5-2016

Effects of sport-specific training conditions on performance in high school field hockey players.

Alexandra Hannah Roberts
University of Louisville

EFFECTS OF SPORT-SPECIFIC TRAINING CONDITIONS ON PERFORMANCE IN HIGH SCHOOL FIELD HOCKEY PLAYERS

By

Alexandra Hannah Roberts

B.S., University of Louisville, 2013

A Thesis

Submitted to the Faculty of the

College of Education and Human Development of the University of Louisville

In Partial Fulfillment of the Requirements

For the Degree of

Master of Science

in Exercise Physiology

Department of Health and Sports Science

University of Louisville

Louisville, Kentucky

May 2016

EFFECTS OF SPORT-SPECIFIC TRAINING CONDITIONS ON PERFORMANCE IN HIGH SCHOOL FIELD HOCKEY PLAYERS

By

Alexandra Hannah Roberts

B.S., University of Louisville, 2014

A Thesis Approved on

04/01/2016

By the Following Thesis Committee

T. Brock Symons (Thesis Director)

Kathleen Carter

Jill L. Adelson

Jessica Gibb

ACKNOWLEDGEMENTS

Firstly, to my thesis advisor, Dr. Brock Symons. Brock, thank you for challenging me to go above and beyond what I thought I was able to do with this project. Thank you for always pushing me to ask the next question, and for allowing me to make mistakes. Thank you to Dr Kathy Carter, for always being the voice of reason and always pushing me one step further. To my thesis committee, thank you for the time and effort you put in to critiquing my research and making this thesis the best it could be. To the Louisville Male High School Field Hockey team and coaches – thank you for allowing me to use you as participants. Without you, this study could not have happened. Thank you to my parents, who despite being so far away were always there for me to talk to. Finally, to my thesis partner Amy. Thank you for keeping me on task throughout this entire process, and for being there through all the ups and downs.

ABSTRACT

EFFECTS OF SPORT-SPECIFIC TRAINING CONDITIONS ON PERFORMANCE IN HIGH SCHOOL FIELD HOCKEY PLAYERS

Alexandra H. Roberts

March 01, 2016

Many sports (e.g. field hockey, lacrosse, ice hockey) require the use of a mouthguard (MG) and the constraint of carrying a stick during play. Previous research has shown that these two conditions individually can cause decrements to athletic performance; however no research has been conducted into effect of the combination of these two conditions on both aerobic and anaerobic performance parameters. **PURPOSE:** The purpose of this study was to determine the effects of both chronic (during all conditioning) and acute MG and stick (MG-STK) use on aerobic fitness and anaerobic capacity over the course of a 12-week training and competition period. Additionally, this study aimed to determine whether chronic mouthguard use changes perceptions related to comfort and use of mouthguards. **METHODS:** 38 apparently healthy female field hockey (FH) players (15±2 yrs) from a local high school team completed the study. Participants were placed in to one of two groups: experimental (EXP; completing all conditioning with MG-STK) or control (CTL; completing all conditioning without MG-STK) by stratified random sampling matched for team level (i.e. Freshman, Junior Varsity and Varsity) and initial aerobic testing performance. Aerobic fitness was measured using a standard multi-stage fitness test (the beep test), and anaerobic capacity was measured using six repeated 40m sprints. FH-specific training as prescribed by coaching staff was performed throughout the study, with testing performed at baseline (0 weeks), mid-season (6 weeks) and post-season (12 weeks). Participants performed two sets of testing at each time point, first without mouthguard and stick (WOMG-STK) and then with mouthguard and stick (MG-STK). Tests were performed >48hrs apart and results were analyzed using a 3-way analysis of variance (ANOVA). **RESULTS:** No difference was found in any anthropometric measurements, either between or within groups throughout the season. No main effect was found in aerobic capacity between groups; however, MG-STK testing produced a reduction in aerobic fitness at every time point (WOMG-STK: 37.41 ± 6.65 mL·kg^{-1}·min^{-1} vs. MG-STK: 33.16 ± 4.32 mL·kg^{-1}·min^{-1}; $p<.01$). It also was found that estimated VO_{2max} increased from baseline to mid-testing and decreased from mid- to post-testing, resulting in no significant change from pre- to post-season testing (PRE: 33.37 ± 4.29 mL·kg^{-1}·min^{-1}; MID: 37.52 ± 6.81 mL·kg^{-1}·min^{-1}; POST: 34.94 ± 6.65 mL·kg^{-1}·min^{-1}). No difference was found between groups or test conditions in 10m sprint, but there was a significant difference between pre- and post-testing (PRE: 2.38 ± 0.16s; POST: 2.27 ± 0.25s; $p<.05$). Sprint decrement over 10m was improved by 2.4% in MG-STK test condition but worsened by 7.3% in WOMG-STK testing. No difference was found in 40m sprint or sprint decrement. Mouthguard satisfaction increased by 30%, and difficulty breathing during use decreased by 37%. **CONCLUSION:** Chronic use of a

stick and mouthguard does not negatively affect aerobic or anaerobic capacity; however acute use does create performance decrements, regardless of training group.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE PAGE

INTRODUCTION

Statement of the problem

In any sporting environment safety concerns are paramount, second only to performance goals. This is just as true, if not more so, in the world of high school athletics. Here, many coaches struggle between trying to ensure that their team will win while also making sure that they are protected from the dangers of sport participation. One sport in which these difficulties are particularly prevalent is field hockey.

Field hockey is a sport that requires substantial contributions from both aerobic and anaerobic energy systems. It has been found that many field hockey players have a maximal oxygen uptake, or VO_{2max}, that is pointedly higher than that of average young women, showing the need of a good aerobic base fitness in order to succeed [1]. These athletes also need to be capable of making a large number of high intensity, repeated sprint efforts – similar in many respects to lacrosse, rugby, and ice hockey[2].

One major constraint faced in all of these sports is the need to carry an item (stick or ball), thus changing the biomechanical basis of an athlete's running technique. It is well-known that a critical aspect of sports performance is an athlete's speed and agility, in addition to the kinetic energy that they create during these motions[3]. By improving kinetic energy production, overall sports performance will be improved in every parameter. It has been hypothesized that performing sprint work while carrying a field hockey stick may increase a players' sprinting ability, by allowing an exact mechanical replication of the skills required for successful game play[4].

A second major restriction to performance faced by field hockey athletes is that of mouthguard use. Mouthguard (MG) use has been proven to protect teeth and other oral-facial areas from trauma during physical activities, which is especially important as the most common type of facial injuries during sports participation are dental[5, 6, 7, 8]. Despite becoming a mandatory part of football safety equipment at the high school level in 1962, it took until 1973 for the NCAA to make MGs compulsory[9]. Since then, MG usage rules have trickled through the ranks of high school and collegiate sports, with MGs becoming either recommended or required in more sports every year [9, 10, 11]. As such, it is required by the National Federation of State High School Associations (NFHS) and the National Collegiate Athletic Association (NCAA) that all field hockey players wear a MG during games[7, 10, 11, 12, 13].

There are three different types of intra-oral MGs for sports: stock (non-custom), self-adapted ('boil-and-bite'), and custom-made MGs. Stock and self-adapted MGs are purchased over the counter, whereas custom-made MGs are made from a dental mold by a dentist or orthodontist[14, 15, 16, 17]. If not enforced, most high school athletes choose not to wear any type of MG during either practice or competition[13, 18]. This is reportedly due to athletes claiming that mouthguards negatively affect their breathing and therefore performance, and also are uncomfortable and hinder communication[6, 7, 16, 19]. This leaves athletes vulnerable to severe oral-facial injuries.

Research has shown that although non-custom MGs may cause a decrease in maximal oxygen uptake and ventilation during maximal exercise, there is no difference in either measure at submaximal workloads[16]. However, it has been found that when using self-adapted MGs, there is no difference in respiratory function, regardless of exercise intensity[6, 14, 18]. It also has been established through a number of studies that there are no performance decrements in any physiological parameter when a customized MG is used[6, 7, 14, 17, 18, 20].

Ratings of perceived exertion, or RPE's, tend to be higher while using MGs, and researchers have hypothesized that these perceptions may be changed by the everyday use[7]. This premise has been supported, with one study finding that attitudes towards MGs were better after just four weeks of consistent use [13]. Recent research has found conflicting results regarding whether usage increases the acceptance of MGs. One study found that MG acceptance and ultimately usage increased when adolescents were encouraged to train with MGs, thus enabling them to become more used to the sensation and increasing communication ability and perceived respiratory function[6]. However, conflicting research has shown that four months of usage brought no changes in satisfaction with MGs[20].

Despite the pervading opposing opinion among MG users, it has been shown that wearing a MG can improve physical performance in a number of areas that are required for success in field hockey. It has been well established that wearing a self-adapted, 'boil-and-bite' MG creates greater force and power production during power exercises, especially in females[17, 21, 22]. This is especially useful in field hockey, as many aspects of the sport require quick power (sprinting) and force production (hitting the ball). Previous research has indicated that lactate levels were lower in participants using a mouthguard during sprinting than those who did not[23]. Additionally, it has been found that using a MG can have a positive effect on both visual and auditory reaction times, both of which are vital for optimum sports performance[15].

There is very little research into the 'sport-specificity' of using both stick and MG during conditioning sessions, especially in the high school population. The vast majority of conditioning in field sports occurs without the apparatus (stick or ball) or MG, yet both conventional wisdom and scientific research tells us that sport specific training will produce better game-time results[24]. This study asks the following questions: (a) Will conditioning with a stick and MG impact an athletes' sport-specific abilities? (b) Will training with a MG change the attitudes of athletes towards using it consistently?

Purpose of the Study

The primary purpose of this study was to establish whether a sport-specific training group (EXP; completing all conditioning with MG and stick) will perform better than a control group (CTL; completing all conditioning without MG and stick) in sport-specific (MG-STK; with MG and stick) and neutral (WOMG-STK, without MG and stick) testing conditions. Additionally, the study aimed to examine whether attitudes towards MG use changes as a result of increased usage, and therefore familiarization. Finally, this study aimed to establish whether any differences between groups recorded at the end of preseason training were maintained throughout the season.

The participants for this study were recruited from a high school field hockey squad, consisting of members of the Freshman, Junior Varsity, and Varsity teams. This ensured that all participants were experienced in the sport and movement patterns required. Additionally, the age and experience spread allowed for greater observation of the effectiveness of the intervention. This allows for inferences to be made on the best way to train athletes of different ages and abilities. Very few studies have been performed on the high school population in field hockey, and the testing battery used also established a basic physiological profile of the high school field hockey athlete.

A goal of this study was to aid field-sport coaches in developing conditioning programs that will not only allow them to have greater time efficiency, but also encourage better safety practices in their athletes. A secondary goal of the study was to establish changes in attitudes towards mouthguards after twelve weeks of consistent use.

Significance of the study

The results of this study can be replicated by field-sport coaches, especially in the high school arena, and be adapted to fit the needs of the individual sports and teams. The foundational concepts can be applied to other field sports, ages, and genders, and could substantially increase the effectiveness of conditioning practices. Establishing the changes in attitude towards mouthguards is important for all sports in which a MG is required or recommended. Additionally, very little research has been conducted on field hockey athletes in recent years, especially of the high school age. With this in mind, this study is significant because it updated previous research on the sport, and established for the first time a physiological profile of the female high school field hockey player.

Research Questions and Hypotheses

A) Will 'sport-specific' (EXP group) conditioning show greater improvements in sport-specific (MG-STK) testing than a control (CTL) conditioning group? It was expected that the EXP group would perform better than the CTL group on MG-STK testing at mid and post-season testing.

B) Will any recorded differences between EXP and CTL groups be maintained throughout the season, or will they even out by the end of the competitive season? It was expected that the EXP group would maintain better performance measures than the control group.

C) Will increased mouthguard usage create a more favorable attitude towards the mouthguards, especially in related to perceived communication and respiratory difficulties? It was expected that the EXP group would also have more favorable opinions on MG usage after the season when compared to the CTL group.

Operational Definitions and Terms

For the purposes of this study, the MGs used were over-the-counter self-adapted, or 'boil-and-bite' MGs (Adult Form-Fit Mouthguard, SafeTGuards, CO). This style of MG was chosen based on previous research showing no physiological differences between using this style of MG and no MG, as well as due to ease of access and molding capabilities[6, 11, 13, 14, 18, 20].

Term	Definition
Sport-specific	Training or practice that occurs in a condition as similar to game conditions as possible. For the purposes of this study, sport specific refers to training occurring while wearing a mouthguard and carrying a field hockey stick.
Mouthguard	Protective equipment used in many sports. Molded piece of plastic placed over the top teeth, aiming to prevent oral injuries as well as concussions and other oral-facial injuries.
Stick	A regulation field hockey stick is composed of wood, fiberglass, or a combination of the two. It must have a curved head and be a maximum of 105cm long.
NFHS	National Federation of State High School Associations. The governing body for high school athletics in the United States.
NCAA	National Collegiate Athletics Association. The governing body for collegiate sports in the United States.
VO_{2max}	Maximal oxygen uptake. The amount of oxygen that the body can extract from the air during exercise.
KHSAA	Kentucky State High School Athletic Association. The governing body for all high school sport in the state of Kentucky.
FIH	International Federation of Hockey. The international governing body for the sport of field hockey.
Playing the ball	Movement of the ball using the stick. This can include hitting,

	dribbling, passing, stopping or deflecting.
Playing distance	The distance within which a player is capable of taking possession of and playing the ball
Dribble/dribbling	The act of running with the ball. Can be performed as ‘closed’ (the ball remains touching the stick at all times) or ‘open’ (the ball is tapped frequently in front of the stick)
Group	Group in to which players were placed for the duration of the intervention. Either EXP (experimental, all conditioning performed with mouthguard and stick) or CTL (control, all conditioning performed without mouthguard and stick).
EXP	Intervention group. All members of this group performed conditioning with a mouthguard and stick throughout the season.
CTL	Control group. All members of this group performed conditioning without a mouthguard and stick throughout the season.
Test Condition	Experimental condition under which the testing was performed. Either MG-STK or WOMG-STK
MG-STK	Testing performed with all participants holding their stick in their right hand, with their molded mouthguard in their mouth
WOMG-STK	Testing performed without mouthguards or holding sticks.

Limitations

The major limitation of the study was the age and potential developmental differences in the chosen population. The age difference in the population was small, yet fell over a significant physical developmental time period for the athletes. In addition to physical development, adolescents are notorious for their comparatively lower emotional development, which can hinder participation in activities they they don't believe they directly benefit from.

Therefore, ensuring that the teenage girls returned all questionnaires and gave full effort in every testing and training session was a limitation, as there was no way to fully enforce this.

Delimitations

Delimitations include the choice to only collect data from one high school and the gender of the participants. This is crucial to the experimental design process, as all athletes have had the same off-season conditioning plan and the same preseason skill sessions. This prevents bias from differing practice, game or school schedules. However, by limiting the population sample to only one school, the generalizability of the study has been limited.

The gender of the participants was all female, as in the United States field hockey is primarily played by women, and is only sanctioned by the KHSAA, NFHS and the NCAA as a women's sport.

Assumptions

It was assumed that all participants who began the experiment would finish the competitive season, and would attend all practice and testing sessions as required for the research. Additionally, it was expected that all participants would give their best efforts in both practice and testing sessions. In line with this, it was assumed that the training sessions set by coaching staff (both conditioning and skills) would be effective in providing improvements in field hockey specific parameters of physical fitness. It was further assumed that the players would not perform any additional conditioning outside of this study.

Participants were strongly encouraged to record and report any out-of-practice exercise performed, and to adhere to nutrition, recovery and hydration advice from coaches. Finally, it was assumed that all participants were truthful and accurate when reporting questionnaire all data.

Ethical Considerations

The Institutional Review Board (IRB) at the University of Louisville approved this study. Due to the age of the participants, informed consent was obtained from parents, and also, assent from the participants themselves was obtained prior to data collection. Safety policies and procedures from the National Federation of State High Schools Associations (NFHS), the Kentucky High Schools Athletic Association (KHSAA) and the high school in question were followed at all times. There were no forseeable risks to participants beyond that of typical sporting participation. Participants were informed that all questionnaire and physiological testing was optional, and they did not have to answer any questions or complete any testing that they felt uncomfortable with.

LITERATURE REVIEW

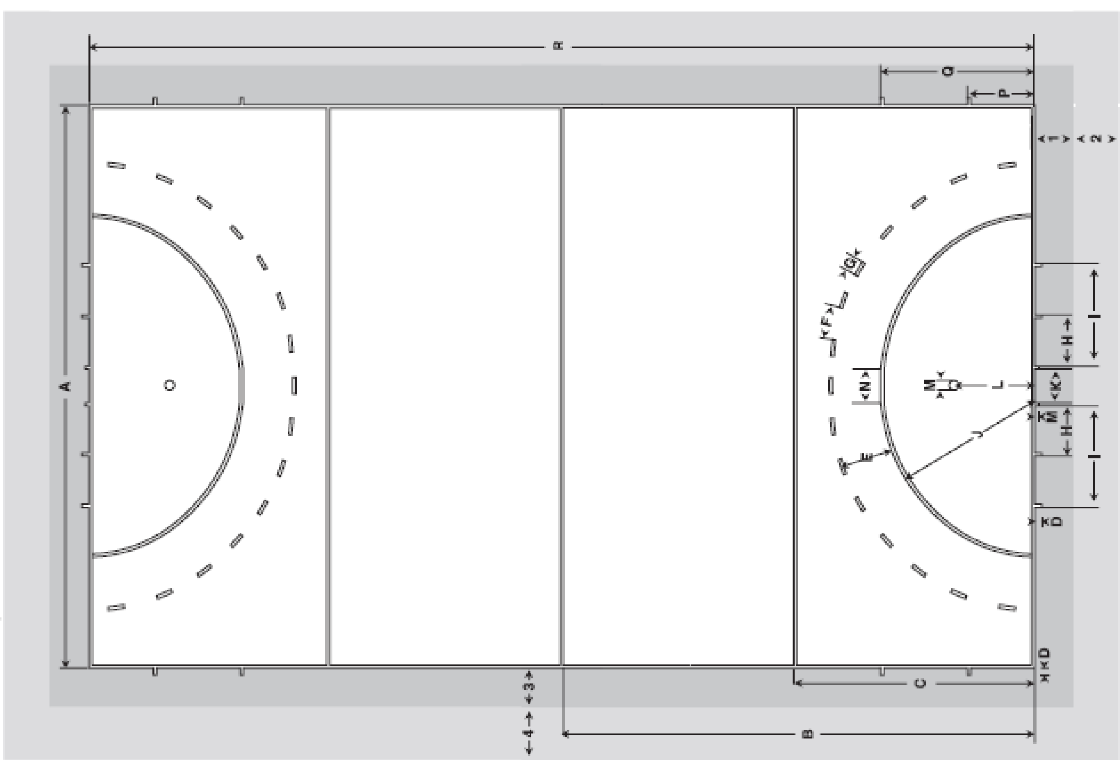
Field hockey is a sport that is extremely popular throughout the world, with well over one million people participating each year from 127 countries[25]. It has been compared to a number of other sports in terms of physical demands, including soccer, lacrosse, rugby, ice hockey and basketball[2]. Collectively, field hockey, lacrosse, soccer and rugby (among other sports) are often referred to as 'field sports', or more specifically as 'field invasive games'[2, 26]. In the United States, the vast majority of participants are females with nearly 6000 women competing on 270 National Collegiate Athletic Association [NCAA] sanctioned collegiate teams and over 61,000 girls competing on 1,795 high school teams in the 2013-14 season[10, 27, 28, 29]. It is with this in mind that this study will focus on a solely female population.

A field hockey team may have up to eleven players (including a goalkeeper) on the field during a match[26]. The game is played in two halves, with a ten-minute break for half time. In high school, match length is determined by level of play. Freshman games have 20-minute halves, Junior Varsity (JV) games have 25-minute halves and Varsity play 30-minutes in each half[30]. Both the International Hockey Federation (FIH) and USA Field Hockey recommend that all field players wear shin, ankle and mouth protection[30, 31]. This suggestion has been made mandatory for participation in all organized field hockey within the US, with the NCAA, the National Federation of State High School Associations [NFHS] and the Kentucky High School Athletic Association [KHSAA] all requiring a mouthguard in order to play, regardless of field position[10, 12, 32].

Playing Area and Equipment

A regulation field (Figure 1) is 100 yards (91.4m) long and 60 yards (55m) wide, divided into quarters (25 yards/22.9m long)[30]. In each end quarter, the goal is placed on the outside edge of the field of play, with a solid drawn semi-circle surrounding it. The semi-circle (referred to as ‘the circle’) is 16 yards (14.6m) from the top of the circle to the center of the goal. A broken semi-circle surrounds the first at a distance of 5m[30].

Figure 1: Regulation field of play[30]



Hockey Sticks

Every player must have a hockey stick ('stick') in his or her hand while playing. During the game of field hockey, the stick is used for a number of tasks, including striking, dribbling, stopping and deflecting the ball. No player (with the exception of the goalkeeper) is allowed to touch the ball with any body part at any time. There are a number of requirements for the design of the stick, including that the stick must not weigh more than 373g, or be more than 105cm long from the top of the handle to the bottom of the head[30]. The stick has evolved greatly as the sport has increased in popularity, with sticks now typically being constructed out of combinations of wood, fiberglass, Kevlar and aluminum. This allows for the sticks to be lighter and more rigid, allowing greater power transfer and control when playing the ball[26].

The rules of use and design of the hockey stick call for one side to be flat while the other side is rounded (Figure 2). The flat side is the only side of the stick allowed to touch the ball, and all sticks must be right handed. As a result, the easiest and most logical position from which to execute most skills is with the ball to the right hand side of the body[26, 30]. This creates an inherent asymmetry within the game of field hockey. This asymmetry carries over into the running technique of players, as the loading produced by carrying the stick is also not symmetrical.

As players must hold their sticks at all time while on the field, it is imperative that their running ability not be impaired. Previous research has found that carrying an object (such as a hockey stick or a rugby ball) produces a drastically slower speed than running without, regardless of the position the object is held in[33, 34]. Most running in field hockey is performed off the ball with the stick in the right hand, positioned at the end of the handle in a balanced position[26]. This results in a small decrement in speed, due to the restriction placed both by the weight and the lack of freedom imposed by the stick[34]. It is hypothesized that due to the constraint of holding a stick, the arm cannot attain its full range of movement, leading to balance difficulties[33, 34]. A study by Ropret and colleagues showed that an increased arm load of 220g (less than that of a hockey stick) caused a decrease in running ability, due to a decrease in stride rate[35].

When running in field hockey, the player is required to switch from one-handed carrying to two-handed in order to play the ball, often while maintaining speed. This causes a large difference in the kinematics of running styles, as by switching to a two-handed hold, players arms move more laterally across the body, causing a significant increase in body rotation and thus affecting both stride length and acceleration ability[34]. In order to effectively play the game, field hockey players need to be able to switch between one- and two-handed running styles in order to pass, receive or tackle, but also need to be able to maintain top sprinting speed. While it has been demonstrated that there is a relatively small (but still statistically significant) difference in constrained and unconstrained running times, it should be remembered that in a fast-paced game like field hockey, gaining a few centimeters on an opposing player could easily be the difference between reaching the ball and losing it.

Figure 2: Back (round) and front (flat) sides of a field hockey stick[69]

Mouthguards

As stated above, the use of mouthguards is mandatory for participation in high school field hockey. This is due to their proven ability to protect the teeth and gums, as well as to potentially preventing more serious trauma including facial fractures and concussions[5, 16, 19]. Although field hockey is a non-contact sport, contact with the stick or ball is responsible for more than 47% of injuries. Additionally, preseason injury rates during practice are almost three times higher than in-season injury rates[28].

Despite the well-researched and well-known benefits to wearing a mouthguard, many players still choose not to wear mouthguards during practice and/or games[7, 16]. Many reasons are cited, but the two most common complaints are that the mouthguard restricts breathing ability and communication[7, 16, 19]. It has been shown that non-custom (as opposed to self-adapted 'boil-and-bite' and custom fitted) mouthguards can potentially have a negative effect on ventilation[16]. This is why in the present study, all participants will be provided with a boil-and-bite mouthguard, with fittings supervised by experienced field hockey coaches in order to ensure the best possible fit.

The subject of mouthguards and their effect on aerobic performance, and in particular oxygen uptake, has been thoroughly investigated[16, 19, 23]. Previous research has shown that wearing a molded mouthguard had no effect on VO_{2max}, minute ventilation, tidal volume or respiratory exchange ratio during maximal exercise. This research also demonstrated that wearing a mouthguard during sport-specific activities may improve respiration patterns, ultimately leading to a lower metabolic cost of exercise[19]. A similar lack of negative impact on physiological function has been reported by a number of authors[7, 23].

Recent research has also shown that in addition to their protective qualities and a lack of negative effect on respiration, mouthguards may also provide some performance benefits for performance[5, 7, 22, 23]. When runners train with mouthguards, it has been shown that they consistently run and recover faster, and all runners rated their perceived exertion level as being less than usual [22]. Additionally, it has been found that mouthguards may have a positive impact on power production, particularly during the vertical jump[7]. Mouthguard use has also been associated with improved lactate levels during high intensity exercise, a significant increase in both auditory and visual reaction times, improved muscular endurance and improved grip strength[15, 23]. Adaptation to training is extremely specific[24]. This is why the sport-specific intervention of training while holding a stick and wearing a mouthguard was chosen.

Demands of the Game

The game of field hockey has changed a lot in the last few decades, with most changes causing remarkable differences to the physical demands of the game. Most notable is the introduction of artificial playing surfaces at nearly all levels[26]. This has caused the speed of the game to increase drastically, as the ball moves a lot faster on water-based artificial turf than it does on grass. Additionally, the 2009 introduction of 'self-passing' as a rule (allowing players to self-play the ball when taking a free hit) has dramatically increased the pace of the game, as players no longer have to stop and wait for teammates to reposition before passing – they can now simply run themselves[36]. Finally, a 2013 addendum to the rules allowing intentionally raised balls has ensured that overhead passing is now relatively commonplace[36]. This has again forced an increase in the speed and intensity of the game, as the play has now moved from two dimensions in to three, as well as the additional speed required to chase down an airborne (as opposed to rolling) ball.

Different positions also place different demands on players. Especially in modern field hockey, players are expected to be able to play in multiple positions and therefore need to have attributes of more than one specific position[26, 37]. Typically, forwards and halves are more engaged in the physical act of dribbling the ball down the field, compared to the defensive mindset of backs and goalkeepers. This explains the differences in fitness between positions, particularly explaining why forwards and halves have much higher maximal oxygen uptake levels[37].

Field hockey requires significant levels of both aerobic and anaerobic capacity, as well as muscular strength and power. The previously discussed asymmetry created by the rules governing stick use cause a great increase in the physiological demands of the game, as maintaining the correct body position in relation to the ball and other players increases the work required during play[26]. The contemporary game of field hockey is primarily aerobically based, with frequent anaerobic requirements superimposed upon the demands of the cardiovascular system[26, 37, 38, 39].

Many studies have attempted to quantify the workload of field hockey players during a game. These studies are consistently decades old, and provide data on matches of national and international standard[40]. One such study determined that players are in action for approximately 21 minutes of a game, and other studies have determined a total distance of between 5.6 and 10.9km covered during a game, depending on position and level of play[40, 41]. While the amount of time spent active may well be similar at the high school level, the distances covered during a game are likely much higher in the elite athletes.

Aerobic capacity, often quantified by VO_{2max}, or the maximal amount of oxygen consumed, is a vital part of team field sports such as field hockey. Aerobic fitness is positively correlated with the ability to recover from repeated maximal exertions, as is found in field hockey[42]. VO_{2max} in female hockey players is extremely high, usually recorded at well over 50ml/kg/min[26, 27, 42, 43]. This places them in the 95th percentile, or superior category according to the American College of Sports Medicine's (ACSM) normative charts[47]. It has been found that cardiorespiratory measures tend to be highest in offensive players, and lowest in goalkeepers[43, 48]. It has been established that during field hockey games, athletes can reach absolute VO_2 values of up to 2.25L/min, which places it in the category of 'heavy exercise'[26]. High levels of aerobic fitness have also been linked to recovery from high intensity anaerobic fitness, which demonstrates the need for field hockey players to have sufficient aerobic and anaerobic capacities[42]. Higher VO_{2max} scores have also been linked with players' skill levels and concentration towards the end of a game[49]. VO_{2max} has been highly correlated with success in field hockey[27, 50].

Anaerobic capacity is an essential part of the sport, as players are frequently required to chase down free balls, dribble and tackle – all of which are activities that require quick bursts of speed. It has been shown that in high school aged field hockey athletes; members of more successful teams were faster over a 40m sprint than members of less successful squads[50].

Related to sprinting ability is repeated sprint ability (RSA) – the capacity of a player to make multiple sprints with a very short recovery time. This is especially valid in sports such as field hockey, as players are frequently performing multiple sprints, without much recovery time[42, 51, 52, 53]. RSA has been linked to both aerobic and anaerobic capacity, with significant correlations to the demands of field sports[54]. Indications have been found that differences in RSA were sufficient to allow discrimination between different levels of players, an idea that has been supported in multiple investigations[27, 54, 55].

The vast majority of work that is performed by field hockey players is 'off-the-ball', during which players are running with their sticks in their hands, without a focus on dribbling the ball[26]. This is a significant reason why the testing battery chosen will be performed without the added constraint of dribbling a ball. To be as sport-specific as possible, the players will perform most of the tests with constraints they will face during the entire game – namely, performing various tasks with a stick held in their right hand and a mouthguard in their mouth.

Anthropometric Profile

As in any running-based sport, hockey players are typically lean; with a tendency to be shorter than most other athletes, based on the necessity of being close to the ground in order to effectively play the ball. The mean height of field hockey players has been reported at between 162 and 167cm with body masses ranging from 58 to 63kg[26, 38, 43, 50].

Field hockey players display above average muscularity when compared to both the general population and other female athletes[43]. Body composition has been linked to success in field hockey, especially in high school aged players[27, 50].

METHODS

Subjects

The participants included in this study were female high-school aged (13-18 yrs) field hockey players (n= 46) on Freshman, Junior Varsity and Varsity teams. The players were recruited from a local high school. Every participant and her parents were provided with an informed consent and assent document explaining the potential risks, responsibilities and benefits of participating in this study. The investigator was available to answer questions from players and their parents both prior to and for the duration of the study. There was a familiarization period prior to the first day of testing.

Subjects were eligible for participation in the study if they were named as members on one of the three field hockey teams for the high school. There were no other standard requirements for participation.

Settings

All testing, as well as the training intervention, occurred at facilities at the high school's grass field. During all training, testing and games, the heat index was recorded, and no physical activity occurred when the heat index was over 100, as per KHSAA rules[70].

Procedures

This study consisted of basic anthropometric data collection, self-report questionnaires, sport-specific physiological testing and the training intervention. Aerobic fitness testing occurred at three time-points (pre-season, mid-season and post-season), while anthropometric data, sprint performance measures and mouthguard satisfactions data were gathered both pre- and post-season. The self-report maturation scale was completed only at the beginning of the study, as 12 weeks was determined to be insufficient time to see major developmental changes in this population.

Measurements

The measurements used within this paper are based on the testing batteries that have previously been used in field hockey testing, covering many of the indicators of field hockey performance[27, 52]. The protocols used are aimed at establishing the difference between the two groups as well as enabling tracking of physiological measures during both the preseason and the competitive season.

Questionnaires

Each participant completed a validated self-report maturation scale created by Carskadon and Acebo (Appendix 1)[56]. This was essential due to the age range (13 to 18 years) of the participants in the study. Adolescent females can experience as much as five years difference in developmental timing for factors such as peak height velocity and secondary gender characteristics, regardless of chronological age[57]. Additionally, in high school sport competition levels are often delineated by chronological age groups, in which a child may be up to 11 months younger than her peers. Therefore, in order to provide valid and comparable physiological and/or performance measures, the physical maturity level of participants must be controlled for[56, 57]. Self-report maturation measures have been shown as valid for use in the adolescent population and also for use with team sport athletes[56, 58].

Each participant was also asked to complete a mouthguard satisfaction questionnaire, both before the training intervention and after. This questionnaire was modeled off previously validated and used questionnaires, and quantifies the participants' feelings towards mouthguard usage in relation to comfort, breathability, and communication ability[7, 16]. Previous research into the usage of mouthguards has shown conflicting results as to the effects of long-term use on acceptance. Thus, performing a mouthguard satisfaction questionnaire was important to further the body of research on this matter.

The mouthguard satisfaction questionnaire used (Appendix 2) was validated through accepted means, and was shown to allow valid inferences in athletic populations. After the creation of an initial questionnaire, 10 cognitive interviews were conducted with athletes who wear mouthguards during sports participation. Based on their feedback, the questionnaire was adapted and then administered to 112 participants who currently or previously participate/d in a sport in which mouthguard use is recommended.

Anthropometric Measurements

The initial measurements taken for each athlete was their standing height and body mass without shoes. Many authors have established that height and weight can be significant indicators of success in field hockey[43, 52].

Body composition was measured using skinfold calipers (Lange, CA) on three sites. The three sites used were the triceps, suprailliac and thigh. Skinfolds were chosen as the measurement for body composition due to their accuracy in the field and relative ease of use[59]. The same technician took all skinfold measurements to ensure consistency of results. A three-site measurement was chosen because it is less invasive than four- or seven-site measurements, and is much more economical with time. Body density was calculated using the widely accepted equation developed by Durnin and Womersley (Equation 1), and the Siri equation will be used to calculate body fat percentage (%BF)[60, 61]. These equations have been validated for their use in athletic populations, and have been used in many studies on female field hockey players[52, 57].

Equation 1: Durnin and Womersley's equation for prediction of body density:

$$BD = 1.1567 - 0.0717(log_{10}X_1)$$

In addition to performance predictors, body composition is important, especially in adolescent females, to identify and treat potential eating disorders or other components of the Female Athlete Triad[38].

Physiological Tests

The physiological tests chosen were taken from an established testing battery, which enables differentiation of talent levels in field hockey players and can also be applied to monitor progress throughout a season[52].

VO_{2max} was determined using the Multistage Fitness Test Shuttle Run, or Beep Test . This test has been validated in a number of studies and is a reliable indicator of aerobic fitness[19, 26, 62, 63]. It is frequently used to establish VO_{2max} in field hockey players, due to its specificity and competitive nature, as well as its economy when compared to direct laboratory measurements[41, 50, 52, 62, 64]. Essentially, it is a series of shuttle runs over 20m, in time with a series of beeps which become progressively faster. Participants are required to complete each shuttle before the next beep until reaching volitional fatigue. The last completed shuttle is recorded, and equivalent VO_{2max} is estimated using validated calculations[52]. It has been firmly established that VO_{2max} is an essential component of field hockey, especially due to the increasing need for players to be able to perform in multiple positions. Aerobic power can distinguish between different levels of field hockey ability, and has been proven to be a useful measurement for assessing changes in female field hockey players[52].

Sprinting speed was determined over 10m and 40m. These two distances were used as they have been validated for identifying talent and tracking progress over a season in field hockey players[50, 52, 57]. There has also been a correlation identified between sprinting ability and stick-eye coordination, pushing power and pushing accuracy[27]. The use of stopwatches to track sprinting ability has been validated, which is why hand-held stopwatches were chosen to time sprinting speed[65].

Repeated sprint ability (RSA) was calculated by estimating the speed decrement over six 40m sprints (Equation 2). Each sprint occurred 30s apart and participants jogged back to the start between each sprint. This protocol has been validated as being specific to the demands of field hockey[52, 64]. An estimate of the decrement in speed for each athlete will be determined for both the 10m and 40m distances using Equation 2.

Equation 2: Eston, Eston & Reilly's Speed Decrement Equation[57]

$$\text{Speed Decrement \%} = \left[\left(\frac{Slowest\ Time}{Fastest\ Time}\right) \times 100\right] - 100$$

Running RSA tests have been shown to be valid for field-invasive sports such as field hockey, lacrosse and soccer[20,, 53, 54]. It has been indicated that speed decrement may have a negative correlation with VO_{2max}, and studies have also shown speed decrement as being positively related to sprinting speed[52, 66, 67, 68].

Initial Testing

On the first day of the study, participants (n=46) were fitted with self-adapted 'boil-and-bite' mouthguards (SafeTGuards, Wheatridge CO)(Figure 3), following the instructions on the packages. Experienced field hockey coaches ensured that the fit of the mouthguards was correct.

Figure 3: Molded Adult Form-Ft Mouthguard from Safe-T-Guard

Anthropometric measures of standing height and weight (without shoes) were taken. Skinfold measurements were taken using calipers (Lange, CA). Skinfolds were taken at three sites: the triceps, suprailliac, and thigh. All measurements were taken on the right hand side of the body for consistency. Each site was measured three times, with the average of the three readings recorded. Body density was calculated using Durnin and Womersley's prediction equation, and the Siri equation was used to determine body fat percentage (%BF)[60, 61].

Before commencing physiological testing, all participants completed a self-directed warm up lasting approximately 10 minutes, consisting of running/jogging and dynamic and static stretching. On the first day of testing, participants performed all testing without mouthguards and sticks in order to establish a baseline measurement.

Sprinting speed and repeated sprint ability (RSA) were tested over 40m. Investigators were positioned with stopwatches at the 10m and 40m markers. The participants began the sprint from a stationary position on the starting line, with the cue of a whistle blown by an investigator. The time at which they crossed the 10m and 40m lines was recorded. Participants were then given 30 seconds to return to their starting position, ready to sprint again. This test was repeated six times to enable measurement of maximal sprint speed and RSA. Speed decrement was calculated using Fitzsimons and colleagues' equation[67].

Aerobic capacity testing utilized the Multistage Fitness Test Shuttle Run or Beep Test (BT). Participants took part in this test as a group, and it was completed as teams (Freshman, Junior Varsity and Varsity). Participants lined up on a marked line, and ran to another marked line 20m away, in time with beeps from a recording. The beeps got progressively faster, and participants were required to complete the 20m shuttle before or in time with the beeps. Participants were required to maintain this increasing speed until they missed two beeps in succession, at which point their test was over and the last stage reached was recorded. VO_{2max} was calculated using estimation equivalents validated by the Léger, Mercier, Gadoury and Lambert[70].

One week later, the tests were repeated with all participants completing testing with mouthguards and sticks. This allowed for baseline comparison. The beep test was repeated to measure aerobic fitness at the end of preseason training (6 weeks) and at the end of the competitive season (12 weeks). Anaerobic sprint testing was repeated only at the end of the season (12 weeks) due to unforeseen time constraints during the midseason testing points. Testing at all time points involved two rounds of testing, one with and one without sticks and mouthguards.

Statistical Analyses

Mouthguard use and satisfaction was measured using a validated survey. Binary questions were compared for pre- and post-testing using Cochran's Q test. Cochran's Q test was chosen as it is a frequent test used for binary responses with two or more groups[103]. A nonparametric repeated measures Friedman test was used on Likert scale items, as the subjective measures were ordinal in nature. Physiological testing was analyzed using a 3-way analysis of variance (ANOVA) with post-hoc testing. The main effects tested were group (EXP vs. CON), time point (pre, mid or post), and test condition (MG-STK vs. WOMG-STK). Post-hoc analyses involved multiple comparison procedures with a Tukey correction. Statistical significance was declared at $p<.05$ unless otherwise noted, and the data were analyzed using a statistical software package (SPSS Version 21.0, IBM SPSS Statistics Inc, Chicago, IL).

Research Design

A matched pairs design was used following initial testing. Participants were matched based on team selection (Freshman, Junior Varsity or Varsity teams) and initial sprint performance. Participants were then randomized into an experimental (completing all conditioning with mouthguard and stick, MG-STK) or control (completing all conditioning without mouthguard and stick, WOMG-STK) group for the remainder of the study. The Lee Notation for this study was $S_{20}(G_2) \cdot T_6$. Participants were tested at the beginning and end of preseason training and at the end of the competitive season.

Sample Size Calculation

The program G*Power (G*Power Version 3.1.7, Universität Kiel, Germany) was used to determine sample size. An F-test and repeated measures ANOVA within and between interactions was chosen. Effect size was set at medium (0.25), with alpha level type 1 error set at .05 and power (1-B error probability) set at .80. There were two groups with three time points studied. The correlation among repeated measures was kept at 0.5, with the non-sphericity correction also set at 0.5. The sample size determined was 24 participants (*df=23)*. To account for experimental mortality and to allow for the whole team to participate, the total participant count was kept at 46. Twenty-three participants were placed in the experimental (EXP) group and 23 participants were placed in the control (CTL) group.

Data management and storage

Survey, anthropometric and physiological testing data were collected on specifically formatted collection sheets. All data sheets were collected by researchers at the conclusion of each testing session and placed in a locked file cabinet in the office of faculty advisors. The office was locked at all times and access was only granted to members of the primary research team. Electronic files were saved on password-protected computers at the faculty advisor's office.

RESULTS

Forty-six subjects (15.2$\pm$1.2 yrs) were recruited for participation during this study, all females between the ages of 14 and 17. After completing the first set of testing, participants were placed into either experimental (n=23) or control groups (n=23) by stratified random sampling based on team level (Freshman, Junior Varsity or Varsity) and initial beep test performance.

The two athletes with the highest beep test score in each team were paired, then each were randomly assigned to either the EXP or CTL intervention groups. This was continued until all participants had been assigned a group.

During the study, one participant was withdrawn due to transferring schools, and another three were injured during the season and unable to continue with the study. A further 11 participants were excluded from either the aerobic or anaerobic testing due to missing one or more testing sessions. The four participants who withdrew from the study were all members of the Junior Varsity team, and were evenly divided into both intervention groups. Two athletes were the two highest performers in that group and therefore matched with each other, and the remaining two participants were not matched, despite a similar beep test performance.

The 11 participants who missed testing sessions were not evenly distributed between groups, nor were they matched in stratification within teams. This may have caused a skewness within the results causing a lack of significant findings.

Therefore, 38 participants remained for aerobic testing (EXP = 18; CTL = 20), and 32 participants remained for anaerobic testing (EXP = 17; CTL = 15). As anthropometric data were collected during anaerobic testing, 32 participants were included in anthropometric measurements. There was no significant difference found between pre- and post-season data in any anthropometric variable (Table 1). Self-report maturation scale data showed all participants to be at the same stage of pubertal development (average of 4/4 for all developmental landmarks), indicating that all participants were physically mature.

Table 1: Participant anthropometric characteristics at baseline

Variable	Control (n=15)	Experimental (n=17)	*p*-value	Combined
Age (years)	15.2 (1.3) [13 – 17]	15.2 (1.04) [14 - 17]	.957	15.2 (1.2) [13 - 17]
Height (cm)	161.1 (4.6) [150.5 – 167.4]	162.5 (6.7) [143.6 – 172.3]	.502	161.8 (5.9) [143.6 – 172.3]
Weight (kg)	58.8 (7.6) [46.7 – 74.3]	59.2 (10.7) [37.3 – 83]	.901	59.0 (9.4) [37.3 – 83]
BMI (kg/m^2)	22.76 (3.39) [17.49 – 28.35]	22.29 (3.06) [16.68 – 28.74]	.696	22.51 (3.23) [16.68 – 28.74]
Body Density	1.04 (0.01) [1.02 – 1.06]	1.04 (0.01) [1.03 – 1.06]	.881	1.04 (0.01) [1.02 – 1.06]
Body fat %	20.97 (4.46) [13.3 – 28.23]	22.4 (3.63) [15.6 – 29.97]	.339	21.73 (4.11) [13.3 – 29.97]

Mean (SD), [range]

Physiological Data

Baseline, midpoint, and post-season testing occurred at zero, six and twelve weeks respectively, to fit with the competition schedule of the team. The amount of days between baseline and midpoint testing was 35±2 days, and there were 40±2 days between midpoint and post-season testing. Testing occurred on different days within the sixth and twelfth weeks, based on game and practice schedules of the three teams. At each testing point, participants performed testing without the mouthguard and stick (WOMG-STK), then performed the same tests with the mouthguard and stick (MG-STK). There was a minimum of 24 hours and a maximum of 72 hours between each test. Each participant completed at least 95% of the training sessions, with a team average of 98% attendance.

Aerobic Fitness

No main effect was found in estimated aerobic capacity between the experimental and control groups at any time point, regardless of test condition ($p>.05$) (Tables 2 and 3).

Table 2: Estimated VO_{2max} scores ($mL \cdot kg^{-1} \cdot min^{-1}$) MG-STK

Time point	Control (n=18)	Experimental (n=20)	*p*-value	Combined mean
PRE	31.84 (3.96) [25.1 – 38.8]	31.77 (4.67) [24.7 – 39.9]	.96	31.8
MIDDLE	35.66 (4.59) [29.6 – 43.2]	34.75 (3.34) [27.2 – 41.5]	.49	35.18
POST	32.84 (3.87) [26.8 – 40.5]	33.49 (3.91) [28 – 39.9]	.62	33.18

Mean (SD), [range]

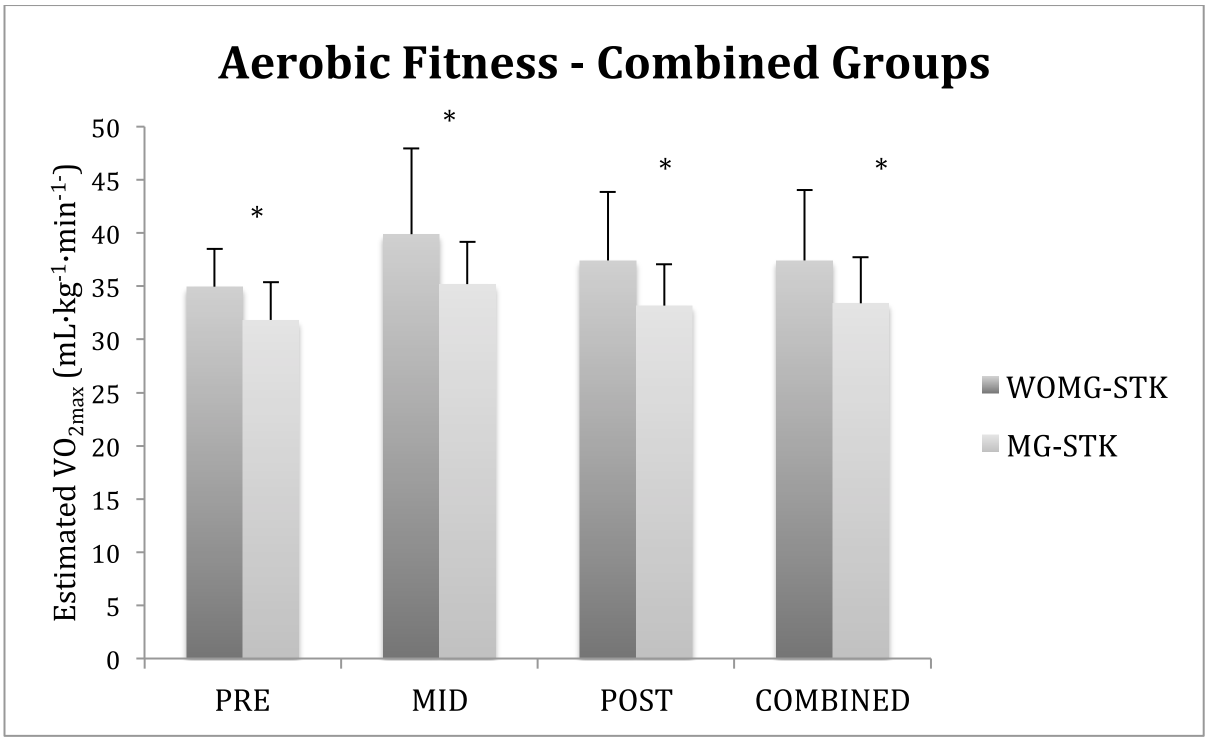
Table 3: Estimated VO_{2max} scores ($mL \cdot kg^{-1} \cdot min^{-1}$) WOMG-STK

Time point	Control (n=18)	Experimental (n=20)	*p*-value	Combined mean
PRE	35.12 (3.93) [28.8 – 41.2]	34.79 (3.23) [28 – 40.5]	.78	34.94
MIDDLE	40.32 (8.67) [29.9 – 59.1]	39.47 (7.54) [26.8 – 57.5]	.75	39.87
POST	37.19 (6.5) [29.9 – 59.4]	37.61 (6.45) [29.9 – 58.6]	.85	37.41

Mean (SD), [range]

When results were combined, there was a significant reduction in aerobic performance when performing the beep test with a stick and mouthguard at all time points (WOMG-STK: 37.41$\pm$6.65 mL·kg^{-1}·min^{-1} vs. MG-STK: 33.16$\pm$4.32 mL·kg^{-1}·min^{-1}; $p<.01$) (Figure 4).

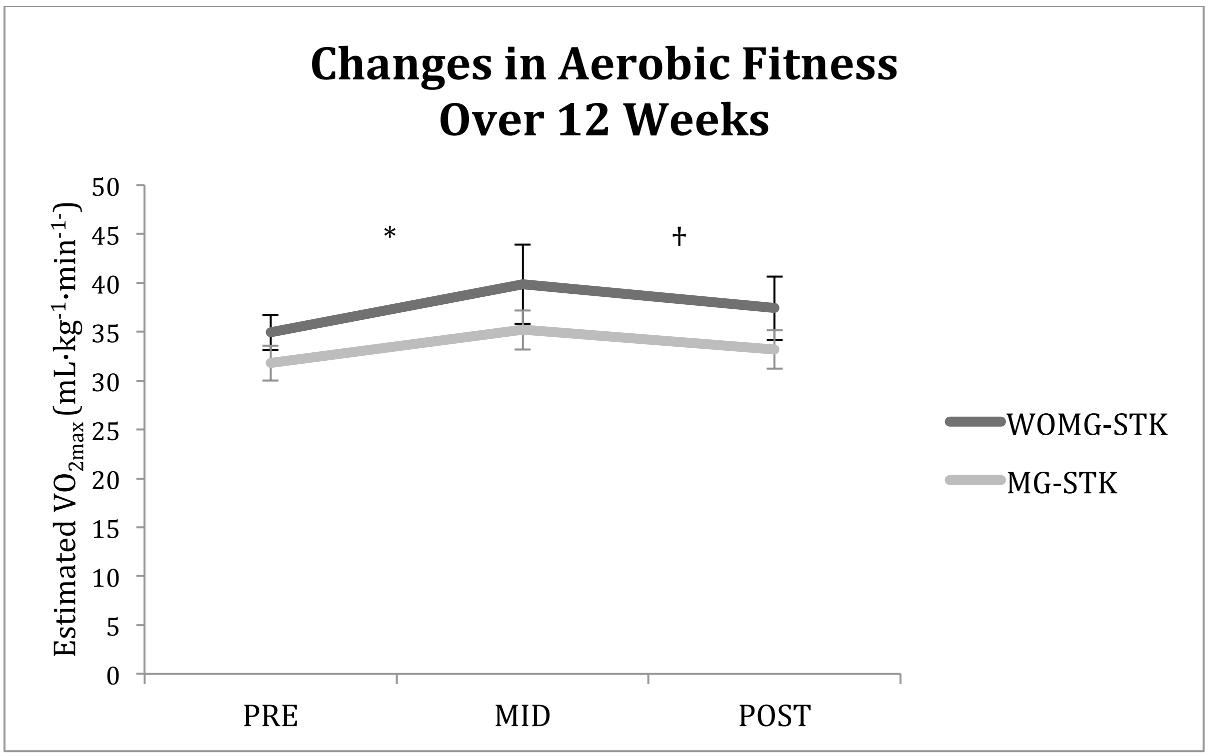
Figure 4: Estimated VO_{2max} scores (mL·kg^{-1}·min^{-1}) WOMG-STK vs. MG-STK



*Significant difference

Further, it was found that FH-specific training altered aerobic performance across the twelve weeks ($p<.05$). Estimated VO_{2max} increased from baseline to midpoint ($p<.05$) and then decreased at post-testing ($p<.05$) (PRE: 33.37$\pm$4.29 mL·kg^{-1}·min^{-1}; MID: 37.52$\pm$6.81 mL·kg^{-1}·min^{-1}; POST: 34.94$\pm$6.65 mL·kg^{-1}·min^{-1}) (Figure 5). There was no significant change from pre- to post-testing.

Figure 5: Changes in estimated VO_{2max} scores ($mL \cdot kg^{-1} \cdot min^{-1}$) over 12 weeks



*Significant change between pre- and mid-testing

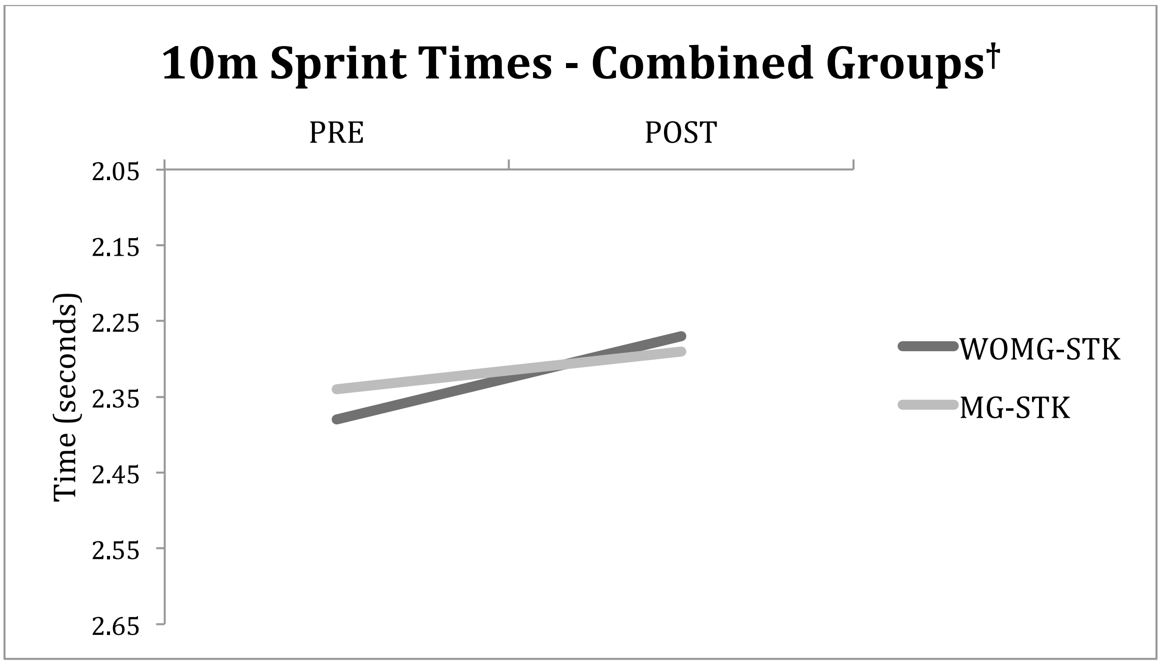
†Significant change between mid- and post-testing

††Significant change from pre- to post-testing

Sprinting Speed

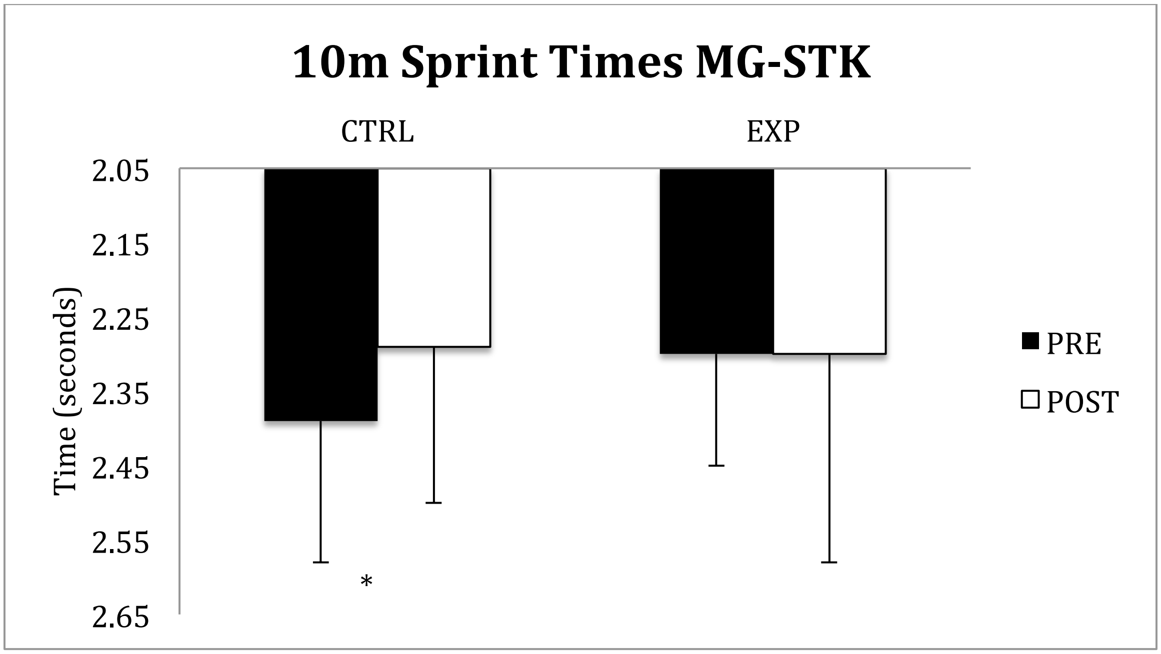
There was no difference found between groups or test conditions in the 10m sprint (p>.05). However, there was a significant time effect found between pre- and post-testing time points (p<.05) (PRE: 2.38$\pm$0.16s; POST: 2.27$\pm$0.25s) (Figures 6, 7 and 8).

Figure 6: Fastest 10m sprint times (s) combined groups



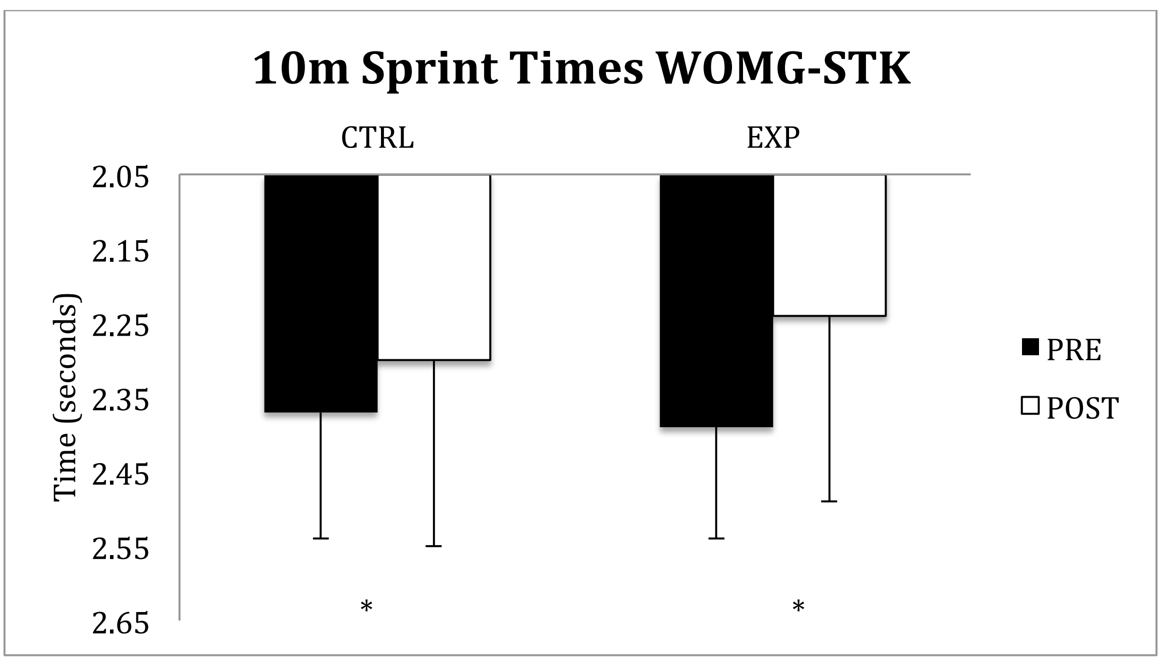
† Significant difference in both test conditions

Figure 7: Fastest 10m sprint time (s) MG-STK



*Significant difference

Figure 8: Fastest 10m sprint time (s) WOMG-STK



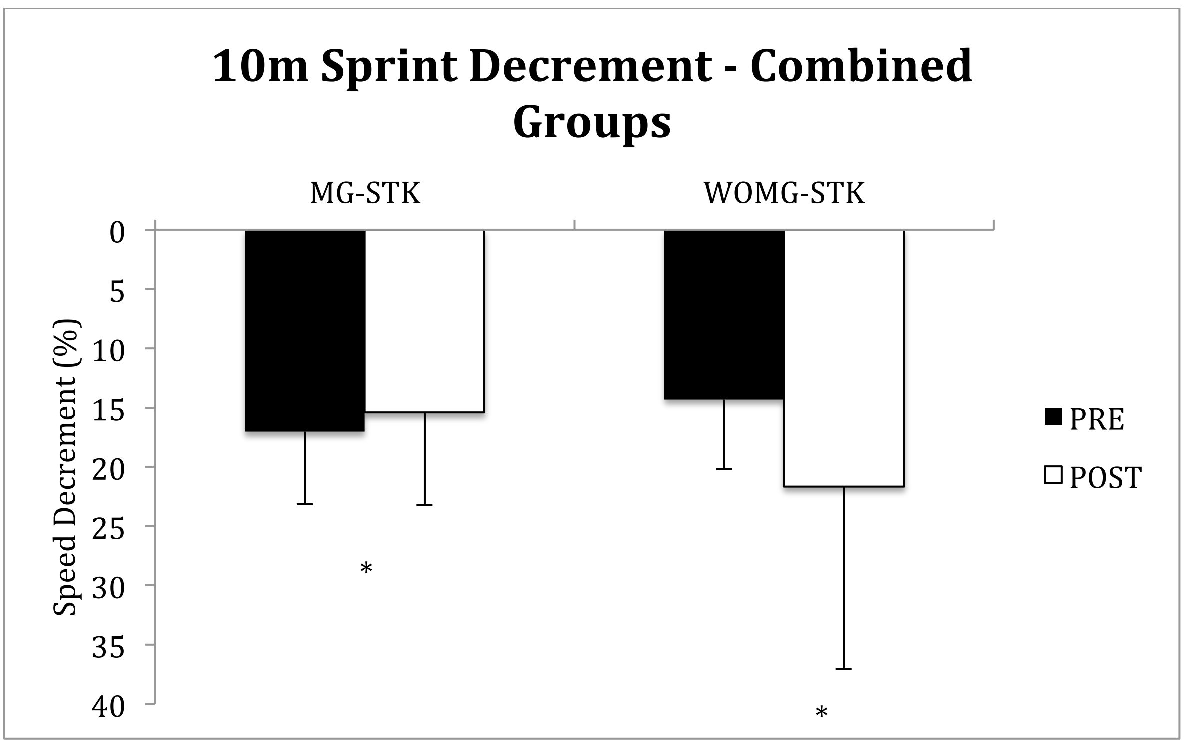
*Significant difference

There was no significant difference found in the results of the 40m sprints, regardless of test condition, experimental group or time point (p>.05).

Sprint Decrement

There was no difference found in 10m sprint decrement between control and experimental groups (p>.05). A significant interaction between test type and time was found (p<.05). Pooled data for MG-STK tests showed a 2.4% improvement in RSA (repeated sprint ability) from pre to post (p<.05), whereas pooled data for the WOMG-STK demonstrated a 7.3% sprint decrement (p<.05) (Figure 9).

Figure 9: 10m sprint decrement (%) combined groups



* Significant difference

There were no significant differences found in 40m sprint decrement between groups or across time ($p>.05$). There was a significant difference found between MG-STK and WOMG-STK tests in pre-testing ($p<.05$), however this was not maintained throughout the season (Table 4).

Table 4: 40m sprint decrement (%) combined groups

Time point	MG-STK	WOMG-STK	*p*-value	Combined mean
PRE	14.47 (5.28) [5.71 – 27.54]	10.71 (5.49) [1.01 – 27.08]	.007*	12.59
POST	13.19 (7.35) [4.41 – 36.87]	12.75 (7.62) [5.06 – 32.85]	.136	11.95
COMBINED	13.83 (6.43) [4.41 – 36.87]	11.73 (6.72) [1.01 – 32.85]	.075	12.78

Mean (SD), [Range]

Mouthguard Survey

Only seventeen participants returned both the pre- and post-testing mouthguard survey with all questions completed. Although these numbers did not allow for adequate statistics to be obtained, it is worth noting a number of trends in the survey data. Each question was analysed separately, and trends were reported for both groups.

The number of players who perceived problems while wearing a mouthguard decreased by 30% from pre- to post-intervention (47% to 17%), regardless of intervention group (Figures 10 and 11)

Figure 10: Reported problems during mouthguard use – CTL Group

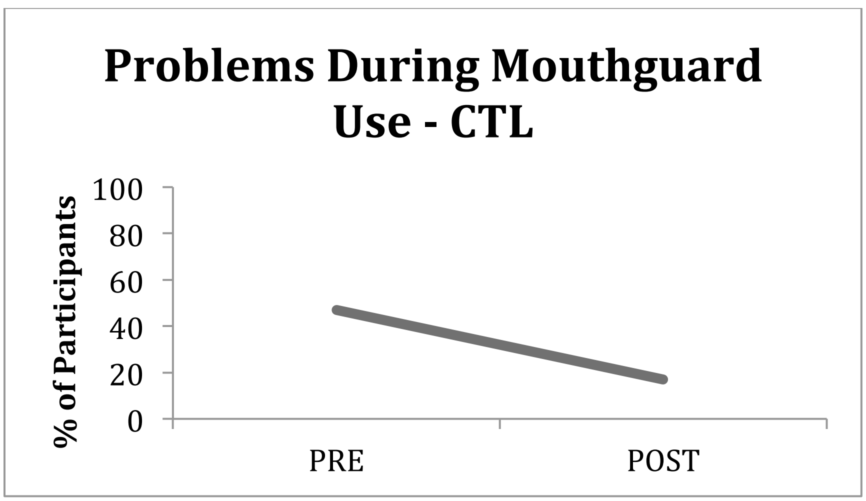
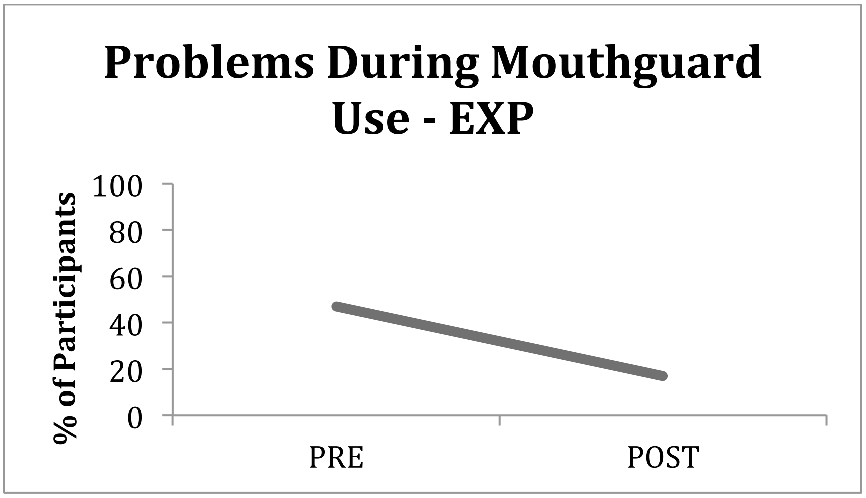


Figure 11: Reported problems during mouthguard use – EXP Group



Additionally, the percentage of players who felt that mouth guards hindered their breathing decreased from 100 to 63% in the CTL group and from 100% to 60% in the EXP group (37% and 40% decrease respectively) (Figures 12 and 13). The number of players who reported that they would wear a mouthguard during practice if it was not enforced by coaching staff rose by 18% in the control group (41% to 59%) and by 22% in the EXP group (41% to 63%) (Figures 14 and 15).

Figure 12: Difficulty breathing during mouthguard use – CTL Group

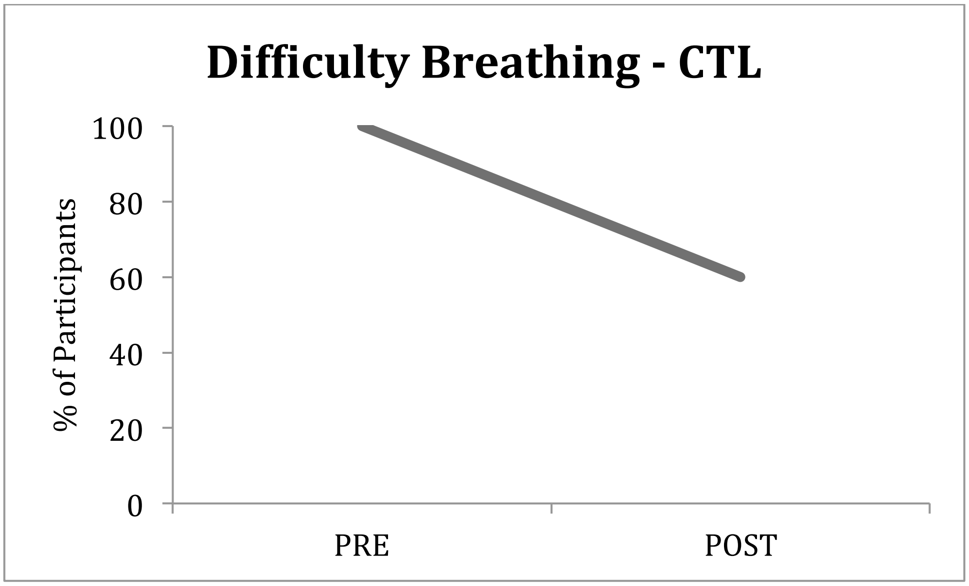


Figure 13: Difficulty breathing during mouthguard use – EXP Group

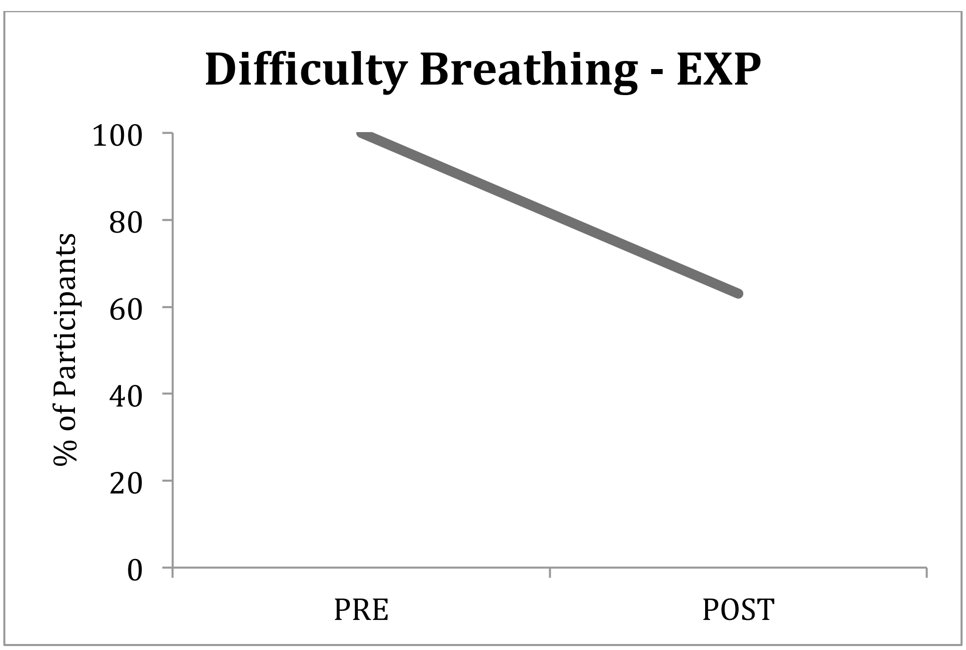


Figure 14: Mouthguard use if not enforced - CTL

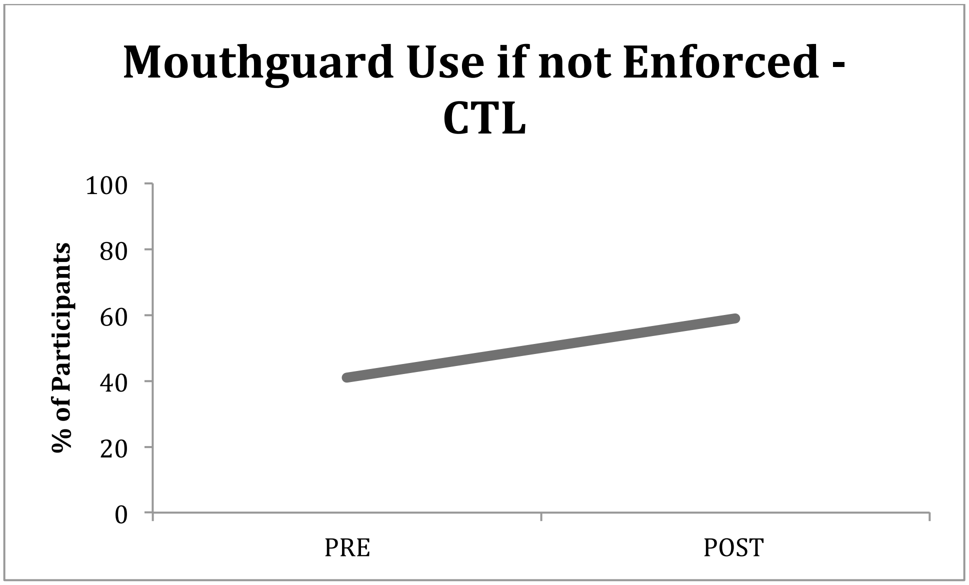
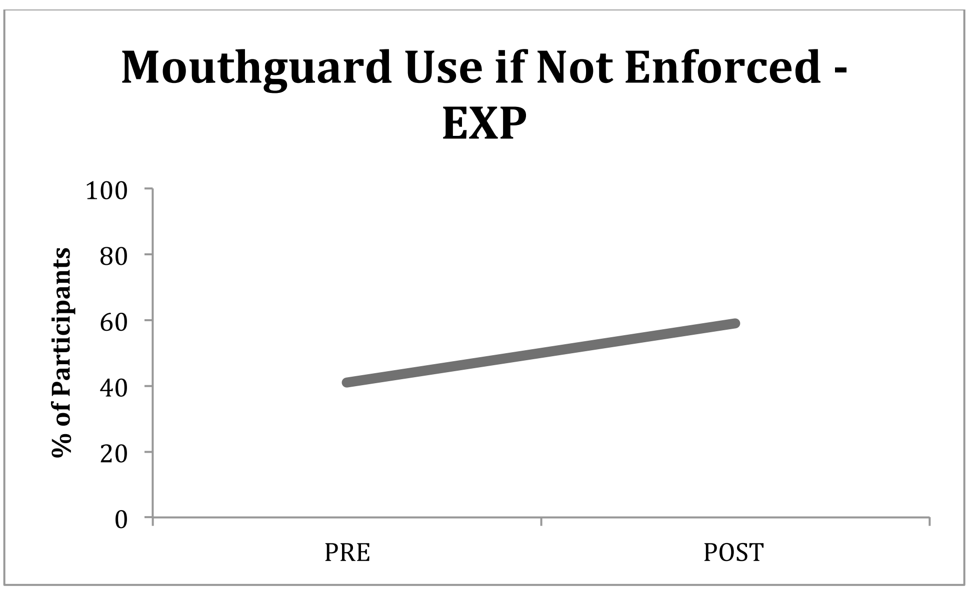
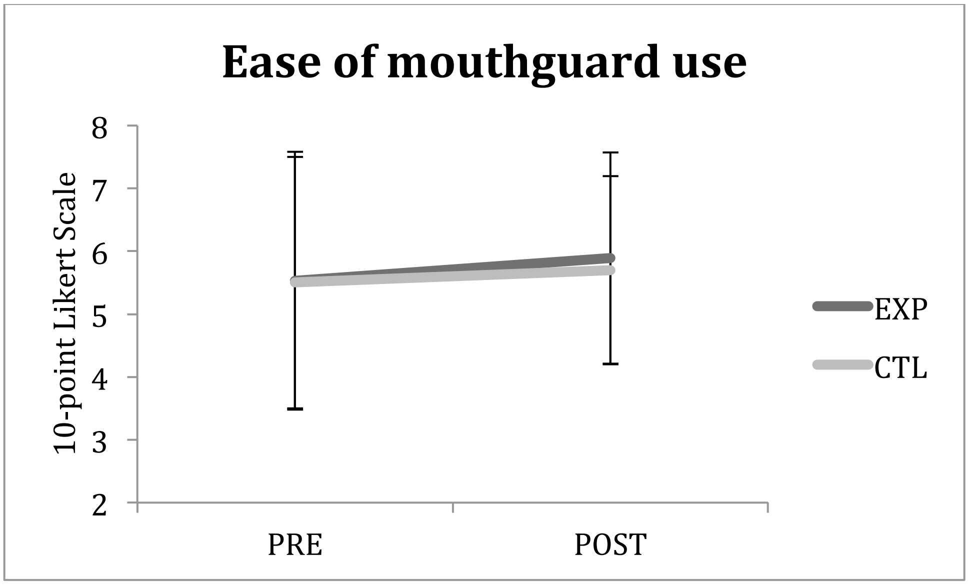


Figure 15: Mouthguard use if not enforced - EXP



Perceived ease of mouthguard use, measured on a 10-point Likert scale, showed a slight increase (5.53 to 5.89) (Figure 13).

Figure 15: Ease of mouthguard use



DISCUSSION

The purpose of this study was to analyze three research questions. First, we aimed to determine whether 'sport-specific' conditioning creates greater improvements than neutral conditioning in high school field hockey athletes. Although it was hypothesized that the EXP group would see a greater improvement, there was no difference in aerobic or anaerobic performance between EXP and CTL groups. However, a significant decrement in performance was seen in both groups when a stick and mouthguard was used during testing. Next, we wished to assess differences between the two groups across the season. Although once again there was no difference between groups, it was found that both aerobic and anaerobic performance significantly increased from pre- to mid-testing and decreased from mid- to post-testing. Finally, we assessed whether chronic mouthguard use would create a more favorable attitude towards them, and found that there were a number of positive changes in attitude associated with chronic mouthguard usage.

Anthropometric Measures

As previously stated, there is very little research into the anthropometric and physiological profile of female high school athletes, especially in field hockey. It has been noted that body size and composition, among other anthropometric characteristics, can be a significant indicator of future success in field hockey[71]. Due to the scarcity of research, especially into adolescent field hockey, meaningful comparisons cannot be made. However, comparisons can be made to collegiate, representative and club level players, which can provide benchmark for successful performance. Additionally, comparisons to other adolescent field sports such as lacrosse and soccer can help contribute to performance standards.

The participants in this study had a similar height and weight to recreational club-level players in related studies, despite the age difference (15.2 yrs. vs. 20.3 yrs) [52]. Due to the lack of change in height and weight throughout the study, it can be assumed that the participants in the present investigation had reached their full adult height [56, 72, 73, 74]. When compared to National Collegiate Athletic Association (NCAA) Division II (DII) field hockey players, the participants in the present study weighed less (59kg vs. 63.03kg), but had a higher body fat percentage (21.73% compared to 17.29%)[27]. This discrepancy in weight and body fat percentage is easily explained due to the difference in level of competition, amount of time spent training (10 hours/week vs. 20 hours/week) and participant motivation[76].

Sports motivation is measured through a number of parameters, with the major factors including task/ego motivation, perceived peer acceptance/friendship quality, perceived ability, sport enjoyment and satisfaction with performance[77]. Youth athletes (10.9 ± 0.6yrs) tend to be more focused on peer acceptance/friendship quality than any other measurement[77]. The same has been shown for female high school athletes (14-17yrs) across a variety of both team and individual sports[78, 79]. While in high school athletes, motivation sources tend to start shifting towards perceived ability and task/ego motivation, it is still primarily the social aspect of team sports that is the number one motivator for participation[78, 79].

Collegiate level athletes (British premier league and Midlands 1, equivalent to NCAA DI and NCAA DII) of both genders (19.78±1.6yrs) have shown that perceived ability and task/ego motivation creates a much greater motivation to perform well in practices than was found in lower levels of competition (NCAA DIII, British Midlands 3 and 4)[80]. This indicates that the major reason for participating in high school sports is principally increasing perceived peer acceptance/friendship quality bonds, rather than winning (task motivation). The lack of task/ego motivation creates a potential difference in priorities between the average high school and the average collegiate-level athlete, explaining the large differences in body fat percentage, despite similarities in weight and other anthropometric measures.

There was a lack of significant changes in any anthropometric measures throughout the season, a result which was consistent with the findings of a full season's work in both NCAA DIII FH players (19.69±1.37yrs) and elite female handball players (23.1±4yrs) [1, 81]. A lack of %BF change over a season has also been reported in a number of female sports and competition levels, including collegiate level swimming, tennis and volleyball, and elite gymnasts[82]. Research conducted on the 1996 US Olympic Women's Field Hockey team showed a decrease in body fat throughout the course of a season[41]. This discrepancy in results can be attributed to the significant difference in training level and motivation difference between an amateur high school team and an Olympic representative team.

Aerobic Fitness

The primary limiting factor for many field sports is aerobic fitness, which is typically field-tested by using the MSSRFT (Multi-stage shuttle-run fitness test), or beep test. There was a significant difference found in the estimated aerobic fitness of high school field hockey players from baseline to midpoint to endpoint, regardless of group or testing condition.

The average estimated VO_{2max} scores seen in this study were similar to that seen in club players who were also tested using the beep test (present study: 39.87 $mL \cdot kg^{-1} \cdot min^{-1}$; club players: 38.9 $mL \cdot kg^{-1} \cdot min^{-1}$)[2]. They were also lower than that reported by collegiate teams (47.2 $mL \cdot kg^{-1} \cdot min^{-1}$) [1]. The similarities to the club players could be attributed to the similar level of competition, training and motivation, as compared to the much higher standards, training volume, intensity and training age typically found in collegiate athletics.

Another similarity between this and previous research is the VO_{2max} scores found in differing field positions. It has been reported that center midfield players have the highest VO_{2max} in several teams, while full-backs have the lowest, by a substantial amount[41]. The present study also demonstrated this, as the two highest estimated VO_{2max} scores (59.1 $mL \cdot kg^{-1} \cdot min^{-1}$and 57.5 $mL \cdot kg^{-1} \cdot min^{-1}$) were shown by center midfield players, while the two lowest scores (29.9 $mL \cdot kg^{-1} \cdot min^{-1}$ and 26.8 $mL \cdot kg^{-1} \cdot min^{-1}$) were demonstrated by full-backs.

The initial increase in estimated VO_{2max} values could be expected, as the athletes were returning from summer break and off-season when testing began. The first six weeks of training were focused on developing an aerobic base for players, which is demonstrated by the 11% increase in average VO_{2max} values for the team. This increase mirrors the 12% increase that has been reported in Olympic level FH teams during preseason training[83]. This result is also in agreement with several other studies which show significant increases (5-20%) in aerobic fitness throughout preseason training in NCAA DIII and club field hockey, collegiate rowing, semi-professional soccer and both junior and elite rugby [1, 41, 84, 85, 86].

The decrease in aerobic performance during the competitive phase of the season has also been reported in multiple team sports, including NCAA D1 collegiate basketball players, semi-professional soccer players, NCAA D1 women soccer players, and both junior and elite rugby players [84, 85, 87, 88, 89, 90]. However, research has also shown that aerobic fitness is maintained in collegiate basketball starters, club soccer players, elite male handball and soccer players, junior rugby league players and DIII field hockey athletes[82, 85, 86, 87, 91, 92].

It may be that the significant decrease in training volume and intensity during the competitive season created a detraining effect, which has been shown to have a greater effect on younger, lesser trained females (as were participants in the present study) than on older, better trained male athletes[93]. Previous studies have also demonstrated that VO_{2max} can decrease by 4-14% with less than four weeks of training decrease or cessation[93]. This is in agreement with the present finding of a 7% decrease from mid- to post-testing resulting from six weeks of increased competition but decreased training load.

Another theory to explain the decrease in aerobic fitness is that residual fatigue from increased intensity and decreased recovery time can limit the physical development of players, in some cases causing a decrease[88]. Finally, the decrease could be explained by a lack of participant motivation due to the timing of the final testing session. As the last testing session occurred after the last game of the season for two of the teams in the squad, it is likely that most participants did not put forth the same amount of effort that they would have shown had their season still been in progress.

Use of a mouthguard and stick (MG-STK) created a significant decrease in aerobic fitness test scores, regardless of chronic or acute use. Previous research has shown that mouthguards have no effect on maximal oxygen uptake or ventilation levels when using a custom fit or boil-and-bite mouthguard, especially in women [5, 6, 16, 18, 19, 94, 95]. However, it has also been noted that the there is a significant psychological impact on performance when a mouthguard is worn [6, 18, 96, 97, 98]. As there is, to my knowledge, no research that shows a significant decrease in aerobic capacity when using MG-STK, it is difficult to determine why there was such a decrease, unless it occurred due to psychological factors (a distinct possibility), or was caused by carrying the stick.

Running performance while carrying an object such as a stick or a ball has been shown to create a significant decrease in sprinting time[33], however to this author's knowledge there is no current research regarding the effect of carrying an object on aerobic performance. Further research is needed as to whether the constraint of carrying a field hockey stick or similar causes a decrement to aerobic performance, independent of any psychological impact caused by wearing a mouthguard.

Anaerobic Capacity

Sprinting is an integral part of field hockey, as is acceleration. It was found that there was no significant change in 40m sprint results. When groups were combined, there was a significant difference found in 10m sprint (acceleration) times. These results were found regardless of test or group condition.

Repeated sprint testing is an especially useful form of anaerobic capacity testing, as in many field sports an athlete is required to make multiple all-out sprint efforts without full recovery in between[64, 100]. The participants in the present study were slower over 10m during their fastest test than club and representative level female field hockey players (18-21yrs) (Present: 2.27$\pm$0.25s; club: 2.16$\pm$0.03s; rep: 2.01$\pm$0.02s) [52]. This result could be expected based on the age difference, in addition to the previously discussed motivational differences between representative level athletes and high school athletes. The improvement in 10m times is greater than that seen in highly trained male adolescent male handball players (15.5$\pm$0.9yrs) over the same time period (FH: 2.13% improvement; handball: 1.5%)[101]. The mechanism behind this improvement is unknown, as there are very few studies that examine the effect of a season's training on 10m sprint time. However, the aforementioned handball study utilized high intensity training as an intervention, with protocols similar to the typical running prescribed for the FH team by their coaching staff.

Although there was no significant difference between groups or test conditions during the 10m sprints, it is worth noting that post-hoc testing revealed that the experimental group were a great deal faster in the MG-STK condition during pre-testing than during the WOMG-STK test, as well as much faster than the control group in either test condition (Figures 4 and 5). They then remained consistent across the season, with the other groups and test condition improving performance to essentially match the speeds shown during pre-testing in the experimental group.

Research has shown that there is no difference in anaerobic power when using a mouthguard, however, it has also been demonstrated that the acute use of a mouthguard can decrease auditory and visual reaction times[5, 15, 99]. There have been no studies relating to the chronic use of mouthguards and their effect on performance or reaction time. Perhaps extended use of a mouthguard removes the reaction advantage that comes with acute use? This is a potential further area of research.

The present participants were slower over 40m than both club and representative FH players, as well as elite women's rugby union players (Present: 7.29$\pm$0.58s; club: 7.09$\pm$0.11s; rep: 6.53$\pm$0.09s; rugby: 6.51$\pm$0.31s) [52, 102]. The lack of change in 40m sprint times throughout the full season has been mirrored in one other study involving elite female handball players (23.1$\pm$4yrs), although this was the only study that could be found for comparison[81].

Loading of the arms (by carrying an object such as a field hockey stick) has been shown to have a negative affect on sprinting velocity, due to altered kinematics of the running motion [4, 33, 35]. The lack of significant difference between the groups and tests indicates that this loading may have less of an effect on the adolescent player than on the adults used in the above-mentioned studies. Additionally, any improvement in reaction time that may have been caused by the acute use of mouthguards could have negated any decrements caused by carrying a stick.

In addition to sprint speed, sprint decrement is an equally important part of a field hockey player's physiological and performance profile, as it is a measurement of a players' ability to make repeated sprints during a game[64, 100]. There was no difference found between groups for 10m or 40m sprint decrement, however there was a significant increase in post-test decrements between MG-STK and WOMG-STK test conditions ($p<0.05$). The repeated sprint ability (RSA) of the athletes in the present study was worse and had greater variability over 10m than that of club and representative FH players (14.3±5.89% vs. club: 12.7±1.4% and rep: 13.1±1.0%)[52]. There is presently no research into the effects of either stick or mouthguard usage on sprint decrements or RSA, so there is no reliable theory as to what caused the large difference between test conditions at the end of the season. However, it is hypothesized that the difference was caused by the chronic training effect of mouthguard and stick usage. Single sprints may not be enough to demonstrate a training effect, and repeated sprints do not create the same psychological barriers as typically accompany aerobic testing. Although they are different distances, it is theorized that if a longer training period was available or midpoint sprint data had been obtained, a pattern would begin to emerge showing a significant improvement RSA when chronically training with a mouthguard and stick, over both 10 and 40m. This is important, as RSA and sprint decrement are arguably the most important aspects of field invasive sports, especially field hockey.

Mouthguard Usage Questionnaire

The mouthguard usage questionnaire demonstrated that players in the EXP group decreased their scores on all negative aspects of mouthguard usage (problems when wearing mouthguard, trouble breathing) by 80%. The entire sample showed a 37% decrease in trouble breathing, and their willingness to wear a mouthguard rose by 20%.

These data, although extremely limited in sample size, indicate that chronic mouthguard usage may increase acceptance and tolerance of mouthguards. This result is supported by past research demonstrating that chronic use over four and six weeks can increase acceptance of mouthguards in adolescent populations[8, 19, 20].

Limitations

The present study faced a number of limitations, including the study population, injuries, and weather problems.

The study population posed the biggest challenge, as many of the participants did not return all of the requested survey information. This accounts for the lack of mouthguard usage questionnaire data, in addition to potentially having affected post-testing results due to lack of motivation at the end of the season. As two-thirds of the participants had finished their season by the time post-testing occurred, many had very little motivation to continue with the study[78]. This resulted in missing data points for several athletes, as well as perhaps skewing the post-testing results, especially for the beep test. Additionally, the team that was still in the championships knew that they were likely to be eliminated in the next round and, therefore, were not as highly motivated as they were at the beginning of the season. As in any field-based, team-based study, there were unavoidable injuries that caused athletes to be removed from the study.

Finally, as all testing occurred on the outdoor, grass home field of the team, weather played a part in the ability of the research team to collect data. Early in the season, there were several heat advisory days on scheduled data collection days, causing us to have to fit testing around a busy game and practice schedule to allow the least interruptions to the team's training as possible. Mid-point sprint and RSA measurements were unobtainable due to heavy rain during the data collection time, which could not be rearranged due game schedules.

Practical applications/Future Studies

There are many practical applications for the results of this research. It is apparent that although acute use of a mouthguard and stick diminishes performance, the chronic use of these objects does not affect an athlete's ability to adapt to aerobic and anaerobic changes caused by sport-specific training. Additionally, it is indicated that the chronic use of a mouthguard creates a more favorable attitude towards its use. Therefore, sport-specific training with a mouthguard and stick can be recommended, especially for adolescent teams who have problems with adhering to mouthguard use. Chronic sport-specific training with a stick and mouthguard will have the same effects on aerobic and anaerobic performance as neutral training, while allowing for a much more sport-specific form of conditioning and engendering better attitudes towards mouthguards and safety practices in adolescent athletes.

Future studies may look towards repeating the study using a more highly motivated group such as a higher-level high school team, or perhaps high-school aged club and representative teams who would be more highly motivated to participate to their fullest ability for the entirety of the study. Another adaptation may be to perform all testing indoors, to ensure that weather concerns do not alter testing schedules and all data are able to be collected at the ideal times.

As stated above, to the best of my knowledge there have been no studies that examine the chronic effect of mouthguard use on auditory or visual response times. This is worth further investigation; because if chronic use negates the improvements in reaction times then perhaps mouthguards should only be used when required for safety and during competition, not during regular conditioning work.

The results of this study have been confounded by the ambitious nature of the work, and it is difficult to determine whether the stick or the mouthguard created the results that were seen. Therefore, a future study should examine the chronic use of a stick throughout the season, as many studies on mouthguards have been performed. By establishing the effects of holding a stick throughout all conditioning, we will be able to establish which part of the equation (the stick or the mouthguard) has both the most detrimental and beneficial effects on parameters of field hockey performance.

Finally, the suggested changes for future studies should be applied to other field invasive sports that require the constraints of carrying a stick and wearing a mouthguard. For example, lacrosse and rugby both require players to carry an object in order to play.

In conclusion, it can be seen that the results of this study create many more questions than answers. Answering these questions will lead to great improvements in not only training efficiency and game play; as well as allowing for recommendations regarding mouthguards and safety during conditioning in youth athletes.

REFERENCES

1. Astorino, T.A., Tam, P.A., Rietschel, J.C., Johnson, S.M., & Freedman, T.P. (2004). Changes in Physical Fitness Parameters During a Competitive Field Hockey Season. *Journal of Strength and Conditioning Research, 18*(4), 850-854.

2. Chapman, D.W., Newton, M.J., & McGuigan, M.R. (2009). Efficacy of Interval-Based Training on Conditioning of Amateur Field Hockey Players. *Journal of Strength and Conditioning Research, 23*(3), 712-717.

3. Jones, J.N., Priest, J.W., Marble, D.K. (2008). Kinetic energy factors in evaluation of athletes. *Journal of Strength and Conditioning Research, 22*(6), 2050-2055.

4. Wdowski, M.M. & Gittoes, M.J.R. (2012). Kinematic adaptations in sprint acceleration performances without and with the constraint of holding a field hockey stick. *Sports Biomechanics*. DOI 10.1080/14763141.2012.749507

5. Jung, J.K., Chae, W.S., & Lee, K.B. (2013). Analysis of the characteristics of mouthguards that affect isokinetic muscular ability and anaerobic power. *Journal of Advanced Prosthodontics, 5,* 388-395.

6. Collares, K., Correa, M.B., da Silva, I.C.M., Hallal, P.C., & Demarco, F.F. (2014). Effect of wearing mouthguards on the physical performance of soccer

and futsal players: a randomized cross-over study. *Dental Traumatology, 30*, 55-59. DOI: 10.111/edt.12040

7. Bailey, S.P., Willauer, T., Balilionis, G., Wilson, L., Salley, J., Bailey, E., & Strickland, T.L. (2015). Effects of an over the counter vented mouthguard on cardiorespiratory responses to exercise and physical agility. *Journal of Strength and Conditioning Research*, *29*(3), 678-684. DOI: 10.1519/JSC.0000000000000668

8. Jalleh, G., Donovan, R.J., Clarkson, J., March, K., Foster, M., & Giles-Corti, B. (2001). Increasing mouthguards usage among junior rugby and basketball players. *Australian and New Zealand Journal of Public Health, 25*(3), 250-252.

9. American College of Sports Medicine [ACSM] (2007). *ACSM's primary care sports medicine.* Lippincott Williams & Wilkins.

10. National Federation of State High School Associations [NFHS]. (2014b). *Position statement and recommendations for mouthguard use in sports*. Retrieved from http://www.nfhs.org/media/1014750/mouthguard-nfhs-smac-position-statement-october-2014.pdf

11. Knapik, J.J., Marshall, S.W., Lee, R.B., Darakjy, S.S., Jones, S.B., & Mitchener, T.A. (2007). Mouthguards in sport activities: History, physical properties and injury prevention effectiveness. *Sports Medicine, 376*(2), 117-144.

12. National Collegiate Athletic Association [NCAA]. (2014a). *NCAA Field Hockey Rules Modifications 2014: Divisions I, II and III.* Retrieved from

http://www.ncaa.org/sites/default/files/2014_NCAA_Field_Hockey_Rules_Modifications_072214.pdf

13. von Arx, T., Flury, R., Tschan, J., Buergin, W., & Geiser, T. (2008). Exercise capacity in athletes with mouthguards. *International Journal of Sports Medicine, 29*, 435-438. DOI 10.1055/s-2007-965341

14. Amis, T.E., Di Somma, E., Bacha, F., & Wheatley, J. (2000). Influence of intra-oral maxillary sports mouthguards on the airflow dynamics of oral breathing. *Medicine & Science in Sports and Exercise, 32*(2), 284-290.

15. Garner, D.P. & Miskimin, J. (2009). Effects of Mouthpiece use on Auditory and Visual Reaction Time in College Males and Females. *Compendium of continuing education in dentistry, 30*(2). Retrieved from https://dentalaegis.com/special-issues/2009/08/effects-of-mouthpiece-use-on-auditory-and-visual-reaction-time-in-college-males-and-females

16. Delaney, J.S., & Montgomery, D.L. (2005). Effect of Noncustom Bimolar Mouthguards on Peak Ventilation in Ice Hockey Players. *Clinical Journal of Sports Medicine, 15*(3), 154-157.

17. Dunn-Lewis, C., Luk, H.Y., Comstock, B.A., Szivak, T.K., Hooper, D.R, Kupchak, B.R., … Kraemer, W.J. (2012). The Effects of a Customized Over-the-Counter Mouth Guard on Neuromuscular Force and Power Production in Trained Men and Women. *Journal of Strength and Conditioning Research*, *26*(4), 1085-1093.

18. Bourdin, M., Brunet-Patru, I., Hager, P.E., Allard, Y., Hager, J.P., Lacour, J.R., & Moyen, B. (2006). Influence of Maxillary Mouthguards on Physiological Parameters. *Medicine & Science in Sports and Exercise, 38*(8), 1500-1504.

19. Keçeci, A.D., Çetin, C., Eroglu, E., & Baydar, M.L. (2005). Do custom-made mouth guards have negative effects on aerobic performance capacity of athletes? *Dental Traumatology*, *21*, 276-280.

20. DeYoung, A.K., Robinson, E., & Godwin, W.C. (1994). Comparing comfort and wearability: custom-made vs. self-adapted mouthguards. *Journal of the American Dental Association, 125*(8), 1112-1117.

21. Fuchs, C.Z. (1981). *The effect of the temporomandibular joint position on isometric muscle strength and power in adult females.* (Unpublished thesis). Boston University, Boston.

22. Garabee, W.F. (1981). Craniomandibular Orthopedics and Athletics Performance in the Long Distance Runner: A Three Year Study. *Basal Facts, 4*(3), 77-81.

23. Garner, D.P. & McDivitt, E. (2009). Effects of Mouthpiece Use on Airway Openings and Lactate Levels in Healthy College Males. *Compendium of continuing education in dentistry, 30*(2). Retrieved from https://www.dentalaegis.com/special-issues/2009/08/effects-of-mouthpiece-use-on-airway-openings-and-lactate-levels-in-healthy-college-males

24. Saltin, B., Nazar, K., Costill, D.L., Stein, E., Jansson, E., Essén, B. & Gollnick, P.D. (1976). The nature of the training response; Peripheral and central

adaptations to one-legged exercise. *Acta Physiologica Scandinavica, 96*(3), 289-305.

25. International Hockey Federation [FIH]. (2015a). *History of Hockey*. Retrieved from http://www.fih.ch/en/fih/history

26. Reilly, T. & Borrie, A. (1992). Physiology applied to field hockey. *Sports Medicine, 14*(1), 10-26.

27. Wassmer, D.J. & Mookerjee, S. (2002). A descriptive profile of elite US women's collegiate field hockey players. *The Journal of sports medicine and physical fitness*, *42*(2), 165-171.

28. Dick, R., Hootman, J.M., Agel, J., Vela, L., Marshall, S.W. & Messina, R. (2007). Descriptive epidemiology of collegiate women's field hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003. *Journal of athletic training, 42*(2), 211.

29. National Federation of State High School Associations [NFHS]. (2014a) *Participation Statistics.* Retrieved from http://www.nfhs.org/ParticipationStatics/ParticipationStatics.aspx/

30. International Hockey Federation [FIH]. (2014). *Rules of Hockey*. Retrieved from www.fih/ch/files/sport/rules/FIH-rulesofhockey2015-interactif.pdf

31. USA Field Hockey. (2011). *Rules of Field Hockey*. Retrieved from http://www.teamusa.org/~/media/USA_Field_Hockey/Documents/2011_12_Rules_of_Field_Hockey.pdf

32. KHSAA. (2014a). *Kentucky High School Athletic Association: 2014-2015 Handbook*. Retrieved from http://khsaa.org/Publications/Handbook/20142015/20142015fullhandbook.pdf

33. Walsh, M., Young, B., Hill, B., Kittredge, K., & Horn, T. (2007). The effect of ball-carrying technique and experience on sprinting in rugby union. *Journal of sports sciences, 25*(2), 185-192.

34. Grant, S.J., Oommen, G., McColl, G., Taylor, J., Watkins, L., Friel, N., … & McLean, D. (2003). The effect of ball carrying method on sprint speed in rugby union football players. *Journal of Sports Science, 21*(12), 1009-1015.

35. Ropret, R., Kukolj, M., Ugarkovic, D., Matavulj, D. & Jaric, S. (1998). Effects of arm and leg loading on sprint performance. *European Journal of applied physiology and occupational physiology, 77*(6), 547-550.

36. International Hockey Federation [FIH]. (2015b). *History of the Rules*. Retrieved from http://www.en/fih/history/ruleshistory

37. Boyle, P.M., Mahoney, C.A. & Wallace, W.F. (1994). The competitive demands of elite male field hockey. *The journal of sports medicine and physical fitness, 34*(3), 235-241.

38. Calò, C.M., Sanna, S., Piras, I.S., Pavan, P. & Vona, G. (2009). Body composition of Italian female hockey players. *Biology of Sport, 26*(1), 23.

39. Elferink-Gemser, M.T., Visscher, C., Van Duijin, M.A.J. & Lemmink, K.A.P.M. (2006). Development of the interval endurance capacity in elite and sub-elite youth field hockey players. *British journal of sports medicine, 40*(4), 340-345.

40. Wein, H. (1981). *The advanced science of hockey*. (M. Copus & J. Cadman, Trans.). London, Great Britain: Pelahm Books Ltd.

41. Podgórski, T. & Pawlak, M. (2011). A half century of scientific research in field hockey. *Human Movement, 12*(2), 108-123.

42. Aziz, A.R., Chia, M. & Teh, K.C. (2000). The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. *The Journal of sports medicine and physical fitness, 40*(3), 195-200.

43. Bale, P. & McNaught-Davis, P. (1983). The physiques, fitness and strength of top class women hockey players. *The Journal of sports medicine and physical fitness, 23*(1), 80.

44. Withers, R.T. & Roberts, R.G.D. (1981). Physiological profiles of representative women softball, hockey and netball players. *Ergonomics, 24*(8), 583-591.

45. Reilly, T., Secher, N., Snell, P. & Williams, C. (Eds.). (1990). *Physiology of Sports*. New York, NY: Chapman and Hall

46. Zeldis, S.M., Morcanroth, J. & Rubler, S. Cardiac hypertrophy in response to dynamic conditioning in female athletes. *Journal of Applied Physiology, 44*(6), 849-852.

47. American College of Sports Medicine [ACSM]. (2010). *ACSM's Guidelines for Exercise Testing and Prescription*. (8th ed.). Baltimore, MD: Lippincott, Williams & Wilkins.

48. Kansal, D.K., Verma, S.K. & Sidhu, L.S. (1980). Intrasportive differences in maximum oxygen uptake and body composition of Indian players in hockey and football. *The journal of sports medicine and physical fitness, 20*(3), 309.

49. Bangsbo, J. (1993). The physiology of soccer – with special reference to intesnse intermittent exercise. *Acta Physiological Scandanavica. Supplementum, 619*, 1-155.

50. Nieuwenhuis, C.F., Spamer, E.J. & Rossum, J.H.V. (2002). Prediction function for identifying talent in 14- to 15-year-old female field hockey players. *High Ability Studies, 13*(1), 21-33.

51. Lothian, F. & Farrally, M.R. (1995). A comparison of methods for estimating oxygen uptake during intermittend exercise. *Journal of sports sciences, 13*(6), 491-497.

52. Keogh, J.W., Weber, C.L. & Dalton, C.T. (2003). Evaluation of anthropometric, physiological, and skill-related tests for talent identification in female field hockey. *Canadian Journal of Applied Physiology, 28*(3), 397-409.

53. Aziz, A.R. (2004). Correlation between tests of running and repeated sprint ability and anaerobic capacity by Wingate cycling in multi-sprint sport athletes. *International Journal of Applied sports sciences (IJASS), 16*(1), 14-22.

54. Nikolaidis, P.T., Dellal, A., Torres-Luque, G. & Ingebrigtsen, J. (2014). Determinants of acceleration and maximum speed phase of repeated sprint ability in soccer players: a cross-sectional study. *Science & Sports.*

55. Reilly, T. & Bretherton, S. (1986). Multivariate analysis of fitness of female field hockey players. *Perspectives in kinanthropometry*, 135-142.

56. Carskadon, M.A. & Acebo, C. (1993). A self-administered rating scale for pubertal development. *Journal of Adolescent Health, 14*(3), 190-195.

57. Eston, R., Eston, R.G. & Reilly, T. (Eds.). (2009). *Kinanthropometry and Exercise Physiology Laboratory Manual: Anthropometry* (Vol. 1). Taylor & Francis.

58. Dellagrana, R.A., Silva, M.P.D., Smolarek, A.D.C., Bozza, R., Stabelini Neto, A. & Campos, W.D. (2010). Body composition, sexual maturation and motor performance in the young practitioners handball. *Motriz: Revista de Educaçäo Física, 16*(4), 880-888.

59. National Strength and Conditioning Association [NSCA]. (2012). *NSCA's guide to tests and assessments*. T. Miller (Ed.). Champaign, IL: Human Kinetics

60. Durnin, J.V.G.A & Womersley, J.V.G.A. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *British Journal of Nutrition, 32*(01), 77-97.

61. Siri, W.E. (1961). Body composition from fluid spaces and density: analysis of methods. *Techniques for measuring body composition, 61* , 223-44.

62. Grant, S., Corbett, K., Amjad, A.M., Wilson, J. & Aitchison, T. (1995). A Comparison of methods of predicting maximum oxygen uptake. *British Journal of Sports Medicine, 29*(3), 147-152.

63. Léger, L. A. & Gadoury, C. (1989). Validity of the 20m shuttle run test with 1 min stages to predict VO_{2max} in adults. *Canadian journal of sports sciences, 14*(1), 21-26.

64. Reilly, T. (2001). Assessment of sports performance with particular reference to field games. *European Journal of Sport Science, 1*(3), 1-12.

65. McMaster, D.T., Gill, N., Cronin, J. & McGuigan, M. (2014). A brief review of strength and ballistic assessment methodologies in sport. *Sports Medicine, 44*(5), 603-623.

66. Dawson, B., Fitzsimons, M. & Ward, D. (1993). The relationship of repeated sprint ability to aerobic power and performance measures of anaerobic work capacity and power. *Australian Journal of science and medicine in sport, 25*, 88.

67. Fitzsimons, M., Dawson, B., Ward, D. & Wilkinson, A. (1993). Cycling and running tests of repeated sprint ability. *Australian Journal of Science and Medicine in Sport, 25*, 82.

68. Wadley, G., & Le Rossignol, P. (1998). The relationship between repeated sprint ability and the aerobic and anaerobic energy systems. Journal of Science and Medicine in Sport, 1(2), 100-110.

69. East Bay Field Hockey Association (n.d.). *Introduction to field hockey.* Retrieved from: http://www.eastbayfieldhockey.com/introduction.html

70. Kentucky High School Athletic Association [KHSAA] (2014b). *Heat Index Measurement and Record*. Retrieved from http://khsaa.org/forms/ge20.pdf

71. Sharma, A., Tripathi, V., & Koley, S. (2012). Correlations of anthropometric characteristics with physical fitness tests in Indian professional hockey players. *Journal of Human Sport and Exercise, 7*(3), 689-705.

72. Rogol, A.D., Clark, A.C., & Roemmich, J.N. (2000). Growth and pubertal development in children and adolescents: effects of diet and physical activity. The *American Journal of Clinical Nutrition, 72*(2), 521s-528s.

73. Christie, D. & Viner, R. (2005). ABC of adolescence: Adolescent development. *British Medical Journal, 330* (7486), 301-304.

74. Gavin, M.L. (2015). Growth and your 13- 18-year-old. *KidsHealth from Nemours* Retrieved from http://kidshealth.org/PageManager.jsp?lic=1&ps=107&cat_id=162&article_set=21529

75. Amorose, A.J. & Anderson-Butcher, D. (2007). Autonomy-supportive coaching and self-determined motivation in high school and college athletes: A test of self-determination theory. *Psychology of sport and exercise, 8*, 654-670.

76. NCAA. (2012). *Division II playing and practice seasons and membership requirements: 2012 NCAA regional rules seminar* [ppt]. Retrieved from http://fs.ncaa.org/docs/regional_seminars/2012/PowerPoint Presentations/Division II/Division II Playing and Practice Seasons and Membership Requirements ONLINE.ppt

77. Smith, A.L., Balageur, I., Duda, J.L. (2006). Goal orientation profile differences on perceived motivational climate, perceived peer relationships,

and motivation-related responses of youth athletes. *Journal of Sports Sciences, 24*(12), 1315-1327.

78. Kipp., L. & Amorose, A.J. (2008). Perceived motivational climate and self-determined motivation in female high school athletes. *Journal of sport behavior, 31*(2), 108-129.

79. Schilling, T.A. & Hayashi, C.T. (2001). Achievement motivation among high school basketball and cross-country athletes: A personal investment perspective. *Journal of applied sport psychology, 13*(1), 103-128. DOI: 10.1080/10413200109339006

80. van de Pol., P.K.C., Kavussanu, M., Kompier, M. (2015). Autonomy support and motivational responses across training and competition in individual and team sports. *Journal of applied social psychology, 45*, 697-710.

81. Granados, C., Izquierdo, M., Ibanez, J., Ruesta, M., & Gorostiaga, E.M. (2008). Effects of an entire season on physical fitness in elite female handball players. *Medicine and Science in Sports and Exercise, 40*(2), 351-361.

82. Koutedakis, Y. (1995). Seasonal variation in fitness parameters in competitive athletes. *Sports Medicine, 19*(6). 373-392.

83. Ready, A.E., & van der Merwe, M. (1986). Physiological monitoring of the 1984 Canadian women's Olympic field hockey team. *Australian Journal of Science and Medicine in Sport, 18,* 13-18.

84. Gabbett, T.J. (2005a). Changes in physiological and anthropometric characteristics of rugby league players during a competitive season. *Journal of Strength and Conditioning Research, 19*(2), 400-408.

85. Gabbett, T.J. (2005b). Physiological and anthropometric characteristics of junior rugby league players over a competitive season. *Journal of Strength and Conditioning Research, 19*(4), 764-771.

86. Metaxas, T., Sendelides, T., Koutlianos, N., & Mandroukas, K. (2006). Seasonal variation of aerobic performance in soccer players according to positional role. *Journal of sports medicine and physical fitness, 46*(6), 520-525.

87. Caterisano, A., Patrick, B.T., Edenfield, W.L. & Batson, M.J. (1997). The effects of a basketball season on aerobic and strength parameters among college men: Starters vs. reserves. *The Journal of Strength and Conditioning Research, 11*(1), 21-24.

88. Caldwell, B.P., & Peters, D.M. (2009). Seasonal variation in physiological fitness of a semiprofessional soccer team. *Journal of Strength and Conditioning Research, 23*(5), 1370-1377.

89. Tavino, L.P., Bowers, C.J., Archer C.B. (1995). Effects of basketball on aerobic capacity, anaerobic capacity, and body composition of male college players. *Journal of Strength and Conditioning Research, 9*(2), 75-77

90. Miller, T.A., Thierry-Aguilera, R., Congleton, J.J., Amendola, A.A., Clark, M.J., Crouse, S.F., … & Jenkins, O.C. (2007). Seasonal changes in VO_{2max} among division 1A collegiate women soccer players. *Journal of Strength and Conditioning Research, 21*(1), 48-51.

91. Gorostiaga, E.M., Granados, C., Ibáñez, J., González-Badillo, J.J., & Izquierdo, M. (200). Effects of an entire season on physical fitness changes in elite male handball players. *Med Sci Sports Exerc., 38*(2), 357-366.6

92. Casajus, J.A. (2001). Seasonal variation in fitness variables in professional soccer players. *Journal of sports medicine and physical fitness, 41*(4), 463-469.

93. Mujika, I. & Padilla, S. (2001). Cardiorespiratory and metabolic characteristics of detraining in humans. *Medicine & Science in Sports and Exercise*, *33*(3), 413-421.

94. Rapisura, K.P., Coburn, J.W., Brown, L.E., Kersey, R.D. (2010). Physiological variables and mouthguard use in women during exercise. *Journal of Strength and Conditioning Research, 24*(5), 1263-1268.

95. Francis, K.T. & Brasher, J. (1991). Physiological effects of wearing mouthguards. *British Journal of Sports Medicine, 25*, 227-231.

96. Hurst, J.S. (2004). The effect of wearing mouthguards on VO_2, ventilation, and perceived exertion at two different exercise intensities. (Unpublished thesis). Brigham Young University, Utah.

97. Queiróz, A.F.V.R., de Brito Jr, R.B., Ramacciato, J.C., Motta, R.H.L., & Flório, F.M. (2013). Influence of mouthguards on the physical performance of soccer players. *Dental Traumatology, 29*(6), 450-454.

98. Hendrick, K., Farrelly, P., & Jagger, R. (2008). Oro-facial injuries and mouthguard use in elite female field hockey players. *Dental Traumatology, 24* 189-192.

99. Çetin, C., Keçeci, A.D., Erdogan, A., & Baydar, M.L. (2009). Influence of custom-made mouth guards on strength, speed and anaerobic performance of taekwondo athletes. *Dental Traumatology, 25*(3), 272-276.

100. Girard, O., Medez-Villanueva, A., Bishop, D. (2011). Repeated Sprint Ability – Part 1: Factors Contributing to Fatigue. *Sports Medicine, 41*(8), 673-694.

101. Buchheit, M., Laursen, P.B., Kuhnle, J., Ruch, D., Renaud, C., & Ahmaidi, S. (2009). Game-based training in young elite handball players. *International Journal of Sports Medicine, 30*, 251-258.

102. Hene, N.M., Bassett, S.H., & Andrews, B.S. (2011). Physical fitness profiles of elite women's rugby union players. *African journal for physical, health education, recreation and dance, 6*, 1-8.

103. Striner, D.L., & Norman, G.R. & Cairney, J. (2014). *Health measurement scales: A practical guide to their development and use.* Oxford University Press, USA.

APPENDIX A:

Self-Administered Rating Scale for Pubertal Development

Introduction: The next questions are about changes that may be happening to your body. These changes normally happen to different young people at different ages. Please answer carefully. If you do not understand a question or do not know the answer, just mark "I don't know."

Question	Response Options	Point Value
1. Would you say that your growth in height:	has not yet begun to spurt[2]	1
	has barely started	2
	is definitely underway	3
	seems completed	4
	I don't know	
2. And how about the growth of your body hair? ("Body hair" means hair any place other than your head, such as under your arms.) Would you say that your body hair growth:	has not yet begun to grow	1
	has barely started to grow	2
	is definitely underway	3
	seems completed	4
	I don't know	
3. Have you noticed any skin changes, especially pimples?	skin has not yet started changing	1
	skin has barely started changing	2
	skin changes are definitely underway	3
	skin changes seem complete	4
	I don't know	
FORM FOR BOYS:		
4. Have you noticed a deepening of your voice?	voice has not yet started changing	1
	voice has barely started changing	2
	voice changes are definitely underway	3
	voice changes seem complete	4
	I don't know	
5. Have you begun to grow hair on	facial hair has not yet started	1

your face?	growing	
	facial hair has barely started	2
	growing	
	facial hair growth has definitely started	3
	facial hair growth seems complete	4
	I don't know	

FORM FOR GIRLS:

4. Have you noticed that your breasts have begun to grow?	have not yet started growing	1
	have barely started growing	2
	breast growth is definitely underway	3
	breast growth seems complete	4
	I don't know	
5a. Have you begun to menstruate (started to have your period)?	yes	4
	no	1
5b. If yes, how old were you when you started to menstruate?	age in years _______	

APPENDIX B:

Mouthguard Satisfaction Questionnaire

1. Do you think that mouthguards protect your teeth when playing sports?

Yes	No	I Don't Know

2. What kind of mouthguard do you typically wear?

Stock (over the counter)	Boil-and-bite (self-molded)	Custom made (by dentist/orthodontist)

3. Do you wear a mouthguard during practice if it is not enforced?

Yes	No

3a. If you do not wear a mouthguard, why not?

Unnecessary	Uncomfortable	Hard to talk	Hard to obtain	Hard to breathe	Too expensive	Other (please specify)

4. When you do wear a mouthguard, do you experience problems?

Yes	No

4a. If you answered yes to Q4, what problems do you experience?

Uncomfortable	Bulky	Difficulty speaking	Loose	Expensive	Hard to breathe	Other (please specify)

5. Please answer the following questions on a scale of 1 through 5 (1 = not at all, 5 = considerably)

To what degree do mouthguards affect your speech?	1	2	3	4	5
To what degree do you find mouthguards comfortable?	1	2	3	4	5
To what degree do mouthguards affect your breathing?	1	2	3	4	5

5. Please answer the following question on a scale of 1 through 10 (1 – not at all, 10 = considerably)

How easy do you find using a mouthguard? (Please consider breathability, communication, sports play, etc)	1	2	3	4	5	6	7	8	9	10

APPENDIX C:

Supplemental Results

Table 1: Reasons for study withdrawal

Reason for withdraw	Number
School transfer	1
Injured during season	3
Absent from 1 or more aerobic testing sessions	5
Absent from 1 or more anaerobic testing sessions	6

Figure 1: Estimated VO_{2max} scores (mL/kg/min) MG-STK

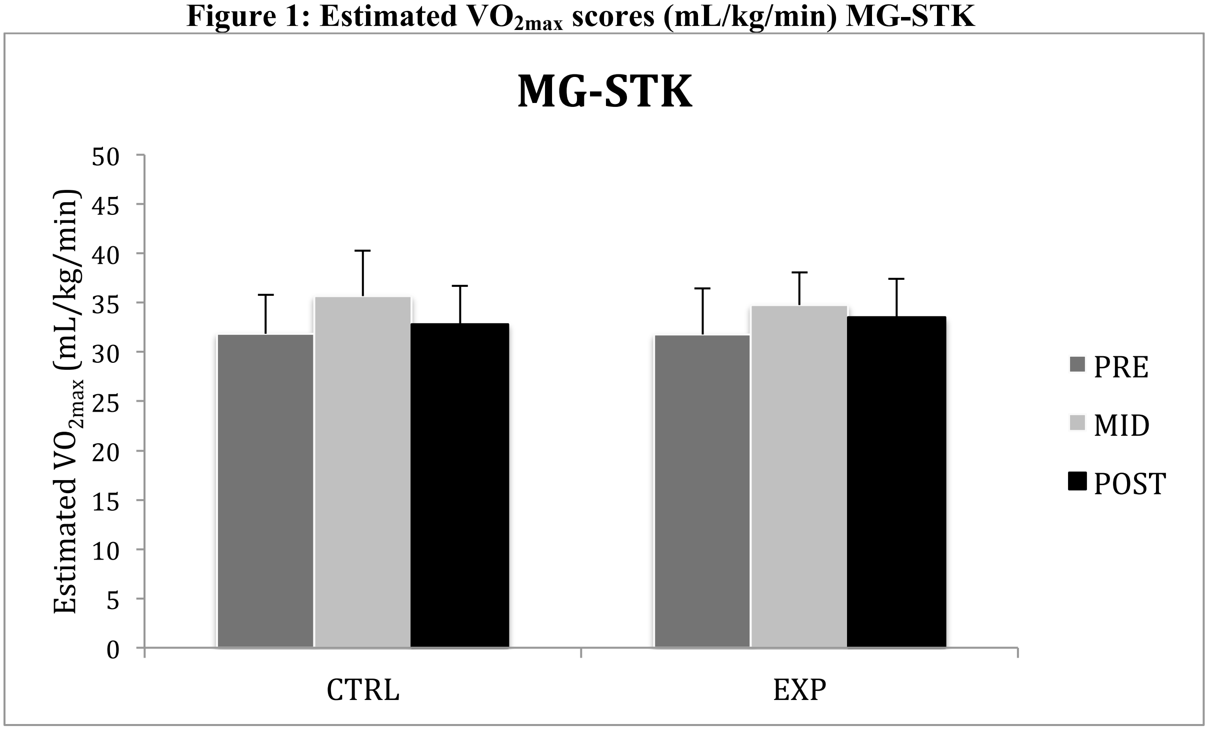


Figure 2: VO_{2max} scores (mL/kg/min) WOMG-STK

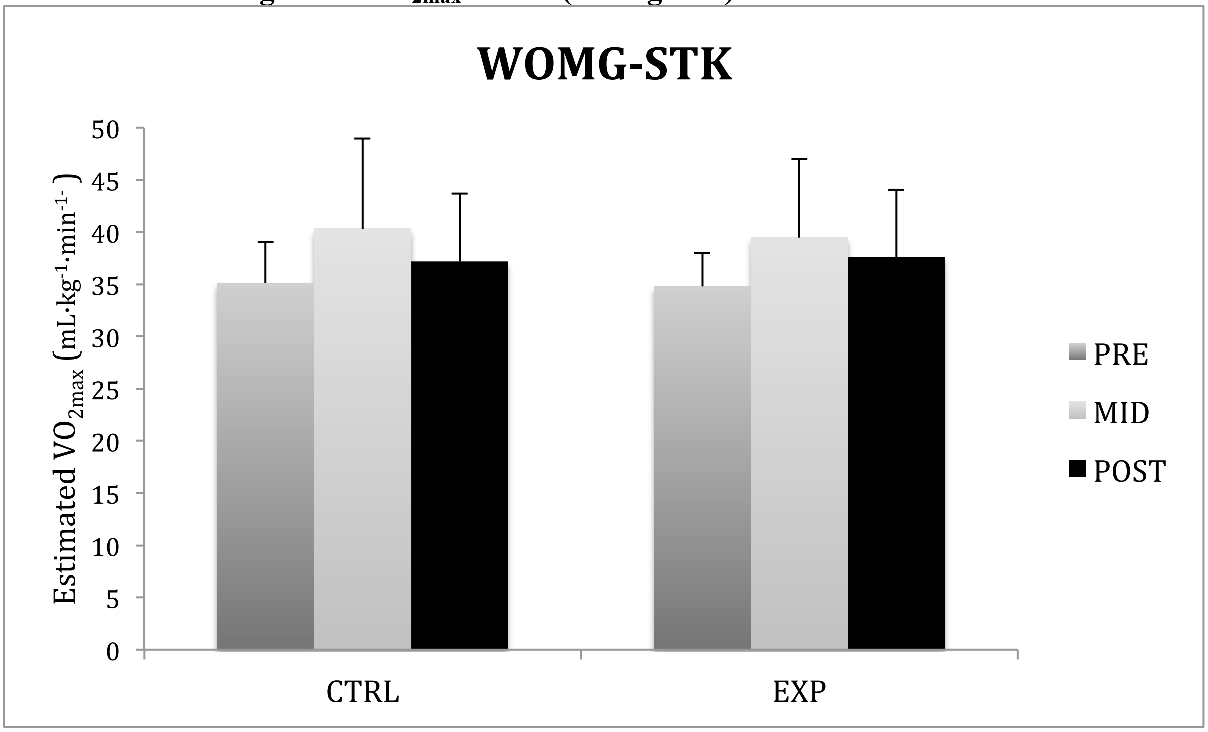


Table 2: Estimated VO_{2max} scores ($mL \cdot kg^{-1} \cdot min^{-1}$) combined groups

	MG-STK	WOMG-STK	P-Value	Combined mean
PRE	31.8 (4.35) [24.7 – 39.9]	34.94 (3.58) [28 – 41.2]	0.001*	33.37
MIDDLE	35.18 (4.01) [27.2 – 43.2]	39.87 (4.01) [26.8 – 59.1]	0.002*	37.52
POST	33.18 (3.9) [26.8 – 40.5]	37.41 (6.48) [29.9 – 59.4]	0.001*	35.29
COMBINED	33.39 (4.32) [24.7 – 43.2]	37.41 (6.65) [26.8 – 59.4]	<0.001*	35.39

Mean (SD), [range]
*significant result

Significant reduction in combined aerobic performance w/MG-STK.

Table 3: Fastest 10m sprint times (s) combined groups

	MG-STK	WOMG-STK	P-Value	Combined mean
PRE	2.34 (0.18) [2.03 – 2.87]	2.38 (0.16) [2.19 – 2.81]	0.378	2.36
POST	2.29 (0.25) [1.79 – 2.91]	2.27 (0.25) [1.75 – 2.72]	0.638	2.28
COMBINED	2.32 (0.22) [1.79 – 2.91]	2.38 (0.16) [2.19 – 2.81]	0.080	2.35

Figure 3: Fastest 40m sprint times (s) WOMG-STK

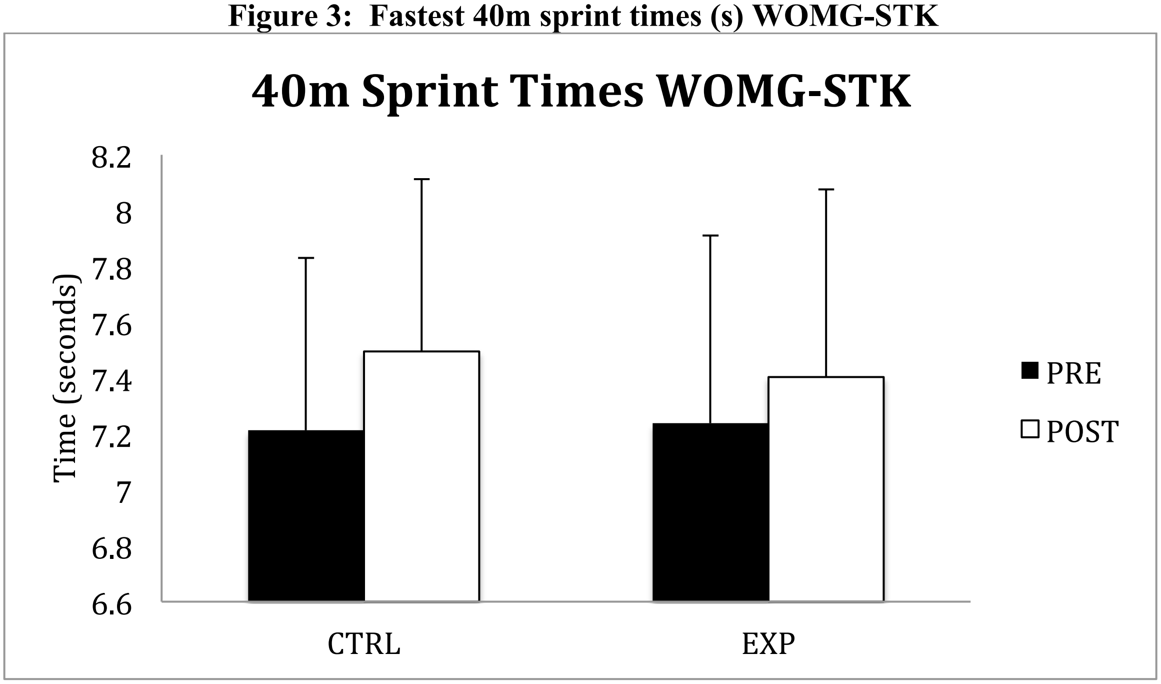


Figure 4: Fastest 40m sprint times (s) MG-STK

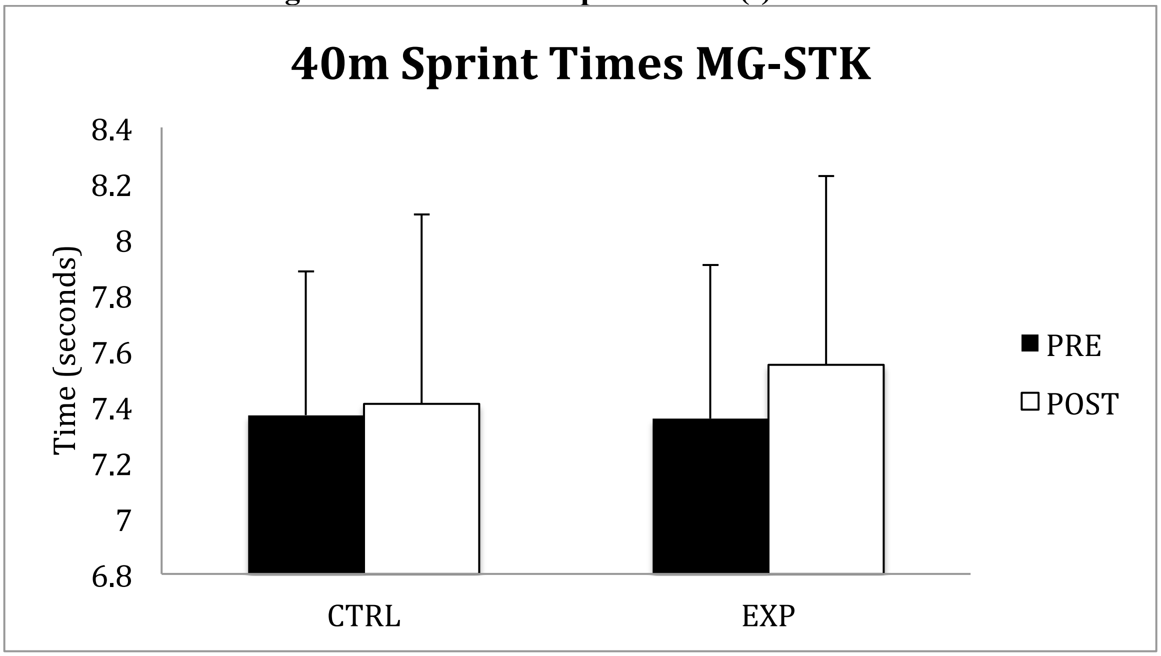
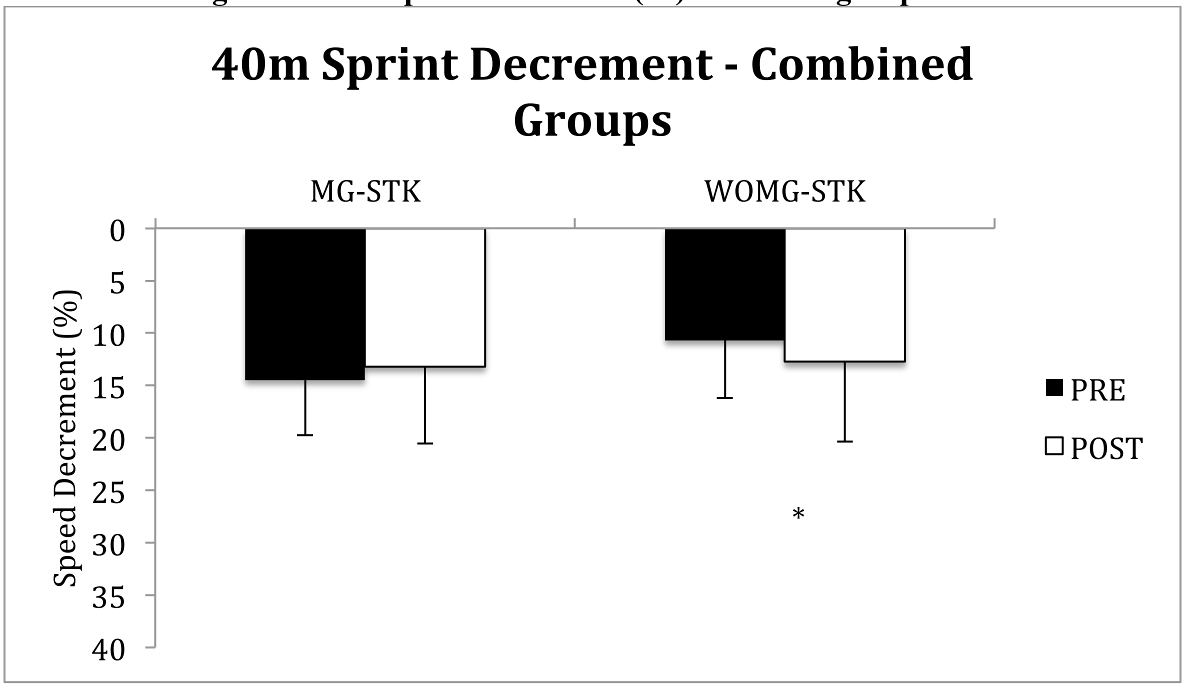


Table 4: 10m Sprint Decrement (%) combined groups

Time point	MG-STK	WOMG-STK	p-value	Combined mean
PRE	17.03 (6.12) [4.26 – 27.27]	14.3 (5.89) [6.25 – 30.22]	0.078	15.67
POST	15.4 (7.82) [5.58 – 36.87]	21.64 (15.41) [3.56 – 90.36]	0.049*	15.85
COMBINED	16.22 (7.06) [4.26 – 36.87]	17.97 (12.23) [3.56 – 90.36]	0.326	17.09

Figure 5: 40m sprint decrement (%) combined groups



*Significant difference

CURRICULUM VITAE

ALEXANDRA ROBERTS, B.S., CISSN

Department of Health and Sport Sciences
2301 S Brook St.
University of Louisville,
Louisville, KY 40292
DOB: Benowa, Queensland, Australia – April 17, 1991
Email: ahrobe01@louisville.edu

EDUCATION

Master of Science, Exercise Physiology **Anticipated May 2016**
University of Louisville – Louisville, KY
Concentration: Strength and Conditioning

Bachelor of Science, Health and Human Performance **May 2013**
University of Louisville – Louisville, KY
Major: Exercise Science

PROFESSIONAL EXPERIENCE

Teaching Experience

Graduate Teaching Assistant, Exercise Physiology Dept.
August 2014 – Present
Department of Health and Sport Sciences, University of Louisville; Louisville KY

Research Experience

Publications in Submission

Martin, J.L., Perry R.A., Baptista R.A., McArtor, J.D., Clutter, L.B., Symons, T.B., Terson de Paleville, D., **Roberts, A.**, Cesarz, G., & Caruso, J.F. (2016). Workload's impact on perceived gender-based differences in delta blood lactate values from high-speed exercise. *Isokinetics and Exercise Science* (In Press).

Perry, A., Vickers, S., Martin, J., McArtor, J., Cesarz, G., Roberts, A., Parmar, P., & Caruso, J. Lower leg anthropometry as a correlate to performance metabolism from dynamic exercise. Submitted April 2016.

Ueberschlag, S.L., Seay, J.R., **Roberts, A.H**., DeSpirito, P.C., Stith, J.M., Folz., R.J., Carter, K.A., Weiss, E.P., Zavorsky, G.S. The effect of Protandim supplementation on oxidative damage and athletic performance. Submitted November 2015.

Poster Presentations

Wooten-Burnett, S.C., Sunderman, S., **Roberts, A.H.,** Carter, K.A. The effect of taekwondo training on lower body strength and balance in adults with Down Syndrome. *IASSIDD World Congress*, Melbourne, VIC, Australia, August 2016

Roberts, A.H., Walden, A.J., Carter, K.A., Symons, T.B. Effect of mouthguard and stick use on aerobic capacity in high school field hockey athletes. ACSM National Convention, Boston, MA., May 2016

Symons, T.B., **Roberts, A.H.** Effects of twelve weeks of high-intensity training on power production in high school field hockey players. ACSM National Convention, Boston, MA., May 2016

Walden, A.J., **Roberts, A.H.,** Symons, T.B., Carter, K.A. Sleep-wake patterns effects on the beep test and sprints in high school field hockey players: A pilot study. ACSM National Convention, Boston, MA., May 2016

Roberts, A.H., Walden, A.J., Carter, K.A., Symons, T.B. Effects of stick and mouthguard use on conditioning in high school field hockey athletes. SEACSM, Greenville, SC., February 2016

Walden, A.J., **Roberts, A.H.,** Symons, T.B., Carter, K.A. Sleep-wake patterns on VO_2 utilizing the beep test and sprints on female high school field hockey players: A pilot study. SEACSM, Greenville, SC., February 2016

Roberts, A.H., Walden, A.J., Carter, K.A., Symons, T.B. The effect of stick and mouthguard use on sport-specific conditions in high school field hockey players. Research! Louisville, Louisville, KY., October 2015

Walden, A.J., **Roberts, A.H.,** Symons, T.B., Carter, K.A. Sleep-wake patterns effects on the beep test and sprints in female high school field hockey players: A pilot study. Research! Louisville, Louisville, KY., October 2015

Roberts, A.H., Ueberschlag, S.L., Seay, J.R., Folz, R.J., Carter, K.A., Weiss, E.P., Zavorsky, G.S. Three months supplementation of Protandim does not affect quality of life in runners. ISSN National Convention, Austin, TX., July 2015

Ueberschlag, S.L., **Roberts, A.H**., Seay, J.R., DeSpirito, P.C., Stith, J.M., Folz, R.J., Carter, K.A., Weiss, E.P., Zavorsky, G.S. Three months supplementation of Protandim does not reduce oxidative damage or improve endurance running performance. ISSN National Convention, Austin, TX., July 2015

Research in Progress

Muscle activation during wheelchair basketball
Department of Health and Sports Sciences, University of Louisville

Validation of a nutrition knowledge questionnaire for teenage athletes
Department of Health and Sports Sciences, University of Louisville

The effects of high-intensity interval training on performance in female high school lacrosse players
Department of Health and Sports Sciences, University of Louisville
Validation of a mouthguard usage and satisfaction questionnaire
Department of Health and Sports Sciences, University of Louisville
Long-term reliability of isometric and isokinetic dorsiflexion strength testing protocols
Department of Health and Sports Sciences, University of Louisville
Nutrition knowledge in high school athletes
Department of Health and Sports Sciences, University of Louisville
The effect of electrolyte supplementation on aerobic exercise performance
Department of Health and Sports Sciences, University of Louisville
Lower leg anthropometry as a correlate to performance and metabolism from dynamic exercise
Department of Health and Sport Sciences, University of Louisville

Awards / Honors

Graduate Assistant Position – Health and Sport Science Dept., University of Louisville; 2014
Golden Key Honor Society – University of Louisville, 2012-13; 2014-16
Red and Black Scholar Athlete – University of Louisville, 2010-2012
Dean's Scholar – University of Louisville, 2013
Athletic Director's Honor Roll – University of Louisville, 2013
Mortar Board Honor Society – University of Louisville, 2012-13

Professional Certifications & Memberships

Certified Sports Nutritionist (CISSN)	- International Society of Sports Nutrition
Lifeguarding/First Aid/CPR/AED Instructor	- American Red Cross
Student Member	- International Society of Sports Nutrition
Student Member	- American College of Sports Medicine