The Influence of Training Status on the Physiological Responses to Exercise of Young Girls

Submitted by Melitta Anne McNarry
to the University of Exeter
as a thesis for the degree of Doctor of Philosophy in
Sport and Health Sciences,
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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.
Abstract

Exercise training represents a potent stimulus to the parameters of aerobic and anaerobic fitness in adults; whether the same is true in young girls is unclear. For some parameters, such as peak oxygen uptake, the influence of training status remains controversial whilst for other parameters, such as oxygen uptake kinetics, the influence of training status remains simply uninvestigated in young girls. Despite this lack of empirical evidence, it has been suggested for some time now that children may lack trainability and that this may be related to the presence of a maturational threshold below which significant adaptations to training cannot occur. This suggestion requires investigation, not least because the findings of some studies which appear to support this contention may in reality be a reflection of the use of an inappropriate test modality for the investigation of training status influences. The purpose of this thesis was therefore to determine the physiological trainability of girls at different stages of maturation and to investigate the interaction between training status, maturity and exercise modality. To achieve this purpose a series of 5 studies was completed, in which trained and untrained girls completed ramp incremental exercise, constant-work-rate exercise and Wingate exercise on two exercise modalities, one upper (arm crank) and one lower body (cycle). During these tests, cardiovascular, respiratory, metabolic and mechanical power parameters were assessed. In response to ramp incremental exercise, trained girls were shown to have a higher peak $\dot{V}O_2$, $SV$ and $\dot{Q}$ at all stages of maturity, along with an altered $SV$ and fractional muscle oxygen extraction pattern, irrespective of exercise modality. The importance of exercise modality was evident during heavy intensity constant-work-rate exercise in pre-pubertal girls, where training status was only associated with significant influences on $\dot{V}O_2$ kinetics (faster phase II time constant in trained girls) during upper body ergometry. In contrast, pubertal trained girls had faster $\dot{V}O_2$ kinetics during both exercise modalities, an influence which may suggest both central and peripheral adaptations to the delivery and utilisation of oxygen. Exercise modality was also revealed to be an important factor in the demonstration of training status influences during a 30 s Wingate test, with trained girls at all stages of maturity exhibiting higher mechanical power indices during upper body ergometry only. An influence of training status was also evident in the lower fatigue index found in the trained girls at all stages of maturity during both modalities, but no influence was found in the oxidative contribution to the Wingate test. None of these studies revealed an influence of maturity status in determining the magnitude of training status...
effects. Overall, the 5 studies encompassed within this thesis demonstrate that children are trainable and that this is not moderated by maturity.
Acknowledgements

First, to my supervisors, Professor Andy Jones, Dr Jo Welsman and Dr Ann Rowlands, I would like to express my gratitude for their extensive knowledge, support and patient guidance. Circumstance meant I had the privilege of working with three supervisors, each of which has inspired and taught me so much, not least the diverse ways in which to supervise! I would also like to thank Dr Kerstin Stoedefalke for her enthusiasm and encouragement and who presented me with the opportunity to undertake this PhD.

I am indebted to all the volunteers who helped me during the long months (/years!) of testing, both those who completed the tests and those who helped in their implementation. With regard to the latter, I owe a special thanks to Rebecca Willcocks, who gave up her time selflessly to help me conduct, and recover from, my testing. Her friendship is the reason I have a thesis to present.

Finally, my deepest gratitude goes to my parents and my newlywed husband, Stuart. No words are adequate to express the amount I owe to your unwavering love, encouragement and belief. To each I owe this thesis.
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<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>O₂</td>
<td>Oxygen</td>
</tr>
<tr>
<td>VO₂</td>
<td>Oxygen uptake</td>
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<tr>
<td>VO₂ max</td>
<td>Maximal oxygen uptake</td>
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<tr>
<td>RER</td>
<td>Respiratory exchange ratio</td>
</tr>
<tr>
<td>Min</td>
<td>Minute</td>
</tr>
<tr>
<td>Q</td>
<td>Cardiac output</td>
</tr>
<tr>
<td>a - VO₂ difference</td>
<td>arterial-venous oxygen difference</td>
</tr>
<tr>
<td>SV</td>
<td>Stroke volume</td>
</tr>
<tr>
<td>HR</td>
<td>Heart rate</td>
</tr>
<tr>
<td>[HHb]</td>
<td>Deoxygenated haemoglobin and myoglobin</td>
</tr>
<tr>
<td>LT</td>
<td>Lactate threshold</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>VO₂C</td>
<td>Carbon dioxide output</td>
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<tr>
<td>VₚE</td>
<td>Minute ventilation</td>
</tr>
<tr>
<td>GET</td>
<td>Gas exchange threshold</td>
</tr>
<tr>
<td>PCR</td>
<td>Intramuscular phosphocreatine</td>
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<tr>
<td>τ</td>
<td>Time constant</td>
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<tr>
<td>MLSS</td>
<td>Maximal lactate steady state</td>
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<tr>
<td>CP</td>
<td>Critical power</td>
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<tr>
<td>%Δ</td>
<td>% difference between GET and peak VO₂</td>
</tr>
<tr>
<td>Δ</td>
<td>Delta change</td>
</tr>
<tr>
<td>ATP</td>
<td>Adenosine triphosphate</td>
</tr>
<tr>
<td>NIRs</td>
<td>Near infrared spectroscopy</td>
</tr>
<tr>
<td>WAnT</td>
<td>Wingate anaerobic test</td>
</tr>
<tr>
<td>PP</td>
<td>Peak power</td>
</tr>
<tr>
<td>MP</td>
<td>Mean power</td>
</tr>
<tr>
<td>FI</td>
<td>Fatigue index</td>
</tr>
<tr>
<td>PFK</td>
<td>Phosphofructokinase</td>
</tr>
<tr>
<td>³¹P-MRS</td>
<td>P-31 magnetic resonance spectroscopy</td>
</tr>
<tr>
<td>pHᵢ</td>
<td>Intracellular pH</td>
</tr>
<tr>
<td>Pᵢ</td>
<td>Inorganic phosphate</td>
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METs  Metabolic equivalents
ACSM  American College of Sports Medicine
T    Trained girls
UT   Untrained girls
RPM  Revolutions per minute
BSA  Body surface area
SVᵢ  Stroke volume index
w    Weight of Monark flywheel
r    Distance from the axis of rotation to the point of suspension
I    Inertia of the flywheel
l    Length of suspending wires
ω    Angular velocity
Tᵢ   Inertial torque
Tᵣ   Resistive torque
SD   Standard deviation
s    Seconds
A₁   Amplitude of the primary component
δ    Time delay
ANCOVA Analysis of covariance
ANOVA Analysis of variance
BMI  Body mass index
PHV  Peak height velocity
WR   Work rate
[lactate] concentration of lactate
b·min⁻¹ Beats per minute
l·min⁻¹ Litres per minute
ml·kg⁻¹·min⁻¹ Millilitres per kilogram per minute
ml·m⁻² Millilitres per metre squared
ml·m⁻²·min⁻¹ Millilitres per metre squared per minute
W    watts
N    Newtons
m    Metres
n    Sample size
r    Pearson’s correlation coefficient
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>MRT</td>
<td>Mean response time</td>
</tr>
</tbody>
</table>