Today's talented youth field hockey players, the stars of tomorrow? A study on talent development in field hockey
Elferink-Gemser, Marije Titia

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2005

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

Copyright
Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

Take-down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): http://www.rug.nl/research/portal. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.
Chapter V

Development of the interval endurance capacity in elite and sub-elite youth field hockey players

Elferink-Gemser, M.T., Visscher, C., Van Duijn, M.A.J.¹, and Lemmink, K.A.P.M.

¹Interuniversity Center for Social Science Theory and Methodology, University of Groningen, the Netherlands
Abstract

To gain more insight into the mechanisms that underlie the development of the interval endurance capacity in talented youth field hockey players in the 12-19 age band, 377 complete measurements were taken in a period of three years. A longitudinal model for interval endurance capacity was developed using the multilevel modelling program MLwiN. With the model, scores on the Interval Shuttle Run Test can be predicted for elite and sub-elite boys and girls in field hockey in the age-band of 12-19 years. During adolescence both male and female elite youth players have a more promising development pattern of their interval endurance capacity than sub-elite youth players. Besides age, gender, and performance level, the effect of percentage body fat, additional training, and motivation was investigated.
5.1 Introduction

Match analyses make clear that field hockey is a high intensity non-continuous game in which the physiological demands are considerable, placing it in the category of ‘heavy exercise’ (Ghosh et al., 1991; Reilly and Borrie, 1992; Aziz et al., 2000). In terms of energy requirements, the aerobic capacity is most important during matches at the elite level. Although great anaerobic capacity is needed during the many brief bursts of high-energy release, it is the aerobic capacity that is needed for efficient recovery during the short rest periods (Bhanot and Sidhu, 1983; Boyle et al., 1994; Lothian and Farrally, 1994). Field hockey players need a well developed interval endurance capacity to carry out all sorts of explosive actions such as intermittent running, accelerating, decelerating, cruising, and dribbling. While performing these actions they repeatedly change their direction to, for example, overtake an opponent, thereby increasing the overall effort needed in field hockey (Patel et al., 2002). The interval endurance capacity is the ability to perform high-intensity activities like running and sprinting, as well as the ability to recover well during low-intensity activities such as walking and jogging (Lemmink and Visscher, 2003).

In our longitudinal study on performance characteristics of talented youth field hockey players in the age-band of 12-18 years, a strong improvement in interval endurance capacity is apparent. As well in boys as in girls, elite youth players improved themselves more than sub-elite youth players on their interval endurance capacity across a period of two years (Elferink-Gemser et al., in revision 2005). When the youth players were on average fourteen years old, however, differences in interval endurance capacity scores were not significant yet between elite and sub-elite players (Elferink-Gemser et al., 2004). One year later, there was a trend that elite players outscored the sub-elite players on their interval endurance capacity, but again differences were not significant. Two years later, at an average age of sixteen years, differences were significant, favoring the elite players. Therefore, to unravel the relationship between the interval endurance capacity and the level of performance in talented field hockey players, it is essential to gain a deeper insight into the development of this performance characteristic.

In ‘normal’ children, aerobic capacity, i.e., VO$_2$max, increases proportionally to body size and mass in both sexes. Most studies show that, when ‘normalizing’ for body size and mass, VO$_2$max remains stable in males throughout childhood and adolescence while it decreases in females (Krahenbuhl et al., 1985). The Amsterdam Growth Study, a 23-year follow-up from teenager to adult about lifestyle and health (Kemper, 2004), shows that in the adolescent period VO$_2$max increases in males whereas it decreases gradually in females (Kemper and Koppes, 2004). Generally, anaerobic performance also increases with age. Girls improve from late childhood to 14-15 years whereas in boys the increase sustains to 19 years. In late
childhood and early adolescence gender differences are evident and they are magnified later in adolescence (Martin and Malina, 1998).

The adolescent period is characterized by an acceleration of somatic growth and rapid changes in body composition and hormonal status including growth spurt and increase in fat-free mass (Bitar et al., 2000). Anthropometrics such as body height, lean body mass and percentage body fat influence the physiological aspects of a sports performance, i.e., the interval endurance capacity. Increase in body height is related to an increase in lung volume and therefore with an increase in metabolism and endurance. Gain in lean body mass is related to muscle mass increase and therefore positively influences endurance in contrast to gain in body fat, which negatively influences endurance (e.g., Astrand et al., 2003).

Most world-class field hockey players are in their twenties and as a consequence athletes who want to make it to the top have to start training already at a relatively early age, thereby developing their interval endurance capacity. It is generally known that with training players can improve their performance by increasing the aerobic and anaerobic energy output during a particular movement. This is also the case in youth players (e.g. Powers and Howley, 2001). However, it is not self-evident that all players make use of their full interval endurance capacity during training or competition. A player has to be motivated to do so since intense activity can cause uncomfortable side effects such as fatigue and muscle soreness. Motivation affects the intensity and persistence of a player’s behavior, which in sports can obviously have a strong impact on his or her performance (e.g., Silva and Weinberg, 1984).

Is it possible to adequately model the development of the interval endurance capacity of 12-19 year-old talented youth field hockey players? Can the development of the interval endurance capacity of talented field hockey players be explained by age, performance level, gender, anthropometrics, training, and motivation? These questions led to the goal of this present study which aim is to gain more insight into the mechanisms that underlie the development of a performance characteristic that is important for a successful career in field hockey: the interval endurance capacity.

5.2 Methods

Participants
In the period 2000-2003, 217 talented field hockey players in the 12-19 years age-bracket participated in a semi-longitudinal study on the relation between multidimensional performance characteristics and performance level. This group consisted of 110 male and 107 female players. All participants were part of a talent development program of a field hockey club of national prestige, and were playing at the highest level for their age category. For three
consecutive years, measurements were taken at the end of the competitive field hockey season of 2000-2001 (t1), 2001-2002 (t2), and 2002-2003 (t3). In total 404 measurements were taken since 77 players were tested on all three occasions (231 measurements), 33 players were tested on two occasions (66 measurements) and 107 players were tested on one occasion only (107 measurements). Of these measurements, 392 contained scores of the interval endurance capacity and 377 measurements were complete in that there were scores on all variables.

Next to being part of a talent development program, talented Dutch field hockey players who are considered to be current elite youth players are invited to train and play in a youth selection team of the Dutch Field Hockey Association (KNHB). Talented players who are considered to be current sub-elite youth players are part of the talent development program of their field hockey club only. This distinction, based on the performance level of the players was also followed in this study.

Procedure
All players were informed about the procedure of the study before giving their verbal consent to participate. The field hockey clubs and trainers gave permission for this study and procedures were in accordance with the standards of the local medical ethics committee of the University of Groningen. The players completed the Interval Shuttle Run Test for interval endurance capacity on a synthetic field hockey playing surface (water-based pitch). Ambient temperature, humidity and wind conditions were documented. In addition, anthropometric measurements were taken and the players filled in questionnaires for training habits and motivation.

Anthropometric characteristics
Anthropometric measurements were height (m), lean body mass (kg) and percentage of body fat. The latter was estimated by means of leg-to-leg bioelectrical impedance (BIA) analysis (Valhalla BIA, Valhalla, Inc., San Diego, CA). This method proved to be reliable for measuring body fat percentage, and results correlated highly with body fat percentage as measured with underwater weighing and dual energy X-ray absorptiometry (Nunez et al., 1997).

Interval Shuttle Run Test
Interval endurance capacity was measured with the Interval Shuttle Run Test (ISRT) (Lemmink et al., 2000; Lemmink and Visscher, 2003). The ISRT is a field test that contains intervals at a work-rest ratio of 2:1 and turning points at 20 m. Players alternately run for 30 seconds and walk for 15 seconds. The running speed increases from 10 km/hour every 90
seconds until exhaustion. The number of fully completed 20-m runs is recorded as the test score. During the ISRT players were carrying their hockey stick. Although, as a result of the interval character of the test, anaerobic energy production is important, aerobic energy production as indicated by VO$_2$max contributes mainly to the total energy requirement during the test (Lemmink and Visscher, 2003). In previous research, the reliability of the ISRT as a maximal field test for intermittent sport players has been supported (Lemmink et al., 2000; 2004a). The ISRT also shows discriminative power for players at different levels of competition supporting the validity of the ISRT for measuring endurance in a more specific way (Lemmink et al., 2004b).

Training
In the questionnaire players were asked how many field hockey training sessions they attend per week and what the duration of these training sessions is. Time spend in matches is not included in the field hockey training since all players spend equal time in field hockey matches, on average 1 hour per week. Players also filled in how many times per week they train in other sports or by themselves and what the duration of these training sessions is. Time spend on physical education at school, which is on average 2.5 hours per week, is excluded. Outcome variables are field hockey training (hours/week) and additional training (hours/week).

Motivation
Motivation was measured using the Dutch youth version of the Psychological Skills Inventory for Sports. The Psychological Skills Inventory for Sports (PSIS-R-5) consists of 5-point Likert type items that are distributed over 6 scales (Mahoney et al., 1987). The PSIS-R-5 has been translated into Dutch and subjected to psychometric testing (Bakker, 1995; Companjen and Bakker, 2003). The Dutch Youth Version of the Psychological Skills Inventory for Sports (PSIS–Youth) is based upon the Dutch version of the PSIS-R-5, but the formulation of questions is simpler. The Motivation scale contains eight 5-point Likert type items. The answer almost never equates to 1, and almost always to 5. Items worded negatively (indicating a problem or concern) are transformed by reversing the aforementioned 1-5 format. In this way, a high score on each scale corresponds to the psychological skill being present to a large extent. The mean scale score was calculated which ranged from (1) low to (5) high. An example of an item is: ‘In my sport, I want to bring out the best in myself’.
Study design
Measurements were taken annually for three consecutive years from 2001 to 2003. As there were overlaps in ages between the clusters it was possible to estimate a consecutive 7-year development pattern. Although subjects returned each year, they were not measured exactly the same time each year. However, intervals between measurements were never less than 12 or longer than 13 months. The age of the subjects was recorded in months. To create standardized age groups, the players were classified into age groups at the time of measurement. A 14-year old player was defined as a player tested within the age range 13.50-14.49 years.

Data analysis
Longitudinal changes in interval endurance capacity were investigated using the multilevel modelling program MlwiN (Goldstein et al., 1998). Multilevel modelling is an extension of multiple regression, which is appropriate for analysing hierarchically structured data. In the present longitudinal data set, a simple two-level hierarchy was defined with the repeated measurements (defined as level 1 units) grouped within the individual players who form the level 2 units. An advantage of using a multilevel regression modelling approach is that both the number of measurements and the temporal spacing of the measurements may vary between players (Maas and Snijders, 2003). A multilevel model describes not only underlying population trends in a response (the fixed part of the model), but also models the variation around this mean response due to the time of measurement and due to individual differences (the random part) (Snijders and Bosker, 2000).

Following Snijders and Bosker (2000, chapter 12) the first step in the multilevel modelling of the interval endurance capacity data was to establish a satisfactory variance structure for these longitudinal data, using age (measured as months/12 - 15 years). Then, the difference between elite and sub-elite-groups was modelled, taking into account interactions with age and gender. In a next step, the effects of the anthropometric variables, height (m), lean body mass (kg), and percentage body fat, were investigated. Subsequently, the effect of the total number of training hours per week, as well as the effect of different types of training (distinguishing field hockey training and additional training) were investigated. Finally, the effect of motivation was tested.

5.3 Results
In Table 5.1, the players’ anthropometrics, training, motivation, and interval endurance capacity scores are presented by gender, performance level, and age.
Table 5.1. Mean scores (sd) of talented youth field hockey players presented by gender, performance level, and age.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>n</th>
<th>Age (year)</th>
<th>Height (m)</th>
<th>Lean body mass (kg)</th>
<th>% Body fat</th>
<th>Field hockey training</th>
<th>Additional training</th>
<th>Motivation (1-5)</th>
<th>ISRT (runs of 20m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male elite youth players</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-13 years</td>
<td>11</td>
<td>12.88 (0.55)</td>
<td>1.62 (0.06)</td>
<td>43.3 (5.1)</td>
<td>10.75 (2.82)</td>
<td>3.4 (0.7)</td>
<td>6.2 (2.7)</td>
<td>4.51 (0.35)</td>
<td>58.82 (18.64)</td>
</tr>
<tr>
<td>14 years</td>
<td>20</td>
<td>13.95 (0.29)</td>
<td>1.67 (0.07)</td>
<td>49.6 (7.0)</td>
<td>9.23 (2.48)</td>
<td>3.9 (1.2)</td>
<td>5.0 (4.5)</td>
<td>4.56 (0.30)</td>
<td>77.10 (23.03)</td>
</tr>
<tr>
<td>15 years</td>
<td>21</td>
<td>15.04 (0.30)</td>
<td>1.73 (0.07)</td>
<td>52.8 (6.7)</td>
<td>7.94 (2.48)</td>
<td>4.8 (2.2)</td>
<td>3.0 (2.4)</td>
<td>4.24 (0.50)</td>
<td>88.76 (22.53)</td>
</tr>
<tr>
<td>16 years</td>
<td>13</td>
<td>16.06 (0.27)</td>
<td>1.78 (0.04)</td>
<td>59.7 (4.3)</td>
<td>7.97 (2.70)</td>
<td>5.0 (1.7)</td>
<td>2.4 (2.5)</td>
<td>4.27 (0.51)</td>
<td>91.46 (21.55)</td>
</tr>
<tr>
<td>17 years</td>
<td>7</td>
<td>16.98 (0.31)</td>
<td>1.79 (0.06)</td>
<td>64.1 (2.9)</td>
<td>7.46 (3.03)</td>
<td>5.5 (1.4)</td>
<td>2.0 (2.0)</td>
<td>4.18 (0.58)</td>
<td>88.86 (29.13)</td>
</tr>
<tr>
<td>18-19 years</td>
<td>2</td>
<td>17.94 (0.24)</td>
<td>1.81 (0.05)</td>
<td>70.0 (0.3)</td>
<td>8.90 (1.12)</td>
<td>5.3 (1.1)</td>
<td>3.0 (2.8)</td>
<td>3.56 (0.80)</td>
<td>100.50 (0.71)</td>
</tr>
<tr>
<td><strong>Male sub-elite youth players</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-13 years</td>
<td>9</td>
<td>13.04 (0.40)</td>
<td>1.63 (0.09)</td>
<td>44.4 (7.3)</td>
<td>9.96 (4.72)</td>
<td>3.4 (0.7)</td>
<td>2.8 (2.7)</td>
<td>4.22 (0.44)</td>
<td>54.67 (23.77)</td>
</tr>
<tr>
<td>14 years</td>
<td>26</td>
<td>13.96 (0.32)</td>
<td>1.67 (0.08)</td>
<td>47.4 (6.8)</td>
<td>10.54 (5.90)</td>
<td>3.5 (0.6)</td>
<td>3.6 (4.4)</td>
<td>4.27 (0.44)</td>
<td>56.58 (18.64)</td>
</tr>
<tr>
<td>15 years</td>
<td>16</td>
<td>14.83 (0.32)</td>
<td>1.68 (0.10)</td>
<td>48.0 (8.8)</td>
<td>8.47 (4.49)</td>
<td>3.5 (0.9)</td>
<td>4.7 (4.0)</td>
<td>4.35 (0.38)</td>
<td>81.19 (26.16)</td>
</tr>
<tr>
<td>16 years</td>
<td>29</td>
<td>15.97 (0.31)</td>
<td>1.77 (0.06)</td>
<td>57.0 (6.5)</td>
<td>8.89 (3.93)</td>
<td>3.5 (0.7)</td>
<td>3.7 (3.5)</td>
<td>4.17 (0.50)</td>
<td>84.59 (20.48)</td>
</tr>
<tr>
<td>17 years</td>
<td>25</td>
<td>16.83 (0.34)</td>
<td>1.79 (0.06)</td>
<td>60.6 (6.3)</td>
<td>9.16 (4.45)</td>
<td>4.1 (1.4)</td>
<td>3.4 (3.0)</td>
<td>4.17 (0.63)</td>
<td>74.16 (27.16)</td>
</tr>
<tr>
<td>18-19 years</td>
<td>21</td>
<td>17.91 (0.45)</td>
<td>1.81 (0.05)</td>
<td>67.7 (4.4)</td>
<td>7.31 (4.33)</td>
<td>4.3 (0.9)</td>
<td>1.8 (2.5)</td>
<td>4.06 (0.64)</td>
<td>74.90 (21.49)</td>
</tr>
<tr>
<td><strong>Female elite youth players</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-13 years</td>
<td>12</td>
<td>12.95 (0.32)</td>
<td>1.56 (0.08)</td>
<td>38.3 (5.1)</td>
<td>15.64 (5.17)</td>
<td>3.5 (1.1)</td>
<td>5.3 (1.9)</td>
<td>4.54 (0.29)</td>
<td>48.50 (12.56)</td>
</tr>
<tr>
<td>14 years</td>
<td>17</td>
<td>14.01 (0.32)</td>
<td>1.62 (0.08)</td>
<td>41.9 (4.6)</td>
<td>19.05 (6.58)</td>
<td>3.7 (1.3)</td>
<td>3.3 (2.5)</td>
<td>4.55 (0.34)</td>
<td>58.35 (12.92)</td>
</tr>
<tr>
<td>15 years</td>
<td>18</td>
<td>14.98 (0.29)</td>
<td>1.66 (0.06)</td>
<td>43.9 (3.5)</td>
<td>21.57 (4.76)</td>
<td>4.4 (1.1)</td>
<td>2.3 (2.4)</td>
<td>4.57 (0.47)</td>
<td>65.67 (19.42)</td>
</tr>
<tr>
<td>16 years</td>
<td>15</td>
<td>16.07 (0.30)</td>
<td>1.67 (0.06)</td>
<td>44.5 (3.3)</td>
<td>22.65 (5.03)</td>
<td>5.5 (1.6)</td>
<td>1.5 (1.9)</td>
<td>4.36 (0.52)</td>
<td>59.80 (18.16)</td>
</tr>
<tr>
<td>17 years</td>
<td>9</td>
<td>17.00 (0.31)</td>
<td>1.69 (0.07)</td>
<td>48.5 (5.9)</td>
<td>18.88 (5.95)</td>
<td>6.0 (2.2)</td>
<td>2.5 (4.5)</td>
<td>4.68 (0.20)</td>
<td>61.00 (24.12)</td>
</tr>
<tr>
<td>18-19 years</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Female sub-elite youth players</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-13 years</td>
<td>14</td>
<td>12.89 (0.45)</td>
<td>1.61 (0.05)</td>
<td>39.8 (3.5)</td>
<td>17.94 (7.32)</td>
<td>3.1 (0.4)</td>
<td>2.1 (1.8)</td>
<td>3.91 (0.47)</td>
<td>47.79 (16.70)</td>
</tr>
<tr>
<td>14 years</td>
<td>25</td>
<td>13.88 (0.33)</td>
<td>1.64 (0.07)</td>
<td>42.3 (4.2)</td>
<td>18.20 (5.30)</td>
<td>3.1 (0.4)</td>
<td>2.7 (2.2)</td>
<td>4.19 (0.58)</td>
<td>57.08 (16.29)</td>
</tr>
<tr>
<td>15 years</td>
<td>18</td>
<td>14.92 (0.38)</td>
<td>1.66 (0.05)</td>
<td>41.8 (3.2)</td>
<td>21.18 (5.46)</td>
<td>3.3 (0.9)</td>
<td>1.5 (2.5)</td>
<td>4.06 (0.66)</td>
<td>51.44 (10.00)</td>
</tr>
<tr>
<td>16 years</td>
<td>27</td>
<td>15.88 (0.27)</td>
<td>1.69 (0.04)</td>
<td>44.5 (2.8)</td>
<td>24.02 (4.67)</td>
<td>3.4 (0.8)</td>
<td>1.4 (1.5)</td>
<td>3.93 (0.57)</td>
<td>48.88 (15.92)</td>
</tr>
<tr>
<td>17 years</td>
<td>21</td>
<td>16.79 (0.25)</td>
<td>1.69 (0.04)</td>
<td>45.7 (3.8)</td>
<td>25.23 (4.38)</td>
<td>4.5 (1.5)</td>
<td>2.2 (2.5)</td>
<td>4.23 (0.56)</td>
<td>51.29 (13.14)</td>
</tr>
<tr>
<td>18-19 years</td>
<td>16</td>
<td>17.84 (0.38)</td>
<td>1.71 (0.05)</td>
<td>51.06 (3.85)</td>
<td>21.95 (3.56)</td>
<td>4.7 (1.0)</td>
<td>1.8 (2.2)</td>
<td>4.31 (0.38)</td>
<td>46.35 (15.03)</td>
</tr>
</tbody>
</table>

Note: Field hockey training (hours per week) is exclusive of field hockey matches. Additional training (hours per week) is exclusive of physical education at school. 

a One missing value. b Two missing values.
As expected, in both male and female players height and lean body mass increase with age whereas percentage body fat tends to decrease in male and increase in female players. With age, players seem to increase their field hockey training and decrease their additional training. Motivation scores seem to remain relatively stable with age.

In Figure 5.1, predicted mean scores of the ISRT derived from the multilevel model are plotted against age for elite and sub-elite boys and elite and sub-elite girls. The general trend is that the interval endurance capacity increases with age in male youth players. However, elite youth players improve themselves more across time than sub-elite youth players. In females, the interval endurance capacity seems to increase with age in elite youth players only. Sub-elite youth players improve themselves until the age of about fifteen years and decrease their interval endurance capacity afterwards.

**Figure 5.1.** Predicted development of the interval endurance capacity of talented youth field hockey players in the age-band of 12-18 years.

It was found that a polynomial model of order 2 adequately represents the variance structure of the data (deviance 3394.0, difference with a fully saturated model of 43.9 on 36 degrees of
freedom, $p = 0.17$). The fixed part of the model contains a different intercept and linear age term for boys and girls, and a common quadratic term; the random part of the model as a common level 2 (between-individual) variance and gender-specific level 1 (measurement) variances. The model was significantly improved by including differential effects of performance level for age and gender (deviance 3367.8, difference with previous model 26.2 on 3 degrees of freedom, $p < 0.01$). No effect was found for height and lean body mass, but a significant negative effect was found for percentage body fat ($t = 4.423$, $p < 0.01$). A positive significant effect was found for additional training ($t = 3.374$, $p < 0.01$), whereas no effect was found for field hockey training as such. Finally, a positive significant effect of motivation was found ($t = 2.726$, $p = 0.003$). The model parameters are given in Table 5.2. The coefficients of the variables percentage body fat, additional training hours, and motivation are unstandardized. Their effects, however, can be interpreted such that an additional training hour could compensate for 1.23 % body fat (1.093/0.889), or likewise, is equivalent to 0.225 points on the motivation scale (1.093/4.86).

Table 5.2. Final multilevel model for interval endurance capacity data (377 measurements).

<table>
<thead>
<tr>
<th>Fixed effects</th>
<th>Coefficient</th>
<th>S.E.</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>52.6</td>
<td>9.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age (months/12 – 15 years)</td>
<td>6.21</td>
<td>1.20</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age$^2$</td>
<td>-1.83</td>
<td>0.363</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Boy</td>
<td>16.5</td>
<td>4.30</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sub-elite</td>
<td>0.786</td>
<td>2.90</td>
<td>0.393</td>
</tr>
<tr>
<td>Age x boy</td>
<td>5.27</td>
<td>1.33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age x sub-elite</td>
<td>-5.11</td>
<td>1.39</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Boy x sub-elite</td>
<td>-13.0</td>
<td>4.55</td>
<td>0.002</td>
</tr>
<tr>
<td>Percentage body fat</td>
<td>-0.889</td>
<td>0.201</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Additional training</td>
<td>1.092</td>
<td>0.324</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Motivation</td>
<td>4.86</td>
<td>1.87</td>
<td>0.003</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Random effects</th>
<th>Variance</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between-individuals</td>
<td>136.0</td>
<td>25.43</td>
</tr>
<tr>
<td>Within-boy</td>
<td>292.8</td>
<td>39.20</td>
</tr>
<tr>
<td>Within-girl</td>
<td>105.9</td>
<td>16.31</td>
</tr>
<tr>
<td>Deviance</td>
<td>3205.6</td>
<td></td>
</tr>
</tbody>
</table>
With the multilevel model for interval endurance capacity, knowing the age of a player, his or her percentage body fat, additional training hours and motivation, scores on the Interval Shuttle Run Test for elite and sub-elite boys and girls can be predicted. Derived from the model in Table 5.2, the equations for the four subgroups are:

**Elite boys:**
\[
\text{ISRT} = (52.6) + (16.5) + (6.21 + 5.27) \times \text{age} - (1.83 \times \text{age}^2) - (0.889 \times \text{percentage body fat}) + (1.092 \times \text{additional training hours}) + (4.86 \times \text{motivation})
\]

**Sub-elite boys:**
\[
\text{ISRT} = (52.6) + (16.5) + (0.786) - (13.0) + (6.21 + 5.27 - 5.11) \times \text{age} - (1.83 \times \text{age}^2) - (0.889 \times \text{percentage body fat}) + (1.092 \times \text{additional training hours}) + (4.86 \times \text{motivation})
\]

**Elite girls:**
\[
\text{ISRT} = (52.6) + (6.21 \times \text{age}) - (1.83 \times \text{age}^2) - (0.889 \times \text{percentage body fat}) + (1.092 \times \text{additional training hours}) + (4.86 \times \text{motivation})
\]

**Sub-elite girls:**
\[
\text{ISRT} = (52.6) + (0.786) + (6.21 - 5.11) \times \text{age} - (1.83 \times \text{age}^2) - (0.889 \times \text{percentage body fat}) + (1.092 \times \text{additional training hours}) + (4.86 \times \text{motivation})
\]

Thus, the development of the interval endurance capacity in the age-band from 12-19 years can be predicted with the multilevel model. For instance, it is predicted that an elite male player of fifteen years old will increase his performance on the Interval Shuttle Run Test in one year with \((6.21 - 1.83 + 5.27) = 9.65\) runs. In contrast, in the period from fifteen to sixteen years old, a sub-elite male player will increase ‘only’ with \((6.21 - 1.83 + 5.27 - 5.11) = 4.54\) runs. An elite girl is predicted to achieve an extra \((6.21 - 1.83) = 4.38\) runs whereas a sub-elite girl will run \((6.21 - 1.83 - 5.11) = 0.73\) runs less according to the model.

In Figure 5.2 the data are represented for the four different gender and performance groups. In the figure, the lines connect two or three individual yearly observations; the points are single individual observations. The bold solid lines depict the estimated mean ISRT score.
for “average” representatives of each group, i.e., with mean scores on percentage body fat, additional training hours and motivation (8.65, 3.82, and 4.35 for elite boys; 9.15, 3.36, and 4.2 for sub-elite boys; 20.0, 2.84, and 4.53 for elite girls, and 21.6, 1.94, and 4.11 for sub-elite girls, respectively).

The dotted lines around the bold line indicate the 95% confidence region taking into account between-individual (level 2) variation. This variation is estimated by the level 2 variance of 136 (see Table 5.2), which is equivalent to a standard deviation of approximately 12 runs, indicating rather large differences between individuals as is also apparent from Figure 5.2.

The curvature of the lines represents the fitted second-order polynomial (quadratic) model. It can be observed that the linear effect of the model is most strong for the elite boys and least strong for sub-elite girls, and approximately equal for sub-elite boys and elite girls (due to the interaction effects with age and sub-elite). Also visible from the figure is the rather large within-individual (level 1) variance, which is much larger for boys than for girls, estimated as 292.8 (equivalent to a standard deviation of about 17 runs) and 105.9 (standard deviation about 10 runs), respectively.

Figure 5.2. Predicted curves of the interval endurance capacity for elite boys, sub-elite boys, elite girls, and sub-elite girls.
5.4 Discussion

Talented field hockey players of twelve years old score on average 35 runs on the Interval Shuttle Run Test, regardless whether they are a boy or a girl, an elite or a sub-elite player. Only elite girls score on average 10 runs less, which may indicate that at the age of twelve years it is still possible for talented girls in field hockey to compensate a relatively low interval endurance capacity with other performance characteristics, such as great technique and tactics.

During adolescence, differences between boys and girls become apparent. Boys have a much faster development of their interval endurance capacity than girls but also within the male and female group differences are remarkable. At the age of fifteen, elite boys score on average 15 runs more than sub-elite boys (85 versus 70 runs). At the age of eighteen this difference has grown to 30 runs (100 versus 70 runs) because elite boys still improve in contrast to sub-elite boys who seem to remain relatively stable. Although elite girls start of with a lower score on the ISRT when they are twelve years old, they catch up with sub-elite girls at the age of about fourteen. At fifteen, they are already better and they keep improving themselves. After about seventeen years of age they seem to remain relatively stable. The curve of the elite girls resembles that of the sub-elite boys to a high degree in contrast to the sub-elite girls who increase their number of runs until the age of fifteen and decrease afterwards until they fall back to the levels of twelve-year-olds again.

During the Interval Shuttle Run Test for interval endurance capacity both the aerobic and anaerobic energy production contribute to the total energy requirement (Lemminink and Visscher, 2003). In a ‘normal’ population of adolescents, boys increase their aerobic and anaerobic performance with age whereas girls improve to 14-15 years with a gradually decrease afterwards (e.g., Martin and Malina, 1998; Kemper and Koppes, 2004). The development of the interval endurance capacity of talented youth field hockey players, however, is not quite the same as that of ‘normal’ adolescents. Instead of decreasing their performance after the age of fifteen, elite girls are able to sustain the improvement of their interval endurance capacity. Although boys and sub-elite girls seem to follow the ‘normal’ pattern, elite boys improve themselves more than sub-elite boys on the interval endurance capacity.

Although small (one hour extra training represents only one extra run on the Interval Shuttle Run Test), additional training was found to have a significant effect in improving the model. The explanation that we did not find such effect for field hockey training may be that during field hockey specific training more attention is paid to improving other aspects of a field hockey performance, such as technique and tactics than to endurance capacity. We found a large variation in additional training between players. In some cases the standard deviation
was greater than the amount of additional training itself. Apparently there are major differences concerning the amount of additional training between talented players, as well within the elite group as within the sub-elite group.

Motivation was found to have a significant effect in improving the model. The Interval Shuttle Run Test to measure the interval endurance capacity is a maximal test. The intense activity needed in this test causes uncomfortable side effects such as fatigue and muscle soreness, and a player has to be very motivated to continue running until exhaustion. Motivation can be defined as the direction and intensity of one’s effort. The direction of behavior indicates whether an individual approaches or avoids a particular situation and the intensity of behavior relates to the degree of effort put forth to accomplish the behavior (Silva and Weinberg, 1984). Possibly, motivation in sports is one of the greatest differences between ‘normal’ adolescents and talented field hockey players. The latter are more motivated to get the best out of themselves and elite youth players want this even more than sub-elite youth players. Since the road to the top is long, motivation is not only essential for current performance in a match or test, but also in talent development. Talented players have to devote long hours of training for many years in a row in order to improve their performance level (Ericsson et al., 1993; Ericsson, 1996).

Height and lean body mass gave no significant improvement of our model for the development of the interval endurance capacity. Therefore, any difference between a ‘normal’ population of adolescents and this population cannot be explained from these anthropometric variables. However, we did find a significant negative effect for percentage body fat. This is in line with a study on young male gymnasts, swimmers, soccer, and tennis players (Baxter-Jones et al., 1995). Training did not appear to have affected these young athletes’ growth and development. However, training can have an effect on percentage body fat (e.g., Astrand et al., 2003).

There is a rather large variation in interval endurance capacity within and between players. The within-persons variation, i.e. the variance between measurements, is noticeable especially in boys and elite girls. This variation was based upon those players that have been tested repeatedly, which is less than half of the population. Consequently, some bias in this random effect may have occurred, possibly overestimating it. Since previous research underscored the reliability of the ISRT, we do not doubt the reliability of the test (Lemmink et al., 2004a). However, we do not have a clear alternative explanation for this phenomenon. It might have to do with the moment of testing. At the end of the season, the most important matches are played and when players are tested a couple of days before an important match, they might be inclined to take it easy at the test. Other explanations might be differences in weather conditions or previous training sessions for which it was impossible to control for.
The between-persons variation is based on the total population and is distinct in the total age-band of 12-19 years. Evidently, a field hockey performance can be broken down into many multidimensional performance characteristics, from which the interval endurance capacity is only one (Nieuwenhuis et al., 2002; Elferink-Gemser et al., 2004). The combination of anthropometric, physiological, technical, tactical, and psychological characteristics results in a player’s performance level (Elferink-Gemser et al., 2004). In their young adolescent years, players still can compensate for less developed performance characteristics such as their interval endurance capacity. However, towards expertise performance demands increase and all players need to meet high values for all performance characteristics, including the interval endurance capacity. Therefore, it is possible for sub-elite players to possess a great interval endurance capacity, for example because they spend a lot of time to additional training, but when lacking a high level of other performance characteristics they will not be able compete at the highest performance level after all.

In sum, the development of the interval endurance capacity of 12-19 year-old talented field hockey players can be modeled with a polynomial model of order 2 with gender- and performance level specific intercepts and linear age terms as well as different level 1 variances for boys and girls. Differential effects of performance level for age and gender significantly improved the model. Results show that during adolescence both male and female elite youth players have, on average, a more promising development pattern of their interval endurance capacity than sub-elite youth players. After taking into account the effect of percentage body fat, additional training hours, and motivation, the remaining differences between individual players are considerable.
References


voetbaltests. [Interval Sprint Test and Interval Shuttle Run Test – reliability and discriminative power of two new tests for soccer players]. Geneeskunde en Sport, 33, 39-48.


