Endurance training and young people

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Overview

• Training young people
  – Unique considerations
  – Application to developing athletic potential
• Can young people benefit from endurance training?
• Training recommendations
• Conclusions
Exercise training: definition

Exercise training

“exercise is physical activity that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective” Caspersen et al. (1985)

Uses the principles of:

- Frequency, intensity, duration and programme length
- Must be individualised, specific, cause overload and accommodate progression
“It is a grave mistake to submit children to training programs of adults. After all, children are not simply little adults” (Bompa, 2000)

• Health and well-being concerns
  – Musculoskeletal injury
  – Growth and maturation
  – Overtraining/burnout
  – Dropout

• Is training effective in this population?
  – Changes mirror that gained due to growth and maturation
  – Different aerobic and anaerobic capacities
  – Having the ‘right’ hormonal milieu
  – Young people are already habitually active
Exercise training in young people: possible responses
Is there a “golden period” for training young people?

Katch’s trigger hypothesis

“this hypothesis predicts that, pre-pubertally, there will be only small training-induced biological alterations because of the lack of hormonal control.....post-puberty exercise-induced changes are well documented and follow predictable patterns” (Katch 1983)
Katch’s ‘trigger hypothesis’

The young athlete and training

- Long-term athlete development model (LTAD)
- Used by UK national governing bodies as the first step for talent development
- Model ties together athletic development alongside the principles of biological growth and maturation
  - Optimise performance longitudinally
  - Proposes a number of ‘windows of opportunity’
LTAD model and ‘windows of opportunity’

Can young people benefit from endurance training?

- Cross sectional studies
  - Peak oxygen uptake
  - Lactate markers
  - Exercise economy
  - Oxygen uptake kinetics

- Training studies
  - Peak oxygen uptake
Why these markers?

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Performance measure</th>
<th>Predictors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daniels et al. (1978)</td>
<td>10-18 year old male middle and long distance runners</td>
<td>1 mile time, 2 mile time</td>
<td>Economy, Economy</td>
</tr>
<tr>
<td>Sjodin (1982)</td>
<td>11-15 y old male middle distance runners</td>
<td>400 m, 1,000 m, 3,000 m, 4.2 km x-country</td>
<td>OBLA, muscle power, OBLA, muscle power, OBLA, Peak VO$_2$</td>
</tr>
<tr>
<td>Unnithan et al. (1995)</td>
<td>11-12 y old male middle distance runners</td>
<td>3,000 m</td>
<td>Peak VO$_2$, lactate threshold, economy</td>
</tr>
<tr>
<td>Almarwey et al. (2003)</td>
<td>16 y old male and female middle distance runners</td>
<td>1,500 m</td>
<td>B: Velocity at 2.5 mM, peak VO$_2$, v-VO$_2$max, G: Velocity at 2.5 mM, peak VO$_2$, v-VO$_2$max</td>
</tr>
<tr>
<td>Unnithan et al. (2009)</td>
<td>15 y old female swimmers</td>
<td>200 – 1,000 m and ranking</td>
<td>Economy</td>
</tr>
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</table>
Development of peak VO$_2$ in young athletes

1. 8-15 y (27 boys, 27 girls) road racers (>10 k) undertook annual measures over 3-5 y. Training volume was ~ 35-40 km/wk.

2. 10-19 y (48 boys, 22 girls) x-county or track runners. Training volume was ~ 48 and 35 km/wk for boys and girls respectively.

Trained vs. untrained for peak VO$_2$

Blood lactate and exercise economy

Considerations

• Nature or nurture the cause?
• Problems with control group selection
  – Age, sex and maturity
  – Physical activity status
• Training recommendations are difficult
  – Not always described
  – Volume not standardised or objectively quantified
    • Often days/wk or yr, km/day or min/day
    • Basic descriptors: continuous or interval
  – Dose-response not possible
Why do trained young people have a superior peak VO₂ peak compared to their untrained counterparts?

**Fick equation**

\[ \text{VO}_{2\ max} = Q_{\max} \cdot (\text{CaO}_2 - \text{CvO}_2) \]

Central and peripheral factors

<table>
<thead>
<tr>
<th></th>
<th>Maximal Untrained</th>
<th>Maximal Cyclists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac index (L m⁻²)</td>
<td>10.6 ± 0.8**</td>
<td>12.2 ± 1.0</td>
</tr>
<tr>
<td>Arterio-venous difference</td>
<td>13.4 ± 1.2</td>
<td>14.0 ± 1.5</td>
</tr>
<tr>
<td>mm BSA⁻⁰.⁵)</td>
<td>33.5 ± 2.9</td>
<td>37.6 ± 4.0*</td>
</tr>
<tr>
<td>Left ventricular end-systolic</td>
<td>19.6 ± 3.2**</td>
<td></td>
</tr>
<tr>
<td>mm BSA⁻⁰.⁵)</td>
<td>16.2 ± 2.0</td>
<td></td>
</tr>
<tr>
<td>Shortening fraction (%)</td>
<td>51.3 ± 6.4</td>
<td>48.0 ± 5.8</td>
</tr>
<tr>
<td>Systolic time (ms)</td>
<td>134 ± 12</td>
<td>131 ± 8</td>
</tr>
<tr>
<td>Diastolic time (ms)</td>
<td>195 ± 13</td>
<td>181 ± 11</td>
</tr>
<tr>
<td>Systolic arterial pressure (mmHg)</td>
<td>153 ± 17</td>
<td>153 ± 16</td>
</tr>
<tr>
<td>Diastolic arterial pressure (mmHg)</td>
<td>68 ± 10</td>
<td>71 ± 8</td>
</tr>
<tr>
<td>Systemic vascular resistance (AU)</td>
<td>6.7 ± 1.1</td>
<td>6.8 ± 1.1</td>
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Augmented SV and muscle O\textsubscript{2} extraction patterns in trained youth

Blood $O_2$ carrying capacity and volume

Eight well-trained boys

$VO_2$ peak = 59.6 \pm 6.5$ ml/kg/min

Trained status and O$_2$ uptake kinetics

• Successful sports performance requires rapid changes in energy demand to be achieved aerobically preventing the premature depletion of finite anaerobic energy stores
O$_2$ uptake kinetics and the O$_2$ deficit

- ↓PCr, ↑Pi, ↑ADP
- ↑glycolysis
- ↑La$^-$ and H$^+$
Can VO$_2$ kinetics be trained in youth?


Physiological adaptations summary

Does training status influence BV?

Due to an ↑ muscle oxidative capacity which could improve matching of perfusion to demand?

Delayed ↓ in O₂ extraction at exercising muscle

Peak VO₂
↑ in trained children by ~5-6%

↑SV + ~ HR = ↑ Q

VO₂ kinetics
Phase II ↑ faster in trained children

Slow component unchanged

GET
Is an influence of training applicable to training in children?

Exercise economy
Only one exercise modality has been investigated – more modalities need to be studied

Morphological:
↑ LV dimension & mass
Are IV and posterior wall thickness influenced?

Functional:
↑ resting SV
Progressive ↑ during ramp incremental exercise

Does training status influence BV?

If they are influenced, what is the mechanistic basis and why does the influence on the GET differ in children and adults?

Some studies show ↑ but others show no influence – requires resolution

Abbreviations

Key

Accepted
Equivocal/Resolution required

BV Blood volume
VO₂ Oxygen uptake
SV Stroke volume
HR Heart rate
Q Cardiac output
LV Left ventricular
IV Intraventricular
GET Gas exchange threshold

No influence of maturity stage. Is this true for both aerobic and anaerobic training? True irrespective of sex?

Review of endurance training interventions

Criteria for inclusion:
• Published in peer-reviewed literature
• Participants are ‘normal’ and healthy
• Aged between 8.0 to 17.9 y
• Included a control and experimental group
• Used appropriate statistical analysis techniques
• Provide a clear training prescription
• Directly determined VO$_2$ peak

69 studies were located but only 21 satisfied the criteria

Studies reported as two groups: 8.0-10.9 y and 11.0-17.9 y

Methodological considerations

• Participants are not randomly allocated
• Sample sizes are small and often uneven
  – EXP: 8-37, mean = 15; CON: 7-37, mean = 12
• Drop-out rates and training adherence is poorly reported
• Testing and training specificity is generally high although exceptions are evident
• Heart rate is used to quantify training intensity
  – All participants, random selection, self-report, none

Key findings

8.0-10.9 y
• 9/14 (64%) studies reported a significant increase in VO$_2$peak (mean = 6.7%)
  – 7.7% if only considering the successful studies

• Nine studies confirmed participants were pre-pubertal

• No sex differences evident

11.0-17.9 y
• 4/7 (57%) studies reported a significant increase in VO$_2$peak (mean = 5.5%)
  – 8.6% if only considering the successful studies

• Only a single well-controlled study is available > 14 y (9.3% improvement)

• No sex differences evident

Do children have a dampened aerobic trainability?

- Does their high initial fitness reduce the scope for improvement?
- Does their higher level of habitual physical activity reduce the scope for improvement?
- Is a maturational ‘trigger’ needed to promote improvements?
- Do they require a different training stimulus compared to that normally recommended for adults?
Does baseline fitness matter?


Are children too active to improve their fitness?


140 boys and 108 girls aged 8-11 y

Vigorous PA and peak VO$_2$ significantly correlated in boys and girls (~ 9% variance)

Tolfrey et al. (1998) found no relationship between initial physical activity level and the improvement in VO$_2$ peak over a 12 week training programme in prepubertal children
The “trigger hypothesis”: is there a golden period?


12 pairs of *mz* twins completed a 10 wk endurance training

McNarry *et al.* (2011). *J Appl Physiol*

No interaction between training status and maturity group found.
The “trigger hypothesis”: evidence from review articles

• Armstrong and Barker (2011)
  – 8-10.9 y = 6.7% (n=14)
  – 11-17.9 y = 5.5% (n=7)

• Baquet et al. (2003)
  – Prepubertal boys = 6.1% (n=11)
  – Prepubertal girls = 6.9% (n=7)
  – Circumpubertal boys = 7.6% (n=1)
  – Circumpubertal girls = -1.5% (n=1)
Are children less trainable than adults?

Prepubertal boys and men were assigned to a high, low or control training group:

- High = 85% HRmax
- Low = 68% HRmax

Training occurred 3 times/wk for 10 wk and ranged from 2.4-4.8 km

Large inter-individual differences exist for aerobic trainability

Data from Williams et al. (2000) noted a 7.2 and 3.8% improvement in peak VO\textsubscript{2} following 8 weeks of continuous cycling or sprint running respectively. However, the range varied from -9.8 to 25.3% and -6.1 to 16.4% for cycling and running.

Training design

• Mode
  – Improvements can be seen with cycling, running, circuit training, swimming and resistance exercise

• Frequency and duration
  – Most studies show 3-4 session/wk (range 1-5) with a 30-45 min duration will elicit a ~ 5-6% improvement
  – Few studies suggest 2-3 sessions/wk < 30 min in duration can be beneficial (~8-10%) providing intensity is high (> 80-95% HRmax)
Training design

• Intensity
  – 80% of studies with an intensity > 80% HRmax show improvements
  – Only two studies have specifically addressed exercise intensity but did not work match the conditions

• Length of programme
  – No clear consensus with studies ranging from 6 to 52 weeks
  – Frequency, duration and intensity appear more important
Training design

• Continuous exercise
  – 15-40 min of continuous exercise at ~ 80% HRmax

• Interval exercise
  – 30-60 min of interval runs at 80-95% HRmax
  – Sets of ~ 1-3 min exercise with recovery time
  – Limited evidence suggests sets of ‘all-out’ sprints of 10-30 s may be highly effective

• Mixed continuous and interval exercise show positive adaptations
Training design summary

• Mode: Continuous or interval training using large muscle groups

• Frequency: Minimum of 3-4 sessions per week

• Duration and intensity
  – 40-60 min at 80-85% HR max for continuous training
  – 30-60 min at > 90% HR max using training intervals of 1-3 min duration with appropriate recovery
  – < 30 min of ‘all-out’ sprints using training intervals of < 30 s duration with appropriate recovery

• Length: Above 12 weeks

Conclusions

• There are few well-controlled training studies on elite young athletes with holistic aerobic endurance outcomes

• Aerobic fitness is trainable in young people:
  - Peak O\textsubscript{2} uptake
  - O\textsubscript{2} uptake kinetics
  - Lactate markers
  - Exercise economy

• Prescribing a training intensity above 80\%HR\text{max} appears the critical factor to elicit positive adaptations

• A maturity trigger threshold has yet to be proven but improvements may be blunted in those with a high baseline aerobic fitness
Sport should be pleasurable and fulfilling

Sport must focus on promoting the health and well-being of young people

NOT

Young people promoting the health and well-being of sport