Growth Physiology and Training on Cardiorespiratory Fitness in Children and Adolescents

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Overview

1. What is cardiorespiratory fitness (CRF), why should we be interested, how can we measure it?

2. How does CRF change with reference to age, sex, maturity and body size and composition?

3. Is physical activity related to CRF?

4. Can exercise training improve CRF?

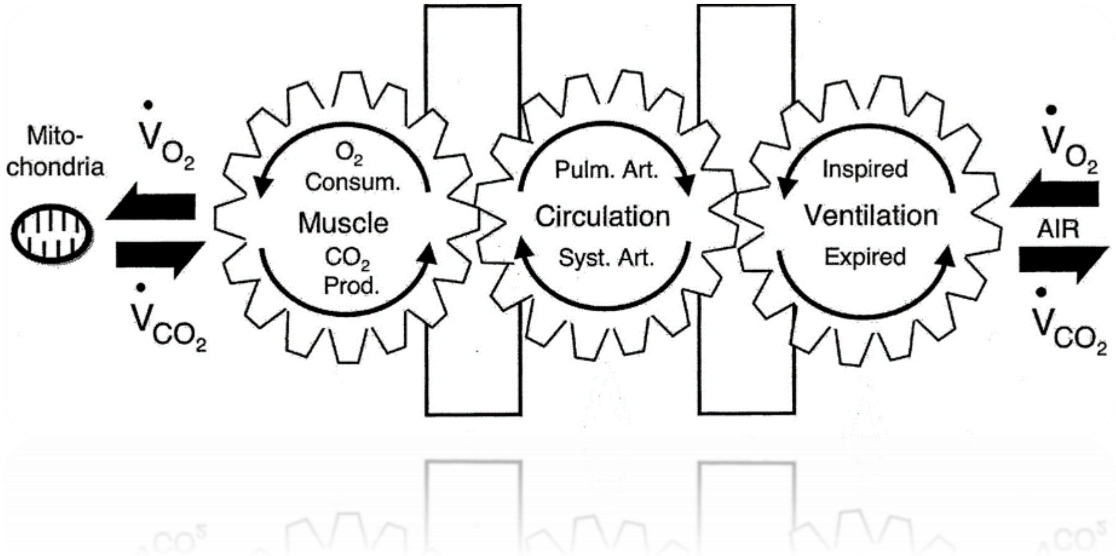
5. Key messages

What is CRF?

Definition: Ability of the body to extract oxygen (O_2) from the atmosphere and supply this to the muscle to perform work during prolonged exercise

Integration of the cardiovascular, respiratory and muscular systems

Other terms: aerobic fitness, aerobic capacity, aerobic endurance, endurance fitness, cardiorespiratory endurance



Wasserman et al. (1999). Principles of Exercise Testing and Interpretation.

Why measure CRF in children and adolescents?

- Understand developmental changes in the cardiovascular, respiratory and muscular systems ability to support exercise
- Predictor of disease status/prognosis in paediatric exercise medicine
- Predictor of current and future health status (e.g. cardiovascular disease risk)
- Exercise prescription and effectiveness of interventions
- Predictor of performance in endurance events and team sports

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AHA SCIENTIFIC STATEMENT

Cardiorespiratory Fitness in Youth: An Important Marker of Health: A Scientific Statement From the American Heart Association

Geetha Raghuveer, Chair, MD, MPH, FAHA, Jacob Hartz, MD, David R. Lubans, PhD, Timothy Takken, PhD, Jennifer L. Wiltz, MD, MPH, FAHA, Michele Mietus-Snyder, MD, Amanda M. Perak, MD, FAHA, Carissa Baker-Smith, MD, MPH, MS, FAHA, Nicholas Pietris, MD, Nicholas M. Edwards, Vice Chair, MD, MPH, FAHA, and On behalf of the American Heart Association Young Hearts Athero, Hypertension and Obesity in the Young Committee of the Council on Lifelong Congenital Heart Disease and Heart Health in the Young

ABSTRACT: Cardiorespiratory fitness (CRF) refers to the capacity of the circulatory and respiratory systems to supply oxygen to skeletal muscle mitochondria for energy production needed during physical activity. CRF is an important marker of physical and mental health and academic achievement in youth. However, only 40% of US youth are currently believed to have healthy CRF. In this statement, we review the physiological principles that determine CRF, the tools that are available to assess CRF, the modifiable and nonmodifiable factors influencing CRF, the association of CRF with markers of health in otherwise healthy youth, and the temporal trends in CRF both in the United States and internationally. Development of a cost-effective CRF measurement process that could readily be incorporated into office visits and in field settings to screen all youth periodically could help identify those at increased risk.

Key Words: AHA Scientific Statements ■ cardiorespiratory fitness ■ cardiovascular diseases ■ cognition ■ exercise ■ mental health ■ physical activity

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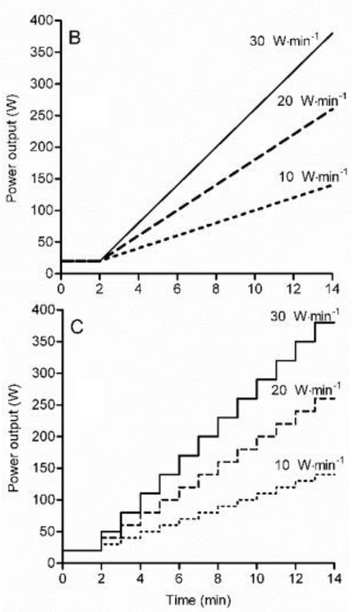
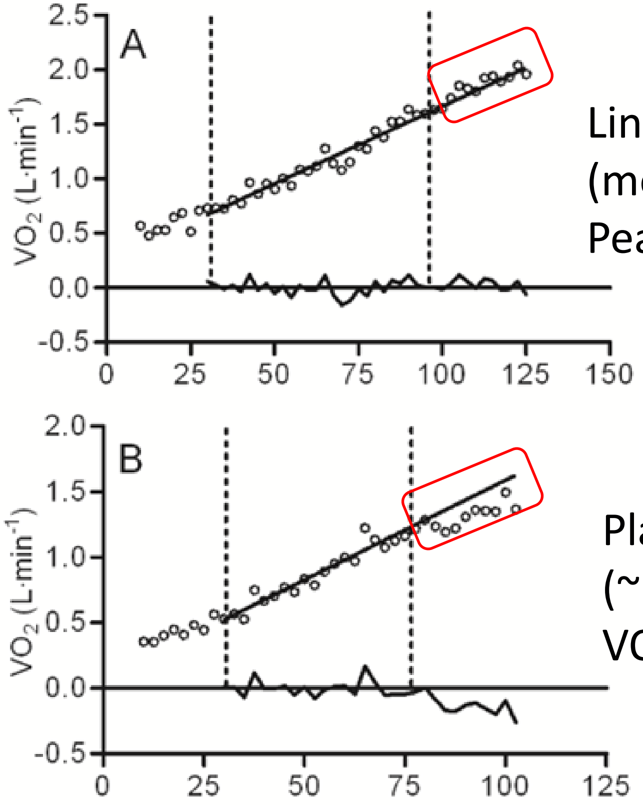
How can we measure CRF?



Peak oxygen uptake (VO_2)
or
maximal VO_2

~ 10-15% higher using treadmill



Linear (most common) Peak VO_2

Plateau (~10-30%) VO_2 max

- Gas exchange and ventilation
- Cycle ergometer – work done, performance

Other measures:

Cardiac – heart rate, cardiac output (PhysioFlow), arterial saturation

Muscle oxygenation – near infrared spectroscopy

Subjective scales – rating of perceived exertion

Questions:

Can a VO_2 max be assumed or should we use VO_2 peak?

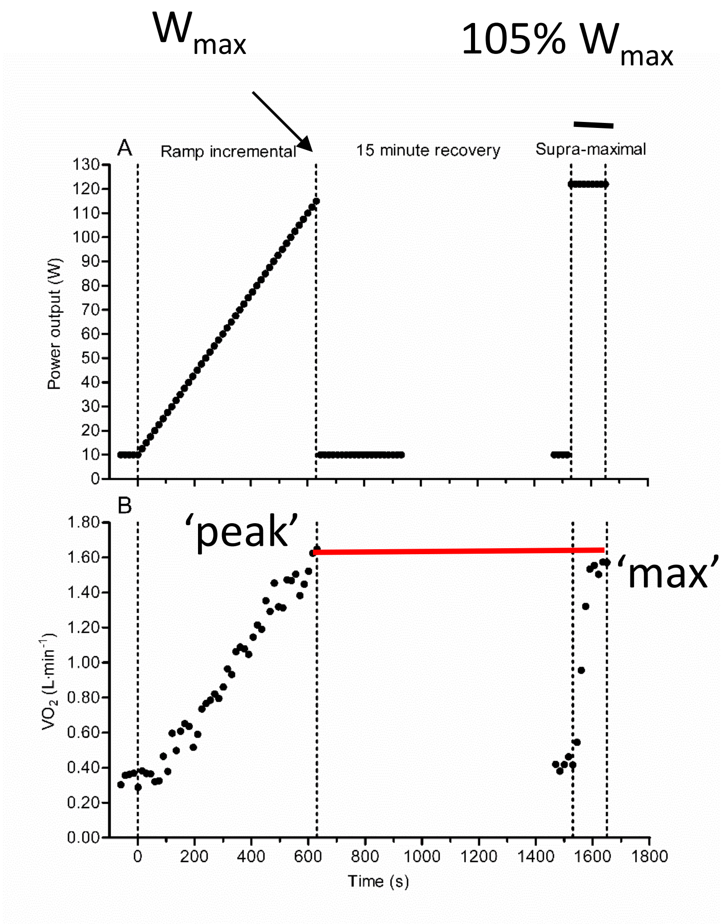
How can a VO_2 max be verified?

Barker et al. (2011). *Brit J Sport Med*. 45: 498-503

Validating a VO_2 max measure

- Secondary criteria (e.g. heart rate, respiratory exchange ratio) have poor validity
- Utility of a verification bout at a supra-maximal intensity

__Rationale:__ If a peak VO_2 value obtained during an exercise test to exhaustion is a ‘true’ max, then performing exercise at an intensity above maximal (supra-maximal) should not elicit a further increase in VO_2.



***__Question:__* Does the verification bout work within a single testing session?*

Yes – ~ 90% success across a range of sample characteristics (age, sex, body size and fitness levels).

VO_2 peak ***is*** reflective of a VO_2 max in children and adolescents.

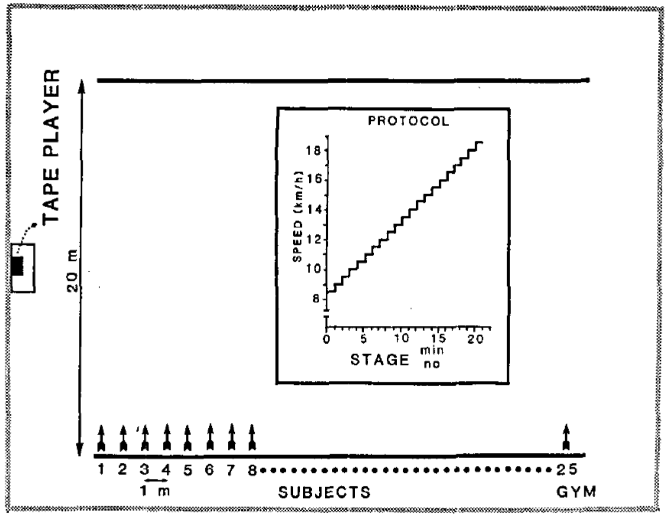
BUT: lack of treadmill data

Barker et al. (2011). *Brit J Sport Med*. 45: 498-503
Sansum et al (2019). *Pediatr Exe Sci*. 31: 213-222

How can we measure CRF?

20 m shuttle run test (20mSRT)

Leger et al. (1988). *J Sport Sci*. 6: 93-101



n=188, 8-18 y
r=0.71
r^2=0.50
Error: ~ 6 mL/kg/min

- CRF is estimated using performance (level, stage, speed)
- Equations available to estimate VO_2 peak

Application of 20mSRT

- Established validity, reliability and feasibility
  - Validity: r^2 ~ 0.6, 95% confidence ~ 10 mL/kg/min
  - Reliability: ICC 0.78-0.93
- Secular changes in CRF across geographical areas
- Relationship with health outcomes
- Health and normative standards

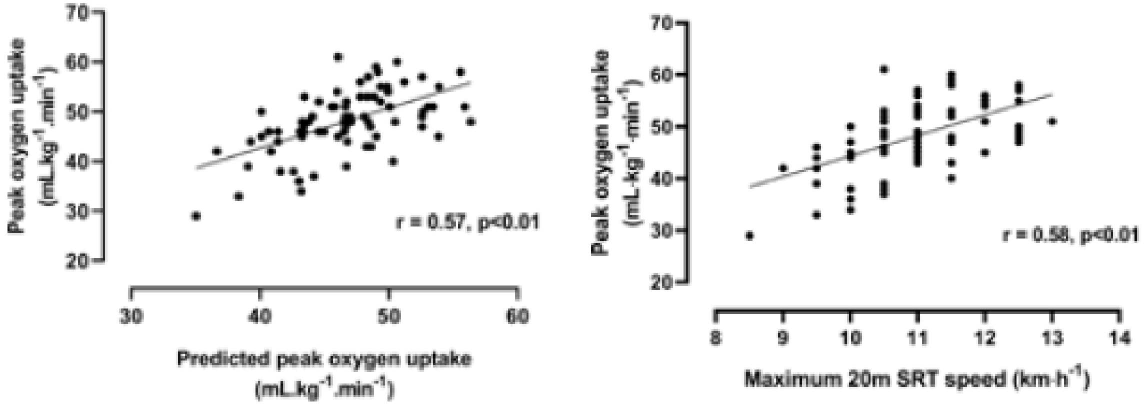
Tomkinson et al. (2019). *Pediatr Exe Sci*. 31: 152-163

How valid is the 20mSRT?

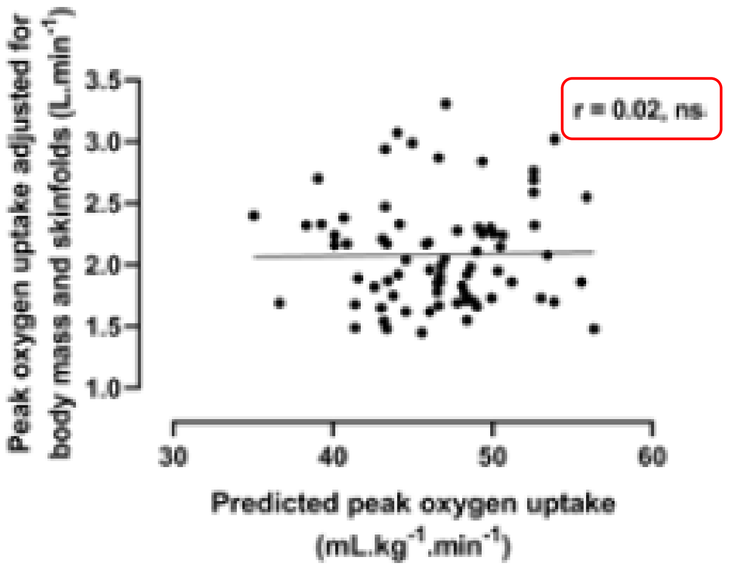
- n=76, 11-14 y old boys
- Treadmill determined peak VO_2
- 20mSRT performance: speed and estimated VO_2 peak

Concerns:

- 20mSRT performance is negatively related with body fatness (*r*=-0.61)
- Peak VO_2 is expressed per unit of body mass



Error ~ 10 mL/kg/min



Welsman and Armstrong (2019). *BMJ Open Sp Ex Med*. 5: e000627.

How valid is the 20mSRT?

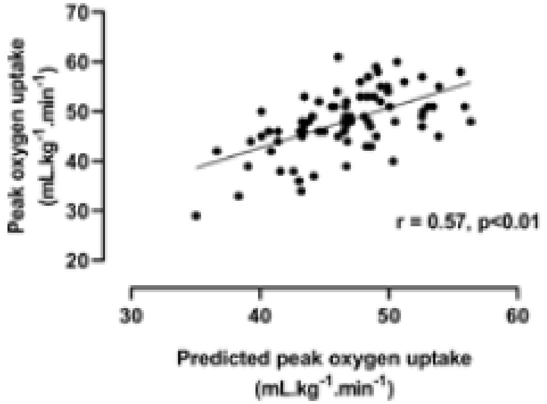
When properly accounting for body size and composition, a weak relationship between directly determined peak VO_2 and 20mSRT predicted peak VO_2 is observed.

Challenges the validity of using the 20mSRT as a measure of CRF.

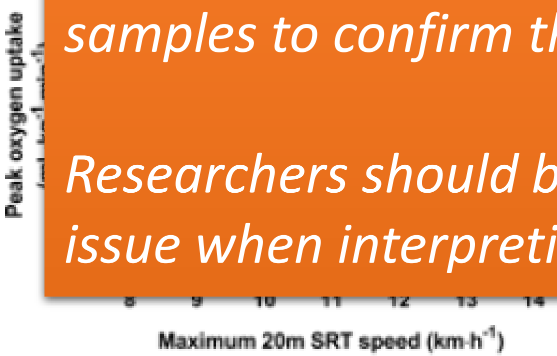
BUT: more data are needed on representative samples to confirm these findings.

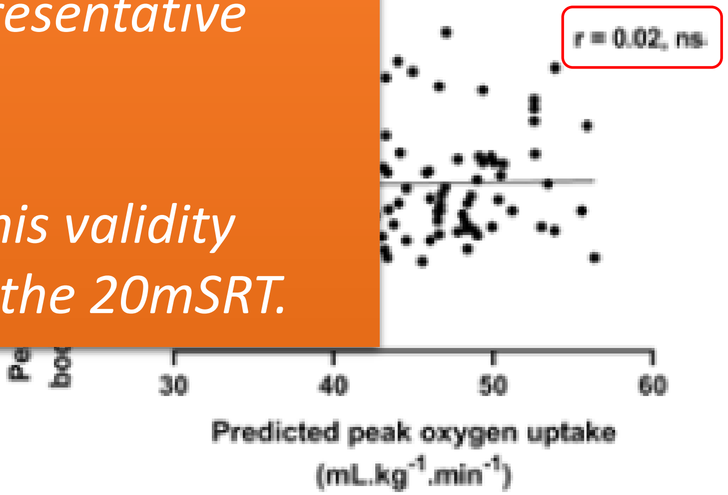
Researchers should be mindful of this validity issue when interpreting data using the 20mSRT.

- n=76, 11-14 y old b
- Treadmill determin … is negatively related with
- 20mSRT performan … per unit of body mass
  estimated VO_2 pea



Error ~ 10 mL/kg/min





Welsman and Armstrong (2019). *BMJ Open Sp Ex Med*. 5: e000627.

Right: Participants undertaking a combined ramp and supramaximal exercise test to exhaustion to determine $\dot{V}O_{2max}$
Courtesy Zoe Saynor

The BASES Expert Statement on Measurement and Interpretation of Aerobic Fitness in Young People

Produced on behalf of the British Association of Sport and Exercise Sciences by Dr Alan Barker, Prof Craig Williams FBASES, Dr Keith Tolfrey FBASES, Dr Samantha Fawkner and Dr Gavin Sandercock.

Introduction

Aerobic fitness is routinely measured in young people[1] and typically consists of either a direct measurement or indirect estimation of maximal oxygen uptake ($\dot{V}O_{2max}$). Maximal oxygen uptake has been used to study:

1. Changes in aerobic fitness during growth and maturation
2. The efficacy of exercise training programmes
3. The impact of disease on aerobic capacity
4. The relationship between physical activity, fitness and health.

For the latter, The BASES Expert Statement on The Importance of Young People's Aerobic Fitness for Health advocated the use of indirect and direct measures of aerobic fitness to identify children most at risk of cardio-metabolic disease and in greatest need of support (Tolfrey *et al.*, 2012). Consequently, there is a strong rationale and interest in the sport and exercise science community to measure aerobic fitness in young people. However, the most appropriate methods to measure and interpret max in this population remain controversial. This statement will, therefore, provide an expert summary of the key issues and conclude with recommendations for researchers and practitioners.

Background and evidence

Can young people produce a valid $\dot{V}O_{2max}$ measurement?

As only ~ 10 to 60% of children and adolescents display a $\dot{V}O_2$ plateau during exhaustive exercise across a variety of protocols (e.g., step-incremental or ramp) and modalities (e.g., treadmill and cycling), it has become conventional to use the term 'peak' $\dot{V}O_2$ in this population (Armstrong & Welsman, 1994). Consequently, objective secondary criteria, based on attaining a predefined heart rate (e.g., 85% of age predicted maximum) and/or respiratory exchange ratio (e.g., RER ≥ 1.00), are routinely used to verify a 'maximal' response in young people. A recent study, however, has demonstrated that the use of secondary criteria results in the acceptance of a 'sub-maximal' peak $\dot{V}O_2$, representing only ~ 80 to 90% of the achieved peak $\dot{V}O_2$, and can falsely reject a 'true' $\dot{V}O_{2max}$ measurement in children (Barker *et al.*, 2011). The authors called for researchers and practitioners to abandon use of such secondary criteria and championed the use of a supra-maximal test following the initial incremental test to verify the measurement of a 'true' $\dot{V}O_{2max}$. In this study, the children performed a supra-maximal bout set at 105% of the peak power achieved during the incremental test after 15 min of rest. This protocol identified a valid $\dot{V}O_{2max}$ measurement in 12 out of 13 children, despite only observing a $\dot{V}O_2$ plateau in 4 children during the initial incremental test to exhaustion. These findings have since been replicated using cycling and treadmill based protocols in young people with cystic fibrosis, children with expiratory flow limitation and children with spina bifida, highlighting the broad application of the combined incremental and supramaximal test to produce a 'true' measurement of $\dot{V}O_{2max}$ in young people.

What is the most appropriate method to scale $\dot{V}O_{2max}$ for body size?

Absolute $\dot{V}O_{2max}$ (mL·min-1) is typically adjusted using the ratio standard method with body mass (kg) as the scaling variable (mL·kg-1·min-1). However, this approach has been criticised due to its failure to create a 'size-free' expression of $\dot{V}O_{2max}$ in young people as it favours lighter individuals (Armstrong & Welsman, 1994). Rather, allometric scaling may provide a more appropriate method to adjust $\dot{V}O_{2max}$ for body size.

Body mass is used typically to scale $\dot{V}O_{2max}$ for body size as it is simple to measure and shares a strong relationship with absolute $\dot{V}O_{2max}$. However, body mass does not account for differences in body composition and expressing $\dot{V}O_{2max}$ relative to an estimation of fat free mass (FFM) is more appropriate in young people. While an estimation of FFM may be achieved using age- and sex-specific algorithms to estimate body fat percentage from skinfold measures, techniques such as air displacement plethysmography or dual-energy X-ray absorptiometry are preferable. The latter is particularly useful, as it can partition out lower body FFM, which offers a slight advantage compared to total FFM when scaling $\dot{V}O_{2max}$ in young people (Graves *et al.*, 2013). Alternatively, a direct measure of the active muscle mass involved during exercise provides the most valid body size variable to adjust $\dot{V}O_{2max}$ (Tolfrey *et al.*, 2006), but requires access to sophisticated equipment such as a magnetic resonance imaging scanner.

Can a reliable and valid estimate of $\dot{V}O_{2max}$ be obtained from field-based measures?

The valid measurement of $\dot{V}O_{2max}$ in the laboratory setting requires expensive equipment and technical expertise, which may be impractical for use in large cohort studies. Field-based tests, which are relatively easy to administer in large groups, and require limited equipment, offer a practical alternative.

The 20-m shuttle run test (20-mSRT) is the most widely used field-based test to assess aerobic fitness in young people and UK centile data and health-related cut points are available (Sandercock *et al.*, 2012). As the test demands limited space, it can be conducted indoors, which controls for environmental conditions, and is not reliant on self-pacing strategies. A systematic review recently concluded the 20-mSRT to be the most reliable and valid field-based method to estimate aerobic fitness in young people (Castro-Pinero *et al.*, 2010). Performance in the 20-mSRT is typically expressed as laps, levels or distance completed. While published equations are available to estimate peak $\dot{V}O_2$ after accounting for factors such as the age, sex and size of the participant (e.g., Mahar *et al.*, 2011)[2], users must be aware of the error associated with the estimated peak $\dot{V}O_2$ (typically 4 to 6 mL·kg-1·min-1) when interpreting their data.

Some Local Authorities and the Association for Physical Education have cautioned against the use of the 20-mSRT in schools, due to health concerns with exercising children to exhaustion. However, the two largest UK-based studies (Liverpool SportsLinx and East of England Healthy Hearts Study) have completed circa 80,000 (35,000 of which are published) 20-mSRT assessments in 9 to 16 year olds and have yet to record a single adverse event. The 20-mSRT is also used routinely for the population-based assessment of aerobic fitness in 5 to 18 year olds across Europe, USA and Australasia.

Popular alternatives to the 20-mSRT are distance walk/run tests, such as the 1 or 0.5 miles tests. Although normative data and criterion referenced cut-offs for fitness are available (e.g., Zhu *et al.*, 2010), some children may have problems with pacing during these tests (e.g., starting too fast or slow) and the reliability and validity of the distance walk/run tests are lower than the 20-mSRT (Castro-Pinero *et al.*, 2010). Finally, sport-specific tests, such as the Yo-Yo intermittent running test, are also available to predict aerobic fitness but currently have limited supporting evidence in comparison to the 20-mSRT and distance walk/run tests in young people.

Recommendations

In the laboratory setting:

- A combined incremental and supramaximal exercise test protocol should be used to obtain a valid measurement of $\dot{V}O_{2max}$ in young people both in health and disease
- Secondary criteria (e.g., heart rate and RER thresholds) should not be used to verify the attainment of $\dot{V}O_{2max}$ in young people as they result in a 'sub-maximal' peak $\dot{V}O_2$
- Allometric scaling procedures should be used to scale $\dot{V}O_{2max}$ for body size provided sufficient data are available to derive a sample specific scaling factor. However, as normative data or thresholds for health are currently only available in the ratio standard format it may be prudent to express $\dot{V}O_{2max}$ using both methods
- As body mass does not account for differences in body composition, $\dot{V}O_{2max}$ should be adjusted for using FFM in young people
- In the research setting, direct quantification of the muscle mass recruited during exercise should be used to adjust $\dot{V}O_{2max}$ for body size as this offers an advantage compared to total FFM.

In the field setting:

- The 20-mSRT is currently the method of choice to provide a safe, reliable and valid estimate of $\dot{V}O_{2max}$ in the field setting, and UK reference data are readily available
- Performance in the 20-mSRT should be expressed as laps, levels of distance completed, as the prediction of peak $\dot{V}O_2$ using the test data is associated with error
- If the 20-mSRT cannot be undertaken, distance walk/run tests are a suitable popular alternative but have poorer reliability and validity in young people. ■

1 The term 'young people' in this expert statement refers to children and adolescents aged <18 years.

2 The 20m-SRT estimates peak $\dot{V}O_2$ as, despite eliciting a maximal effort, the achievement of $\dot{V}O_{2max}$ was not verified appropriately in the majority of these studies.

words:

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SCAN ME

Update is on the way.

Overview

1. What is cardiorespiratory fitness (CRF), why should we be interested, how can we measure it?

2. How does CRF change with reference to age, sex, maturity and body size and composition?

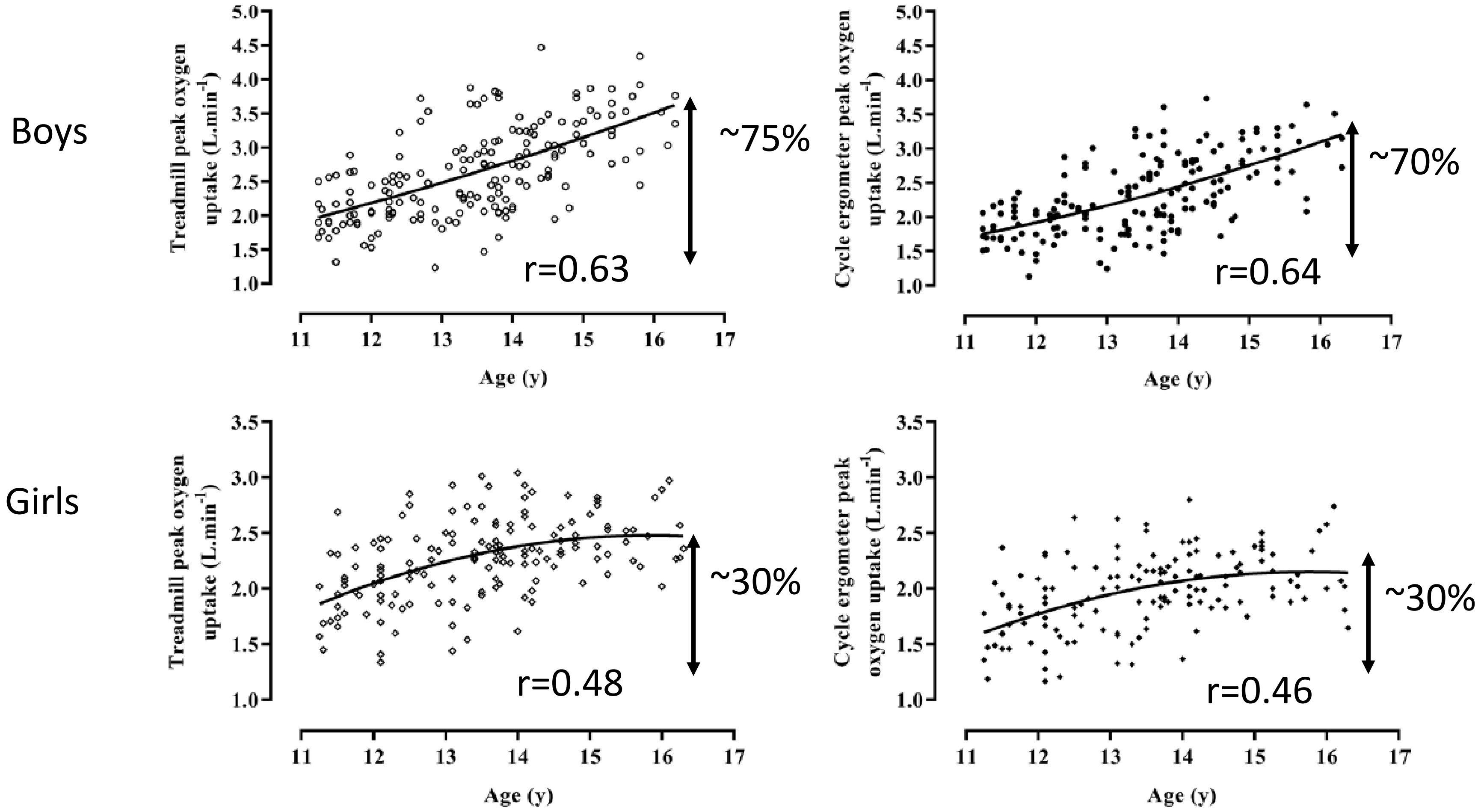
3. Is physical activity related to CRF?

4. Can exercise training improve CRF?

5. Key messages

Peak VO_2 and age: Absolute (L/min)

n=136, 11-14 y olds (72 boys) prospectively followed over 3 years (640 observations in total)



Absolute peak VO_2 increases linearly against age in boys and girls, but distinct sex differences are present.

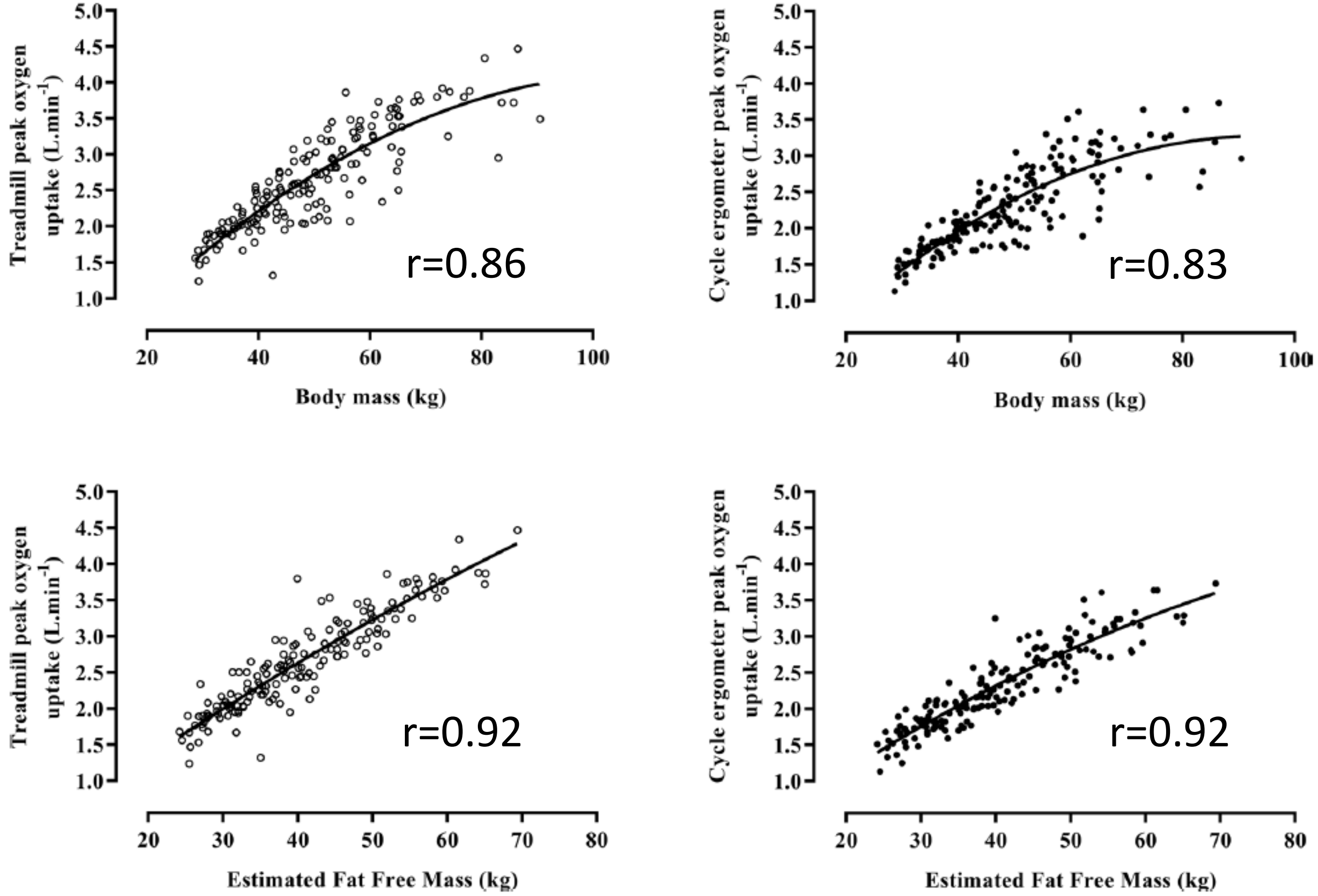
The linear increase in boys is maintained into early adulthood, but begins to 'level-out' in girls from the age of ~ 14 years of age.

What is the cause of this age-related increase?

Armstrong et al. (2019). *Eur J Appl Physiol*. 119: 801-812

Peak VO_2 and body size: Absolute (L/min) in boys

n=136, 11-14 y olds (72 boys) prospectively followed over 3 years (640 observations in total)



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Peak VO_2 and body size: Absolute (L/min) in girls

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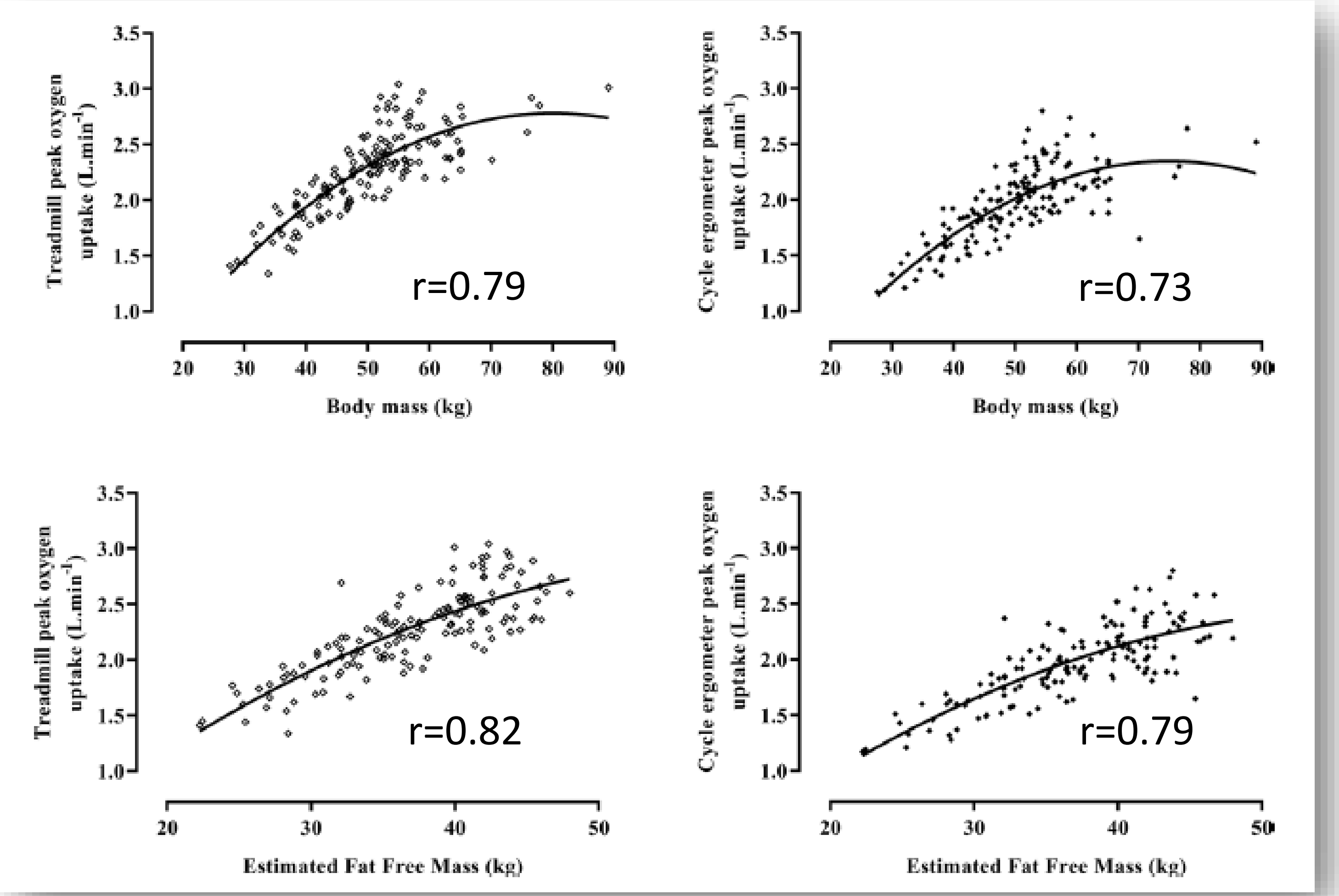


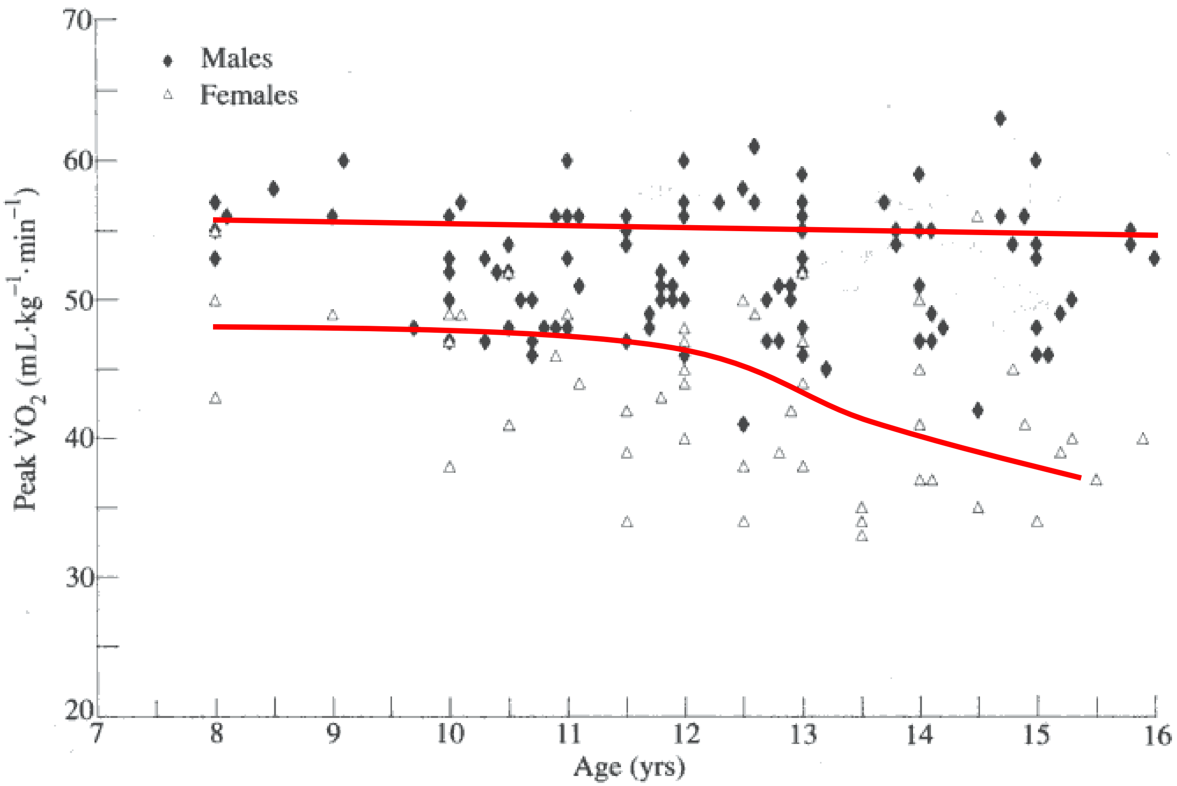
Peak VO_2 in both girls and boys display strong relationships with body size, suggesting a size-dependency for the increase in fitness.

What do the development curves look like if we scale the data?

Traditional approach is to ratio scale the data to body mass (i.e. Y/X).

Armstrong et al. (2019). *Eur J Appl Physiol*. 119: 801-812

Peak VO_2 and age: mL/kg/min (the traditional view)



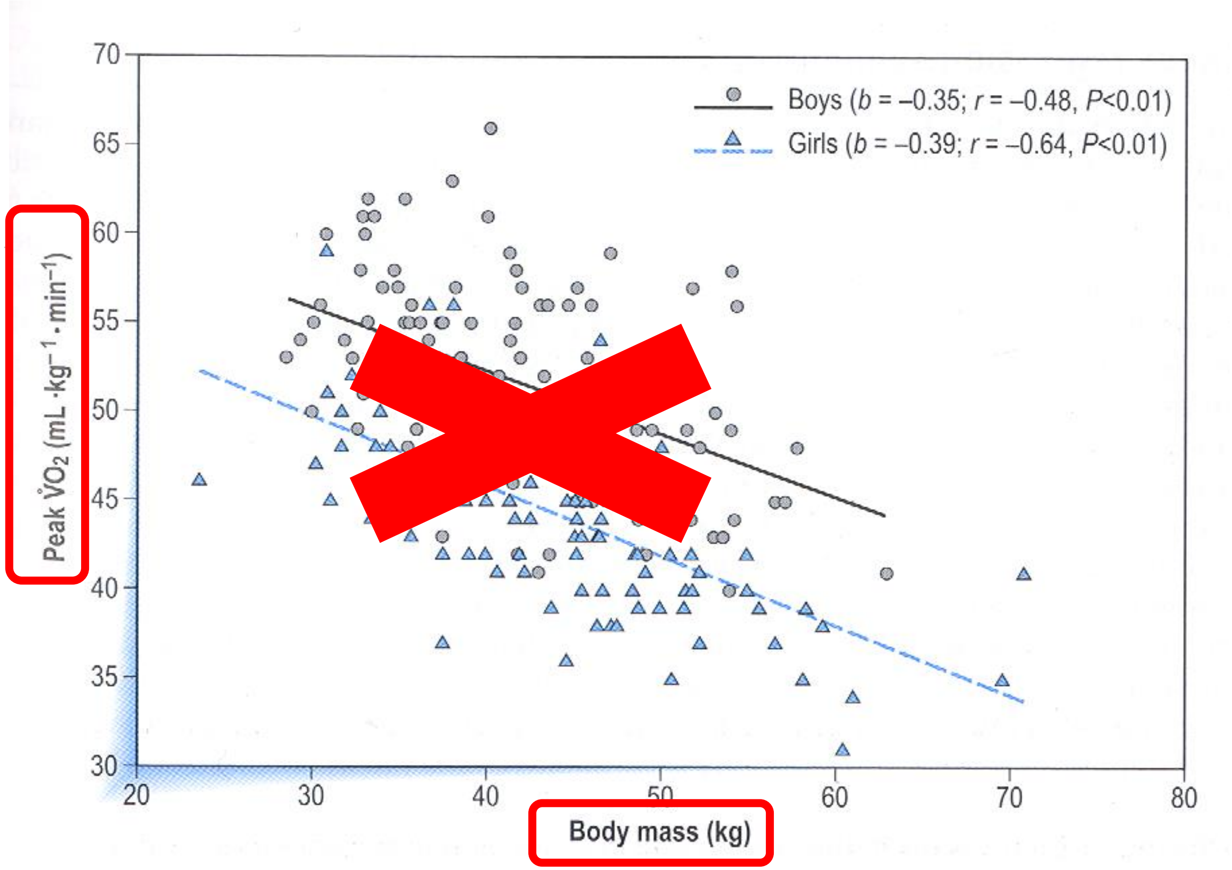
The ratio standard method suggests a stable peak VO_2 during development in boys, and a decline in peak VO_2 in girls during the teen years into early adulthood.

However, the ratio standard method is invalid and this interpretation of fitness is flawed and misleading.

- Boys' body mass related peak VO_2 remains stable
- Girls' body mass related peak VO_2 remains stable until ~ 11-12 yrs and then declines into early adulthood

Armstrong and Welsman (2000). *Pediatr Exe Sci*. 12: 128-149.

Peak VO_2 and age: mL/kg/min (the traditional view)



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Armstrong and Welsman (2000). *Pediatr Exe Sci*. 12: 128-149.

Development of peak VO_2: Allometric models for boys (treadmill)

n=136, 11-14 y olds (72 boys) prospectively followed over 3 years (640 observations in total)

When controlling for body size, what is the effect of:
Age
Maturity status
Body fatness
Fat free mass

Sex-specific models

Variable	Body mass and age 'b' values	Body mass, age and maturity 'b' values	Body mass, age, maturity and skinfolds 'b' values	Fat free mass, age and maturity 'b' values
Body mass	0.73	0.69	0.99	-
Age	0.04	NS	NS	NS
Maturity 2	-	NS	NS	NS
Maturity 3	-	0.08	NS	NS
Maturity 4	-	0.06	NS	NS
Maturity 5	-	0.09	NS	NS
Skinfolds	-	-	-0.21	-
Fat free mass	-	-	-	0.89

NS: not significant

Armstrong et al. (2019). *Eur J Appl Physiol*. 119: 801-812

Development of peak VO_2: Allometric models for girls (treadmill)

n=136, 11-14 y olds (72 boys) prospectively followed over 3 years (640 observations in total)

Using allometric modelling, the development of peak VO_2 is sex-specific in terms of the contributing factors, but the increase in fat free mass is the most dominant factor for augmenting CRF in youth.

Consistent across ergometers.

***<u>Recommendation</u>**: CRF, measured using peak VO_2, should be scaled for fat free mass (or equivalent).*

Variable	Body mass, age and maturity 'b' values	Body mass, age, maturity and skinfolds 'b' values	Fat free mass, age and maturity 'b' values
Body mass	0.61	0.77	-
Age	NS	NS	NS
Maturity 2	NS	NS	NS
Maturity 3	NS	NS	NS
Maturity 4	NS	NS	NS
Maturity 5	NS	NS	NS
Skinfolds	-	-0.12	-
Fat free mass	-	-	0.78

NS: not significant

Armstrong et al. (2019). *Eur J Appl Physiol*. 119: 801-812

Importance of accounting for body composition

n=352, 9-12 y olds with directly measured cycling peak VO_2 and cardiovascular health risk score (waist circumference, insulin, glucose, blood pressure, high-density lipoprotein cholesterol, and triglycerides).

Table 2. Associations of peak oxygen uptake with cardiometabolic risk score in boys and girls

		Boys (n=186)		Girls (n=166)	
		β	p	β	p
	$\dot{V}O_{2peak}$ (mL·min^{-1})	0.229	0.002	0.356	<0.001
Ratio standard	$\dot{V}O_{2peak}$ (mL·kg BM^{-1}·min^{-1})	-0.577	<0.001	-0.484	<0.001
	$\dot{V}O_{2peak}$ (mL·kg LM^{-1}·min^{-1})	-0.252	0.001	-0.245	0.001
Allometric	$\dot{V}O_{2peak}$ (mL·kg BM$^{-0.49}$·min^{-1})	-0.261	<0.001	-0.123	0.127
	$\dot{V}O_{2peak}$ (mL·kg LM$^{-0.77}$·min^{-1})	-0.185	0.012	-0.166	0.036

The values are standardised regression coefficients and *p*-values from linear regression models adjusted for age and the study group.

BM = body mass; LM = lean mass

A strong relationship exists between CRF and cardiovascular health when using the ratio standard method and body mass.

BUT: Confounded by body size and composition. This relationship can be halved by:
*Using lean mass rather than body mass
*Using the allometric method

Weakest relationship between fitness and cardiovascular health exists when using the allometric method and lean mass.

Agbaje et al. (2019). *Scan J Sci Med Sport*. 29: 16-24.

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3. Is physical activity related to CRF?

4. Can exercise training improve CRF?

5. Key messages

Physical activity and CRF

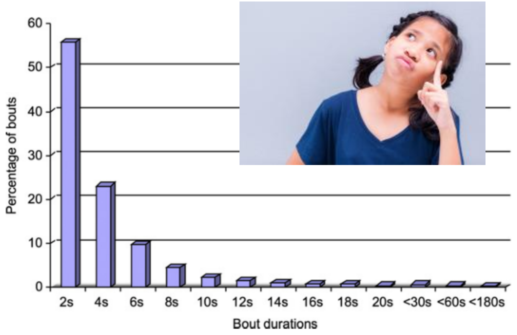
Definition: bodily movement produced by skeletal muscles that increases energy expenditure
Caspersen et al. (1985)

- Developmental curves are different
- Are children doing enough physical activity (intensity and duration) to promote CRF?
- Children's habitual physical activity patterns are technically difficult to measure
- Differences in methodology, analysis approaches and data reporting

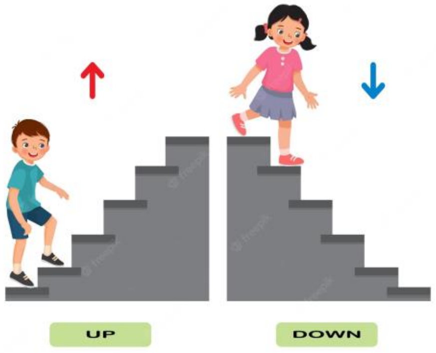
Review (n=15 studies with objective measures): Intensity is important with larger effects for vigorous intensity activity in 10 studies.
Gralla et al. (2019). *Am J Lifestyle Med*. 13: 61-97

Epoch, (non)wear time, cut-points

Physical activity



Baquet et al. (2007). *Prev Med*. 44: 143-147



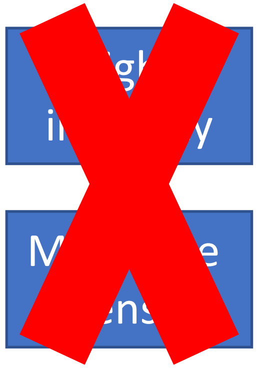
Lab or field

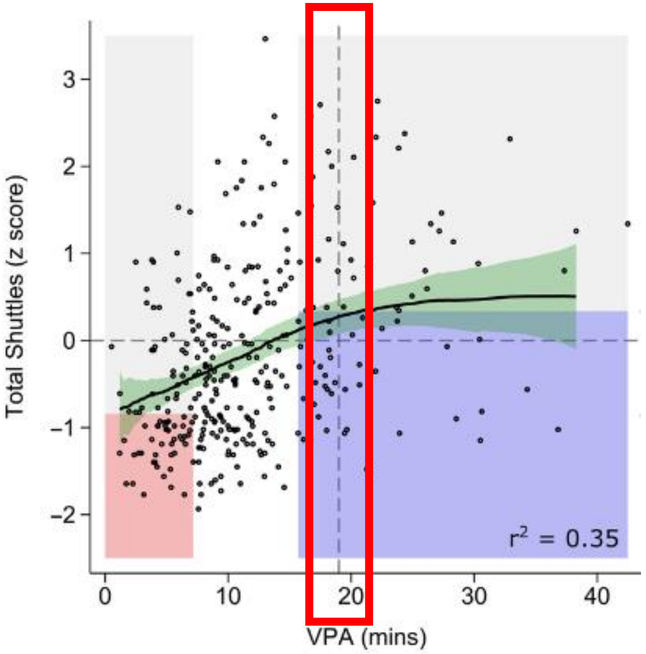
CRF

Body size and composition

How much VPA is needed to promote CRF?

- Cross-sectional study, 13-14 year olds (n=339, 169 girls)
- CRF measured using 20mSRT (shuttles)
- Physical activity using wrist worn accelerometer with 1 s epochs





Importance of physical activity intensity for promoting CRF.

Vigorous intensity physical activity has the strongest relationship with CRF.

20 min/day of vigorous intensity physical activity may be needed for 'maximising' CRF

BUT: study was cross-sectional, large variation is present, and based on indirect measure of CRF

Burden et al. (2022). *Pediatrics*. 150: e2021056003

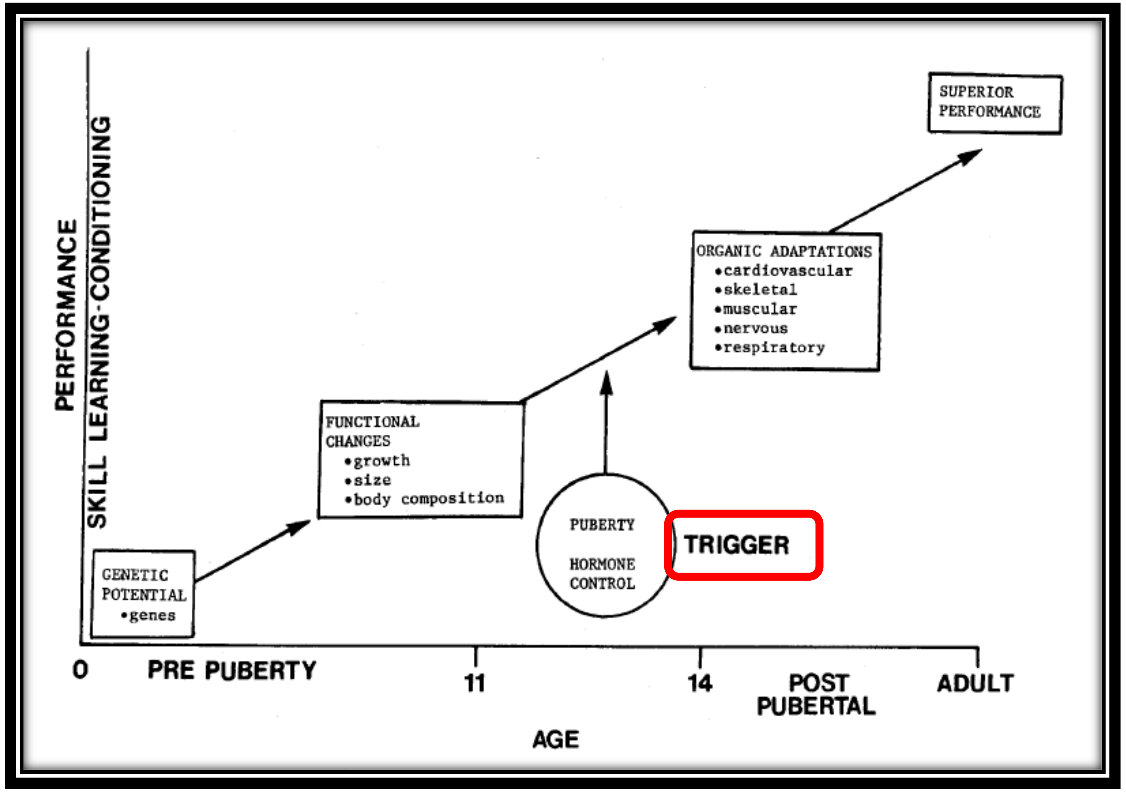
Overview

1. What is cardiorespiratory fitness (CRF), why should we be interested, how can we measure it?
2. How does CRF change with reference to age, sex, maturity and body size and composition?
3. Is physical activity related to CRF?
4. Can exercise training improve CRF?
5. Key messages

Exercise training and CRF?

Definition: planned, structured and repetitive with the objective to maintain or improve fitness
Caspersen et al. (1985)

- Does a high baseline CRF reduce the scope to augment CRF?
- Does a higher level of habitual physical activity reduce the scope for improvement?
- Does a child need a different training stimulus compared to that normally recommended for adults?
- Is a maturational 'trigger' needed to improve CRF?



Katch (1983). *J Adol Health Care*. 3: 41-246

Aerobic exercise training interventions: review

Inclusion criteria:

- Published in peer-reviewed literature
- Participants are ‘normal’ and healthy (i.e. not youth athletes)
- 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 peak VO_2

69 studies were identified but only 21 satisfied the criteria

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

Armstrong and Barker (2011). *Med Sport Sci*. 56: 59-83

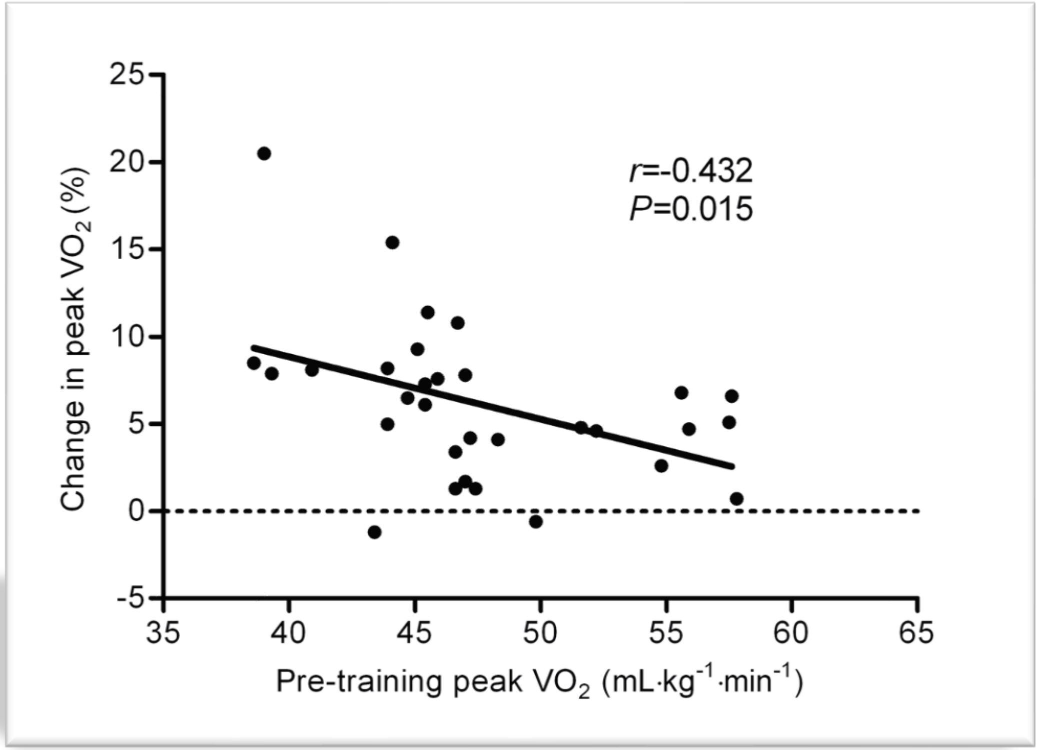
Key findings

8.0-10.9 y	11.0-17.9 y

• 9/14 (64%) studies reported a significant increase in VO_2peak (mean = 6.7%)
  • 7.7% if only considering the successful studies
• Nine studies confirmed participants were pre-pubertal
• No sex differences evident
	• 4/7 (57%) studies reported a significant increase in VO_2peak (mean = 5.5%)
	  • 8.6% if only considering the successful studies
	• No sex differences evident

Armstrong and Barker (2011). *Med Sport Sci*. 56: 59-83

Does baseline CRF matter?



Armstrong and Barker (2011). *Med Sport Sci*. 56: 59-83

Effect of baseline CRF has been shown in individual studies

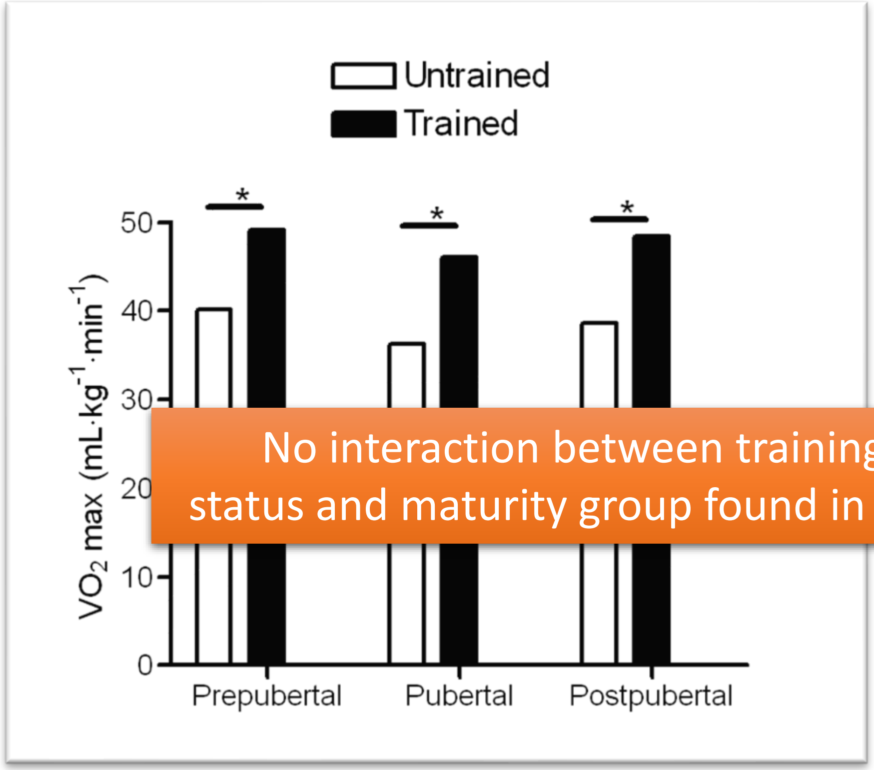
Mandigout et al. (2001). *Acta Paediatr.* 90: 9-15

Baseline CRF is related to the effectiveness of an exercise training programme to increase CRF.

Greater gains expected in children with lower CRF – group most likely to benefit from health-related improvements.

The “trigger” hypothesis: is there a golden period?

Maturity and training status



No interaction between training status and maturity group found in girls

McNarry *et al.* (2011). *J Appl Physiol. 110: 375-381*

- 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)

No robust evidence to support ‘trigger’ hypothesis: increases in CRF are possible across pubertal stages

Limited literature comparing children to adults.

Synthesis of evidence

Mode

Improvements can be seen with cycling, running, circuit training, swimming and resistance exercise.

Frequency and session duration

Most studies show 3-4 sessions/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)

Intensity

80% of studies with an intensity > 80% HRmax show improvements

Few studies have directly compared intensity effects and have not work matched the conditions

Programme length

No clear consensus with studies ranging from 6 to 52 weeks

Frequency, duration and intensity appear more important

Armstrong and Barker (2011). *Med Sport Sci*. 56: 59-83

Can high-intensity interval exercise training (HIIT) improve CRF?

Definition: Repeated intervals of intense exercise separated by periods of low-intensity exercise or rest

Merits to this approach:

- Delivery of vigorous/high intensity bouts – important for CRF
- Intermittent nature aligns with habitual physical activity patterns and sport participation
- Recent physical activity guidelines have called for more evidence on HIIT

PLOS ONE

RESEARCH ARTICLE

School-based high-intensity interval training programs in children and adolescents: A systematic review and meta-analysis

Stephanie L. Duncombe[1,2*], Alan R. Barker[2], Bert Bond[2], Renae Earle[1], Jo Varley-Campbell[3], Dimitris Vlachopoulos[2], Jacqueline L. Walker[1], Kathryn L. Weston[4], Michalis Stylianou[1]

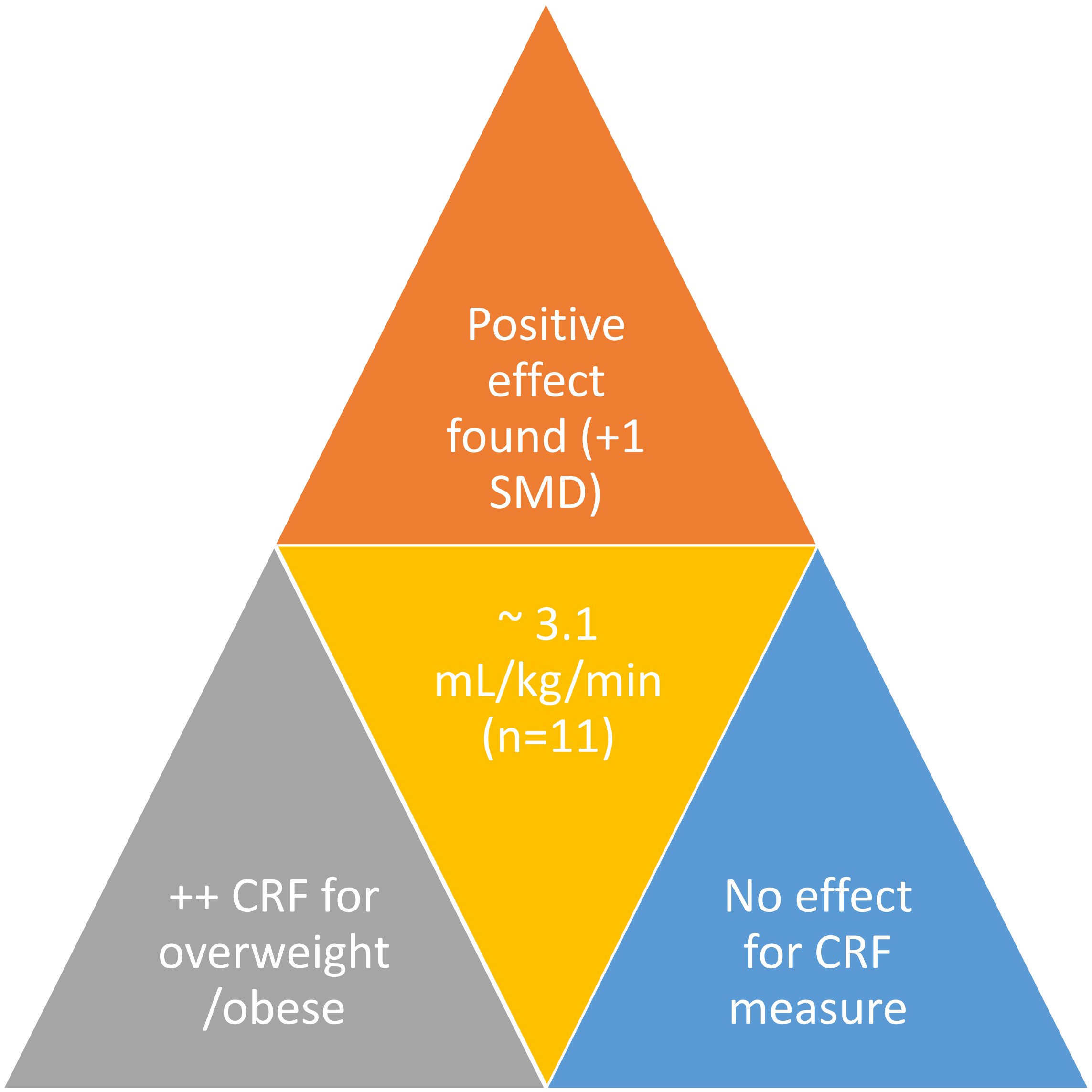
1 School of Human Movement and Nutrition Sciences, University of Queensland, Saint Lucia, Queensland, Australia, **2** Children's Health and Exercise Research Centre, Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter, Exeter, United Kingdom, **3** Department of Clinical, Educational and Health Psychology, University College London, London, United Kingdom, **4** School of Applied Sciences, Edinburgh Napier University, Edinburgh, United Kingdom

Duncombe et al. (2022). PLoS ONE. 17: e026642

Does HIIT improve CRF?

- 5-17 year olds
- HIIT delivered in a school setting
- ≥ 2 weeks duration
- Control or comparative exercise group
- Published in English

- n=42 studies included in the review and n=25 reported CRF (n=2099 participants)
- Range of methods to measure CRF
- Variety of modalities (running, cycling, dance, resistance training, circuits, sports)
- Intervals ranged from 10 s to 2 min bouts



Duncombe et al. (2022). *PLosONE*. 17: e0266427

Overview

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CRF - powerful marker of health and performance

Supramaximal testing can validate a true VO_2 max

20mSRT is readily used but recent data question validity

CRF increases with age in a sex specific manner due to increases in fat free mass

Vigorous intensity physical activity is important for promoting CRF

Aerobic training can improve CRF across pubertal stages

Intensity is important

HIIT may be useful strategy to promote CRF

Take home messages


KIITOS!


W. RUDLING