Soccer: Exercise Physiology

by Jan A. Vos, PhD, Exercise Physiologist, Netherlands, www.ja-vos.nl/
Introduction:

• Contents of this lecture: We try to inform you concerning the situation in Holland of soccer players in the highest division, so called “ere-divisie”, but our main purpose is youth soccer players. Also a large report concerning Soccer written by Jan A. Vos, PhD, Exercise Physiologist will be available. For more information contact www.ja-vos.nl/
Body Composition

- During **off season** period professional soccer players must keep themselves in a good shape, no large differences in body weight (% Fat). **Control:** end of season: Body weight, measuring % body fat and calculating FatFreeMass(kg) and of course when the pre-season training starts repeat these measurements.

- *During season* two or three times repetition of those measurements. Nutrition advice after the results are discussed.
Off season start

- **Nutrition in football:**
- Until recently football was classified as ‘endurance sport’ because you have to play at least for 90 minutes and run between 8 and 14 Km per match. But, compared to running and cycling, soccer players need less carbohydrates, proteins or fat. Ron Maughan (Loughbrough University) controlled 51 players in the Scottish Premier League and found average intake of 2620-3050 kcal daily. But in textbooks, still nowadays, is mentioned 4200 kcal for soccer players!
Nutrition continued

• When you train **seven** times a week, instead of three, than 4200 kcal are more realistic values. An athlete diet must be **high** in carbohydrate, **moderate** in protein and **low** in fat, but with sufficient vitamins and minerals and plenty of fluid.

• The **glycaemic index** of foods, a ranking of foods based on their **immediate effect on blood glucose** is very useful in soccer. Low GI-factor means longer time without ‘hungry’ feelings, high GI-factor means after a short time again ‘hungry’. (Willett, a.o.).
<table>
<thead>
<tr>
<th>Country</th>
<th>Number players</th>
<th>Energy (kcal)</th>
<th>Carboh. (%)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
</tr>
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<tbody>
<tr>
<td>Sweden</td>
<td>15</td>
<td>4929</td>
<td>47</td>
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<td>38</td>
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<tr>
<td>Italian</td>
<td>33</td>
<td>3066</td>
<td>56</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Italian</td>
<td>20</td>
<td>3650</td>
<td>55,8</td>
<td>28,3</td>
<td>15,9</td>
</tr>
</tbody>
</table>
(De)Hydration

- **Weighing** players **before** and **after** training/match gives an indication of their level of **dehydration** and risk of heat illness. A weight loss of 1 kg is, roughly speaking, 1 liter of body fluid, lost from the lungs and through the skin. **Measure also the personal bottles!!** Not only weighing! Measuring **sweat** (salt) losses is a more sophisticated measure but more expensive equipment you need for correct analysis. The better acclimatised players have lower sweat contents, but large individual differences are possible (2 till 10 grammes).
(De)Hydration…

- **Average sweat** loss is about 2 liters, range from 1 to over 3 liter. 2 % weight loses < performance!!
- **Average fluid intake** is 800 – 1000 ml, range from 250 to over 2000 ml. There is **no relationship** between the amount of sweat a player loses and the amount he drinks.
- **Sweat salt** (=sodium chloride) losses can reach almost 10 gramme in a single training session and that two times training a day makes 20 gramme! Other players lose only amounts like 2 gramme.
(De)Hydration…

• When training takes place in the cold (like Finland!) sweat losses may be almost as high as when training in the heat, but players drink far less and end up just as dehydrated, or even more so.

• Don’t drink too much, as some players do, but drink enough to limit weight loss to no more than 1 or 2 % of the pre-exercise weight.

• High salt losses can be a serious factor for muscle cramps in training and competition!
Physical Fitness Tests

• **Physical Fitness Tests** has to be carried out for all players at the very **beginning** of training so that there will be a **clear baseline** from which improvements could be realized. Mental preparation means also winning the first game!

• Important factors while constructing a **test battery**:
  • A. **Sufficient equipment available?**
  • B. **Trained staff to evaluate the test results.**
  • C. **Implantation test results in trainingschedule.**
Design Test Battery

• 1. Measuring **Body Composition**: Body weight, Height; Percentage Body Fat; FatFreeMass; ‘Normal’ Body weight.

• 2. **VO2max** (L.min; ml.kg.min and ml.kgffm.min).

• 3. **Maximal Strength** of large muscle groups like trunk flexion; backward extension; arm extension and flexion; legs extension, etc.

• 4. ‘**Explosive Strength**’, Maximal Jump and endurance jump (15 sec).

• 5. **Shuttle run** test.
Design Test Battery

• **5. Telemetry heartfrequency.** During training and out of competition matches. Systems like Polar or Suunto/First Beat or Pro Pulses Plan (Canada) are used.

• **6. Food intake control by questionnaires,** related to activity state questionnaire. We use Fuel Nutrition software (Canada).

• We *only* discuss here the exercise physiology tests!
Explanation test battery design:

- **Body Composition**: Method: Durnin/Womersley that means 4 skinfolds and calculation by software procedures also for fat free mass (=FFM). ‘Normal body weight’= relationship between height and sum of both epicondyli allows to calculate the ‘normal body weight’ concerning somebodies body stature. (Method De Wijn a.o).

- **VO2max** = aerobic capacity, Method Åstrand. Important measure for *general endurance*.

- **Maximal Strength**, see slides (Vos-test software).
Explanation test battery design:

- *Explosive Strength*, measured by use of jumping mat (former Bosco/Viitasalo mat) software Vosjump. Many test possibilities are developed.
- **Shuttle run test**, modified after Bangsbo.
- **Telemetry Heartfrequency** (=Hf) by Polar or Suunto system during training or out of competition matches.
- **Nutrition**: Food intake questionnaires and activity state forms for individual use. (We use Fuel and ProPulsePlan software, see examples).
Heart rate registration prof. soccer player

- Hf.max
- Anaerobic
- Aerobic

Warm-up

Ball contact

Date: 01-26-1990
Ball contact

Hf.max

Goal!!

Aerobic
Heart rate curve total match Forward player

Hf.max

Anaerobic

Aerobic

Average Hf.Forward=164
Above Anaerobic limit = 56 %

Source: HEART RATE DURING MATCH. PROF. FORWARD SOCCERPLAYER.
Date: 01-26-90

Total time: 91 min

Over Anaer. limit: 51 min = 56 %
Between Anaer. - Aerob. limit: 34.8 min = 38.2 %
Below Aerob. limit: 5.3 min = 5.8 %

Anaer. limit: 164
Aerob. limit: 135
Defender deH

Summary whole match

Over Anaerobic limit = 22 %
Warm-up

• **Common, Non-specific warm-up:**
  1. Six to eight minutes of jogging, followed by neck, shoulder, lower back and abdominal stretches.
  2. Use two-three different routines with 10-12 reps for hamstrings, hip flexors, abductors, quads and calves muscles. Passive and dynamic stretches, increase speed step by step.
  3. Varying-intensity in different directions of sprints.
  4. Hf. at the end of warm-up between 160-170 bpm.
Warm-up

• **Specific warm-up:**
  1. Various kicks of the ball with **both** legs, various technical moves with the ball, such as dribbling and stopping the ball. Medium intensity with one other player and then to high intensity with more players into groups practise all skills with the highest possible intensity at the end. (Method: Spassov).
Young Soccer players:

- **Prepubertal young soccer players (A)** were followed 3.3 years (n=17) compared with 11 matched controls (B). They played soccer for at least 1 year before and 3 times per week. The controls followed 2 times 45 minutes a week a general physical education programme at school.

- **Results**: 1. Group A greater bone mineral content and density in all bone regions. 2. Group A: % Fat remained unchanged, group B increased! 3. Total FatFreeMass increased by > 6 % in group A. 4. In A: better results in 300 m run and 20 m Shuttle run.
Young Soccer players:

• Effect on flexibility training methods and hamstrings strain (=HS) rates were followed in 30 football clubs in 4 divisions (1998/99).

• Results: Hamstring strains (HS) represented 11% of all injuries and > 30% of all muscle strains! About 14% of hamstring strains were reinjuries! Hamstring strains were highest in the Premiership and lowest in division 2. The majority of HS were minor or moderate, two thirds occurring in the late stages of training sessions/matches. Forwards were most often injured.
Young Soccer players:

• A standard stretching protocol (warm-up session followed by static stretching over 15-30 seconds) was the only factor significantly related to hamstring strain rates, suggesting a protective effect. Holding time is important, not the number of repetitions!

• Australian research showed that stretching had no influence on kicking kinematics. Possible explanation: the foot speed at impact with the ball is a function of complex neuromuscular patterns from many other muscles.
Young Soccer players:

- From birth through adolescence our **muscle mass** increases steadily. In **boys** muscle mass peaks at **18-25 yrs** when testosterone production increases by a factor 10! **Girls** muscle mass peaks at age **16-20 yrs** without sharp increase. Myelination of nerve fibers speeds the transmission of electrical impulses and must be completed before fast reactions and skilled movements are fully developed. VO2max peaks between ages **17-21 yrs** in males and **12-15 yrs** in girls, after which it steadily decreases.
Young Soccer players:

• A child’s $\text{VO2max}$ is similar to an adult’s in distance running, child’s performance is inferior to an adult’s performance because of differences in economy of effort! Lower concentration in children of the key rate limiting enzyme phospho-fructokinase makes the anaerobic capacity lower in children compared to adults! Children have less lactate production.

• Regular training: < % Fat; > FFM in boys; > total body mass; no apparent effect on growth in height or maturation (Malina)
Young Soccer players:

• Player development: From 9 years accent on: movement patterns and skill development; Coordination and balance training; Proprioception training, all the whole year around!!

• Strength training: see hand-out!!

• Coordination and teaching technique are optimal between 7 and 11 years of age in males and females. Do **not** train anaerobic capacity and maximal strength during ‘second growth spurt’, that means in girls between 10 and 14 yrs and boys 12-16 yrs.
Young Soccer players:

• Perhaps we can better speak in terms of ‘short interval explosions’ than of anaerobic capacity in young children because we talk about seconds instead of minutes!

• Mechanical, neuromusculair and anthropometric factors are of more influence than anaerobic capacity in children!

Thermoregulation in children: Children sweat less than adults and have relative large body area and produce more heat per kg body weight than adults. They tolerate less well heat in very warm circumstances than adults, result—exhaustion.
Young Soccer players:

• Increase in rectal temperature, level of dehydration and circulation function are **not stronger** influenced in warm circumstances in children compared to adults.

• **Growth development:** * Peak rate of height growth occurs at age of 12 in girls and at age 14 in boys.
  * Full height 16-17 yrs in girls and 18 yrs in boys.
  * Growth in weight **same** as in height.
  * Injury at the epiphysis cause early termination of growth.
Body weight

Selection: 1 = A-sel; 2 = A1-sel; 3 = B1-sel; 4 = C1-sel.
Body height

Selecties: 1 = A-sel;  2= A1-sel;  3= B1-sel;  4= C1-sel

Vos,2000
Percentage Fat

Vos, 2000

Selection: 1 = A-sel; 2 = A1-sel; 3 = B1-sel; 4 = C1-sel.

Talent
Drop out
Maximal Jump (sec)

Selection: 1 = A-sel; 2 = A1-sel; 3 = B1-sel; 4 = C1-sel.

Talent
Drop out

Vos, 2000
Endurance Jump (15 sec)

Selection: 1 = A-sel; 2 = A1-sel; 3 = B1-sel; 4 = C1-sel.

W.kg

1
2
3
4

Vos, 2000

Talent
Drop out
VO\textsubscript{2} max (L.min)

Selection: 1 = A-sel; 2 = A1-sel; 3 = B1-sel; 4 = C1-sel.

Vos, 2000
Soccer: Changes during season 2001/2002 in VO2max (ml.kg.min)

Blue=2001; Orange=2002

Age (yrs) selections
Soccer: Changes during season 2001/2002 in $\text{VO}_2(\text{ml.kg ffm.min})$

Blue=2001; Orange=2002

Age(yrs) selections

<table>
<thead>
<tr>
<th></th>
<th>27</th>
<th>19</th>
<th>17</th>
<th>15</th>
<th>13</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>A1</td>
<td>B</td>
<td>B1</td>
<td>C1</td>
<td></td>
</tr>
</tbody>
</table>
Soccer: Changes during season 2001/2002 in Maximal Jump (sec) 

Blue=2001; Orange=2002

Vos, 2002
**Soccer: Changes during season 2001/2002 in Endurance Jump (15 sec) in W.kg**

Blue=2001; Orange=2002

<table>
<thead>
<tr>
<th>Age (yrs) selections</th>
<th>W.kg·¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 27</td>
<td>19</td>
</tr>
<tr>
<td>B 19</td>
<td>18,5</td>
</tr>
<tr>
<td>A1 17</td>
<td>18</td>
</tr>
<tr>
<td>B1 15</td>
<td>17,5</td>
</tr>
<tr>
<td>C1 13</td>
<td>17</td>
</tr>
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</table>

Vos, 2002
Personal Fitness – Team success

• Iceland study: n=306 from 17 teams soccer players.
• Test battery: A. VO2max; B. Body Composition; C. Leg extensor power; D. Jumping ability and E. Flexibility. Team physiotherapists record the injuries on a special form.

• Results: Significant differences in VO2max and body composition (% fat) between elite and first division players. Team average for jumping height and team success (standing in final league stand) was a significant relationship. Fewer injuries during the season shows better final league standing.
Personal Fitness – Team success

• Midfielders were older than strikers; defenders taller than midfielders and strikers more powerful than midfielders.

• Comment on the study by Jan A. Vos, Exercise Physiologist: To predict team performance from physical tests results is hardly possible. In Holland we can at least compare the fitness tests results with large numbers of tested soccer players. In case of low results the training staff can take measures to stimulate the player. Of course team tactics, player individual technique etc, are important factors also.
Young Soccer players:

<table>
<thead>
<tr>
<th>Energy stores:</th>
<th>Rest</th>
<th>Exercise</th>
<th>Comparison Child-Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATP</strong> supply in mMol.kg muscle</td>
<td>3.5</td>
<td>5</td>
<td>equal</td>
</tr>
<tr>
<td><strong>PCr</strong> supply in mMol.kg muscle</td>
<td>12</td>
<td>22</td>
<td>smaller or equal</td>
</tr>
<tr>
<td><strong>Glycogen</strong> supply in mMol.kg muscle</td>
<td>45</td>
<td>75</td>
<td>smaller (Bar-Or,a.o.)</td>
</tr>
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</table>
Young Soccer players:

- Resistance (Strength) training in young soccer players:

- Accent on strength development in boys starts above 14 years of age, in girls on 12 years of age!

- Accent on maximum strength development in boys starts above 18 years of age, in girls on 16 years of age!

- Volume of training = technique training always before increase in intensity!!
Young Soccer players:

- **Resistance training in young soccer players:**
  - **Age <= 7 years** Basic exercises with little or no weight so mainly with ‘only’ body weight; exercise technique most important; training volume low; with pairs instead of only individual.
  - **Age 8 – 10 years** Gradual progressive loading of exercises and volume; tolerance of load careful controlled; accent on technique; avoid intensive training.
  - **Age 11 – 13 years** Progress to more advanced programs in resistance training; increase volume and add sport specific components.
Young Soccer players:

• **Resistance training in young soccer players:**
  - **Age 14 – 15 years** Progress to more advanced youth programs in strength training; more sport specific components; increase volume and emphasize exercise techniques.
  - **Age 16 years or older** Start with adult programs after you are convinced that all basic technique and background knowledge has been mastered.

(Kraemer, Fleck, 2005)
Young Soccer players:

- **Start Youth Strength Training:**
  1. **Per station** (circuit training) 10-20 repetitions.
  2. **No intensive** reps.
  3. **No eccentric** exercises.
  4. Per exercise **one series.**
  5. Starting period = **months** instead of weeks!
  6. Also **hip-stabilizer** exercises.
  7. Also **rotation- and neck musles** training.
  8. Adequate warm-up and cool down.
  9. Teach stretch exercises well.
  10. Combined with **flexibility** and **coordination/balance** exercises.