THE EFFECT OF A 4 WEEK AEROBIC INTERVAL TRAINING BLOCK USING MAXIMAL AEROBIC SPEED AS THE INTENSITY MEASURE WITH ELITE FEMALE HOCKEY PLAYERS.

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ABSTRACT

The aerobic energy system underpins team sport activities, and therefore, knowledge regarding training methods utilised to develop this energy system is essential. Such information can help direct training prescription and ensure that the most effective conditioning methods and principals are being utilised to obtain the desired aerobic adaptations. The purpose of this study was to assess the effectiveness of MAS guided interval training on eliciting improvements in aerobic fitness with elite females hockey players (n = 25, age = 22.3 ± 2.3 years, stature = 168.4 ± 7.6cm, mass = 61.8 ± 6.8kg). The girls were all Victorian Institute of Sport scholarship holders and were preparing to compete at the Australian Hockey League tournament. During this period they completed three MAS guided conditioning sessions per week. The YOYO IR1 was utilised to measure aerobic fitness and also, direct training intensity via the determination of maximal aerobic speeds. At the conclusion of the four week aerobic interval training block, there was an 18% improvement in YOYO IR1 total distance, with a team average of 1320m recorded at baseline and 1570m recorded at the conclusion of the intervention. In level and shuttle terms, the team average went from 16.6 at baseline to 17.3 at the conclusion of the intervention. Lastly, MAS improved by 0.5kmh, from 15.5kmh to 16kmh. In conclusion, MAS guided interval training is an effective training stimulus for eliciting aerobic energy system improvements in elite female hockey players.

KEY WORDS - Maximal Oxygen Uptake (VO2Max), Maximal Aerobic Speed (MAS), Velocity at VO2Max (vVO2Max), Aerobic Power, Interval Training, YOYO Intermittent Recovery Test – Level 1, Field Hockey

INTRODUCTION

Physical fitness tests are used to evaluate an athlete’s training status and to prescribe training based on the measures obtained. One component of physical fitness that underpins team sport activities is the aerobic energy system. This energy system has been linked with the athlete’s endurance and often determines the outcome of contests and/or results (24). For athletes involved in team sports, time spent completing aerobic training to improve or maintain this system is therefore justified. In response to specifically prescribed training, physiological adaptations occur which can lead to improvements in aerobic measures. These changes can include: lower blood lactate levels at given workloads; increased lactate tolerance and clearance; increased rate of phosphocreatine resynthesis; improved buffering capacity; and increased time to exhaustion at specific intensities (13, 23).

Moreover, in an applied context, enhancement of the aerobic energy system can lead to an increased ability to perform high intensity efforts; increased total distance covered throughout a match; increased level of work intensity during game play; increased ability to recover from high intensity intermittent efforts; increased number of sprints performed during a match; and an improvement in the number of contests made or created (3, 15, 17). Knowledge of an athlete’s aerobic fitness is therefore, worthwhile, as it enables both the head coach and conditioning coordinator to complete ongoing monitoring, whilst also ensuring appropriate and informed decisions for training prescription are made.

The ‘gold standard’ measure of aerobic fitness is maximal oxygen uptake (VO2Max), which is “the maximum rate that oxygen can be taken up from the ambient air and transported to and used by cells for cellular respiration during physical activity” (21). It can be obtained either directly from gas analyses, which is generally laboratory based, or more commonly, indirectly using performance based field testing.

Once the aerobic energy system assessment is complete, the results obtained can be used for exercise prescription. Measures derived include velocity at VO2Max (vVO2Max) and maximal aerobic speed (MAS). The term vVO2Max was introduced in 1994 by Daniels and Scardina and can be defined as the minimal velocity associated with VO2Max determined by an incremental treadmill test (5, 9). The variable vVO2Max combines both VO2Max and running economy into a single factor, which enables identification of aerobic differences between various categories of
runners (7). As such, it has been shown that vVO2Max explained differences in performance that VO2Max or running economy used in isolation did not (7). Similarly, MAS can be defined as the minimal speed that elicits maximal oxygen consumption (19). As opposed to utilising an incremental treadmill test to obtain MAS, performance based field measures such as the Univeriste de Montreal Track test (UMTT) and 20m shuttle run (beep test) are often utilised to determine MAS. Both of these measures (vVO2Max and MAS) are utilised to describe training intensity.

The application of high-intensity interval training using MAS and/or vVO2Max as the intensity measure for aerobic conditioning has been commonly utilised with middle and long distance runners with significant improvements in aerobic measures (5). However, these methods have not received the same attention within a team sports context. Traditionally, aerobic conditioning practices applied with team sports have been based on anecdotal evidence and conditioning methods applied with steady state sports such as rowing, swimming and running. As such, there is limited research available focusing on aerobic conditioning methods and prescription of these methods for team sports. Currently, however, there is an emerging trend within team sports to implement interval based conditioning methods using MAS or vVO2Max as the intensity measure over continuous or steady state type methods to increase VO2Max.

Using MAS and/or vVO2Max to prescribe training have clear benefits, however, obtaining these measures directly from the laboratory is not practical for most organisations and teams. Currently, performance based field tests have been used as an indirect estimate of MAS and/or vVO2Max (4, 10, 11, 19). The efficacy of such practices is, however, questionable. For example, average velocity for 1500 m and 3000 m time trials have been used to estimate vVO2Max (19). One limitation when utilising time trials are pacing strategies (14). Whilst accurate, the use of a graded treadmill test to determine vVO2Max is expensive, time consuming and requires experienced personnel, therefore it is not practical for a squad or group environment. Lastly, the 20m shuttle run has been utilised in the past to determine MAS, however, due to the slow speeds at which the test is completed, it severely underestimates MAS (12). A more novel approach emerging for determining training intensity is based on YOYO Intermittent Recovery tests (YOYO IR). The YOYO Intermittent Recovery test (YOYO IR) consists of repeated 2x20m shuttle runs at increasing speeds, with a 10 second active recovery period between every 2x20m (17). The speeds, changes in direction and active recovery periods more closely replicate the movement patterns of team sports than other continuous tests. Like the Université de Montreal Track Test, 20m shuttle run and time trials used previously, the YOYO IR1 predominantly measures an individual’s aerobic fitness capabilities (3). These tests were specifically designed and validated to evaluate team sport athlete’s aerobic fitness and ability to repeatedly perform and recover from high intensity intermittent exercise (3, 17).

A study compared the peak velocity achieved during the YOYO IR1 (VYOYO) and the maximal aerobic velocity (MAV) determined from the UMTT. This is the first study published that investigated the efficacy of the YOYO IR1 as a means of determining training speeds. The VYOYO obtained from the YOYO IR1 significantly correlated to the MAV obtained from the UMTT (11).

Recently, it has been recommended that to improve an athlete’s VO2Max, exercise intensity should be at, or near, VO2Max for as long as possible during bouts of activity (10). In order to maximise the total amount of time and/or work performed at or near VO2Max, interval or intermittent training, comprising of active or passive periods of recovery interspersed with periods of high intensity exercise should be prescribed (21, 22).

Training speeds at or above vVO2Max should be utilised during the periods of high intensity exercise as it has been found to be an effective method of eliciting VO2Max during interval training (6). Combining training speeds at or above MAS or vVO2Max with high intensity interval training ensures that the work performed and the time spent at or near VO2Max can be sustained for longer when compared to continuous or steady state methods completed at the same intensity (21).

**METHODS & PROCEDURES**

**Participants**

25 state level female hockey players (n = 25, age = 22.3 ± 2.3 years, stature = 168.4 ± 7.6cm, mass = 61.8 ± 6.8kg) participated in the case study. All of the hockey players were Victorian Institute of Sport scholarship holders and were training in preparation for the Australian Hockey League tournament as part of the Victorian Vipers squad. The participants were familiar with all the testing and training procedures prior to the intervention period.
Procedures
MAS Interval Training: During the four week intervention period, the hockey squad completed three MAS guided interval sessions a week. Two of the sessions included both strength training and interval running. For these particular sessions, the interval running was completed first as this was the priority at this stage of the preparation.

The YOYO IR1 test was used to evaluate aerobic fitness and determine training speeds (MAS). Testing was conducted at baseline and post-intervention and was administered at the same time and at the same location on both occasions.

After the initial YOYO test, each athlete in the squad was assigned a particular training group; 4.72, 4.58, 4.44 or 4.31, depending on the result achieved in the YOYO test. The aforementioned training groups represent a velocity in metres per second. Thus, those individuals who obtain a YOYO score of between 19.1 and 19.8 are placed into the 4.72 group. This group figure, in this case 4.72, becomes that particular individuals MAS and equates to 100% when referring to the intervention table below.

The squad was categorised accordingly with three athletes in the 4.72 group, six athletes in the 4.58 group, nine athletes in the 4.44 group and six athletes in the 4.31 group.

Strength Training: The squad completed two strength training sessions per week; Tuesday and Friday. The strength program provided in Table 1 is the generic program, with amendments made to the program where necessary whether that is due to injury, training status and playing position. The main objective of the strength program was to increase lower body strength, improve hip stability and facilitate motor learning.

The preparation and hip stability / reactive strength components of the program were completed prior to completing the MAS guided interval training. Additionally, the split jerks and the primary lower body strength exercises, either back squats or trap bar deadlifts depending on the session, were also completed prior to the MAS guided interval training. This was done to ensure that the potential strength and power adaptations wouldn’t be compromised as would occur if they were completed after the conditioning.

Table 1 - Strength training program. (please click to view this table in excel)

Technical Training: During this four week block, the squad completed three technical sessions per week; Monday, Wednesday and Friday. An example of the weekly schedule can be seen below in table 1.

Table 2 - Weekly schedule.

<table>
<thead>
<tr>
<th></th>
<th>MON</th>
<th>TUES</th>
<th>WED</th>
<th>THURS</th>
<th>FRI</th>
<th>SAT</th>
<th>SUN</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>Hockey Training</td>
<td></td>
<td></td>
<td>Hockey Training</td>
<td></td>
<td>MAS Running</td>
<td></td>
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<tr>
<td>PM</td>
<td>Hockey Training</td>
<td>Strength &amp; MAS Running</td>
<td>Strength &amp; MAS Running</td>
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INTERVENTION, RESULTS & DISCUSSION

The primary goal of this 4 week intervention was to increase aerobic capacity using the abovementioned principles and methods, whilst progressing from velocities at or below MAS to running at velocities at or above MAS with an accompanying decrease in running volume. Ideally, this MAS guided interval training block would have been progressed and continued for at least another 4 weeks if time and scheduling permitted.

TRAINING WEEKS 1 – 4

Objectives
- Increase VO$_2$
- Gradually ↑ intensity via ↑ running velocity

Table 3 - MAS guided aerobic interval training program. (please click to view this table in excel)
As you can see from the table above, the running velocities ranged from 85% to 110% during weeks 1-4 and the total individual session distance ranged from 1.6km to 4.8km, depending on the session type (interval vs. steady state) and running velocity prescribed.

The 1 CoD Continuous Aerobic Running Session was based on the research conducted by Billat (8). In this particular study, an effective protocol for interval training utilised 30 sec efforts at vVO2Max interspersed with 30 sec at 50% of vVO2Max. This protocol enabled participants to elicit VO2Max for longer, than slower continuous running [8min vs. 3 min] (8). The structure of the 1 CoD continuous Aerobic Session is very similar to Billat’s work, with the work periods interspersed with active recovery periods. However, compared to Billat’s study there is a slight difference in the intensities utilised, with 90% (work) : 60% (active recovery) used in week 1, progressing to 100% (work) : 70% (active recovery) in week 4. There is an increase in intensity and volume over the 4 week block, culminating in 18 minutes of work being completed at 100% (work) - 70% (active recovery).

1 CoD Continuous Aerobic Running

100% (4.72 group @ 100% MAS = 94.4m [2x47.2m])
70% (4.72 group @ 70% MAS = 64m [2x32m])

Figure 1: The diagram above is an example of the 1 CoD continuous aerobic running session in week 3. The longer arrows denote the 100% work efforts, which for the 4.72 group are 47.2m each, totalling 94.4m. The 94.4m is to be completed in 20 sec and is to be immediately followed by a further 20 sec at 70%, which is denoted by the shorter arrows. These shorter arrows denote the active recovery period, which are 32m each way, totalling 64m. This 94.4m and 64m sequence is continued for the specified time.

The Track Based Long Shuttles were 100m shuttles, starting with 600m efforts @ 95% MAS with a 1:1 work to rest ratio in week 1. There was a gradual decrease in volume per effort (400m to 200m) and total distance (3km to 1.6km) with an accompanying increase in intensity (95% MAS to 110% MAS) over the 4 week training block. When intensity increased to 110% in week 4, the work to rest ratio was manipulated to 1:2 to enable greater recovery between efforts.

Track Based Long Shuttles

6 x 100m (4.72 group @ 95% MAS = 134s)

Figure 2: The diagram above is an example of the Track Based Long Shuttles running session. The arrows denote 100m, which for the 4.72 group in week 1 running at 95% MAS should be completed 6 times (600m) in 134 sec or 2 min and 14 sec. Passive recovery of that exact duration should be utilised prior to completing another the next effort.

Lastly, the rationale behind the Steady State + Hill Run session was twofold; firstly, it was prescribed to provide the squad with a bit of variety from the preceding two interval based sessions. This was necessary as the MAS guided interval sessions are not only physically challenging, but equally, mentally challenging. Secondly, the steady state run was used to encourage competitiveness amongst the group, with the squad encouraged to use this session as a time trial or a race. As I expected a learning effect to occur with these steady state runs, there was a gradual increase in intensity over the 4 weeks with the intensity increasing from 85% to 90% MAS, which equated to a ~50 sec reduction in 3.8km time. Upon completing the steady state run, the squad then completed four 250m hill efforts @ 110% MAS which took them ~50 sec to complete. These efforts were completed with a work to rest ratio of 1:3.

Testing was conducted at baseline and post-intervention and was administered at the same time and at the same location on both occasions.
Table 4 - Team mean and standard deviation of total YOYO distance, YOYO level and shuttle and maximal aerobic speed at baseline, mid-intervention and post-intervention.

<table>
<thead>
<tr>
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<th>Baseline</th>
<th>Post Intervention</th>
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<tr>
<td>TEAM AVERAGE (m)</td>
<td>1320 ± 353</td>
<td>1570 ± 378</td>
</tr>
<tr>
<td>TEAM AVERAGE (level &amp; shuttle)</td>
<td>16.6 ± 6.0</td>
<td>17.3 ± 6.8</td>
</tr>
<tr>
<td>TEAM AVERAGE (MAS kmh)</td>
<td>15.5 ± 0.49</td>
<td>16 ± 0.55</td>
</tr>
<tr>
<td>TEAM AVERAGE (MAS Equation kmh)</td>
<td>15.9 ± 0.56</td>
<td>16.4 ± 0.61</td>
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</tbody>
</table>

From the results above, it can be said that the application of MAS guided high intensity interval training is an effective means of eliciting improvements in YOYO IR1 score and subsequently, VO2Max.

Furthermore, not only is utilising MAS or vVO2Max as the intensity measure a viable and effective method in eliciting aerobic energy system adaptations. It also ensures that the program or sessions are individualised with each group, or athlete within that group catered for. This is evident when looking at the 4 week training intervention above. Each of the four groups was assigned a different MAS and subsequently, different training speeds and distances whilst maintaining the same relative intensity amongst the entire squad. This ensures that the stimulus imposed upon each of the athletes is kept consistent. Additionally, the application of MAS / vVO2Max as an intensity measure enables the head coach and conditioning coordinator to monitor and supervise training more easily without relying on subjective measures to direct training, such as instructing athletes to run ‘moderately hard’ or at 85%.

Unlike other variables considered when prescribing conditioning, MAS and vVO2Max are stable and are less influenced by external factors such as heat, humidity, dietary intake and hydration. Such external factors are a major concern when other methods, such as using percentage of maximal heart rate to determine intensity for conditioning sessions (1).

Lastly, an alternative method more specific to team sports than interval training is the use of small sided games (also known as game-based conditioning). The purported advantage of small sided games compared to interval training is that VO2Max can be improved as players practice technical and tactical skills (10). By imposing rule changes, varying the number of players per side, and adjusting the pitch dimensions, training intensity can be changed for a desired outcome. For example, training intensity can be increased by reducing the number of players who take part, thereby increasing the number of ball contacts and game-related actions performed (16). Given training time constraints, the advantages of small sided games are obvious. However, most evidence supporting game-based conditioning is derived from heart rate monitoring (2). One additional limitation that has emerged from their use is the large intersubject heart rate responses. Often during small sided games a players effort is dependent upon their own motivation, which can impact on heart rate and amount of work completed (10). In addition, players whom are more proficient at their chosen sports and have greater tactical and technical nous will not elicit the desired heart rate and metabolic response, as they often find themselves in better positions and making better decisions. Those who benefit the most from game-based training are forced to make-up for their lack in technical and tactical nous by increasing their work rate. In the same study, it was found that during interval training sessions there was less intersubject heart rate variability when compared to the heart rates obtained during the small sided games. Based on these findings and the results of this case study, MAS guided interval training enables a more controlled physiological response, and ensures that the stimulus imposed upon each individual athlete is that which was planned.

CONCLUSION & PRACTICAL APPLICATIONS

In conclusion, the MAS guided high intensity; interval training intervention was successful in eliciting improvements in aerobic fitness, with an 18% improvement in YOYO IR1 total distance at the conclusion of the 4 week training block. It would have been desirable to have conducted another 4 week block of MAS guided interval training to ascertain whether the rate of aerobic adaptations could have continued. However, due to scheduling and time constraints, this wasn’t possible.
As evidenced by the results above, not only is MAS guided interval training an effective aerobic training stimulus, it is also very easy to administer with groups and squads of contrasting fitness levels. Additionally, to further increase the individualisation of sessions, an equation, whereby \( V_{\text{YOYO}} = V + 0.5 \times (n/8) \) can be utilised to increase test sensitivity (18) and therefore, obtain more accurate training speeds (MAS), which in turn will increase the effectiveness of the sessions. In the aforementioned equation, \( V \) represents the velocity during the next to last stage; the 0.5 represents the in the increment in velocity after each stage; \( n \) represents the number of run completed in the last stage and 8 represents the number of runs in each stage from level 14.

Future research should utilise a longer intervention period and focus on acute physiological responses to MAS guided interval training as to ascertain what intensities, volumes and sessions are most effective at eliciting high levels of \( \text{VO2} \).

**REFERENCES**

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