Biology of Sport, Vol. 22 N^{o}2, 2005

SEASONAL VARIATION IN THE PHYSIOLOGICAL PROFILE OF HIGH-LEVEL MALE FIELD HOCKEY PLAYERS

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Abstract. Objectives: To measure the physiological profiles of elite players and observe changes throughout a season in order to provide guidelines for training. Secondly, investigate whether recent rule changes have had an impact on the physiological demands of match play. Material and Methods: Nine English premier division male field hockey players participated in this study (mean ±s: age 24±4 years, body mass 80.8±5.2 kg and height 181.8±3.9 cm). Three treadmill exercise tests were performed at pre-season (T1), at the start of the competitive season (T2) and at mid-competitive season (T3), to determine the running velocity at a blood lactate concentration of 4 $mmol \cdot l^{-1}$ (V_{OBLA}), individual HR: $\dot{V}O_2$ regressions, $\dot{V}O_{2peak}$, peak running speed (PRS) and time to exhaustion. Results: There were increases ($p<0.05$) between T1 and T2 in $\dot{V}O_{2peak}$ (54.0±6.3 to 60.1±7.6 $ml \cdot kg^{-1} \cdot min^{-1}$) and PRS (18.2±1.7 to 19.1±1.7 $km \cdot h^{-1}$). V_{OBLA} increased from T2 to T3 (15.1±1.7 to 15.8±1.4 $km \cdot h^{-1}$, $p<0.05$) and time to exhaustion increased from T1 to T3 (30.3±8.0 s to 33.0±5.9 s). The subjects' mean responses to competition match play were; heart rate 167±8 beats $\cdot min^{-1}$, $\dot{V}O_2$ 42.8±6.3 $ml \cdot min^{-1} \cdot kg^{-1}$ and a fractional utilisation of 80±7 %. Conclusions: The high levels of aerobic fitness observed are consistent with the demands of the games. However, there were significant changes in fitness over the course of a training year. Recent rule changes do not seem to alter the physiological demands of match play. ***(Biol.Sport 22:107-115, 2005)***

Keywords: Training – Periodisation - Physiological characteristics

Introduction

Field hockey is an invasive territorial game that involves considerable aerobic energy contribution superimposed with brief though frequent anaerobic efforts [8,23,25]. Competition requires players to sustain 70 min of high intensity intermittent exercise during which they have been reported to exercise at a high percentage of their

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aerobic power [4]. Furthermore, the relatively high $\dot{V}O_{2max}$ values reported by several authors (59.7–69.0 $ml \cdot kg^{-1} \cdot min^{-1}$) [1,22,24,29] would also suggest that the aerobic energy system is of importance during match play. Training for field hockey would therefore be expected to target the requirements of the sport. Such training is usually divided into two phases: a preseason, where extensive work is performed to enhance endurance capacity, and competition training where sport specific technical drills are performed together with tactical training and anaerobic conditioning.

The shift in training emphasis towards anaerobic conditioning and skill development during the season [21] may pose a problem for the maintenance of endurance conditioning during the competition period. However, average oxygen consumption during competition has been reported to range from 70% to 92% $\dot{V}O_{2max}$ [4,22], which will elicit an aerobic training effect in its own right [22] and therefore may provide sufficient stimulus for the maintenance of endurance conditioning during the competitive season [4].

Unfortunately, there is a paucity of data on the profile of high-level male field hockey players [25] and, to our knowledge, no studies have yet examined the seasonal variation in physiological capacity of male players. Furthermore, recent rule changes have led some investigators to suggest that considerable alterations may have occurred in the technical, tactical and physiological demands of the sport at all levels, but in particular at the elite level [4,23]. These changes include the introduction of artificial pitches as the official playing surface of the sport. This factor has been shown to increase the effective playing time of games [23], increase the number of ball touches per player [14] (skills were observed to be more easily executed [14]), players ran with the ball further and more often [18] (increasing the energy cost of running [22]) and hence increase the physiological requirements of games compared to games played on grass [18]. The introduction of ball boys and the abolishment of the ‘off-side’ rule may mean that the ball is in play longer and that defending teams can not negate space on the pitch therefore increasing the speed of the game. Finally, the introduction of the ‘roll-on roll-off’ substitutions may have increased the work rate demands on players. Coaches may rotate players continuously and expect them to perform at a high intensity during the times that they are on the pitch. This may further increase the intermittent nature of the sport with players performing at very high intensities for relatively short bouts of time with complete rest between each intermittent period of activity.

These changes to the sport might therefore imply that players are no longer required to sustain a full 70 min of high intensity intermittent exercise and that the average exercise intensity of 70% to 92% $\dot{V}O_{2max}$ [4,22], previously reported in the literature, may not reflect the demands imposed on players involved in the modern game. In addition, the physiological demands of competitive match play may or may not be enough to maintain the fitness gains made over pre-season. Fluctuations in fitness throughout the season may result in players not being able to compete at the expected level. Whilst there are reports of the physiological characteristics of field hockey players [1,2,4,15], few of these have been published since the previously described changes to the game and none have looked at the seasonal variation in physiological profiles.

The purpose of this study was therefore twofold: firstly, to measure the physiological profiles of English premiership field hockey players at various time points during the training year in order to monitor seasonal variation of these physiological characteristics in response to training throughout a season. Secondly, to examine the heart rate response during competitive field hockey matches in order to estimate workload and form comparisons between the demands of matches pre and post the implementation of the above mentioned rule changes.

Material and Methods

Subjects: Nine male English Premier division hockey players participated in this study; they were all members of the same hockey team and had played at this level for a minimum of three years. Six of the subjects currently represented their country at international level. Mean ±s for age, body mass and height were 24±4 years, 80.8±5.2 kg and 181.8±3.9 cm, respectively. All subjects were informed of the nature of the study, of all associated risks and of their right to terminate participation at any point, before giving written informed consent. The study protocol followed the guidelines laid down by the World Medical Assembly Declaration of Helsinki [30] and was approved by the University Research Ethics Committee.

Test protocols: Subjects underwent physiological assessment at three times during the year: at pre-season (T1), 12 weeks later at the start of the competitive season (T2) and a further 10 weeks later at mid-competitive season (T3). Subjects were asked to refrain from any exercise, alcohol, tobacco or caffeine for 48 h prior to testing.

Subjects performed three exercise tests on a motorised treadmill (Powerjog J100, Sport Engineering Ltd, Birmingham, U.K): a sub-maximal incremental test, a maximal incremental test and a supra-maximal test.

Sub-maximal treadmill test: The sub-maximal test was adapted from Heck *et al.* [11] and consisted of four×four minute workload intervals at running speeds of 10, 12, 14 and 16 $km \cdot h^{-1}$ and a constant gradient of 2% (to replicate running on artificial surfaces [11]). Between each workload there was a one-minute interval, during which a capillary blood sample was taken from a fingertip and analysed for lactate (Analox

Microstat GM7, Analox Instruments Ltd, Hammersmith, U.K). Expired air was analysed throughout (Oxycon Alpha, Jaeger, Germany) and $\dot{V}O_2$ for the final minute of each workload calculated. Heart rate was recorded via short wave telemetry (Polar Accurex Plus, Polar Electro, Finland) throughout the trial. Following the test, blood lactate concentrations were plotted against running speed and oxygen consumption; the speed and $\dot{V}O_2$ corresponding to a blood lactate concentration of 4 $mmol \cdot l^{-1}$ were identified (V_{OBLA} and $\dot{V}O_{2OBLA,}$ respectively). In addition, $\dot{V}O_{2OBLA}$ was expressed as a percentage of $\dot{V}O_{2peak}$ to determine fractional utilisation (FU) and regression equations were established between individual heart rate and $\dot{V}O_2$ responses to sub-maximal workload to estimate $\dot{V}O_2$ during eight competitive games.

Maximal treadmill test: Following a five-minute recovery, subjects undertook a maximal incremental test to volitional fatigue, adapted from Buchfuhrer *et al.* [5]. The treadmill was set at an initial speed of 8 $km \cdot h^{-1}$ for 60 s after which the speed was increased to 10 $km \cdot h^{-1}$ and thereafter by 0.5 $km \cdot h^{-1}$ every 30 s. The treadmill gradient was maintained at 2% throughout. Expired air and heart rate were monitored as previously described. $\dot{V}O_{2peak}$ was determined as the highest rate of oxygen consumption over a 30 s period. Peak running speed (PRS) was determined as the fastest treadmill speed sustained for an entire 30 s step as described by Noakes *et al.* [19].

Supra-maximal treadmill test: After a 45 min rest period the subjects completed a treadmill test adapted from Cunningham and Faulkner [7] with speed and gradient set at 16 $km \cdot h^{-1}$ and 20%, respectively. The test was modified from the original speed of 8 $miles \cdot h^{-1}$ (~13 $km \cdot h^{-1}$) and gradient of 20% to ensure subjects fatigued within 50 s of exercise as suggested by Green [10]. Time to exhaustion was recorded from the moment the subject released his hands from the rails and started running freely until volitional exhaustion, defined as the time the hands were placed back on the side rails. Such work capacity tests have been suggested as a suitable method for assessing anaerobic capacity [7,9,10].

Training Programme

The training programme was designed by the team coach and consisted of 12 weeks pre-season and 10 weeks competition training up to the mid-season break. Pre-season training consisted of a progressive aerobic training program divided into two phases of 6 weeks each. Phase 1 followed the first physiological assessment (T1) and comprised two training sessions a week designed to improve aerobic fitness. The sessions comprised four 6 min runs at 90% maximal effort, separated by 2 min rests for the first 3 weeks and four 8 min runs at 90% maximal effort, separated by 2 min rests for the remaining 3 weeks. Phase 2 consisted of three sessions each week: two aerobic training sessions consisting of five 3 min runs at 100% maximal effort, separated by equal rests, which were followed by technical development training designed to improve game specific skills; a third session comprised a practice game. The second physiological assessment (T2) was conducted after Phase 2 and prior to the commencement of the competitive season. Two training sessions and a competitive match were performed each week during the competitive season; the training sessions comprised small-sided games of approximately 45 min aimed at developing physical fitness, followed by ~95 min of technical and tactical practice.

Statistical Analysis

All results are expressed as mean ±s. Changes in physiological measures over the course of the three times were analysed via repeated measures ANOVA. Maulchy's sphericity test was used and violations of the assumption of sphericity were corrected using the Greenhouse-Geisser adjustment. Where appropriate, post hoc analysis was conducted via paired samples t-tests with the Bonferroni correction. A significance level of $p<0.05$ was established prior to analysis.

Results

Table 1
Physiological parameters measured over the three tests (mean ±s)

Physiological Variable	T1	T2	T3
$\dot{V}O_{2peak}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	54.0±3.67	60.1±4.56*	58.9±5.25*
PRS ($km \cdot h^{-1}$)	18.2±1.0	19.1±1.0*	19.5±1.3*
V_{OBLA} ($km \cdot h^{-1}$)	14.8±0.5	15.1±0.5	15.8±0.89**
$\dot{V}O_{2OBLA}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	49.7±3.8	53.3±2.6*	54.3±3.32**
Time to exhaustion (s)	30.3±2.44	31.0±2.6	33.0±2.6*

*significantly greater than T1, $p<0.05$; **significantly greater than T2, $p<0.05$.

Significant changes were observed in $\dot{V}O_{2peak}$ ($F=43.385$, $p<0.05$), PRS ($F=9.398$, $p<0.05$), V_{OBLA} ($F=6.127$, $p<0.05$) and FU ($F=5.235$, $p<0.05$); Table 1 illustrates when these changes occurred. $\dot{V}O_{2OBLA}$ showed no significant change ($F=3.657$, $p>0.05$);

time to exhaustion during the supra-maximal treadmill increased ($F=5.827$, $p<0.05$), as shown in Table 1.

Mean ±s heart rate, $\dot{V}O_2$ and $\dot{V}O_2$ as a percentage of $\dot{V}O_{2peak}$ (FU) during competitive match play were 167±8 beats·min^{-1}, 42.8±6.3 ml·min^{-1}·kg^{-1} and 80±7 %, respectively.

Discussion

The $\dot{V}O_{2peak}$ values at the start of the competitive season (T2) and midway through the competition period (T3) (60.1 and 58.8 ml·kg^{-1}·min^{-1}, respectively) are similar to previously reported values for field hockey players (59.7 to 64.1 ml·kg^{-1}·min^{-1}) [4,23,29], during the same time of year. These reflect the relatively high level of aerobic power in these players [4]. It would appear therefore, that the aerobic demands of the sport, as indicated by the $\dot{V}O_{2peak}$ values at least, have not changed with the introduction of synthetic surfaces and the more recent rule changes. However, other physiological measures, like V_{OBLA}, $\dot{V}O_{2OBLA}$ and FU that may reflect the aerobic demands of the sport more clearly as they are more sensitive to the training stimulus and are stronger determinants of endurance performance than $\dot{V}O_{2peak}$ [16,26] have not been reported in previous literature. The increase in $\dot{V}O_{2peak}$ during pre-season training is similar to those reported for international rugby union players [13] and is to be expected, as one of the primary goals of pre-season training is to increase aerobic power. The switch to tactical and technical work during the competitive season did not however result in a decrease in $\dot{V}O_{2peak}$. It may be assumed that this was due to the combination of training and match play providing sufficient stimulus for the maintenance of aerobic power.

This is supported by the subjects average response to competition match play, observed as heart rate 168±8 beats·min^{-1}, $\dot{V}O_2$ 42.8±6.3 ml·min^{-1}·kg^{-1} and $\dot{V}O_2$ as a percentage of $\dot{V}O_{2peak}$ 80±7 %. Further analysis of our results showed that during competitive match play subjects spent on average 35±11 min at or above 90% of their maximum heart rate, an intensity suggested by Helgerud *et al.* [12] as effective in eliciting positive changes to aerobic power. The average intensity during games was also found to be similar to that of values observed prior to the introduction of the previously described rule changes (heart rate 159±8 beats·min^{-1}, $\dot{V}O_2$ 48.2±5.2 ml·min^{-1}·kg^{-1} and $\dot{V}O_2$ as a percentage of $\dot{V}O_{2peak}$ 79±7%) [4].

Peak running speed and fractional utilisation both increased between T1 and T2 but did not change between T2 and T3. Several studies have shown these markers to be better predictors of endurance performance than $\dot{V}O_{2peak}$ and to be more sensitive to training adaptations [3,6,16,17,19,20,26]. V_{OBLA} has been found to correlate strongly with the rate of recovery following high intensity intermittent exercise [6], a factor that may influence performance during any team sport characterised by intermittent high intensity activity. The increase in V_{OBLA} observed between T2 and T3, without a concomitant increase in either $\dot{V}O_{2OBLA}$ or $\dot{V}O_{2peak}$ may be a result of enhanced running economy [27]. Further analysis of the results supports this assumption, for example, $\dot{V}O_2$ at 12 $km \cdot h^{-1}$ decreased by 9.3% from 42.9±2.81 $ml \cdot kg^{-1} \cdot min^{-1}$ at T2 to 39±5.32 $ml \cdot kg^{-1} \cdot min^{-1}$ at T3.

According to MacDougall and Sale [17], high intensity intermittent training results in improvements in the ability to extract and utilise oxygen by the working muscles. This would result in an increased V_{OBLA}, which is in close agreement with the findings of the current study. It would therefore follow that if V_{OBLA} is a good measure of both endurance capability [16,19,26] and the rate of recovery following high intensity intermittent exercise [3], and that if the greatest increase was observed during the competitive season, players did not reach an optimal level of fitness during pre-season training. Furthermore, high intensity intermittent exercise places high demands on the anaerobic energy system and hence may improve anaerobic capacity [27]. The improvement in time to exhaustion in the supra-maximal treadmill test during the present study, used as an estimate of anaerobic capacity, is in line with these suggestions.

The results for PRS perhaps support the notion that players were not optimally prepared for the start of the competitive season. According to Noakes *et al.* [19], PRS combines $\dot{V}O_{2max}$, V_{OBLA} and running economy in one index of performance. An increase in PRS was observed from T1 to T2 (18.2±1.7 $km \cdot h^{-1}$ to 19.1±1.7 $km \cdot h^{-1}$). The fact that a further increase in PRS occurred from T2 to T3 (19.1±1.7 $km \cdot h^{-1}$ to 19.5±1.8 $km \cdot h^{-1}$) without a paralleled increased in $\dot{V}O_{2peak}$, but with a similar increase in V_{OBLA}, suggests that players had not reached the optimal level of fitness during pre-season training. Furthermore, anaerobic capacity which is considered to play an essential role to performance in field sports such as hockey [1,4,23,25,29], and as estimated by time to exhaustion in the present study, increased between T1 and T3 (30.3±8.0 s and 33.0±5.9 s respectively, $p<0.05$), but had not increased by the start of the competitive season (T2). Together, these findings suggest that although large improvements in aerobic fitness were observed during the pre-season, athletes were not optimally prepared for the forthcoming competitive season. It may therefore be recommended that pre-season training blend both traditional aerobic conditioning with more high intensity anaerobic training to ensure that players attain an optimal level of fitness at the start of the competitive season.

Conclusions

In summary, the $\dot{V}O_{2peak}$ values observed at T2 and T3 and the responses to match play were similar to those reported in other studies, implying that the demands of the sport on the aerobic energy system have not altered since the introduction of synthetic surfaces and the more recent rule changes. The improvements in aerobic power observed in response to pre-season training were maintained throughout the competition period by match play and technical/tactical training. Other physiological such as V_{OBLA} and time to exhaustion, were only improved during the competition period, suggesting that players did not reach an optimal level of fitness prior to the start of the competition period.

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Accepted for publication 20.08.2004