The effect of sport-specific constraints on aerobic capacity in high school field hockey players

Running head: Sport-specific training in field hockey players

Alexandra H. Roberts[1, 2]

Amy J. Walden[1]

Kathleen A. Carter[1,3]

T. Brock Symons[1,4]

Research conducted at the University of Louisville, Louisville, KY

[1] Department of Health and Sport Sciences, University of Louisville, Louisville, Kentucky

[2]Discipline of Sport and Exercise Science, La Trobe University, Melbourne, Australia

[3]Department of Agriculture and Life Sciences, Central State University, Wilberforce, OH

[4]Department of Counselling, Health and Kinesiology, Texas A&M University, San Antonio, TX

Correspondence should be addressed to: Alex Roberts, Discipline of Sport and Exercise Science, La Trobe University, Kingsbury Drive, Bundoora, VIC, Australia 3086. Email: Alexandra.roberts@latrobe.edu.au

Title: The effect of sport-specific constraints on aerobic capacity in high school field hockey players

ABSTRACT

Many sports require the use of a mouthguard (MG) and carrying an object during play. Research has shown that individually these conditions can cause performance decrements; however, no research has been conducted into the effect of combining both mouthguard and stick with adolescent female field hockey players. This study aimed to determine the effects of MG and stick (STK) use on estimated aerobic capacity over the course of a season long training and competition period. Thirty-eight female high school field hockey players were separated into two groups: experimental (EXP - all training with MG-STK) or control (CTL - all training without MG-STK). Aerobic capacity was estimated using a multi-stage fitness test. Field hockey specific training prescribed by coaching staff was performed throughout the study, with testing at pre-, mid- and post-season. Participants performed two sets of testing at each time point, first without MG-STK (WOMG-STK) and then with MG-STK. No main effect was observed in aerobic capacity estimations between groups; however, MG-STK testing reduced estimated aerobic capacity at each time point, regardless of group (WOMG-STK: 37.4±6. $mL \cdot kg^{-1} \cdot min^{-1}$ vs MG-STK: 33.2±4. $mL \cdot kg^{-1} \cdot min^{-1}$; $p<0.01$). Chronic use of MG-STK does not appear to negatively impact estimates of aerobic capacity over the course of a season in high school field hockey players. Therefore, players should be encouraged to use MGs during all training sessions as it increases safety and familiarity with no decrement in long-term physiological performance.

Key Words: aerobic fitness; mouthguard; hockey stick; constraints

INTRODUCTION

Field hockey is a sport that is growing in popularity worldwide, with participants from 137 countries, including over 60,000 high school aged girls playing within the United States each year (13, 23). High school field hockey athletes have a 10.2% chance of playing field hockey at an NCAA institution, a probability which, in both male and female sports, is surpassed only by ice hockey (12.1% male, 25% female) and lacrosse (12.6% male, 12.4% female) (22). Increasing popularity of these sports has led to implementation of guidelines for protective equipment, including the mandatory use of mouthguards during competition at all levels from high school to international levels (14, 21, 24, 34). Many high school athletes, believing mouthguards negatively affect performance, breathing and communication, would choose not to wear one if this rule were not enforced (3, 6, 15, 19). Despite the pervading negative opinion in adolescent athletes towards mouthguards, research has shown that there is no effect on respiratory function when using a self-adapted mouthguard, regardless of exercise intensity (1, 3, 6). It has also been demonstrated that there is no effect on communication or performance when a mouthguard is worn habitually (15, 30).

In addition to wearing mouthguards, field hockey athletes must carry an implement (stick) while playing, just as in ice hockey and lacrosse. Field hockey sticks can weigh up to 737g (1.6lbs), are up to 105cm (3.4 feet) long, and must be used in a right-handed fashion (14). The asymmetrical loading pattern that this creates can greatly affect the running technique and therefore running efficiency of players (31). Research has shown that carrying an object while running produces a drastically lower sprinting speed, regardless of the position in which the object is held (11, 35, 36). To the best of our knowledge, there is no research which investigates the implications of carrying an implement on aerobic capacity and subsequent aerobic performance.

To our knowledge, there is no research investigating the combined effects of wearing a mouthguard and carrying a stick on aerobic capacity in female high school field hockey players. Thus, the purpose of this study was to explore the differences in estimated aerobic capacity between training in sport-specific conditions (wearing a mouthguard and carrying a stick) and training in 'neutral' conditions (without a mouthguard or stick) over the course of a season. The primary hypothesis was that athletes would exhibit lower estimated aerobic capacity when using mouthguards and sticks, regardless of training condition and time in the season. As specificity of training conditions has been shown to increase athletic performance (32), a secondary hypothesis was that the sport-specific training group would demonstrate higher estimated aerobic capacity than the control (neutral) training group when tested using mouthguards and sticks by the end of the season.

METHODS

Experimental Approach to the Problem

This investigation assigned participants to either an experimental (EXP) group, which wore a mouthguard and carried their field hockey stick during conditioning, or a control (CTL) group, which completed conditioning without the mouthguard and stick. Athletes were placed into the two groups based on team level and initial Multistage Fitness Test Shuttle Run (beep test) results. Participants performed the beep test in two conditions, without mouthguard and stick (WOMG-STK) and with mouthguard and stick (MG-STK), at three separate time points during the season: pre-season, mid-season and post-season. Changes in estimated aerobic capacity were analysed to determine whether wearing the mouthguard and carrying the stick during conditioning throughout the season would affect the aerobic capacity estimation in the experimental group when compared to the control group. A second analysis determined

whether completing the beep test in the MG-STK condition would produce a different result when compared to completing the test WOMG-STK.

Participants completed a familiarization session, in which they completed the beep test under MG-STK conditions, two days before preseason data collection occurred. At this time, anthropometric measures were also taken. During the season, testing occurred at least 48 hours apart, and at the request of the head coach tests were completed in the same order (MG-STK followed by WOMG-STK) by all participants at all time points. All testing occurred at the same time of day (late afternoon), with at least one rest day prior to testing. The experimental group wore their mouthguard and carried their personal stick during all training activities throughout the entire season.

Subjects

The study was approved by the University's Institutional Review Board. Participants and their parents/guardians attended a preseason meeting where the risks and benefits of participation in this investigation were discussed. Interested individuals were given informed consent and informed assent forms to read. Parents/guardians signed an informed consent while participants, all of whom were under 18 years of age, signed assent forms.

Forty-six adolescent female field hockey players (age = 13–17 years) were recruited from a local high school team. Participants had at least three seasons of organized field hockey experience which assured they had experience wearing a mouthguard as required by High School Athletic Association regulations. To control for physical maturation, each subject completed the Self-Administered Pubertal Stage Survey, which has been shown to be consistent with physician-conducted pubertal staging (5, 18). During the course of the investigation, four participants withdrew due to injuries or school transfers, and four participants were excluded due to missing one or more testing sessions. This resulted in 38

athletes remaining for aerobic testing. Thirty-two participants completed anthropometric testing.

Procedures

Prior to the first practice, each athlete was fitted with a standard self-adapted 'boil-and-bite' mouthguard (SafeTGuards, Wheatridge, CO). Experienced field hockey coaches ensured that the fittings were correct. All subjects used their own hockey sticks and wore their own field-hockey shoes for the duration of the intervention and testing. At this time, the anthropometric measures for each athlete were taken. Body composition was measured by an ISAK (International Society for the Advancement of Kinanthropometry) certified Level 1 anthropometrist using Lange Skinfold Calipers (Beta Technology Inc, USA), with the three-site Siri equation (33) used to calculate body fat percentage.

Participants were placed into either the experimental (EXP, n = 23) or control (CTL, n = 23) group based on team level (Freshman, Junior Varsity or Varsity) and initial beep test performance, ensuring that there was matched distribution between the EXP and CTL groups for each team level. The two athletes with the highest beep test scores on each team were paired then randomly assigned to either the EXP or CTL group. Athletes were paired within teams to ensure that practice and game schedules would be the same in each matched pair and that there was an even number of athletes from each group in each team. Athletes in the EXP group performed all conditioning work throughout the season while wearing a mouthguard and holding their personal stick in their right hand, as in game situation. Athletes in the CTL group performed conditioning exercises in a neutral condition, without mouthguard or stick.

Training Plan. Both groups performed identical training work as prescribed by the coaching staff. The general training schedule began with a 10-15 minute self-directed warm up (light jog, basic skills work, stretching). Two days/week there was 30 minutes of aerobic

conditioning, typically consisting of a 3-5km run. Two days/week there was 30 minutes of high-intensity interval conditioning consisting of 10-20m sprints for up to five minutes, up to 10 minutes of alternating sprints of 106m and 55m, and shuttle runs. Conditioning sessions were followed by 15 minutes of skill work, 30 minutes of "game play" drills, and a 30-minute game. Skill work and game play were performed with both groups wearing mouthguards and carrying sticks. Practice ended with 10 minutes of self-directed cool down. During the second half of the season, several games needed to be rescheduled due to inclement weather which reduced the number of conditioning sessions per week. All testing, training and games occurred on natural turf fields.

Practice and game schedules followed the State High School Athletic Association calendar. There were 35 $\pm$ 2 days between pre- and mid-season testing, and 40 $\pm$ 2 days between mid- and post-season testing. Testing occurred on different days for each team in the mid-season and post-season sessions based on game and practice schedules of the teams. Before testing, participants completed a self-directed warm up lasting approximately 10 minutes. At each testing point, participants performed the beep test without their mouthguard and stick (WOMG-STK), then performed the test while using their mouthguard and stick (MG-STK) on the subsequent testing day. There was a minimum of 48 hours and a maximum of 72 hours between each test. No randomisation of testing order occurred. See Figure 1 for an outline of the study design.

[FIGURE 1 about here]

As a requirement of being on the team, athletes were required to attend >95% of training sessions, with a 100% attendance rate for the subjects in this study. Playing time was not recorded, however as a high school team it was a primary objective of the coaching staff to ensure equal playing time for all athletes.

Testing Protocol. Aerobic capacity (VO_{2max}) was estimated using the Multistage Fitness Test Shuttle Run, or beep test (25), performed on a natural turf surface. The beep test has been validated as a reliable indicator of aerobic capacity in adolescents and is frequently used for establishing estimations of aerobic capacity in field hockey players due to its specificity (10, 16, 25, 26, 31). In essence, the beep test involves a series of 20m shuttle runs in time with a series of beeps, which become progressively faster until the athlete is unable to complete the shuttles in time with the beeps. The last completed shuttle was recorded, and estimated VO_{2max} was calculated using the equation of Léger and colleagues (17).

Statistical Analyses

All data are presented as mean $\pm$ standard deviation, with Cohen's D provided as an estimate of effect size. Differences between conditions were analysed using a two factor repeated measures analysis of variance (ANOVA): Group (EXP vs. CTL) by Test (MG-STK vs. WOMG-ST); and Group by Time (Pre, Middle, and Post). Alpha was set at $\alpha = 0.05$. When groups were combined to determine whether wearing a mouth guard and carrying a stick would affect aerobic test results, data were compared utilizing an independent t-test; $\alpha = 0.05$. Data were analysed using SPSS 21 (IBM, Inc., Chicago, IL).

RESULTS

The experimental group wore their mouthguard and carried their personal stick during all training activities, with a 100% adherence rate.

No differences were observed between pre- and post-season anthropometric variables (Table 1). Participants were all found to be physically mature, with a score of 4/4 on the self-report maturation scale at the beginning of the season.

[TABLE 1 about here]

No significant differences were found in estimated aerobic capacity between groups at pre- (p=0.44, Cohen's D=0.22), mid- (p=0.689, Cohen's D=0.28), or post-season (p=0.687, Cohen's D=0.23).

[TABLE 2 about here]

Combined group data revealed a reduction in estimated aerobic capacity when the beep test was performed with a mouthguard and stick compared to testing in the neutral condition. (WOMG-STK: 37.4 $\pm$ 6.7 mL·kg^{-1}·min^{-1} vs. MG-STK: 33.2 $\pm$ 4.3 mL·kg^{-1}·min^{-1}; $p < 0.01$) (Figure 2).

[FIGURE 2 about here]

DISCUSSION

The purpose of this investigation was twofold: to determine whether athletes exhibit lower estimated aerobic capacity when using mouthguards and holding sticks (irrespective of training group); and to investigate whether, by the end of the season, the experimental group would demonstrate higher estimated aerobic capacity than the control group when using mouthguards and holding sticks. It was hypothesized that the use of mouthguards and sticks would decrease estimated aerobic capacity in both groups. The secondary hypothesis was that the experimental group would display higher estimated aerobic capacity than the control group when testing in the MG-STK condition at the end of the 12-week season. The results of this study indicate that the use of mouthguard and stick decreases estimated aerobic performance regardless of training group, with no significant differences found between control and experimental groups in either testing condition at any point in the season.

Aerobic capacity is an integral component of many field sports, however there has been little research into the aerobic fitness of adolescent female athletes, and none in sports that require

carrying a stick and wearing a mouthguard during competition. In the present study, the average estimated VO_{2max} scores WOMG-STK were comparable to those of female high school soccer and basketball players (26, 27). The similarity of the present results to those found in other intermittent sports demonstrates that sport-specific training did not negatively impact the development of aerobic capacity over the season in the EXP group.

The decrease in aerobic performance in the second half of the season mirrors that seen in several team field sports of varying levels, including elite youth, collegiate and semi-professional soccer players (6, 4, 20), and junior rugby players (9). This aligns with our findings of a 7% decrease in estimated aerobic capacity over this six-week period. Another factor which may have impacted final testing results was that the last testing session occurred after the final game of the season for two of the three teams involved. As such, a lack of motivation to complete testing to the best of their ability may have affected the results.

High school players tend to resist wearing a mouthguard even though it is mandatory to use one. Previous research has demonstrated that mouthguards had no effect on aerobic capacity when using a custom fit or boil-and-bite mouthguard (3, 7, 8, 15). Francis and Brasher (1991) showed that when healthy adults wore over-the-counter, self-adapted mouthguards during cycle ergometer testing, there was no difference seen in their VO_2 or ventilation (8). A lack of change in aerobic capacity was seen in 15-17-year-old male soccer players completing the beep test while wearing custom mouthguards (6), which is in agreement with the current study. It has been demonstrated that wearing a mouthguard can have an undesirable psychological impact on performance (3, 6, 12, 29). However, as the participants in this study had a minimum of three years' experience wearing mouthguards, it is expected that any potential negative psychological influence would be significantly attenuated or absent (2).

Wdowski and Gittoes (2012) suggested that training with the task-specific constraint of a field hockey stick could allow for adaptation, and therefore improvement, of running performance. The results of the present study indicate that task- and sport-specific conditions during aerobic training do not improve aerobic performance, as there were no differences seen between the two groups in either testing condition. Further research is needed to confirm this finding, ideally investigating the effect of carrying a stick during aerobic conditioning without the confounding mouthguard variable.

The key novel finding of this study is that use of a mouthguard and stick during all conditioning and practice sessions does not appear to affect the development of estimated aerobic capacity over the span of a season. Additionally, the inclusion of sport-specific constraints (i.e. wearing a mouthguard and carrying a stick) to training does not appear to positively impact performance in sport-specific testing conditions.

Limitations. The results of this investigation may have been affected by the lack of randomisation in test order. As stated above, test order was not randomized by request of the head coach of the team. An additional limitation was cancellation and/or rescheduling of games and training sessions due to weather. The number of affected training sessions was low, however the specific number of affected sessions was not recorded.

PRACTICAL APPLICATIONS: Results of this investigation suggest that there was no difference in estimated aerobic capacity of adolescent athletes that wore a mouthguard and carried a stick during conditioning workouts throughout the season when compared to those who did not. Aerobic capacity is an important part of game performance, as it allows for greater endurance during games and shorter recovery times. As field hockey players must wear mouthguards and carry sticks while performing high levels of aerobic activity, understanding how these constraints may or may not affect aerobic capacity is essential.

Coaches and practitioners should note that it would not be detrimental to the athletes' aerobic capacity if they were encouraged to wear a mouthguard and carry their stick during conditioning, as this would provide simulate game-like conditions.

REFERENCES

1. Amis, TE, Di Somma, E, Bacha, F, and Wheatley, J. Influence of intra-oral maxillary sports mouthguards on the airflow dynamics of oral breathing. *Med Sci Sports Exerc* 32: 284-290, 2000.
2. von Arx, T, Flury, R, Tschan, J, Buergin, W, Geiser, T. Exercise capacity in athletes with mouthguards. *Int J Sports Med* 29: 435-438, 2008.
3. Bourdin, M, Brunet-Patru, I, Hager, PE, Allard, Y, Hager, JP, Lacour, JR, and Moyen, B. Influence of maxillary mouthguards on physiological parameters. *Med Sci Sports Exerc* 38: 1500-1504, 2006.
4. Caldwell, BP and Peters, DM. Seasonal variation in phsyiological fitness of a semiprofessional soccer team. *J Strength Cond Res* 23: 1370-1377, 2009.
5. Carskadon, MA and Acebo, C. A self-administered rating scale for pubertal development. *J Adolescent Health* 14: 190-195, 1993.
6. Collares, K, Correa, MB, da Silva, ICM, Hallal, PC, and Demarco, FF. Effect of wearing mouthguards on the physical performance of soccer and futsal players: A randomized cross-over study. *Dent Traumatol* 30: 55-59, 2014.
7. Dragijsky, M, Maly, T, Zahalka, F, Kunzmann, E, and Hank, M. Seasonal variation of agility, speed and endurance performance in young elite soccer players. *Sports* 5: 12, 2017.
8. Francis, KT and Brasher, J. Physiological effects of wearing mouthguards. *Brit J Sport Med* 25: 227-231, 1991.

9. Gabbett, TJ. Physiological and anthropometric characteristics of junior rugby league players over a competitive season. *J Strength Cond Res* 19: 764-771.

10. Grant, S, Corbett, K, Amjad, AM, Wilson, J, and Aitchison, T. A comparison of methods predicting maximum oxygen uptake. *Brit J Sport Med* 29: 147-152, 1995.

11. Grant, SJ, Oommen, G, McColl, G, Taylor, J, Watkins, L, Friel, N, Watt, I, and McLean, D. The effect of ball carrying method on sprint speed in rugby union football players. *J Sport Sci* 21: 1009-1015, 2003.

12. Hendrick, K, Farrelly, P, and Jagger, R. Oro-facial injuries and mouthguard use in elite female field hockey players. *Dent Traumatol* 24: 189-192, 2008.

13. International Hockey Federation. *Hockey Basics: History of Hockey*. Available at: http://www.fih.ch/hockey-basics/history/. Accessed August 15, 2019.

14. International Hockey Federation. *Rules of Hockey 2019*. Lausanne, Switzerland: The International Hockey Federation, 2018.

15. Keçeci, AD, Çetin, C, Eroglu, E, and Baydar, ML. Do custom-made mouth guards have negative effects on aerobic performance capacity of athletes? *Dent Traumatol* 21: 276-280, 2005.

16. Keogh, JWL, Weber, CL, and Dalton, CT. Evaluation of anthropometric, physiological and skill-related tests for talent identification in female field hockey. *Can J Appl Physiol* 28: 14, 2003.

17. Léger, LA, Mercier, D, Gadoury, C, and Lambert, J. The multistage 20 metre shuttle test run for aerobic fitness. *J Sport Sci* 6: 93-101, 1988.

18. Marshall, WA, and Tanner, JM. Variations in pattern of pubertal changes in girls. *Arch Dis Childh* 44: 291-303, 1969.

19. Miller, MG, Berry, DC, Tittler, JG, and Gariepy, GS. Attitudes of high school ice hockey players toward mouthguard usage. *Internet J Allied Health Sci Prac* 4, 2006.

20. Miller, TA, Thierry-Aguilera, R, Congleton, JJ, Amendola, AA, Clark, MJ, Crouse, SF… and Jenkins, OC. Seasonal changes in VO_{2max} among division 1A collegiate women soccer players. *J Strength Cond Res* 21: 48-51, 2007.

21. National Collegiate Athletic Association. *NCAA Field Hockey: 2019 Rules Modifications*. January 2019. Available at: https://ncaaorg.s3.amazonaws.com/championships/sports/fieldhockey/rules/2019-20PRWFH_NCAAFieldHockeyRulesModifications.pdf. Accessed August 15, 2019.

22. National Collegiate Athletic Association. *Estimated Probability of Competing in College Athletics*. April 2019. Available at: https://ncaaorg.s3.amazonaws.com/research/pro_beyond/2019RES_ProbabilityBeyondHSFiguresMethod.pdf. Accessed August 15, 2019.

23. National Federation of State High School Associations. *Participation Statistics*. Available at: http://www.nfhs.org/ParticipationStatics/ParticipationStatics.aspx/. Accessed August 15, 2019.

24. National Federation of State High School Associations. *Position Statement and Recommendations for Mouthguard use in Sports.* October 2018. Available at: https://www.nfhs.org/media/1014750/position-statement-and-recommendations-for-mouthguard-use-in-sports-october-2018-final.pdf. Accessed August 15, 2019.

25. Nieuwenhuis, CF, Spamer, EJ, and Rossum, JHV. Prediction function for identifying talent in 14- to 15- year old field hockey players. *High Abil Stud* 13: 21-33, 2002.

26. Noyes, FR, Barber-Westin, SD, Smith, ST, Campbell, T, and Garrison, TT. A training program to improve neuromuscular and performance indices in female high school basketball players. *J Strength Cond Res* 26: 709-719, 2012.

27. Noyes, FR, Barber-Westin, SD, Tutalo-Smith, ST, and Campbell, T. A training program to improve neuromuscular and performance indices in female high school soccer players. *J Strength Cond Res* 27: 340-351, 2013.

28. Podgórski, T and Pawlak, M. A half century scientific research in field hockey. *Human Movement* 12: 108-123, 2011.

29. Queiróz, AFVR, de Brito Jr, RB, Ramacciato, JC, Motta, RHL, and Flório, FM. Influence of mouthguards on the physical performance of soccer players. *Dent Traumatol* 29: 450-454, 2013.

30. Ramdas, SS, Ballal, KR, and Shantaram, M. Mouth guard - A dental gift for sports. *Int J Health Rehab Sci* 3: 95-98, 2014.

31. Reilly, T and Borrie, A. Physiology applied to field hockey. *Sports Med* 14: 10-26, 1992.

32. Saltin, B, Nazar, K, Costill, DL, Stein, E, Jansson, E, Essén, B, and Gollnick, PD. The nature of the training response: Peripheral and central adaptations to one-legged exercise. *Acta Physiol Scand* 96: 289-305, 1976.

33. Siri, WE. Body composition from fluid spaces and density: Analysis of methods. *Techniques for Measuring Body Composition, 61*: 223-44, 1961.

34. USA Field Hockey. *Rules of Field Hockey*. Colorado Springs, CO: USA Field Hockey, 2011.

35. Walsh, M, Young, B, Hill, B, Kittredge, K, and Horn, T. The effect of ball-carrying technique and experience on sprinting in rugby union. *J Sport Sci* 25: 185-192, 2007.

36. Wdowski, M., Gittoes, M. Kinematic adaptations in sprint acceleration performances without and with the constraint of holding a field hockey stick. *Sports Biomechanics*, 12: 143-153, 2013.

ACKNOWLEDGEMENTS: The authors note that there are no conflicts of interest to be disclosed. The results of the present study do not constitute the endorsement of SafeTGuards Mouthguards by either the NSCA or the authors. No funding was received to support this study.

Figure Legends

FIGURE 1: Study design outline

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

WOMG-STK = without mouthguard and stick; WMG-STK = with mouthguard and stick.

*Significant change between pre- and mid-season testing. †Significant change between mid- and post-season testing

Table 1

Table 1: Participant anthropometric characteristics (pre-season)

Variable	CTL	EXP	*p*=
Age (years)	15.2±1.2	15.2±1.0	0.96
Height (m)	1.61±0.04	1.62±0.06	0.50
Mass (kg)	58.8±7.6	59.2±10.7	0.90
Body fat (%)	20.9±4.5	22.4±3.4	0.34

CTL = control group; EXP = experimental group

Table 2

Table 2: Estimated VO^2_{max} scores ($mL \cdot kg^{-1} \cdot min^{-1}$)

	Testing Without MG&Stick			Testing With MG&Stick			
Time Point	CTL (n=18)	EXP (n=20)	p=	CTL (n=18)	EXP (n=20)	p=	Cohen's D
Preseason	35.1±3.9	24.8±3.2	0.44	31.8±4.0	31.7±4.7	0.96	0.22
Midseason	40.3±8.7	39.5±7.5	0.69	35.7±4.6	34.8±3.3	0.49	0.28
Postseason	37.2±6.5	37.6±6.5	0.69	32.8±3.9	33.5±3.9	0.62	0.23

CTL = control group; EXP=experimental group; MG=mouthguard

Figure 1

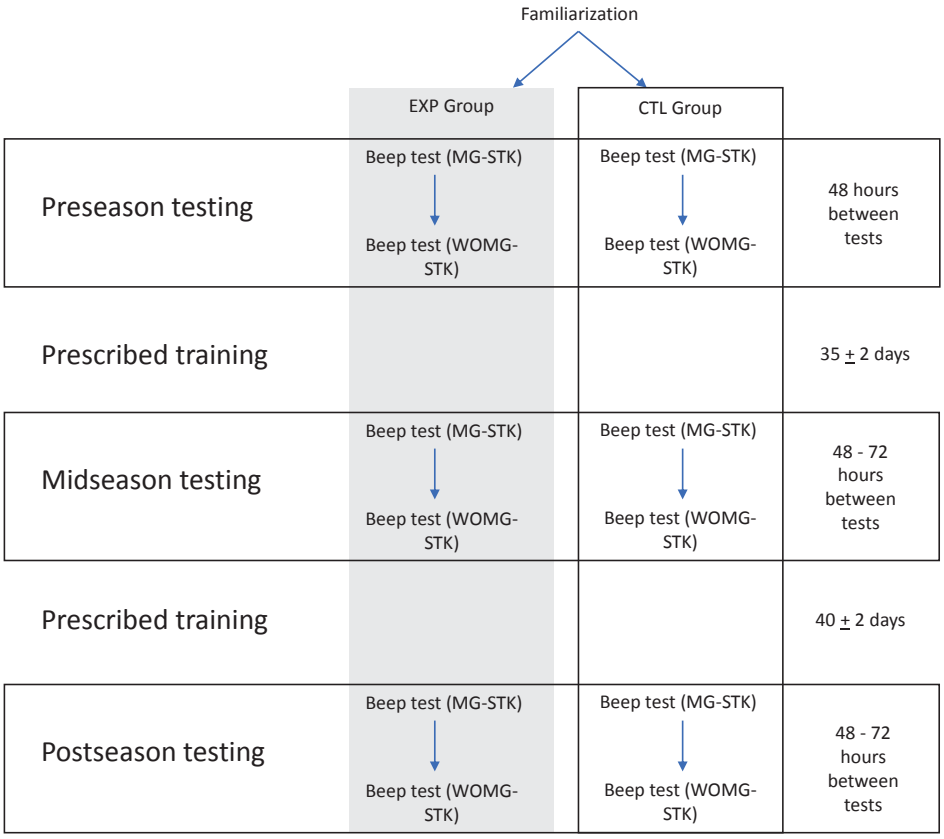
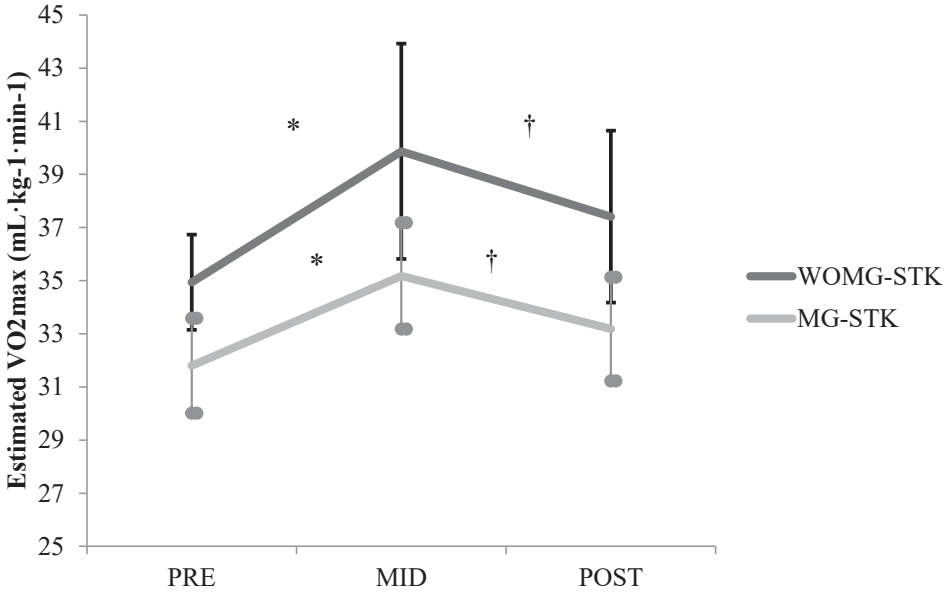

Familiarization
EXP Group
CTL Group
Preseason testing
Beep test (MG-STK)
Beep test (WOMG-STK)
Beep test (MG-STK)
Beep test (WOMG-STK)
48 hours between tests
Prescribed training
35 ± 2 days
Midseason testing
Beep test (MG-STK)
Beep test (WOMG-STK)
Beep test (MG-STK)
Beep test (WOMG-STK)
48 - 72 hours between tests
Prescribed training
40 ± 2 days
Postseason testing
Beep test (MG-STK)
Beep test (WOMG-STK)
Beep test (MG-STK)
Beep test (WOMG-STK)
48 - 72 hours between tests

Figure 2

FIGURE 2: Estimated VO_{2max} scores ($mL \cdot kg^{-1} \cdot min^{-1}$) over a season



*Significant change between pre- and mid-season testing
†Significant change between mid- and post-season testing