been explored at great length in elite soccer. However, little has been presented to juxtapose sport training against PA, specifically MVPA. The standard approach to understanding training outcomes in sport performance literature has been through the lens of time and motion analysis and skill development (Ali, 2011; C. Carling et al., 2008; Casamichana & Castellano, 2010; A. Dellal, Lago-Penas, Wong, & Chamari, 2011; Gabbett & Mulvey, 2008; Gabbett et al., 2009; Gamble, 2004; S. V. Hill-Haas, Dawson et al., 2009; Kuklu, Asci, Kopak, Alemdaroğlu, & Dündar, 2011; Owen et al., 2011; Williams & Hodges, 2005). This is intuitive; sport researchers and coaching communities are interested in outcomes that are demonstrative of performance in their sport of choice. They are also clearly focused on elite level play. However, such examinations of youth sport and PA is not only called for, it is arguably an imperative in a landscape that has fared so poorly in insuring appropriate levels of MVPA for our children (P. T. Katzmarzyk et al., 2014).

While youth sport may play a central role in the accrual of daily recommendations of MVPA (Leek et al., 2011; Wickel & Eisenmann, 2007) it should be acknowledged that distinctions between sport and PA exist. In a sporting context, outcomes such as competition or socialization may take precedence to the accrual of PA for health benefit (Anders Ericsson, 2008). Implicit in the development of young athletes, mastery of a sport specific skill set is required to compete. The process of skill mastery may not always be conducive to high levels of PA. Also, the time, intensity, and approach of training is often moderated by the players chosen competition level and developmental status. Those in higher levels of competition may train more intensely for longer periods of time in conditions meant to simulate match play (i.e. highly competitive). This is evidenced in the literature surrounding both the relative age effect in sport team

selection and expert performance development (Anders Ericsson, Krampe, & Tesch-Römer, 1993; W. Helsen, van Winckel, & Williams, 2005). In both arenas, development of expert performance is mediated by time, focus, and intensity of training. This may occur in training exercises, such as block training exercises developing passing skills, which are not necessarily conducive to high levels of MVPA.

In our trial, CL was significantly associated with MVPA accrued during SSG training ($p<.05$). This is supported by the previously mentioned research examining performance. What is equally telling is descriptive data that demonstrates the high percentages of time spent in MVPA intensities during each respective 8-minute bout. This is suggestive of SSG training as a modality of instruction that has robust movement characteristics that support positive health outcomes along with performance gains. This is in stride with the ample amount of SSG research examining the physiologic outcomes provided through this type of training.

Regarding the effect of CL, by the time players reach adolescence the process of selection may be well established. Players who are at a level commensurate with higher competition have been selected and habituated to that experience. They reap the benefits from that experience. Recreational players have also been identified and are habituated to their environment. They too reap the associated benefits from participation, albeit, those associated with MVPA may come at reduced rate when compared to higher competitive levels of play. In this trial, as players increased their competitive level, the relative amount of time spent at high intensity work rates (MVPA) increased across all groups in all game conditions.

Playing position on the other hand did not demonstrate the same affect on MVPA. This can be understood in different ways. In our trial, the pronounced effect of CL would be mitigated through examination of PP due to the mixing of players across CL.

This would create variability that cannot be sorted out in a sample of this size. Even with this said, the probability that the median scores were different is far from significance in this sample, giving little rationale for further investigation. Ultimately, PP at the youth level is not as defined as within elite levels of play (Gravina, 2008). Physical characteristics, stature, and effort often outweigh skill and opportunity for development within the youth teams (W. Helsen et al., 2005; W. F. Helsen, Hodges, Van Winckel, & Starkes, 2000). This process is also at work when selecting players for positions on the soccer squad. Players who are physically dominant are often used across positional play on the squad, insuring that each respective line (D, M, and F) have at least one physically mature player with high work rates. With this sample, that is a possibility that cannot be discounted.

Strengths and Limitations.

Limitations in this trial include the sample size. Every effort was made to generate the largest sample possible. Constraints with funding, team schedules, weather, and training locations reduced the opportunity to generate a larger sample. While the use of three teams for player assignment is not high, it should be noted that each of these clubs has open try-outs annually, insuring a annual rate of player turn over. This reduces the likelihood that the data operated on a group level. As rosters change annually, the group effect of learning and familiarity is reduced. This was further mitigated by the randomization process that was employed. Eventually three teams were randomized to 18 unique game conditions, a strength in this trial. A strong attribute of the design was also the use of 1-second epochs for data capture. The use of longer epochs in PA research may not accurately represent the actual movement characteristics found in youth ((Edwardson & Gorely, 2010). Through capturing data in

1-second epochs, made possible by the length of the data collection (8-minute games), great levels of detail about movement patterns are provided.

The trial employed utilized previously mentioned game conditions to best model the research question. The use of 8-minute bouts allowed for the randomization to best maximize the number of unique bouts while still maintaining a physiologic load that is in alignment with MVPA (> 3METS). The use of 4-minute recovery periods also allowed for the full restoration of physiologic mechanisms insuring that these did not bias the results due to fatigue. This was supported through examination of the non-significant effect of T on MVPA across all game conditions. Logistically, this trial met all the requirements of feasible field research. The high correlation between self-reported BMI and directly measured BMI (r = .91, p<.01) suggests that this is an effective mechanism for future research. The equipment employed is functional, easily transported, and feasible for use in the field.

Further research should also include direct calibration of the accelerometer to the subjects. Due to the nature of this field research, this was not feasible. In the future, attempts to go beyond comparative measures, for instance developing estimations of energy expenditure, should be completed with development of accelerometer counts to VO_2 curves for the chosen sample (Freedson et al., 2012). This would be made more feasible in a repeated measures design using a smaller sample where this type of laboratory data collection is possible as opposed to larger samples often employed in PA research.

The choice of a common training modality, 4v4 SSG, reduces the likelihood that data was biased due to observation, however it must be noted that the use of technology and an outside observer may have influenced PA levels during play. To combat this, players were introduced to the trial early in the winter training season, meeting three

times with the co-investigator prior to the data collection period. Each team was also given an introductory period to walk though the collection process prior to performing.

Applications and Conclusion.

Care needs to be taken whenever attempting to generalize results from trials such as this one. The size of the effect of CL on MVPA was impressive; however continued research looking at larger samples with greater levels of heterogeneity in the sample may be required to fully understand the effect of CL. There is supportive literature, such as relative age and expert performance, which has examined this concept in various paradigms. Important in future research investigating the PA characteristics of sport, care must be taken to examine the effect of CL as well as the training modality selected.

Another application of this information can be modeled in a best practices approach to training. Regardless of the motivation of the participant, soccer as a sport demands high levels of PA. Maintaining a tight practice schedule with limited instructional time and high percentages of training time will obviously increase MVPA accrued at practice. Using modalities that encourage MVPA should be a goal of all coaches and trainers. The use of SSG's is one such training modality, however any modality can be adapted to increase time spent in MVPA. Physical Education is a discipline where teachers have been taught methods for inclusive games. Much could be gained from continued exploration of cross disciplinary approaches in reaching the goals and objectives in youth sport.

Previously mentioned were the high MVPA percentages in each SSG, regardless of differences in CL. This is a key finding in this trial. While the hypothesis was not developed to compare the levels between training time and instructional time (i.e. time management), a simple examination of the total time spent in training (36 minutes)

stratified by PA intensities, demonstrates that training time appears to be the major provider of MVPA, while instructional time does not afford that stimulus. **Figure 3.9** illustrates the median total PA time (min) stratified by PA level, moderated by CL. MVPA was over 24 minutes for each group. This is equal to the total of the three bouts combined. When examined against the high percentages at MVPA during each bout, it is apparent that training time was the great contributor to MVPA as opposed to instructional time. Further research looking at the effect of this relationship is a next step in understanding the mechanisms by which MVPA is accrued in youth sport practice. When doing so, it is important to consider the effect of CL designing research and generalizing to recommendations.

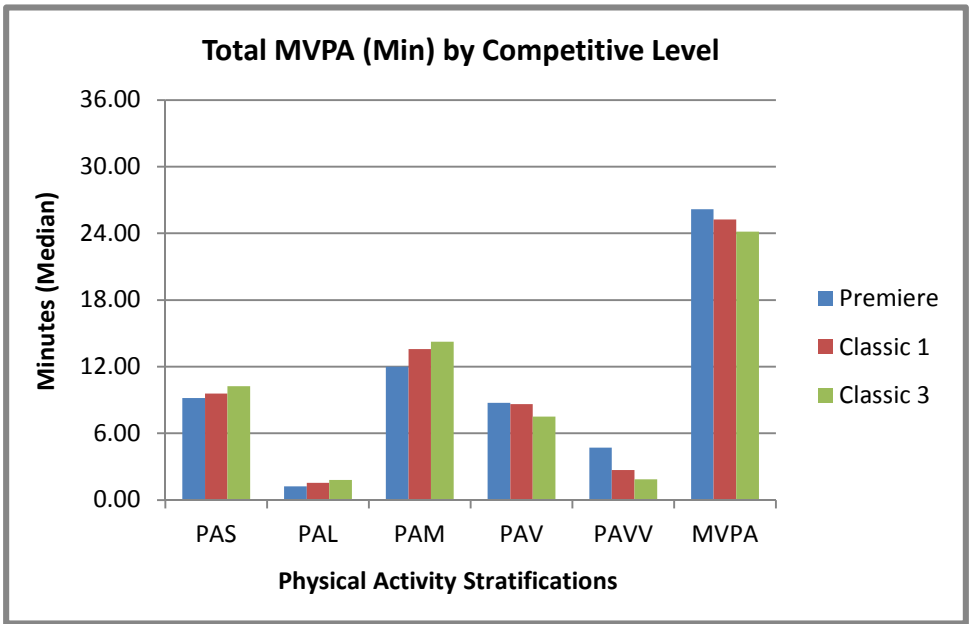


Figure 3.9 Total PA (min) Stratified by PA Level

CHAPTER 4: Exercise intensity in small sided games: An analysis of time and competition level on heart rate during repeated small sided games in adolescent, club-level female soccer players

Introduction

Soccer coaches and trainers have employed the use of small sided games (SSG) in training for soccer throughout the history of the sport (Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014a; S. V. Hill-Haas, Dawson et al., 2009). Small sided games offer a training staff a robust method to incorporate multiple facets of match play into a single training session (Gabbett, 2006). These facets include physical conditioning, technical skill development, and tactical problem-solution processes (Gabbett et al., 2009). Throughout this development, soccer coaches have become skilled in employing conditional play (e.g. rules) on SSG's to increase the efficacy of training to deliver specific performance outcomes. Through manipulations of training parameters, trainers isolate match conditions (e.g. time, space, team size, player overloads, number of ball contacts), to place players in environments that mirror game scenarios. Exercise Intensity (EI) is one training parameter that is often the focus of conditional play in SSG training. As a result EI has received great attention from exercise physiologists and sport researchers interested in SSG research.

The methods for generating EI data in the field are many. These include the use of video, GPS, and accelerometers to quantify time and motion characteristics of play. Physiologic measures of EI include the tracking of heart rate (HR), blood lactates, body temperatures, and respiratory rates, as well as others (A. Dellal et al., 2012). Challenges exist however with the practicality and feasibility of capturing time and motion and physiologic data for associations and teams without the means or skilled physiotherapists to employ the most current technology (A. Dellal et al., 2012). One popular method of quantifying EI is the use of HR monitors. Implicit in applying HR to training paradigms, is the relationship between HR and time and motion. A linear relationship exists between HR and velocity, below supra-maximal efforts (sprints). This

phenomenon is demonstrated in graded exercise testing; as HR increases, so will intensity (work). In soccer, when considering time and motion parameters of play, one natural output of increased work is increased velocity. In this manner, HR monitoring is an effective method to understand both physiologic and time and motion characteristics, albeit with some acknowledged limitations (A. Dellal et al., 2012). Characteristics that make HR monitoring an effective method for the tracking of EI in the field include practicality and feasibility factors (e.g. availability, cost, ease in use) as well as the previously mentioned relationship between HR and work (Esposito et al., 2004). When compared to other measures of EI (e.g. Blood Lactate), the non-invasive, relative comfort of HR monitoring is positive for subjects. While possessing some limitations, these factors make HR monitoring a common choice for measuring EI in training within coaching circles (A. Dellal et al., 2012).

Soccer, and other team sports such a basketball, hockey, and rugby, have used HR to describe the relative EI of a training and competition with great frequency. This is found throughout the literature (A. Dellal et al., 2012; Esposito et al., 2004; S. V. Hill-Haas et al., 2011). The relationship between training and competition is central in this application. Heart rate is demonstrative of multiple complex physiologic processes. This can also be viewed as a limitation when seeking to describe EI in bioenergetic terms (e.g. aerobic, anaerobic). The bias created from moderators such as sleep, nutritional status, and mental stress can decrease the sensitivity of the device in terms of demonstrating physiologic phenomena, often the focus of research using EI as an outcome (Achten & Jeukendrup, 2003). However, when used for the calibration of EI in the field, this limitation becomes strength for coaches and trainers attempting to gauge the relative EI of the training or competition against known player responses (standards) developed through previous training and match sessions. In these scenarios, the

omnibus nature of HR monitoring is an advantage to understanding the relative stress of the moment. While creating artifact for physiologic applications, HR does allow training and coaching staff to register the allosteric stress load of the player, an important facet of managing game scenarios. This method is particularly effective when combined with Rate of Perceived Exertion (RPE) scores
(F. M. Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004).

Soccer is best described as possessing long periods of aerobic EI (walking, jogging) with randomized, acyclic periods of anaerobic demand (jumping, cutting, cruising, and sprinting) (C. Carling et al., 2008; Gabbett & Mulvey, 2008; Harley et al., 2010; S. V. Hill-Haas, Dawson et al., 2009). The quantification of time and motion characteristics and their associated physiologic markers has been well documented, albeit gaps in the literature exist. Currently, much is known about both males and elite level players. However, there is an underrepresentation in the literature with both women and club-level players. There are over 4-million youth association players in the U.S alone, with approximately 33% being female, and estimates place non-association participation at near 20-million (Federation of International Football Associations, 2012; National Sporting Goods Association, 2011). Describing the outcomes associated to training modalities in these underrepresented populations will provide coaches and trainers with insights currently not described.

Examination of moderators influencing outcomes generated through SSG training has been well documented in previously mentioned elite male participants. Factors such as pitch size, player numbers, duration, various rule modifications, coach encouragement, use of goalkeepers, game duration and work to rest ratios have been reviewed elsewhere (Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014a; S. V. Hill-Haas et al., 2011). Within the literature, gaps exist describing the influence of

competition level (CL) on performance outcomes. It is the purpose of this paper to examine the HR outcomes associated with SSG training (4v4, free-play) in adolescent, club-level female soccer players. Differences between times spent above and below both 70% and 85% HR_{max}, will be described (Helgerud, Engen, Wisløff, & Hoff, 2001). Secondary aims include the measurement of effect of CL on time differences at both thresholds. Included is further descriptions of time spent at the flowing EI zones, <70% HR_{max}, 70% – 85% HR_{max}, 85% - 90% HR_{max}, 90% - 95% HR_{max}, 95% - 100% HR_{max} (Helgerud et al., 2001). We hypothesize that significant differences will be found between times spent above and below 70% and 85% HR_{max}, with greater time spent above these markers. Furthermore it is hypothesized that CL will act as a moderator. Time above these thresholds will be greater for P than for C1 than for C3.

Methods

Participants.

Forty-three club-level, female adolescent soccer players registered to Minnesota Youth Soccer Association (MYSA) participating member clubs (Centennial Soccer Club, North East Soccer Club, and St. Croix Soccer Club) volunteered to participate in this trial. This convenience sample was solicited through soccer clubs who had responded to an email seeking participation. Correspondence with club leadership identified teams that met the inclusion criteria: Girls team; Under-13 through Under-16 (age); Classic 3 (C3), Classic 1 (C1), and Premier (P) (CL). Electronic communications with head coaches' followed leading to a players-only meeting where participants were directly recruited for volunteer participation in the trial. All subjects were currently participating on one of three unique teams, one each at P, C1, and a C3 level of play. Each team finished in the upper half of group play in the year preceding the trial. The subjects were healthy, high school aged students who had no known metabolic disorders, physical

limitations or medication use that would preclude them from participation. The study was approved by the Institutional Review Board at the University of Minnesota, Twin Cities. All subjects gave written informed assent with parental consent to participate.

Data Collection.

Training dates were chosen based on convenience for the teams participating. Dates were affected by training availability and game schedules. Data collection occurred during the competitive season of 2013. At least one full rest day prior to data acquisition was required. On one date, July 11, data was captured in concurrent time slots (6p-7p; 7p – 8p), otherwise data was collected on two separate dates for each team. On the July 11 date, no players were required to participate in consecutive sessions, eliminating any fatigue effect within the group from concurrent training bouts.

Subjects were required to be present 30-minutes prior to the arranged training session to fill out informed consent paperwork and for equipment set-up. Following the informed consent process, anthropometric data (self-reported) was acquired through a questionnaire. Subjects were informed that they were to come prepared with a self recorded height and weight prior to testing. Subsequent to the survey, a direct measure of height and weight were taken (Seca 763; Chino, CA). Procedures for this measure are outlined by the Minnesota Department of Health (Minnesota Department of Health, 2011). Ultimately, self-reporting of height and weight was required for statistical analysis following an equipment failure in the stadiometer scale used for direct measurement on July 11. Prior to this, 27 of the 42 participants had completed both self-report and direct measure. This nested data was statistically analyzed (Pearson's Product-Moment Correlation) to establish the strength of association. The correlation between directly measured and self-reported Body Mass Index (BMI) was very high (r=.91, p<.01). This

presents a strong case for the validity of using self-reported height and weight as a functional alternative to directly measured height and weight in this trial.

Other descriptive variables of interest were culled through the use of the pre-competition questionnaire. These included:

- Age
- School grade
- Race
- Predominate playing position
- Years of soccer experience
- Highest level of soccer competition (team placement)
- Outside sport participation, years of experience

Following a brief overview of the rules for play, subjects were outfitted with Polar *Team 2* HR monitors (Polar *Team 2*, Kempele, Finland. Placement was even with the xiphoid process at the inferior aspect of sternum. The *Team 2* system is a HR monitoring system that affords users the ability to use telemetry (blue tooth, 2.4 MHz) to record all participants in real time during training. HR data is also stored locally in the transmitter, allowing for reconciliation of HR data during transmitter docking in the event that telemetric signal transmission was degraded for any reason. Signal transmission was established and all three scrimmages and recovery periods were played. At the commencement of play, equipment was recovered followed by a 5-minute cool down before releasing the subjects.

Game Format and Design.

Subjects from each team (P, C1, and C3) were randomized to one of two waves (Wave 1 and Wave 2), creating six unique waves of subjects (3 Teams x 2 Waves). Waves were then assigned to one of the two sessions (per team) for data collection. At

the assigned session the selected Wave participated in three games (G1, G2, and G3). An illustration of the distribution of players is provided in **Figure 4.1**.

For G1, players were randomly selected to one of two teams (Red and Yellow). Between each successive game (G1 and G2, G2 and G3) random assignment was re-applied, giving the Red and Yellow rosters unique combinations for each 8-minute bout. The effect of this process created 18 unique 8-minute bouts (3 Teams x 2 Waves x 3 Games) for analysis. Randomization between game conditions allowed for the analysis of data free from bias from player grouping, an important factor when attempting to generalize to the population of adolescent players.

The scrimmage format was a 4v4, free-play scrimmage. Conditions on play included immediate ball availability on those played out of bounds, all restarts from the ground (no throws) and free touches (no restrictions on dribbling). Each scrimmage was 8-minutes in length, separated with a 4-minute recovery (instructional time). Randomization was managed during recovery. Three scrimmages and recoveries were linked together making the entire training time 36-minutes (24 minutes play, 12 minutes recovery). A 10-minute progressive, dynamic warm-up was administered to the subjects prior to their participation. The adapted format for the scrimmages has been described elsewhere (Casamichana & Castellano, 2010; A. Dellal et al., 2011; S. V. Hill-Haas et al., 2011). Field dimensions were 30m x 20m, using “Pugg” goals (Boston, MA) on each end line, goalies were not used. Cones were equally dispersed to establish touch and end lines.

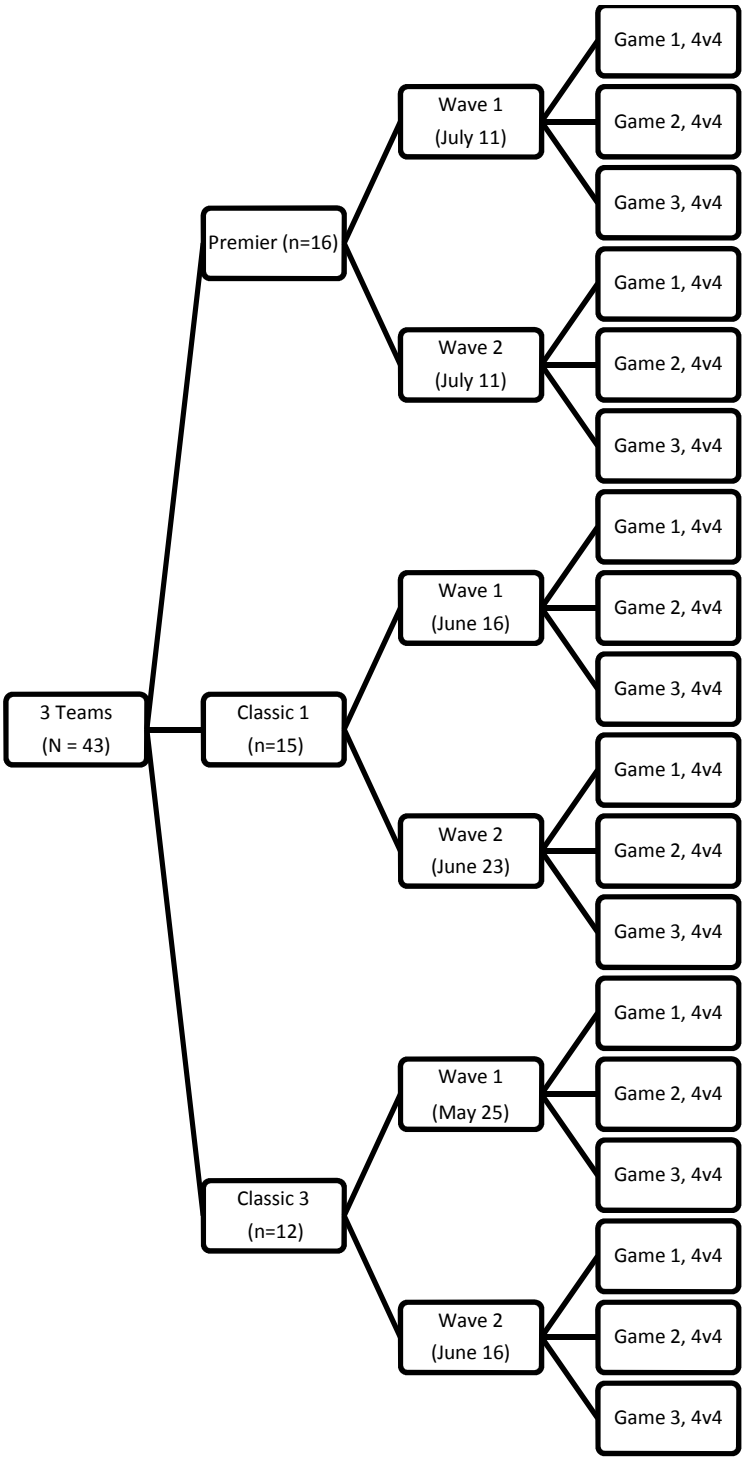


Figure 4.1 Distribution of teams by Competitive Level and Wave

Exercise Intensity

As mentioned, heart rate was selected as the measure of EI (%HR_{max}) due to its consistent use within the coaching community (Achten & Jeukendrup, 2003; A. Dellal et al., 2012; Esposito et al., 2004; S. V. Hill-Haas et al., 2011; F. Impellizzeri, 2005; F. M. Impellizzeri et al., 2004; E. Rampinini et al., 2007a). Maximal HR was established through the use of estimations (Mahon, Marjerrison, Lee, Woodruff, & Hanna, 2010). The need to use estimations was a logistic consideration. This was made mandatory due to the shortened 2013 season resulting from weather constraints, limiting training time available for data collection. This eliminated the feasibility of measuring HR_{max} directly (e.g. reduction of data collection sessions).

The choice of estimation, 208 – (.7-age) (Tanaka et al., 2001), was supported through a trial of children, 7 – 17 years (*n*=52). Using graded exercise testing, Mahon et al. (2010) found that while individual differences existed between directly measured HR_{max} and estimated HR_{max} (220 – age vs. 208-[.7*age]), the later equation, first generated by Tanaka et al. (2001), was superior for the estimation of adolescent participants (Mahon et al., 2010; Tanaka, Monahan, & Seals, 2001). Stratification into five EI zones (%HR_{max}) followed the previously described approach of Helgerud et al. (2001). These were <70%, 70 – 85%, 85 – 90%, 90 – 95%, >95% HR_{max}. Originally developed to describe bioenergetic thresholds in adults (70%HR_{max} – Aerobic Threshold, 85% HR_{max} – Anaerobic Threshold), and controversial in application as such for adolescents, the selection of these EI intensities follows research previously reported ((A. Dellal et al., 2012; Helgerud et al., 2001) increasing the utility of this trial in association with previously reported data.

Statistical Analysis

Statistical analysis was completed by using SPSS software (IBM, Armonk, NY), v19v. Prior to statistical analysis all variables were checked for normality (Histogram and Q-Q Plot). As previously described, normality could not be assumed, therefore non-parametric techniques were employed. Statistical significance for all tests was set at p=.05.

Results

Normality.

A normal distribution of the data was not generated in this sample (N = 43), except for Heart Rate Average (HR_{ave}). However, normality could not be met when HR_{ave} was stratified by CL. Examinations of both Histograms and Normal Q-Q plots indicated that a normal distribution of variability did not exist for all other measures. As a result, non-parametric statistical analysis was chosen to evaluate the results generated during data collection. For HR_{ave}, parametric tests were used in analysis when appropriate. Descriptive statistics are listed as medians (*Mdn*) and inter-quartile ranges (*IQR*) or Means (*M*) and Standard Deviations (*SD*).

Participant and Environmental Descriptive.

All 43 recruited participants completed this trial. Ages *(Mdn[IQR]*) for the sample were 15.23yrs (1.02). Players were 1.68m (.11) tall, weighing 56.29kg (12.29). The group had substantial playing experience, with many of the participants having started soccer participation in their elementary grade school years, albeit at differing levels of play. The median number of years played was 11.00yr (2.00). Other sport participation was mixed, with large variability coming from the P and C3 groups. Participant characteristics for the entire sample (N=43) are presented in **Table 4.1**. Stratification of participants by CL (P, n=16; C1, n=15; and C3,n=12) is presented in **Table 4.2**. Both the

P and C1 team participated in U-15 age groups while the C3 team participated in the U-14 age group.

Table 4.1. Descriptive Statistics - Total sample*	
	All Subjects (*N*=43)
Age (yrs)	15.23 (1.02)
Ht (m)	1.68 (.11)
Wt (kg)	56.29 (12.26)
BMI	20.99 (3.59)
Soccer Experience (yrs)	11.00 (2.00)
Other Sport Experience (yrs)	4.00 (8.00)
*Data is expressed as *Mdn* (*IQR*)	

Table 4.2. Descriptive Statistics - Stratified by CL*			
Stratified by Competition Level	Premier (*n*=16)	Classic 1 (*n*=15)	Classic 3 (*n*=12)
Age (yrs)	15.41 (.53)	15.49 (.29)	14.06 (1.36)
Ht (m)	1.68 (.11)	1.68 (.11)	1.57 (.15)
Wt (kg)	58.57 (8.40)	54.48 (14.07)	50.62 (19.41)
BMI	21.03 (2.06)	19.64 (4.59)	20.59 (7.71)
Soccer Experience (yrs)	11.00 (1.00)	11.00 (1.00)	8.00 (4.00)
Other Sport Experience (yrs)	4.50 (8.00)	8.00 (7.00)	2.00 (4.00)
*Data is expressed as *Mdn* (*IQR*)			

Environmental characteristics demonstrated variability as expected over the course of the 7-week data collection window. Results are described in **Table 4.3.** Values listed were recorded at the start of the training session (www.accuweather.com). The range for temperature was recorded as 17.78℃ - 29.00 ℃ (*Mdn [IQR]* = 27.00 [4.00]), for relative humidity 37.00% - 74.00% (*Mdn [IQR]* = 46.00 [21.00]), and for wind speed 0.00kph – 25.90kph (*Mdn [IQR]* = 11.27 [9.01]). Sun and shade, as well as field conditions are also listed for review. Concern over the effect of increased heat and humidity proved inconsequential. Analysis of environmental conditions on the dependent variables (70%HR_{max} and 85% HR_{max}) indicated that no significant effects were found.

Table 4.3. Descriptive Statistics - Environmental Conditions					
Date, CL	Temp. (^{0}C)	Humidity	Wind (kph)	Sun	Field
7/11, P	29.0	37%	11.1	Full	Dry, Hard
7/11, P	27.0	45%	18.3	Full	Dry, Hard
6/23, C1	27.0	66%	25.9	Full	Dry, Hard
6/21, C3	25.0	74%	0.00	Overcast	Dry, Soft
6/16, C1	29.0	47%	9.3	Full	Dry, Hard
5/24, C3	17.5	46%	11.3	Overcast	Dry, Soft

Heart Rate.

Heart Rate Average (HR_{ave}) and Heart Rate Maximum (HR_{max}) demonstrated a normal distribution of variance across all game conditions for the entire sample (*N*=43). Normality was not found when stratifying by CL. For the sample, HR_{ave} (173.90 ± 11.38) was 88.04% (±5.77%) of the estimated HR_{max} (197.51 ± .58) across all game conditions. The recorded HR_{max} (184.81 ± 30.46) was 94.40 % (±15.42%) of the estimated HR_{max} (197.51 ± .58) across all game conditions. A game by game description of HR_{ave} (**Table 4.4, Table 4.5**), and recorded HR_{max} stratified by CL follow (**Table 4.6, Table 4.7**).

Table 4.4. HR_{ave} as a Percentage of HR_{max} Estimated Across all Game Conditions*			
	HR_{ave}	HR_{max}Est.	Percentage
Total (*N* = 43)	173.90 (±11.38)	197.51 (±.58)	88.40% (±5.77%)
*Data expressed as *M*(*SD*)			

Table 4.5. HR_{ave} Stratified by CL for each Game Condition*			
	G1	G2	G3
Premier (*n* = 16)	170.31 (160.45 - 184.54)	173.14 (164.22 - 189.34)	173.02 (167.44 - 181.21)
Classic 1 (*n* = 15)	172.07 (167.58 - 179.06)	171.89 (165.08 - 180.47)	175.59 (168.56 - 178.41)
Classic 3 (*n* = 12)	178.81 (167.37 - 183.88)	176.03 (166.17 - 184.19)	171.77 (164.29 - 184.54)
*Data expressed as *Mdn*(*IQR*)			

Table 4.6. HR_{max} as a Percentage of HR_{max} Estimated Across all Game Conditions*			
	HR_{maxRec}	HR_{aveEst}	Percentage
Total (*N* = 43)	184.81 (30.46)	197.51 (.58)	94.40% (15.42%)
*Data expressed as *M*(*SD*)			

Table 4.7. HR_{max} Stratified by CL for each Game Condition*			
	G1	G2	G3
Premier (*n* = 16)	180.00 (176.25-194.25)	185.00 (177.25-198.00)	184.00 (181.00-196.75)
Classic 1 (*n* = 15)	183.00 (179.00-191.00)	186.00 (179.00-193.00)	186.00 (180.00-192.00)
Classic 3 (*n* = 12)	191.00 (185.75-198.50)	193.50 (187.25-198.50)	189.50 (181.50-198.75)
*Data expressed as *Mdn*(*IQR*)			

Heart rate data from the July 11 data collection session (session 1) is illustrated in **Figure 4.2**. An examination of the flow of HR during the training session demonstrates the consistent increases that occur with SSG training. While individual responses (%HR_{max}) were unique, the overall pattern of the HR response is evident.

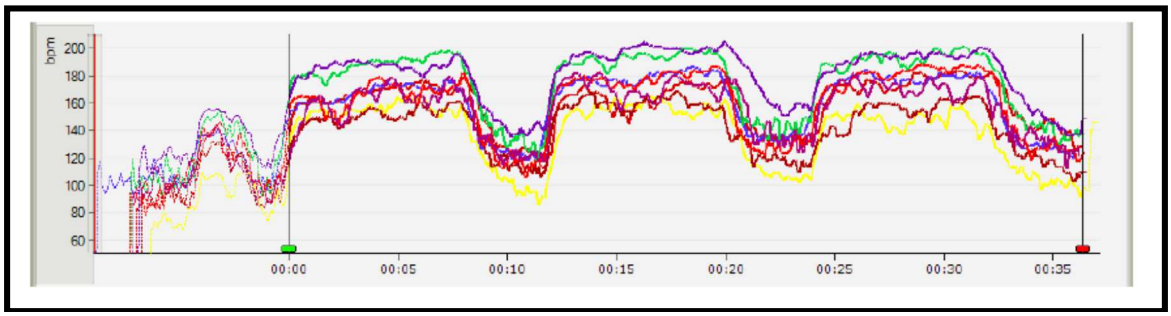


Figure 4.2. Polar *Team 2* heart rate data taken from July 11 (session 1)

Time.

Across all games HR_{ave}. Differences in HR_{ave} were examined between game conditions (T) and CL using a One Way Repeated Measures ANOVA (*N* = 43). There were no significant effects ($p < .05$) for either T or T*CL, Wilks' Lambda (T) = .988, F (2,41) = .243, p = .786; Wilks' Lambda (T*CL) = .798, F (4,82) = 2.326, p = .064. Heart rate average were similar between games for the sample and when stratified by CL.

Thresholds across All Games. Differences in time spent >70%HR_{max} and >85%HR_{max} were analyzed across all game conditions to determine the effect of Time (T) on the entire sample (*N*=43). Using a Friedman Test, differences (p<.05) were found between time spent >70%HR_{max} (χ^2 (2, n=43) = 15.65, p < .001) between G1, G2, and G3. Differences did not appear when examining time spent >85%HR_{max} (χ^2 (2, n=43) = 1.86, p = .394).

Further analysis of the differences in >70%HR_{max} between G1, G2, and G3, utilizing a Wilcoxon Signed Ranks Test, indicates the following, G1 > G2 and G3; G2 = G3, demonstrative of variability in time spent above this threshold between game conditions, specifically G1. Examination of the absolute difference of *Mdn* times demonstrates that effect generated in this analysis, while significant, is only a few seconds in real terms. The results are described in

Table 4.8.

Table 4.8. Wilcoxon Signed Ranks Test – Difference between Game Conditions; >70%HR_{max} (sec) (*N* = 43)

	G1 > G2	G1 > G3	G2 = G3
Z	-3.932	-3.771	-1.001
p Value	*p* < .001	*p* < .001	*p* = .317
Effect Size	Medium (*r* = .42)	Medium (*r* = .41)	Small (*r* = .11)

Above and below thresholds. Significance (p<.05) was found for both >70%HR_{max} and >85%HR_{max} when examining the differences in time spent above and below each threshold in each game condition using the Wilcoxon Signed Ranks Test. Results of analyses are given in **Table 4.9** (>70%HRmax) and **Table 4.11** (>85%HRmax) respectively. Descriptive data for time spent above each threshold is listed in **Table 4.10** and **Table 4.12**. Effect sizes listed are .1 = small, .3 medium, and .5 = large (Cohen, 1992).

Median times (>70%HR_{max}) were 99%, 96%, and 96% of total time respectively for G1, G2, and G3. Median times (>85%HR_{max}) were 81%, 81%, and 79% respectively for G1, G2, and G3. These differences are illustrated in both **Figure 4.3** (>70%HR_{max}) and **Figure 4.4** (>85%HR_{max}). Greater detail inclusive of *Mdn* (*IQR)* is provided in both **Table 4.10** (>70%HR_{max}) and **Table 4.12** (>85%HR_{max}). Of note in the data are the relatively tight *IQR* ranges for >70%HR_{max}, ranging from 440.00 – 480.00 (sec) across all games.

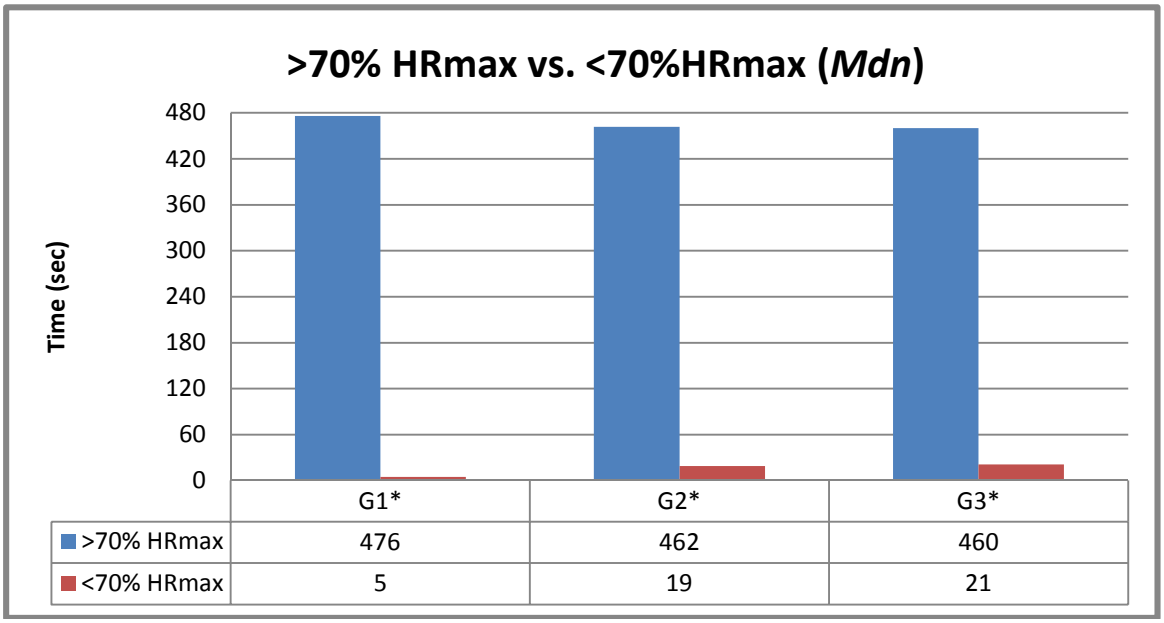


Figure 4.3 Times above and below 70%HR_{max}; *p<.05

Table 4.9. Wilcoxon Signed Rank Test Results - >70% HR_{max} (sec) (N = 43)			
	G1	G2	G3
Z	-5.731	-5.701	-5.723
p Value	p < .001	p < .001	p < .001
Effect Size	Large (r = .62)	Large (r = .61)	Large (r = .62)

Table 4.10. Total time >70% HR_{max}, *Mdn*(*IQR*)			
Time	N	*Mdn* (sec)	*IQR* (sec)
Game 1	43	476.00	467.00 – 480.00
Game 2	43	462.00	440.00 – 474.00
Game 3	43	460.00	441.00 – 480.00

While time spent >85%HR_{max} was significantly greater than time below, the *IQR* for >85%HR_{max} has a greater range in the distribution of variability when compared to >70%HR_{max}. The *IQR* for >85%HR_{max} ranges from 260.00 – 447.00 (sec).

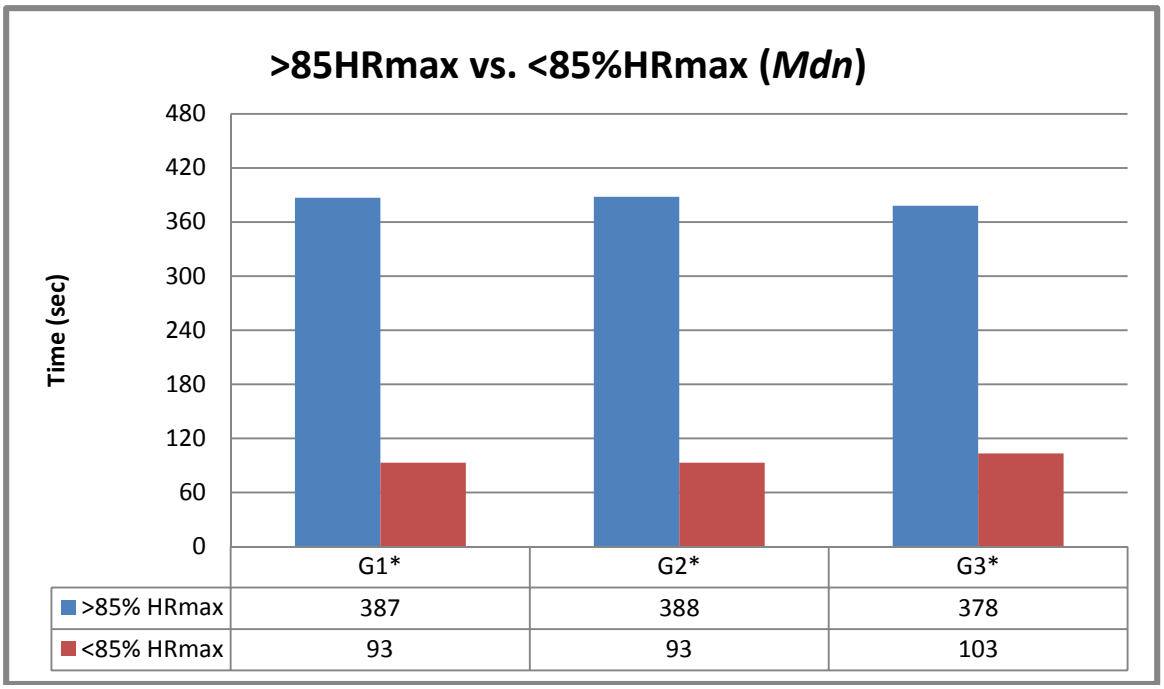


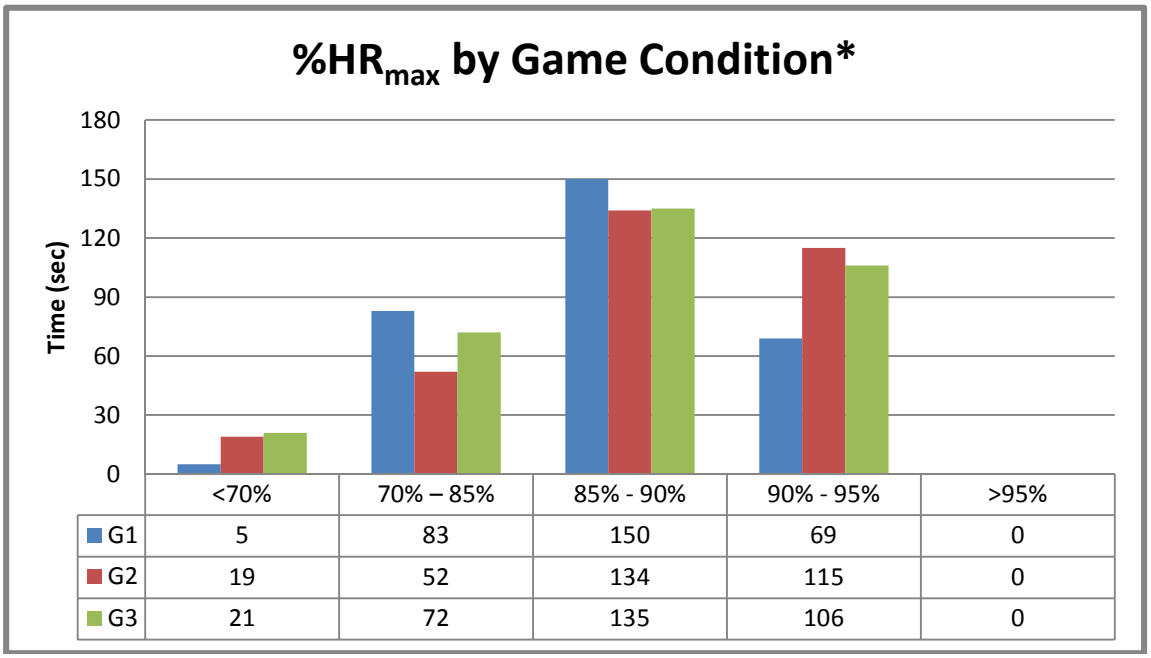
Figure 4.4 Times above and below 85%HR_{max}; *p<.05

Table 4.11. Wilcoxon Signed Rank Test Results - >85% HR_{max} (sec) (N = 43)			
	G1	G2	G3
Z	-3.526	-3.430	-4.033
p Value (p=.05)	p < .001	p < .001	p < .001
Effect Size	Medium (r = .38)	Medium (r = .37)	Medium (r = .43)

Table 4.12. Total time >85% HRmax, *Mdn*(*IQR*)			
Time	N	*Mdn* (sec)	*IQR* (sec)
Game 1	43	387.00	260.00 – 447.00
Game 2	43	388.00	269.00 – 436.00
Game 3	43	378.00	285.00 – 430.00

An illustration (**Figure 4.5**) of the relative time spent at each of five stratifications of HR_{max} is provided. The selection of these stratifications (Helgerud et al., 2001), while equivocal in their use to describe the bioenergetic demand in adolescents is none the

less represented throughout the literature (A. Dellal et al., 2012). Of note is the obvious effect of this SSG training format had on EI, measured as a function of HR_{max}. Further visual inspection demonstrates the clustering of time spent between 70% and 95% HR_{max}.



	<70%	70% – 85%	85% - 90%	90% - 95%	>95%
G1	5	83	150	69	0
G2	19	52	134	115	0
G3	21	72	135	106	0

Figure 4.5. Time (sec) spent at selected stratifications of HR_{max}; * = *Mdn* (sec)

Further exploration of these stratifications is provided in **Table 4.13.** Variability within each is present, although the *IQR* on the lowest strata is fairly condensed. By way of comparison median scores of time spent above 95% HR_{max} were 0.00, however there was a large *IQR* in each case, demonstrating that some players were able to achieve high HR during play, albeit a small group within the total sample. While inconclusive, this does describe the variability of HR present within this sample.

Table 4.13. Time (sec) at Stratifications of %HR_{max} for each Game Condition* (*N*=43)			
%HR_{max}	G1	G2	G3
>95%	0.00 (0.00 – 106.00)	0.00 (0.00 – 181.00)	0.00 (0.00 – 228.00)
90% – 95%	69.00 (27.00 – 215.00)	115.00 (12.00 – 189.00)	106.00 (32.00 – 191.00)
85% - 90%	147.00 (28.00 – 226.00)	131.00 (14.00 – 156.00)	135.00 (11.00 – 216.00)
70% - 85%	83.00 (28.00 – 214.00)	52.00 (26.00 – 156.00)	72.00 (37.00 – 162.00)
<70%	5.00 (0.00 – 14.00)	19.00 (7.00 – 41.00)	21.00 (0.00 – 40.00)
*Data is expressed as *Mdn* (*IQR*)			

Competition Level

Competition level was hypothesized to be a moderating factor in the accrual of time at two specific thresholds of HR_{max} during SSG training. Using a Kruskal-Willis Test to explore the moderating effect of CL, significant differences did not appear at either threshold. In our analysis *p* values ($p<.05$) did not reach significance. Results from analysis exploring time spent >70%HR_{max} moderated by CL are shown in **Table 4.14**. These relationships are further illustrated in **Figure 4.6**.

Table 4.14. Kruskal-Willis Test Results – >70% HR_{max} (sec) by CL; $p = .05$			
	G1	G2	G3
χ^2 (2, *n*=43)	5.269	2.432	3.570
p Value (*p*=.05)	$p = .072$	$p = .296$	$p = .168$

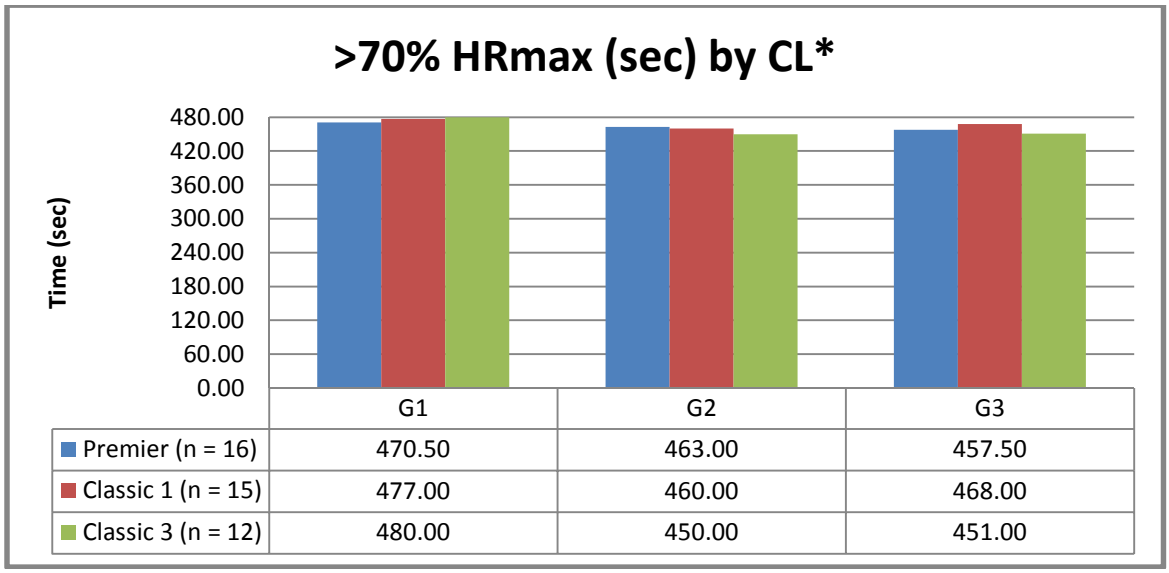


Figure 4.6. Time (sec) spent >70%HR_{max} stratified by CL; * = *Mdn* (sec)

Results from analysis exploring the time spent >85%HR_{max} moderated by CL are shown in **Table 4.15**. As with the previous analysis, *p* values (*p*<.05) did not achieve significance. These relationships are further illustrated in **Figure 4.7**. While not statistically significant, inspection of the data for the C3 group indicates a drop in >85%HR_{max}. This may lack statistical detection due to the relatively small sample size, a consideration for future research.

Table 4.15. Kruskal-Willis Test Results – >85% HR_{max} (sec) by CL*

	G1	G2	G3
χ^2 (2, *n*=43)	.654	.270	1.884
p Value (*p*=.05)	*p* = .721	*p* = .874	*p* = .390

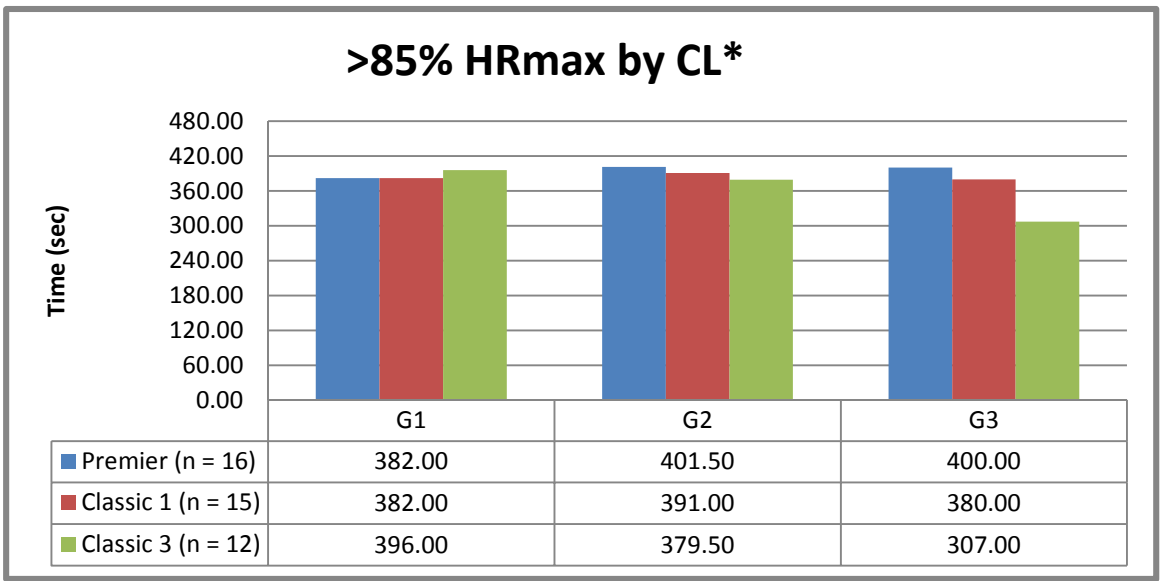


Figure 4.7. Time (sec) spent >85%HR_{max} stratified by CL; * = *Mdn* (sec)

Discussion

The original research question has its roots in the efficacy of SSG training in providing a training stimulus (%HR_{max}) to club-level, adolescent female participants that had previously been seen in elite players. The primary aim of this trial was to examine time spent above two unique EI thresholds (>70%HR_{max}, >85%HR_{max}) during repeated SSG training bouts, while exploring the moderating effect of CL in this underrepresented population. Previous research, reviewed elsewhere, has demonstrated that SSG training is efficacious in delivering a training stimulus that mirrors the energy demands of match play while providing opportunities for additional training in both technical and tactical components found in the game in elite level players (Ali, 2011; Burgess & Naughton, 2010; Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014a; S. V. Hill-Haas et al., 2011). Within the published research however, gaps exist describing the effect of SSG training in the population of interest. With the large numbers of girls participating in youth soccer in the U.S. (Federation of International Football Associations, 2012; National Sporting Goods Association, 2011), there is a need for continued research into the outcomes associated with this popular training modality. This necessity is not only true

for coaches and trainers interested in utilizing these training tools, but also within the larger scope if public health.

Heart Rate Averages and Time.

The distribution of EI (%HR_{max}) recorded during this trial are within ranges found throughout the literature. For example, in a study of elite, male players of a similar age (15.6 ±.8), exploring rule and player number changes, Hill-Haas et al. (2010) reported EI (%HR_{max}) was consistently found to be in the low to mid 80%'s (81.4% - 84.8% HR_{max}) across all game conditions. As with the exploration of CL on HR in this trial, while changes in moderators such as rules and player numbers did influence other outcomes of interest (e.g. RPE, Blood Lactate), there was little effect of %HR_{max} (S. V. Hill-Haas, Coutts, Dawson, & Rowsell, 2010).

In another example comparing differences in %HR_{max}, moderated by CL (professional and amateur players), Dellal et al. (2011) did not find statistical differences (A. Dellal et al., 2011). In similar format games (4v4, free-play), the %HR_{max} for amateur French 4th division players was 84.7% (±2.7%) of HR_{max}. For the professional French 1st division players %HR_{max} was 85.1% (±2.4%). These were found to be similar, although CL did produce differences in several other outcomes of interest.

The HR_{ave} found within this trial appear to be similar to those found throughout the literature (A. Dellal et al., 2012; A. Dellal et al., 2008; A. Dellal et al., 2011; Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014b; S. V. Hill-Haas, Dawson et al., 2009; S. V. Hill-Haas et al., 2009; S. V. Hill-Haas et al., 2011; Koklu, Asci, Unver Kocak, Alemdaroglu, & Dundar, 2011). Stratification into chosen EI zones follows the work of Helgerud et al. (2001). A visual inspection of **Figure 4.5** supports the premise that this format of SSG training is a sound method of generating EI between 70% and 95% of HR_{max}. This is further supported when investigating the time results (*Mdn*[IQR]) for each

strata in each game condition. With that said, the *IQR* found in most of the strata is indicative of reasonable levels of individual variability within measured HR responses. Centralized values of EI can be described, but the range of the *IQR* within most strata is evident. Care must be taken when generalizing results such as these, especially at the individual level. What is readily apparent is the significant amount of time spent above identified thresholds, allowing group level generalizations to be applied to this population regarding the relative EI of SSG training.

Time did not demonstrate a significant effect on HR_{ave} across all game conditions for either the entire sample or when stratified by CL. There were no significant differences found in HR_{ave} between games and levels of play. The findings with regard to T is in contradiction to the results found by Köklü et al. (2011) in their work with young elite players. In their research, differences in HR_{ave} between repeated SSG's were found in a 6-bout format, where differences between Game 1 and the remaining five games appeared (G1<G2=G3=G4=G5), independent of player numbers (e.g. 1v1, 2v2, 3v3, and 4v4).

Thresholds

The use of 70%HR_{max} and 85%HR_{max} as thresholds represents the theoretical estimated Aerobic Threshold and Anaerobic Threshold in adults (Helgerud et al., 2001). While accepted as threshold estimates for adults, their use with adolescents is equivocal (A. Dellal et al., 2012). To the contrary, the use of these thresholds does allow for the comparison of results across groups, maintaining integrity in reporting. Continued research into the specific bioenergetic thresholds found in adolescents is warranted.

70% HR_{max} and Time. Prior to examination of the time above and below this threshold, an analysis of the effect of T (changes in T from G1 to G3) was run on >70%HR_{max}. Using a Wilcoxon Signed Ranks Test, an exploration of the effect of T

across all games for the entire sample demonstrated a significant difference in time (sec) >70%HR_{max} between game conditions. Time >70%HR_{max} in Game 1 was greater than Game 2 and Game 3 (p <.001), which was equal to Game 3 (p=.317) (476 sec > 460 and 462 sec; 460 sec = 462 sec). While interesting, the absolute difference in time spent above this threshold was relatively small, 16 and 14 seconds (*Mdn*) respectively.

The time spent above 70%HR_{max} is the most conclusive finding from this trial. The high percentage of time spent above 70%HR_{max} is obvious. Significant differences between time spent above and below 70%HR_{max} occurred (p<.001). Effect sizes were impressive for this outcome, with "Large" effects for each game condition (r =.62, r =.61, r =.62) (Cohen, 1992). This coupled with the low *IQR* (440 – 480 across all games), is indicative of an EI above 70% for most time spent in SSG training matching these criteria (4v4, free-play, 8 min). This format of training provided a strong training stimulus above the selected threshold in each game. In each game condition, less than 30 seconds of time (*Mdn*) was spent below this threshold. Not only are SSG's apparently effective at providing training opportunities to promote this level of EI, they also may provide time management and instructional advantages due to their structure (e.g. multiple players, all involved, conditional play) for the club-level trainer and coach (Gabbett et al., 2009). This finding is positive for youth coaches, providing a stimulus that can have positive effect on both musculoskeletal and cardiovascular adaptations that promote match readiness as well as potential health improvements (Krustrup et al., 2010; Krustrup, Dvorak et al., 2010; Krustrup et al., 2010).

85%HR_{max}. This finding is another positive result from this trail. High intensity (>85%HR_{max}) running is a function of soccer matches regardless of sex (Gabbett & Mulvey, 2008; Gabbett et al., 2009). Significant differences between time spent above and below 85%HR_{max} did appear in the data (p<.001). However, unlike the previous outcome of

70%HR_{max}, the *IQR* associated with this threshold (260 – 447 across all games) does not support the ease in group level generalization found with 70%HR_{max}. Inspection of the *Mdn* times (G1 = 387 sec, G2 = 388 sec, G3 = 378 sec) does however point out the great amount of time spent at high levels of EI, irrespective of *IQR*. Combined with the level of significance, in this population this format of SSG training appears to be effective at eliciting an EI commensurate with this level of play.

The lack of consistent time spent above 95% HR_{max} does seem to fit within previous reported findings around SSG training. Factors such as the choice in field size (mid), length of game time (8 min), instructional time between games (4 min), and choice of player number (4v4) all support a HR response similar to that found here, 70% to 95% HR_{max}. Previous research has demonstrated that in order to elicit HR response in this maximal zone (>95%HR_{max}), larger spaces, smaller player numbers, and shorter intervals, inclusive of reduced rest phases all increase the time spent at near HR_{max} (Casamichana & Castellano, 2010; Owen, Twist, & Ford, 2004). It is important to recognize however that much of the interest in maximal workloads in focused on the repeated sprint and change of direction aspects of play, in such cases the selection of HR as a descriptive outcome suspect. Other methods of time and motion analysis, such as Global Positioning Systems and accelerometers, are more sensitive at detecting short changes in maximal EI, often just a few seconds during the flow of play. While such activity was not the focus of this trial, there is reasonable support here for further examination of this SSG training format to deliver repeated sprint activity, or sustained maximal work, at a level that would positively increase performance in this important facet of play.

Competition Level

Competition level failed to produce significant differences (p<.05) in the amount of time spent above these thresholds. This finding is a positive result when considering the use of SSG training modalities across a wide range of players. As previously mentioned, the robust nature of SSG training encompasses the technical and tactical aspects of match competition. This may be important to the youth coach where time

constraints in training are many. It has been acknowledged that the randomized, non-structured format of the training stimulus found in SSG's is beneficial to the retention and application of learned techniques, with the added training factors of time and oppositional pressure (Gabbett, 2006; Gabbett, 2006; Williams & Hodges, 2005). When given the opportunity to incorporate several components of a match play into one drill format, there is strong rationale for its use, not to the exclusion of other more linear formats, but with an understanding that its use provides multiple positive outcomes (e.g. fitness training, technical opportunity, and tactical decision making).

The selection of CL as a moderator of interest was based on suspected differences in the habituation of players to the higher pace of play associated with P (competitive level) soccer when compared to C3 (recreational level). It was proposed that P may play at higher work rates than C1 and C3 due to the competitive nature of their competition and the expectations of performance that coincide with a higher team placement. While the technical and tactical ability of the participants was readily apparent to all observers, this did not change the effect of the training format to elicit HR_{ave} at a level commensurate with improved fitness outcomes. Not only does this format of SSG training support these EI's, but it does so independent of the CL of the players. Since it is understood that CL is a stratification of players that occurs through a "try-out" process, CL then becomes is a proxy measure of skill. In effect, this format of SSG training is effective at eliciting a fitness straining response, regardless of the skill level of the participant.

Public Health Implications.

The previously mentioned finding, that SSG training elicits a work rate identified with cardiovascular improvement, becomes more essential when considering youth sport from a public health perspective. It is generally understood that chosen team sports (e.g.

soccer, basketball) may require movement patterns that are beneficial to improved health outcomes. However, there is much room for increased documentation of the direct physiologic effects of youth sport (P. T. Katzmarzyk et al., 2014; Pate & O'Neill, 2011). With the prevalence of childhood obesity and associated co-morbidities at high level (P. T. Katzmarzyk et al., 2014; Ogden, Carroll, Kit, & Flegal, 2012; U. S. Department of Health & Human Services, 2008), youth sport may be poised to combat these negative health outcomes.

This has been explored in adults. A series of trials exploring SSG training (5v5) to improve selected health measures in healthy adults has demonstrated efficacy to positively affect these parameters. In an executive summary of the health and fitness benefits of participation in SSG's Krustup, et.al (2010) concluded that the substantial health and fitness benefit was realized following consistent play of 5v5, SSG scrimmages (Krustrup, Dvorak et al., 2010). Summarizing the effects of a series of randomized controlled trials conducted through the Department of Exercise and Sport Science, University of Copenhagen, Denmark, Krustup determined that SSG training provided health outcomes equal to, and often greater than steady state endurance running (E) in untrained men and women. Both modalities demonstrated significant, positive outcomes to inactive controls in eliciting physiologic and phenotypic adaptations (p<05). The strong outcomes associated with soccer participation in SSG's are a positive finding in the fight against non-communicable (NCD) and chronic disease (CD).

Within these trials, muscle adaptations included the greater development of lean mass and losses in fat mass (Knoepfli-Lenzin et al., 2010; Krustrup et al., 2010). Strength was also increased in hamstring and quadriceps with a concurrent increase quadriceps cross sectional size. Muscular fiber type and distribution were affected demonstrating movement away from Type IIx indicative of a greater utilization of oxygen,

considered to be an increase in aerobic function (Krustrup, Christensen et al., 2010). Also found was increased bone mineral density and bone mineral content in the group that maintained soccer participation for the year following the trial (Randers et al., 2010). Cardiovascular changes included improvements in HR_{rest}, HR_{var}, HR_{pace}, VO_{2max}, relative $VO_{2max,}$ $O_{2uptake}$, citrate synthase concentrations, body composition, and blood profiles clearly outpacing that of E (J. Bangsbo et al., 2010; Knoepfli-Lenzin et al., 2010; Krustrup et al., 2010; Randers et al., 2010). Increases in capillary profusion were also recognized.

These results, combined with multiple research trials demonstrating the positive impact of SSG's on physiologic, motor control, and musculoskeletal adaptations create a strong argument for the continued exploration of sport as a combatant in the fight against lifestyle related disease in our youth.

Strengths and Limitations

As with any trial, there are associated strengths and limitations. Strengths of this trial include the sample population. The use of club-level female participants is the first of its kind to the knowledge of the authors. Furthermore, the choice of a SSG format found across the soccer fields of the U.S. possesses high levels of ecologic validity. Including an examination of the effect of CL in the trial also has high degrees of ecologic validity.

Limitations include the use of estimates to provide HR_{max} values as reference points. Use of either field based maximal aerobic testing (Beep testing) or laboratory based testing (VO_{2max} GXT) would provide a more accurate analysis of this research question. Finally, this was a sample of convenience from the metro Minneapolis/St. Paul region. Generalizing results to a more varied population would require a sample that is more representative of our cultural diversity.

CHAPTER 5: Small Sided Games and Ball Possession Outcomes in Adolescent Female Soccer Players: The Effect of Time and Competitive Level on Positive Possession

Introduction

Small sided games (SSG) are used throughout the sport of soccer as a training modality. The robust nature of SSG's is generally recognized as an effective means for the development of skills in the sport. Small sided games have been shown to be efficacious in the transition of a technique, an unopposed motor development, into a skill, the addition of time and oppositional constraints (Ali, 2011; Williams & Hodges, 2005). While block training modalities have shown a greater proficiency in increasing player's abilities with the ball when compared to SSG training, these occur in unopposed environments. When compared in match play, those who practiced using SSG training had greater positive skill outcomes than that of block training (Ali, 2011; Gabbett et al., 2009; Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014a; Williams & Hodges, 2005).

Factors influencing SSG's have been thoroughly examined in elite level players. While this is true, very little research exists describing their use in club-level players, specifically females, the population of interest in this paper. While there is much research to document the efficacy of SSG's as a training intervention, it has been changes in game conditions that have been the specific focus of research for more than two decades. Several thorough reviews exist summarizing these effects elsewhere (Ali, 2011; Francis, 2005; Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014a; S. V. Hill-Haas et al., 2011; S. V. Hill-Haas et al., 2010; Krustrup et al., 2010; T. Reilly, 2003).

As a brief overview, several studies have been conducted that have isolated factors that either increase or decrease physiologic, time and motion, and skill outcomes in soccer. Casamichana and Castellano (2010) explored changes in pitch size relative to effective playing time, physical (time and motion), physiologic, motor skill (ball skills) and rate of perceived exertion (RPE) in boys aged 15 years (*n*=10). Using a cross sectional

design, significant differences were found in these outcomes. Changes to the area of the playing surface had the effect of increasing effective playing time, physical, physiologic, and RPE outcomes, while decreasing motor skills performed. Competitive level (CL) and rule changes (ball contact limits) were also shown to effect SSG outcomes. Dellal et al. (2011) examined the differences between first and fourth division players in French professional leagues. Outcomes of interest were time and motion, physiologic, technical, and RPE. Between groups, professional players (1st division) consistently demonstrated less physiologic stress, greater distances covered during play, greater technical outcomes, all with a reduced RPE regardless of the ball touch limitations.

Continuous and intermittent play was explored in elite boys aged 16-years (*n*=16). Hill-Haas et al. (2010) used a cross sectional format to establish that continuous play (24 minutes) lead to a higher mean percentage of heart rate maximum ($\%HR_{max}$) and RPE, while interval style games (4 x 6 minutes) lead to greater time and motion outcomes associated with distance covered and time spent sprinting. These results support the connection between players' subjective understanding of time available in the game condition and their willingness to extend maximal effort. The greater the time that a player has to play, the less likely they are to maximize work rate, possibly with the understanding that to do so would tax "reserves" that they may feel necessary to complete the longer time requirement. The increase found in $\%HR_{max}$ during continuous play supports that commonly held belief (e.g. players subjective decision making). In another trial, Hill-Haas et al. (2009) changed player numbers between a 2v2, 4v4, and 6v6 format. Time and motion, physiologic, and RPE were compared in a cross sectional model maintaining the same relative player areas (increasing pitch size in relation to player numbers). Decreases in player number had the effect of increasing several time

and motion outcomes (i.e. Sprints, Time spent sprinting, Sprint maximum) and well as physiologic (time at specific %HR_{max}) and RPE.

With the emphasis on SSG training, there has also been increased use of SSG's to stratify players according to ability, specifically during player selection processes (W. Helsen et al., 2005; Williams & Hodges, 2005). The large numbers of participants in association soccer has increased the demand for efficacious methods to stratify players based on talent level into appropriate competition levels (Federation of International Football Associations, 2012; National Sporting Goods Association, 2011). Using SSG's may provide a time effective manner to stratify large numbers of players. When using SSG's, it is implicit on the organizing bodies to define both feasible and valid metrics for player stratification. One such metric, Positive Possession (PosP), the combination of completed passes and shots on goal, may provide valid measures for player stratification. The further exploration of this metric in club-level players is warranted due to the large numbers of participants at this level of play (National Sporting Goods Association, 2011). Should PosP demonstrate significant differences between CL in SSG training, this may become a feasible, scientifically valid metric for the separation of players in developmentally appropriate CL's. Another factor that needs further exploration is the effect of Time (T) on repeated game performance. This becomes a necessity when considering the manner in which player selection processes occur, often with repeated trials of a given SSG format. This paper seeks to inspect the moderating effect of these two factors. The specific aim of this trial is to examine the effect of Time (T) and CL on PosP on adolescent club-level, female soccer players in free, play 4v4 SSG training.

Methods

Participants.

Forty-three club-level, female adolescent soccer players registered to Minnesota Youth Soccer Association (MYSA) participating member clubs (Centennial Soccer Club, North East Soccer Club, and St. Croix Soccer Club) volunteered to participate in this trial. This convenience sample was solicited through soccer clubs who had responded to an email seeking participation. Correspondence with club leadership identified teams that met the inclusion criteria: Girls team; Age group Under-13 through Under-16 (age); and Competition level Classic 3 (C3), Classic 2, Classic 1 (C1), and Premier (P). Electronic communications with head coaches' followed leading to a players-only meeting where participants were directly recruited for volunteer participation in the trial. All subjects were currently participating on one of three unique teams, one each at P, C1, and a C3 level of play. Each team finished in the upper half of group play in the year preceding the trial. The subjects were healthy, high school aged students who had no known metabolic disorders, physical limitations or medication use that would preclude them from participation. The study was approved by the Institutional Review Board at the University of Minnesota, Twin Cities. All subjects gave written informed assent with parental consent to participate.

Data Collection.

Training dates were chosen based on convenience for the teams participating. Dates were affected by training availability and game schedules. Data collection occurred during the competitive season of 2013. Subjects were required to be present 30-minutes prior to the arranged training session to fill out informed consent paperwork and for equipment set-up. Following the informed consent process, anthropometric data (self-reported) was acquired through a questionnaire. Subjects were informed that they

were to come prepared with a self recorded height and weight prior to testing. Subsequent to the survey, a direct measure of height and weight were taken (Seca 763; Chino, CA). Procedures for this measure are outlined by the Minnesota Department of Health (Minnesota Department of Health, 2011). Ultimately, self-reporting of height and weight was required for statistical analysis following an equipment failure in the stadiometer scale used for direct measurement on July 11. Prior to this, 27 of the 42 participants had completed both self-report and direct measure. This nested data was statistically analyzed to establish the strength of association. The correlation between directly measured and self-reported Body Mass Index (BMI) was very high (r=.91, p<.01). As BMI is a function of Height and Weight (BMI = kg/m^2), this significant high correlation presents a strong case for the validity of using self-reported height and weight as a functional alternative to directly measured height and weight in this trial.

Other descriptive variables of interest were culled through the use of the pre-competition questionnaire. These included:

- Age
- School grade
- Race
- Predominate playing position
- Years of soccer experience
- Highest level of soccer competition (team placement)
- Outside sport participation, years of experience

Game Format and Design.

Subjects from each team (P, C1, and C3) were randomized to one of two waves (Wave 1 and Wave 2), creating six unique waves of subjects (3 Teams x 2 Waves). Waves were then assigned to one of the two sessions (per team) for data collection. At

the assigned session the selected Wave participated in three games (G1, G2, and G3). An illustration of the distribution of players (CL) and game flow (W) is provided in **Figure 5.1**.

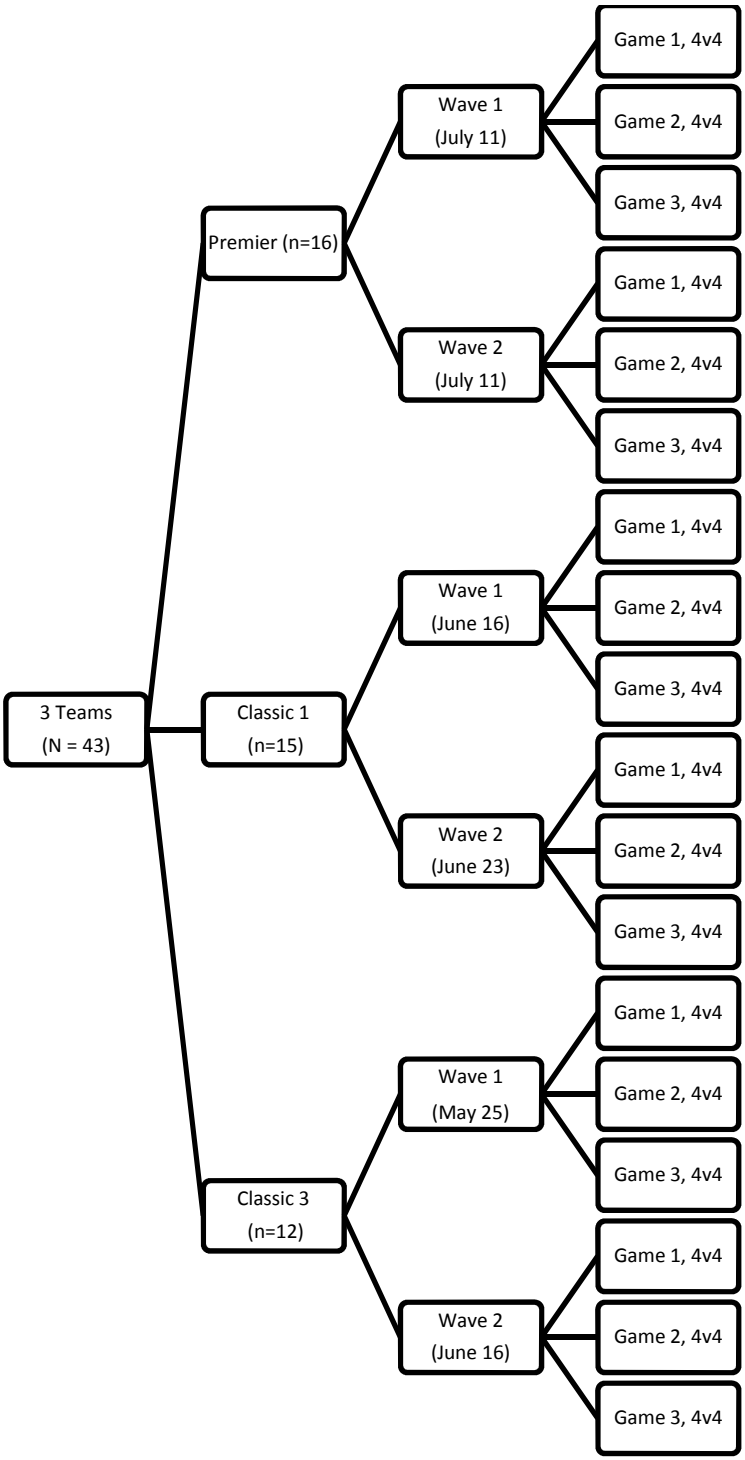


Figure 5.1 Distribution of teams by Competitive Level and Wave

For G1, players were randomly selected to one of two teams (Red and Yellow). Between each successive game (G1 and G2, G2 and G3) random assignment was re-applied, giving the Red and Yellow rosters unique combinations for each 8-minute bout. The effect of this process created 18 unique 8-minute bouts (3 Teams x 2 Waves x 3 Games) for analysis. Randomization between game conditions allowed for the analysis of data free from bias from player grouping, an important factor when attempting to generalize to the population of adolescent players.

The scrimmage format was a 4v4, free-play scrimmage. Conditions on play included immediate ball availability on those played out of bounds, all restarts from the ground (no throws) and free touches (no restrictions on dribbling). Each scrimmage was 8-minutes in length, separated with a 4-minute recovery (instructional time). Randomization was managed during recovery. Three scrimmages and recoveries were linked together making the entire training time 36-minutes (24 minutes play, 12 minutes recovery). A 10-minute progressive, dynamic warm-up was administered to the subjects prior to their participation. The adapted format for the scrimmages has been described elsewhere (Casamichana & Castellano, 2010; A. Dellal et al., 2011; S. V. Hill-Haas et al., 2011). Field dimensions were 30m x 20m, using “Pugg” goals (Boston, MA) on each end line, goalies were not used. Cones were equally dispersed to establish touch and end lines.

Following a brief overview of the rules for play, subjects were prepared for play. Camera placement for the video recording of events was standardized at 5-meters from the touch line at the mid-point of the playing surface. A high speed, high definition video camera (Sony AVC-HD HDR-CX360; Sony Corporation; Tokyo, Japan) was used to capture games, set on a tripod at the height of 1.50-meters. The recording angle was set to capture 50% of the playing surface at once, while maintaining a field of view that allowed for the clear delineation of jersey numbers. Play began with all “on the ball” skill

events captured through video recording. The focus of this data collection was specific to the recording of skill events, not the calculation of time and motion characteristics, reducing the emphasis on calibration of the playing surface for analysis. Slight variability in the video set-up will not bias skill cataloguing during analysis, so long as clear line of sight was present during play. At the commencement of play, equipment was recovered followed by a 5-minute cool down before releasing the subjects.

Data Cataloging.

Video recordings were analyzed with skill events catalogued by Match Analysis™ (Emeryville, CA), a private sports analytics firm that specializes in the video cataloging of soccer matches for both professional and collegiate clients. Match Analysis™ currently holds contracts with the United States Soccer Federation, Major League Soccer (US), Liga MX (Mexico), and the National Collegiate Athletic Association. Following cataloging, the video was mined for data specific to skill events using Tango Online™, proprietary software developed by Match Analysis™.

Cataloguing skill events that occur during play is a process of using frame by frame analytics to create time-coded digital markers in the software. Events are then transmitted to a data base for sorting and recall. Game analysis occurs when researchers/coaches utilize the data base to recall specific queries. Catalogued events are then analyzed for agreement and recorded. For this trial, the dependent variable PosP, was operationalized as the combination of shots and completed passes. As a point of reference, negative possession was operationalized as incomplete passes and lost dribble. Ultimately, for each player, possession of the ball will result in one of these four outcomes, two being positive and two being negative. **Figure 5.**2 is a visual graphic of PosP generated through Tango Online™.

Figure 5.2 Tango Online™; Possession Graphic

Descriptions of other various skill events are also included (**Table 5.5**):

- *Dual Won Percentage* – the percentage of duals won vs opponent
- *Touches* – the numbers of unique times a player controlled the ball
- *Shots* – the number of unique shots taken by a player
- *Goals* – the number of goals scored during play by a player
- *Passing Efficiency Percentage* – Passes completed / Total Passes Attempted
- *Assists* – the number of passes that lead directly to a goal by a player

Statistical Analysis.

Statistical analysis was conducted using SPSS software (IBM, Armonk, NY), version 19. Prior to statistical analysis all variables were checked for normality (Shapiro-Wilk Test, Histogram and Q-Q Plot). The Shapiro-Wilk Test was selected due to the small sample sizes (Howell, 2007; Pallant, 2013). Both parametric and non-parametric statistical analyses were conducted as dictated by the distribution of the variance. The

interactions and main effects of both T and CL were analyzed using a Mixed Between-Within Subjects Repeated Measures ANOVA (Howell, 2007; Pallant, 2013). Descriptive data was also provided in either Means and Standard Deviations or Medians and Inter-Quartile Ranges as appropriate. Statistical significance for all tests was set at p=.05.

Results

Participant and Environmental Descriptive.

All recruited participants completed this trial (N = 43). Both the P and C1 team participated in U-15 age groups while the C3 team participated in the U-14 age group. Median ages (*IQR*) for the sample were 15.23yrs (1.02). Players were 1.68m (.11) tall, weighing 56.29kg (12.29). The group had substantial playing experience, with many of the participants having started soccer participation in their elementary grade school years, albeit at differing levels of play. The number of years played was 11.00yr (2.00). Other sport participation was mixed, with large variability coming from the P and C3 groups. Participant characteristics for the entire sample (N=43) are presented in **Table 5.1**. Stratification of participants by CL (P, n=16; C1, n=15; and C3, n=12) is presented in **Table 5.2**.

Table 5.1. Descriptive Statistics* - All Subjects

	All Subjects (N=43)
Age (yrs)	15.23 (1.02)
Ht (m)	1.68 (.11)
Wt (kg)	56.29 (12.26)
BMI (kg/m^2)	20.99 (3.59)
Soccer Experience (yrs)	11.00 (2.00)
Other Sport Experience (yrs)	4.00 (8.00)

*Data is expressed as *Mdn* (*IQR*)

Table 5.2. Descriptive Statistics* - Stratified by CL			
Stratified by Competition Level	Premier (*n*=16)	Classic 1 (*n*=15)	Classic 3 (*n*=12)
Age (yrs)	15.41 (.53)	15.49 (.29)	14.06 (1.36)
Ht (m)	1.68 (.11)	1.68 (.11)	1.57 (.15)
Wt (kg)	58.57 (8.40)	54.48 (14.07)	50.62 (19.41)
BMI (kg/m^2)	21.03 (2.06)	19.64 (4.59)	20.59 (7.71)
Soccer Experience (yrs)	11.00 (1.00)	11.00 (1.00)	8.00 (4.00)
Other Sport Experience (yrs)	4.50 (8.00)	8.00 (7.00)	2.00 (4.00)
*Data is expressed as *Mdn* (*IQR*)			

Environmental characteristics are described in **Table 5.3.** Values listed were recorded at the start of the training session (www.accuweather.com). The range for temperature was recorded as 17.78℃ - 29.00 ℃ (*Mdn [IQR]* = 27.00 [4.00]), for relative humidity 37.00% - 74.00% (46.00 [21.00]), and for wind speed 0.00kph – 25.90kph (11.27 [9.01]). Sun and shade, as well as qualification of field conditions (Saturation description, Surface type) are also listed for review. All playing surfaces were natural grass.

Table 5.3. Descriptive Statistics - Environmental Conditions					
Date, CL	Temp. (^{0}C)	Humidity	Wind (kph)	Sun	Field
7/11, P	29.0	37%	11.1	Full	Dry, Hard
7/11, P	27.0	45%	18.3	Full	Dry, Hard
6/23, C1	27.0	66%	25.9	Full	Dry, Hard
6/21, C3	25.0	74%	0.00	Overcast	Dry, Soft
6/16, C1	29.0	47%	9.3	Full	Dry, Hard
5/24, C3	17.5	46%	11.3	Overcast	Dry, Soft

Normality.

Exploration of PosP identified a normal distribution of the data when stratified by CL (P, *n*=16; C1, *n*=15; C3, *n*=12). Analysis of the Shapiro-Wilk statistic indicated that the assumption of normality (p>.05) was supported across all game conditions at each CL. **Table 5.4** lists all associated significance statistics. This outcome of normality was supported by a visual inspection of both Histograms and Q-Q Normality Plots.

Table 5.4 Shapiro-Wilk Normality Statistics (*p*<.05)			
	Game 1	Game 2	Game 3
Premier	.632	.154	.130
Classic 1	.187	.756	.512
Classic 3	.549	.342	.886

Assumptions

Analysis of the Levene's Test and Box's Test indicate that both assumptions were met (p>.05) in the statistical model. Levene's Test indicates homogeneity of variance in each game condition was met (G1, F (2,40) = .65, p=.53; G2, F (2,40) = 2.12, p=.13; G3, F (2,40) = .121, p=.11). Box's Test indicates equality in the covariance of matrices, this was also met (p=.231).

Positive Possession, Time, and Competition Level.

A Mixed Between-Within Subjects Repeated Measures ANOVA was conducted to examine the interaction and main effects of both T and CL on PosP. Descriptive statistics of PosP are presented in **Table 5.5**. The range of percentages (*M*) of PosP, stratified by CL is:

- P, 60.46% - 61.23%
- C1, 51.78% – 57.76%
- C3, 34.28% – 38.49%

Table 5.5 Positive Possession stratified by Competitive Level for Games 1 , 2, and 3*			
	Game 1	Game 2	Game 3
Premier	61.23% (13.57)	60.57% (11.98)	60.46% (14.34)
Classic 1	51.78% (11.91)	56.65% (14.60)	57.76% (10.18)
Classic 3	34.28% (9.88)	38.16% (8.52)	38.49 (11.20)
*Results listed as *M* (*SD)*			

There was no significant effect of the interaction of T and CL (T*CL) on PosP, Wilks' Lambda = .79, F (4,78) = .32, p = .86, partial eta squared = .02. This result demonstrates the independent effect of T and CL on PosP, allowing for clearer

generalizations concerning the main effects of these variables on PosP. The analysis of the main effects of both T and CL followed.

There was no significant effect of T on PosP across games, Wilks' Lambda = .97, F (2,39) = .73, p = .49, partial eta squared = .04. This result supports the null hypothesis that there was no within subjects difference in PosP across the game conditions. In addition, this result implies that this format of SSG may produce consistent PosP results across games, possibly a future outcome of interest.

Examination of CL as a moderating factor of PosP did produce significant results, F (2,40) = 53.59, p < .001, partial eta squared = .73. This result is indicative of a large effect (Eta squared = .73) of CL in moderating PosP results (Cohen, 1992; Pallant, 2013). Post-hoc analysis using the Tukey HSD Test indicated significant results represented in **Table 5.6**. These can be summarized as P > C1 > C3 for PosP across all games.

Table 5.6 Post-hoc results (Tukey HSD), Positive Possession stratified by Competitive Level**

	Premier	Classic 1	Classic 3
Premier	NA	p = .05*	p < .001*
Classic 1	p = .05*	NA	p < .001*
Classic 3	p < .001*	p < .001*	NA

*Indicates a significant result; **Significance set at p = .05

Within subject trends and between subjects differences are illustrated in **Figure 5.3**. The "flat" line of the within subjects analysis is evident as are the relative differences between groups for this metric (PosP). The differences are most apparent between P, C1 and C3.

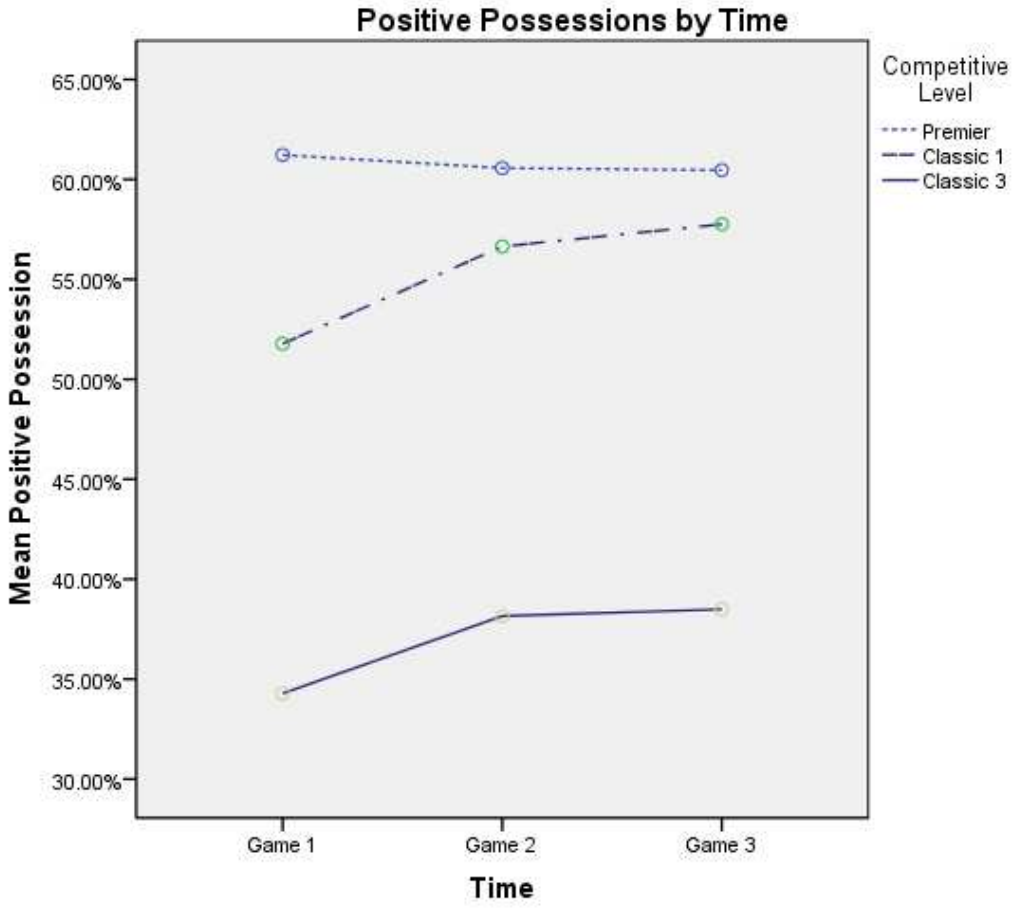


Figure 5.3. Positive Possession by Time stratified by Competition Level

Descriptive Statistics, Skills.

Further descriptions of selected skill events are listed in **Table 5.7.** These statistics document events that were accumulated over the course of the total time (all game conditions). Median ranges included Dual Won Percentage (47.51% – 49.23%), Touches (67.00 – 68.50), Shots (4.00 – 7.00), Goals (1.00 – 2.00), Pass Efficiency Percentage (45.26% – 63.39%), and Assists (1.00 – 2.00).

The selection of total time as the reference for these descriptive statistics allows for the capture of less frequent events such as Shots, Goals, and Assists.

Table 5.7. Skills events for total time (24 min) by Competitive Level*			
	Premier	Classic 1	Classic 3
Dual Won Percentage	49.23% (43.88% – 53.92%)	47.51% (44.17% – 50.67%)	48.64% (43.11% – 53.25%)
Touches	68.50 (64.25 – 73.00)	67.00 (59.00 – 71.00)	67.00 (45.50 – 80.25)
Shots	7.00 (4.50 - 8.00)	4.00 (2.00 – 7.00)	5.00 (4.00 – 9.50)
Goals	1.00 (1.00 – 3.75)	2.00 (0.00 – 3.00)	1.00 (1.00 – 3.50)
Pass Efficiency Percentage	63.39% (61.70% – 73.23%)	64.49% (54.40% – 68.54%)	45.26% (39.90% – 51.75%)
Assists	2.00 (1.00 – 3.00)	1.00 (0.00 – 2.00)	1.50 (1.00 – 2.00)
*Results listed as *Mdn (IQR)*			

Discussion

The primary hypothesis of this trial was that T and CL would moderate PosP across repeated 4v4 (free-play) SSG training. The exploration of PosP as a metric is necessitated by the increasing use of SSG formats in player selection processes as well as during team training (Ali, 2011). Quantifying the outcomes associated with SSG training can assist in the appropriate player placement based on developmental ability.

It was hypothesized that T would affect PosP leading to increases in PosP as games were repeated. In essence this could also be referred to as “warming up”, a euphemism that refers to increases in proficiency with greater exposure to a stimulus. Time did not produce statistical within group differences (Wilks’ Lambda, p = .49). Changes in PosP did not occur from G1 to G2 to G3. However, this may be due to a limited sample to some degree. Examination of **Figure 5.3** illustrates a trend that was apparent in both the C1 and C3 groups, with increases in the slope from G1 to G3. The P group had its highest PosP in G1 (61.56%) although the absolute difference across games in the P group was quite low (-0.77%) compared to C1 (+5.98%) and C3

(+4.21%). It is quite possible that the sample in this trial was too small to recognize this pattern. These results however are in alignment with the work done by Köklü (2011) who found that physiologic values (HR and blood lactate) were not sensitive to repeated games. It is prudent to be cautious when applying this premise to PosP. Evidence of the relationship between physiologic and skill outcomes is moderate at best. Dellal (2011) demonstrated a lower HR with increased skill outcomes in professional players when comparing CL. This however was done at the elite (1st) and professional (4th) level of play, and not in a repeated measures design.

The most interesting finding in this research was the large effect that CL had on PosP (Eta Squared = .73) (Cohen, 1992). This was a central question this trial sought to address. The methods in which player assignment occur are fraught with challenges. Logistically feasible methods for player assignment into developmentally appropriate levels of play are a process that has great impact on all stakeholders (i.e. players, coaches, officials). The development of match notational systems has allowed for the identification of factors that affect outcomes in SSG training (C. Carling et al., 2008; Gabbett, 2006; Gabbett & Mulvey, 2008; Gabbett et al., 2009; Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014a; S. V. Hill-Haas et al., 2009; S. V. Hill-Haas et al., 2011; T. Reilly & White, 2005; Wright, Atkins, & Jones, 2012). Simple and easy to apply metrics that can be calculated either through hand notation, video recording and playback, or with more advanced software (albeit freeware exists), may assist in this process of player development.

Positive possession is one such metric. Ultimately, a player has one of three options with a ball, shoot, pass or dribble. The dribble has the end-result of a shot, a pass, or a loss of possession as those are the only outcomes available to the player. This metric considers any shot a positive outcome along with a completed pass. The

antithesis of this metric is negative possession which is comprised of incomplete passes or lost dribble. The model is balanced with two possible positive outcomes and two negative. The results of the analysis indicate that CL moderates PosP. This has implications for the support of this metric in the identification of player competencies. The most obvious differences occurred between the most competitive and most recreational level of play (P and C3) ($p<.001$). The differences found between C1 and C3 are also quite significant ($p<.001$), however the differences found between P and C3 were not as clear, albeit significant ($p=.05$). A closer look at the absolute difference of the mean scores indicates that C3 was very different than P and C1, -23.77% and -18.42% respectively. The difference between P and C1 was much closer at -5.35%. Further research will need to be done to validate the reliability of these results; however the demonstration of differences between CL in PosP is a positive finding as a point of reference for player assignment.

Strengths and Limitations

As with any trial, there are associated strengths and limitations. Strengths of this trial include the population of interest. The use of club-level adolescent female participants is the first of its kind to the knowledge of the authors. Furthermore, the choice of a SSG format found across the soccer fields of the U.S. possesses high levels of ecologic validity. The use of this modality for both training and player assignment is commonplace. The examination of CL offers insight on the ability of the independent variable, PosP, to identify developmental abilities commensurate with specific CL (e.g. P, C1, or C3). Another major strength of this trial was the use of expert third party analytics firm, Match Analysis™. The use of a third party firm increases the validity of the data set with the use of state of the art software and professional cataloguing from experts in sport analytics.

Limitations include the small sample size from which to generalize results. Care must be taken when generalizing results. Further research is needed with larger samples on a greater number of exposures to various SSG formats. This will also allow for a greater statistical analysis, allowing for challenges in power associated with the small sample.

Applications and Conclusion

Positive possession holds promise as a metric that can delineate players between levels of play. This may have implications on the process of player selection due to its relative ease to calculate and ability to discern player CL. The effect of T on this outcome is also worth continued exploration. While T was not statistically significant within this sample, there is the potential that differences between games will occur with either a lack of appropriate preparation (warm-up) or fatigue (repeated bouts). This information is important in understanding the ability of this metric to assign player stratifications. Care however must be taken when generalizing these results without further research, especially in light of the gravity of player assignment to the participants.

Chapter 6: Conclusion

Conclusion

The primary aim of this dissertation was to address gaps in the published research that exist regarding the effect of Time, Competition Level, and Playing Position on Moderate to Vigorous Physical Activity, Heart Rate, and Positive Possession in SSG training in adolescent, club-level females. Three manuscripts were authored to address these gaps, specifically testing the following hypotheses:

- Manuscript 1 - Time spent in MVPA will be significantly greater than time spent in SPA or LPA during SSG training. CL and PP would have a significant effect on MVPA. CL will moderate the time spent in MVPA in the following manner, P > C1 > C3. This same effect would be demonstrated with regard to PP, demonstrating the following pattern M > F > D.
- Manuscript 2 - T and CL would have significant effects on >70%HR_{max} and >85%HR_{max}. T will demonstrate significant differences in >70%HR_{max} and >85%HR_{max} in the following manner, >70%HR_{max} > <70%HR_{max} and >85%HR_{max} > <85%HR_{max} across all game conditions. T will also demonstrate the following between game conditions, G3 > G2 > G1. CL will have the effect of stratifying both thresholds in the following manner P > C1 > C3
- Manuscript 3 – T and CL would have significant effects on PosP. T will demonstrate the following pattern in PosP across all game conditions G3 > G2 > G1. CL will demonstrate the following pattern in PosP across all game conditions, P > C1 > C3.

The results of these analyses were mixed, although filling in gaps effectively from which future research can proceed. The question of MVPA patterns during SSG training

was quite clear. The vast majority of time spent during SSG training was above thresholds that equate to MVPA. The differences were quite large with large effect sizes. The hypothesis that MVPA would be sensitive to CL was also found to be valid. Players from the P group were significantly higher in time spent in MVPA than C1 and C3. This same pattern existed between C1 and C3. It appears that those participating at a higher CL demonstrate increased MVPA during SSG training. This is in contrast to previously published research that did not attempt to account for instructional time or CL while measuring the omnibus effect of sport participation on the accrual of MVPA. This result is important in the education of coaches and trainers in methods to increase MVPA accrual during sport participation.

The same results did not follow for HR. While SSG training clearly created significantly greater time >70%HR_{max} and >85%HR_{max} (p = .05), neither CL nor PP moderated this effect. It appears that the physiologic stress (%HR_{max}) is universally consistent across game conditions. The large effect of SSG training to produce EI's above the assigned thresholds (estimated aerobic and anaerobic thresholds in adults) follows other published research that indicates the high %HR_{max} that accompanies this type of training. The description of time spent at various strata of %HR_{max} is also in alignment with previously published research indicating the challenge of establishing training EI in players >95%HR_{max}.

Skill was the final area of investigation in this SSG trial. Exploration of the metric PosP in stratifying CL for the use in player evaluations was a central theme in this work. Significant differences resulted in PosP when stratifying by CL (p = .05). This has implications in player assessment and assignment within club evaluation processes. The use of 4v4 SSG formats is prevalent on youth soccer evaluations. The logistic feasibility of the game format as well as the organic nature of the assessment, 4v4v is often said to

be demonstrative of all aspects of soccer tactics including field spacing, create a demand for the evaluation of quantifiable metrics that can delineate between playing levels. While T did not demonstrate significant results, indicating that G1 = G2 = G3 for PosP, the trend shown in the analysis, increasing slope in both C1 and C3, does warrant further research.

These results, while positive, are just one more piece describing the effect of SSG training.These robust training modalities create random, acyclic stress loads that have demonstrated continued efficacy in the development of both youth and adult players. Regardless of proficiency, amateur to professional, SSG training has shown itself to be a useful tool for trainers and coaches. This data supports these outcomes, and their continued use, in the population of interest, club-level, adolescent females.

CHAPTER 7: References

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CHAPTER 8: Appendices

Appendix 1 – IRB Approval

UNIVERSITY OF MINNESOTA

Twin Cities Campus

Human Research Protection Program
Office of the Vice President for Research

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Minneapolis, MN 55455

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Website: http://research.umn.edu/subjects/

01/24/2013

Stacy J Ingraham
Room 221 CookeH
1900 University Ave S E
Minneapolis, MN 55455

RE: "Physical activity in off-season youth soccer training"
IRB Code Number: **1211S24844**

Dear Dr. Ingraham:

The Institutional Review Board (IRB) received your response to its stipulations. Since this information satisfies the federal criteria for approval at 45CFR46.111 and the requirements set by the IRB, final approval for the project is noted in our files. Upon receipt of this letter, you may begin your research.

IRB approval of this study includes the consent form, assent form, and e-mail script, all received January 16, 2013.

The IRB would like to stress that subjects who go through the consent process are considered enrolled participants and are counted toward the total number of subjects, even if they have no further participation in the study. Please keep this in mind when calculating the number of subjects you request. This study is currently approved for 125 subjects. If you desire an increase in the number of approved subjects, you will need to make a formal request to the IRB.

For your records and for grant certification purposes, the approval date for the referenced project is December 19, 2012 and the Assurance of Compliance number is FWA00000312 (Fairview Health Systems Research FWA00000325, Gillette Children's Specialty Healthcare FWA00004003). Research projects are subject to continuing review and renewal; approval will expire one year from that date. You will receive a report form two months before the expiration date. If you would like us to send certification of approval to a funding agency, please tell us the name and address of your contact person at the agency.

As Principal Investigator of this project, you are required by federal regulations to inform the IRB of any proposed changes in your research that will affect human subjects. Changes should not be initiated until written IRB approval is received. Unanticipated problems or serious unexpected adverse events should be reported to the IRB as they occur.

The IRB wishes you success with this research. If you have questions, please call the IRB office at 612-626-5654.

Sincerely,

Jeffry Enkey

for
Christina Dobrovolny, CIP
Research Compliance Supervisor
CD/ks

CC: Eric Statt

Appendix 2 - Abbreviations

- <70%HRmax – Below 70% HR_{max}
- 75 – 84%HR_{max} – 75 – 84% HR_{max}
- <85%HRmax – Below 85% HR_{max}
- 80 – 89%HR_{max} –80 – 89% HR_{max}
- $30m_{sprint}$ – 30 Meter Sprint
- >90%HR_{max} - Percent above 90% HR
- %$Dist_S$ – Percent of Distance in Sprint
- %HR_{max} – Percent of HR Maximum
- %$Pass_S$ – Percent of Passes, Successful
- %HR_{mean} - Percent of Mean HR
- Bal_l – Balance, Left Leg
- Bal_r – Balance, Right Leg
- $Balls_L$ – Balls Lost
- $Balls_{LM}$ – Balls Lost per Minute
- $Ball_P$ - Putting Ball in Play
- BLa – Blood Lactate
- BF% –Body Fat Percentage
- BMD_{quad} – Bone Mineral Density, Quad
- BMC_{quad} – Bone Mineral Content, Legs
- BMI – Body Mass Index
- BP - Blood Pressure
- BP_{dias} – Blood Pressure Diastole
- BP_{sys} – Blood Pressure Systole
- $Cap_{density}$ – Capillary Density
- $CHOL_T$ – Total Cholesterol
- $CHOL_T$/HDL – Total Cholesterol / High-density Lipoprotein Ratio
- CL – Competitive Level
- Clr - Clearance
- Con_D - Control and Dribble
- Con_S – Control and Shoot
- CMJ – Counter Movement Jump
- CS – Citrate Synthase
- Duels – 1v1 Challenges
- $Duels_M$ – Duels per Minute
- $Dist_H$ – Distance at High Intensity
- $Dist_L$ – Distance at Low Intensity
- $Dist_M$ – Distance at Medium Intensity
- $Dist_{Mn}$ – Distance Covered per Minute
- DistS – Distance Covered Sprint
- $Dist_T$ – Total Distance Covered
- EE – Energy Expenditure
- EI – Exercise Intensity
- EP - Effective Playing Time
- $Fiber_{mean}$ – Fiber Size, Mean
- $Fiber_{dist}$ – Fiber Type Distribution
- FM – Fat Mass
- Gly_{mus} – Glycogen Content, Muscle
- HDL – High-density Lipoprotein
- HR_{pace} – Heart Rate at Specific Pace
- HR_{rest} – Hearty Rate, Resting

- ITT – Incremental Treadmill Test
- Inter - Interceptions
- LDL – Low-density Lipoprotein
- LDL/HDL – Low-density Lipoprotein / High-density Lipoprotein Ratio
- $Plantar_f$ – Plantar Flexion Force
- $Plantar_p$ – Planter Flexion Power
- $Plantar_w$ – Plantar Flexion Watts
- MVPA – Moderate to Vigorous Physical Activity
- PA_L – Physical Activity, Low
- PA_M – Physical Activity, Medium
- PA_V – Physical Activity, Vigorous
- PP – Player Position
- $Poss_{\#}$ – Number of Possessions
- $O_{2uptake}$ – Oxygen Uptake
- RPE – Rate of Perceived Exertion
- RCT – Randomized Controlled Trial
- RER_{pace} – Respiratory Exchange Ratio at a Specific Pace
- SV_{peak} – Sprint Velocity Peak
- Spr_f – Sprint Frequency
- Spd_M – Speed, Maximum
- $Sprint_D$ – Sprint Distance
- $Sprint_{DMax}$ – Sprint Distance Maximum
- $Sprint_R$ – Sprint Ratio
- $Sprint_T$ – Sprint Total Number
- $Sprint_{Time}$ – Sprint Time
- $Sprint_{TimeB}$ – Sprint Time Between
- $Sprint_{TimeMax}$ – Sprint Time Maximum
- SJ – Squat Jump
- T - Time
- $TrTime_{>90\%HR}$ – Training Time Over 90% Heart Rate Max
- V_{peak} – Velocity, Peak
- VO_{2max} / VO2peak – Maximal Oxygen Uptake
- WC – Waist Circumference
- W/H – Waist to Hip Ratio
- W:R – Work to Rest Ratio
- YYIET2 – Yo-Yo Intermittent Endurance Test

Appendix 3 – Environmental Conditions Worksheet

Date_____

Club_____ Team: _____ Level/Sex/Age:

_____

	1	2	3	4	5
Sun	Sun 0%	Sun 25%	Sun 50%	Sun 75%	Sun 100%
Field condition (effect on play)	Poor (inhibits)	Fair (impacts)	Good (neutral)	Very Good (supports)	Excellent (promotes)
Field saturation	Poor (sloppy)	Fair (wet)	Good (soft)	Very Good (firm)	Excellent (dry)

Temperature: _____

Wind: _____

Relative Humidity: _____

Notes:

Appendix 4 – Player Checklist

Official use: Club _____ Age _____ Level _____ Sex M / F

Coach _____ Recorder initials _____

Player number _____
Parental Consent Signed _____
Participant Assent signed _____
Height (cm, round to 0.5cm) _____
Weight (kg, round to 0.1kg) _____

Player number _____
Parental Consent Signed _____
Participant Assent signed _____
Height (cm, round to 0.5cm) _____
Weight (kg, round to 0.1kg) _____

Player number _____
Parental Consent Signed _____
Participant Assent signed _____
Height (cm, round to 0.5cm) _____
Weight (kg, round to 0.1kg) _____

Player number _____
Parental Consent Signed _____
Participant Assent signed _____
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Parental Consent Signed _____
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Height (cm, round to 0.5cm) _____
Weight (kg, round to 0.1kg) _____

Player number _____
Parental Consent Signed _____
Participant Assent signed _____
Height (cm, round to 0.5cm) _____
Weight (kg, round to 0.1kg) _____

Player number _____
Parental Consent Signed _____
Participant Assent signed _____
Height (cm, round to 0.5cm) _____
Weight (kg, round to 0.1kg) _____

Player number _____
Parental Consent Signed _____
Participant Assent signed _____
Height (cm, round to 0.5cm) _____
Weight (kg, round to 0.1kg) _____

Appendix 5 – Demographic Survey

Demographic Survey

Name: _____ Date_____

Coach _____

This survey is designed to acquire demographic information. All responses are confidential.

PLEASE CIRCLE REPSONES OR FILL IN WHERE APPROPRIATE

Childs Birthdate	____/____/____	(mm/dd/yyyy)	Childs Grade	_____	(current, if in summer upcoming grade)
Has the player with diagnosed with any medical condition that may either increase or decrease heart rate or impair movement? Yes No					
Does the player take medication that may either increase or decrease heart rate? Yes No					
Childs height	_____		Childs weight	_____	
Childs Race	African American	Asian	Caucasian	Hispanic	Other _____
Soccer Playing Position (see back)	Goalie	Defender	Midfield	Forward	
Years Played Soccer	_____				
Highest Level Played	Classic 3	Classic 2	Classic 1	Premiere +	
Other Organized Sport	Yes	No			
Other Organized Sport Years	_____				

Please ask if you have further questions. Thank you.

Soccer Playing Positions

Forward Forward Forward

Midfield Midfield Midfield

Defender \Defender Defender Defender

Appendix 6 – Equipment Checklist and Session Plan

Forms Needed				
Last	First			
		Consent	Assent	Survey

Notes:

Equipment set-up order:

- Sign Assent Forms
- Fill out survey
- Select 8 for trial, enter transmitter numbers Team 2
- Weight and height, enter Team 2
- Place HR monitor – moisten straps, tight fit, snap in transmitter, green light should come on
- Place accelerometer

Equipment Checklist

- Sony Video Camera (1) / Tridpod (2)
- Polar Team 2 set (1) / Computer
- Accelerometers (8)
- Cones (20) / Flags (4)
- Pinnies (8)
- Balls (8)
- Stopwatch / Whistle
- Pup Goals (2 sets)

Session A

Time	Player Task	Researcher Task	Researcher Task
2:30 – 3:30		Field set-up, Assign players to teams	
330 - 400	Assent, Survey, Choose 8, Wt/Ht, Equipment Placement	Enter Team 2 data (transmitter and ht/wt)	
0 - 5 mins	Active Warm-up, Coach	Prep equipment	
5 - 10 mins	Prepare for scrimmages	Prep equipment	
10 – 18 mins	Game 1	Video / Computer	Ball assts
18 – 22 mins	Rest	Reset teams, trade pinnies / RPE	
22 – 30 mins	Game 2	Video / Computer	Ball assts
30 – 34 mins	Rest	Reset teams, trade pinnies / RPE	
34 – 42 mins	Game 3	Video / Computer	Ball assts
42 – 46 mins	Rest	Take in equipment. RPE	
46 - close		Collect equipment	

Rules:
Start / stop on whistle
Ball in from ground
First pass free
Free touch
Water ready to go during rest
8 min games – 4 min rest (reset teams during rest), must be on time

Notes:

- Double check to see if they filled out survey, if not after practice
- Get other sport and years player (count from the grade they started playing)
- Get RPE directly after each game

Random assignment for games (R = red, Y = yellow)

Team	Session 1 Game and Team Assignment		Session 2 Game and Team Assignment	
Name Blaney, 5/24/2013 (S1), 6/21/13 (S2)	R 01, 02, 03, 04 vs. B 05, 06, 07, 08	R 04, 02, 06, 01 vs. Y 03, 05, 07, 08	R 6 3 7 2 V Y 1 8 4 5	
Club / Level NESA, C3 U14G	R 01, 02, 05, 07 vs. Y 03, 04, 06, 08		R 7 8 2 5 V Y 3 1 6 4	R 6 3 8 2 V Y 5 7 1 4
Name Dennis, 6/13/2013 (S1)	R 8 4 5 6 V Y 7 2 1 3			
Club / Level SCV, C1 U15G	R 4 3 8 5 V Y 6 1 7 2	R 4 5 1 2 V Y 7 2 8 6		
Name				
Club / Level				
Name				
Club / Level				

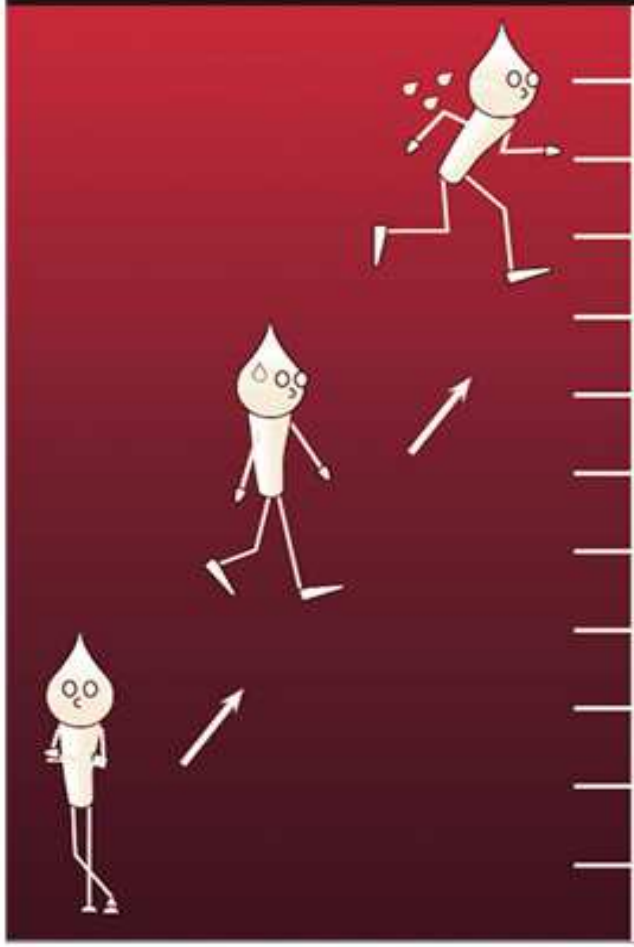
Notes: Players randomly selected from each pool at practice (8). Players randomly assigned to each team for each individual game-condition. Used sampling without replacement, number could not be chosen more than once.

Date 6/13/2013	Coach Dennis			Team SCV U15 C1G			Notes:			
Player Name	Ht	Wt	HR #	AG #	G1 Jersey	G2 Jersey	G3 Jersey	Borg 1-10	Borg 1-10	Borg 1-10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										

Equipment set-up order:

- Sign Assent Forms
- Fill out survey
- Select 8 for trial, enter transmitter numbers Team 2
- Weight and height, enter Team 2
- Place HR monitor – moisten straps, tight fit, snap in transmitter, green light should come on
- Place accelerometer

Rate of Perceived Exertion Scale



LEVEL	DESCRIPTION
10	Extremely strong (almost maximum)
9	
8	
7	Very strong
6	
5	Strong (heavy)
4	Somewhat strong
3	Moderate
2	Weak (light)
1	Very weak
½	Extremely weak (just noticeable)
0	Nothing

Appendix 7 – Informed Consent and Assent Forms

Coach Informed Consent Form

You are being asked to participate in a research study about the amount and quality of physical activity included in youth sport practice. You were selected based on your coaching background and characteristics of the team you coach. We ask that you read this form and ask any questions you may have before agreeing to have your child in this study.

The study: The purpose of this study is compare the use of game based training techniques (small games) with the amount of moderate and vigorous physical activity accrued during participation in sport practice. It is also designed to explore the effect of various training circumstances, such as game play, on accrual of moderate to vigorous activity. If you agree to participate, you will be asked to fill out a short survey, the Coach Efficacy Scale and provide demographic data. This should only take 10 – 15 minutes to complete. Also, during practice, video recording will take place of the training session to document the time participants spend in various training circumstances. This recording is used for documentation purposes only. All recording angles are wide shots, with no deliberate identifiable close-ups of any players or coaching staff.

Risks/benefits: There are no known other risks to participation in this study beyond that normally found in soccer participation. The information gained from this study will be used to further educate coaches about training techniques and physical activity at youth sport practice, directly benefitting all participants.

Confidentiality: The records of this study will be kept private. Since questionnaires will ask only for coach demographic data, it has been made impossible to identify subjects by name. Consent forms will be kept securely along with results for 7 years after completion of this study.

Voluntary nature/questions: Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota or with your sport team / club. If you decide to participate, you are free to withdraw at any time without affecting your relationship with the University of Minnesota or your sport team / club. The researcher conducting this study is Mr. Eric Statt, M.S. under the direction of Dr. Stacy Ingraham, Ph.D. You may ask any questions you have now. If you have any questions later, you may contact us at statt011@umn.edu.

Signature of Participant _____ Date _____

Signature of Investigator _____ Date _____

Parental Consent Form

Your child is invited to participate in a research study about the amount and quality of physical activity included in youth sport practice. Your child was selected as a possible participant because your child is in the age range and participates in the sport we are interested in studying. We ask that you read this form and ask any questions you may have before agreeing to have your child in this study.

The study: The purpose of this study is compare the use of small sided games with the amount of moderate and vigorous physical activity accrued during participation in sport practice. It is also designed to explore the effect of various training circumstances, such as game play, on accrual of moderate to vigorous activity. If you agree to have your child in this study, your child will be asked to complete a short questionnaire including their current playing level. They will have their height and weight measured. They will then wear a small device (accelerometer, approximately 1.5 inches square, .75 inches deep) during practice attached to their waist to record their movement. This devise is non-invasive, simply measuring the amount of movement of the participant during activity. There is a potential that another participant may hit with a ball or bump the device during play. Also, during practice, video recording will take place of the training session to document the time participants spend in various training circumstances. This recording is used for documentation purposes only. All recording angles are wide shots, with no deliberate identifiable close-ups of any players.

Risks/benefits: Risks of participation include the potential for the accelerometer to become dislodged during play. There are no exposures associated with this device. There are no known other risks to participation in this study beyond that normally found in soccer participation. The information gained from this study will be used to further educate coaches about training techniques and physical activity at youth sport practice, directly benefitting all participants.

Confidentiality: The records of this study will be kept private. Since questionnaires will ask only for participant sex, age, and playing experience, it has been made impossible to identify subjects by name. Consent forms will be kept securely along with results for 7 years after completion of this study.

Voluntary nature/questions: Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota or with your sport team / club. If you decide to allow your child to participate, you are free to withdraw your child at any time without affecting your relationship with the University of Minnesota or your sport team / club. Furthermore, your child may also discontinue participation at any time. The researcher conducting this study is Mr. Eric Statt, M.S. under the direction of Dr. Stacy Ingraham, Ph.D. You may ask any questions you have now. If you have any questions later, you may contact us at statt011@umn.edu.

Signature of Participant _____ Date _____

Signature of Investigator _____ Date _____

Children's Assent Form

We are doing a study to try to learn about playing games at sport practice and how much activity kids get. We are asking you to help because we don't know very much about whether kids your age get more activity when they play games or when they do other kinds of practice drills.

If you agree to be in our study, we are going to ask you to wear a small device that measures how much you move during practice. It is a small box worn on your hip. It is smaller than the size of your palm. You will wear it during practice and return it after. There is a chance that the box may get hit with the ball during the training session.

We will also be using a camera to video record the training session. We are interested in how the whole practice works, not any player specifically. Sometime players don't like to be video taped, because of this, we are not taking any close up shots. We will also measure your height and weight wearing your soccer clothes, with no shoes. All of the information we get will be used to help coaches teach future players.

You can ask questions at any time that you might have about this study. Also, if you decide at any time not to finish, you may stop whenever you want. Remember, this is not a test. There is no right or wrong way to do it, just play.

Signing this paper means that you have read this or had it read to you and that you want to be in the study. If you don't want to be in the study, don't sign the paper. Remember, being in the study is up to you, and no one will be mad if you don't sign this paper or even if you change your mind later.

Signature of Participant _____ Date _____

Signature of Investigator _____ Date _____

Participant Number _____Club_____ Team: _____ Level/Age/Sex: _____

Appendix 8 – Introduction Letter

Who are we?

Eric Statt is a doctoral candidate in Kinesiology at the University of Minnesota. His advisor, Dr. Stacy Ingraham, is the Director of the Human and Sport Performance Laboratory. During the past 20 years, Dr. Ingraham has studied sport performance as both a coach and collegiate researcher / instructor. Eric has also enjoyed a long career in soccer coaching and fitness / athletic administration. He currently holds a USSF C license (1995) as well as having held several performance-training certifications. Eric's coaching has concentrated on high school aged competitive players. His academic background and research interests are in exercise physiology, sport performance and youth sport.

What is this study about?

The purpose of this study is to examine the use of small-sided games (diagram included) as a tool for training U.S. youth soccer players. Information gained from this study will be used to further educate coaches about specific training techniques used during youth soccer practice at all levels of play.

What does the study entail?

We would like to measure physical performance that occurs during small-sided games used in soccer practice. We need your help in identifying girls', between the ages of 13 – 16, who may be interested in participating in our study. For our analysis, we would like between four to six groups of 12 to 16 players playing at the same level. We are seeking all levels of play from C3 through Premiere / MRL.

How will that be done?

The length of participation is between two and four training sessions. Scheduling of the training is negotiable. The coaches may be present, although the games will be described and facilitated by Eric. During each session, team members will wear a heart rate monitor (picture included). This is an elastic band worn around the chest. The actual monitor is about the size of a small watch face. The heart rate monitor measures specific physiologic variables (heart rate, breathing rate, movement patterns) of the player. Video recording of the session from a wide angle will also occur. This will be used to document things like passes completed (technical and tactical activities). Video will be used only for documentation and will be stored in secure environments. Wide angled shots will be used, minimizing any risk of recognition. All data is private and confidential.

What is the benefit of our study?

The benefit of the study includes expanding our knowledge of the effect of various training techniques on training outcomes at practice. While there is no direct benefit to the project participants, globally players, coaches and club / team administrators will all benefit from this research. A summary report shall be provided to all participant clubs and team members outlining the results of the trial. Recommendations for maximizing outcomes shall also be included.

Next step?

Dates are being set for data collection. Your coach will let you know. Data collection will take place during regularly scheduled training.

Procedures and timelines

- February – March – recruit participant teams, secure consent (team meeting / practice)
- March – schedule training sessions
- April – May – attend practices, collect data
- May – June – Analyze data

- July – write up results

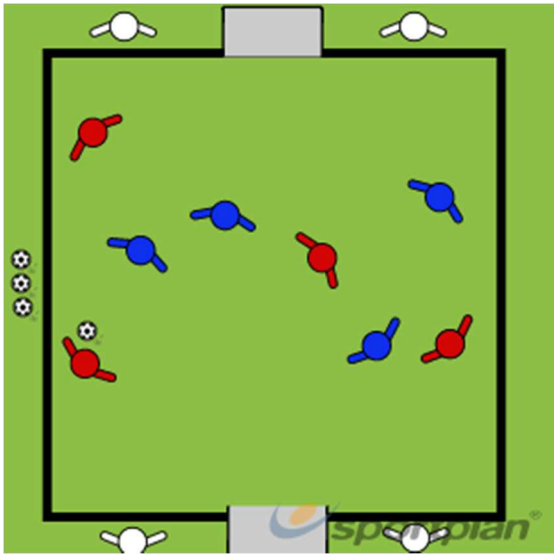
Thank you

Your support of sport research is essential as we all seek to improve outcomes associated with sport participation. Regardless of the level of competition, sport provides opportunities for growth in many areas. Your support of this trial is one step in validating approaches to increase participant enjoyment and success.

Contact info:
Eric Statt, (University of Minnesota, Department of Kinesiology)
statt011@umn.edu
651-373-1280

Research Model

This diagram demonstrates the basic format for the small-sided games.



This is a photo of the monitor that will be worn.

Appendix 9 – Team Instructions; Data Collection

U of MN Soccer Research Instructions

Example Team Instructions

The date of your first data collection session is Friday May 24. Please come prepared as you normally would for practice with these exceptions:

Please follow these instructions for the session of data collection scheduled for your team.

Height and weight (for May 24):

If you have <u>not yet given</u> your height and weight: Measure your height (stand tall, eyes and ears level, no shoes) and weight ("emptier" stomach is best). Bring these values with you.

Diet data collection:

No caffeine or stimulant for 3 hours prior
Normal breakfast / lunch, light snack is okay up to 1 hour before session (no sugary snacks)
Normal fluids

Rest for data collection:

Full night's sleep prior to session

Dress for data collection:

Normal soccer attire.

Some type of undergarment (e.g. compression shirt / sports bra) that allows for assistance with the heart strap is helpful.

Thank you for your involvement in this research and your support of youth soccer.

Eric Statt – Co-Investigator
University of Minnesota

Appendix 10 – Height and Weight Methods

Methods for measuring height (adapted from Anthropometric Manual Minnesota WIC Program)

1. Remove shoes, hats, and hair accessories. Flatten interfering hairstyles, if possible.
2. The child should stand tall and straight, with heels close together, shoulders level and relaxed, hands at sides, facing away from the measuring board. Heels, buttocks, shoulders and head should touch the measuring board. *If making all these points touch is impossible or uncomfortable, have as many of these points touch as is possible.* Ask the participant to inhale deeply and to stand fully erect without altering the position of the heels. Make sure that the heels do not rise off the footplate.
3. The assistant, who could be the mother, presses the knees and feet firmly so they are straight.
4. The person taking the measurement should be directly to the left side of the child or adult.
5. Determine the position of the head by locating the Frankfort plane (see example below)**,** which is the imaginary line drawn from the hole in the ear to the bottom of the orbit of the eye (the eye socket). The Frankfort Plane should be perpendicular to the measuring board that is located behind the child's head. The participant may appear to be looking slightly downward, but do not be concerned about this, as this will ensure that the crown of the participant's head is in the proper position to measure standing height of the head.
6. Lower the headboard (or right angle block) until it firmly touches the crown of the head and creates a right angle with the measurement surface. Ensure that the lower body stays in position by having the assistant firmly pressing their hands on the knees and ankles.
7. Record the measurement immediately, recording to nearest 0.5 centimeter.
8. Use a step stool whenever the person being measured is taller than the person doing the measuring.

Methods for measuring weight (adapted from Anthropometric Manual Minnesota WIC Program)

1. Turn on or activate the scale.
2. Zero balance (calibrate) the scale.
3. Take off shoes. Wear only light training apparel.
4. Have the participant stand on the scale with both feet in the center of the platform with body upright and arms hanging naturally.
5. Read the weight in the display area of scale. Record to nearest 0.1 of a kilogram