Seminar – Saint Etienne - Thursday 3 October 2019

# Metabolic and Fatigue Profiles Are Comparable Between Prepubertal Children and Well-Trained Adult Endurance Athletes


UNIVERSITÉ Clermont Auvergne

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AME2P LABORATOIRE Activité Physique Métabolisme > Santé

# Background

- Most prepubertal children are able to play for hours without tiring
- When children play, they choose to perform short bouts of activity separated by brief periods of rest, whereas us adults perform long bouts of slow exercise like running or walking long distances
- But when children do play, they are able to do it for a very long time and it is impossible to keep up with them !

# Main questions?

- To understand why prepubertal children fatigue less than adults during repeated bouts of high-intensity exercise

- To know how maturation acts on the development of fatigue during high-intensity intermittent exercise?

# What does science say?

- Growth- and maturation-related differences
  - Whole body dynamic activities
    - Cycling
    - Running
    - Hopping
    - Bench press
  - Maximal voluntary muscle contraction

- Comparison children/endurance athletes
  - Whole body dynamic activities
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- Sex-related differences during growth

- Effect of exercise modality

- Conclusions

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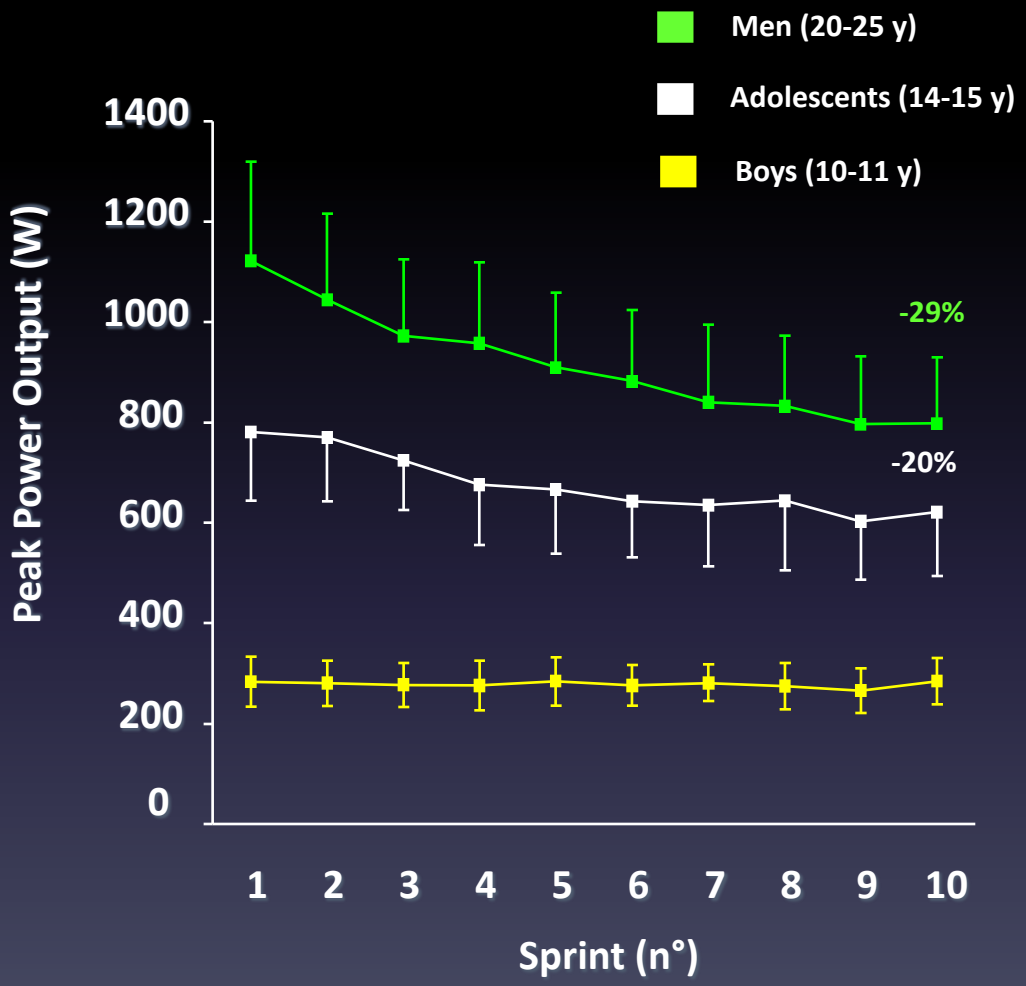
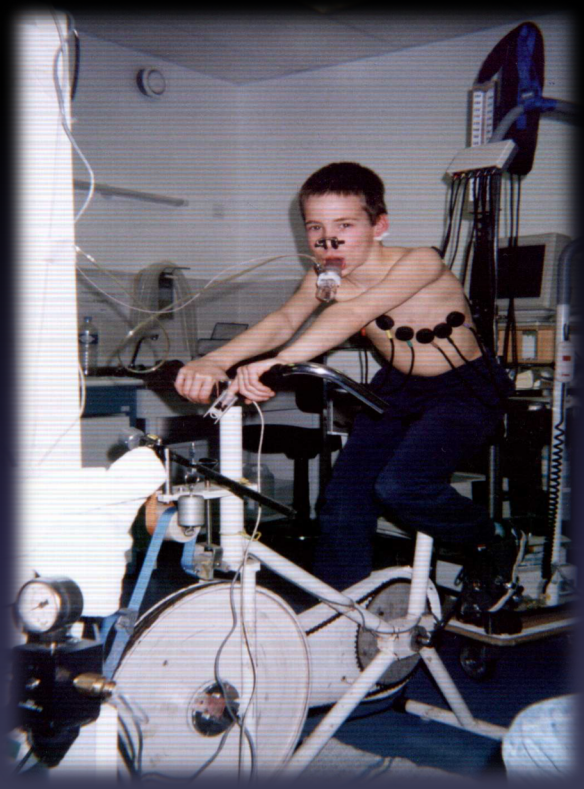
# Cycling

## Ten 10 s sprints R = 30 s



Ratel et al., Int. J. Sports Med., 23: 397-402, 2002

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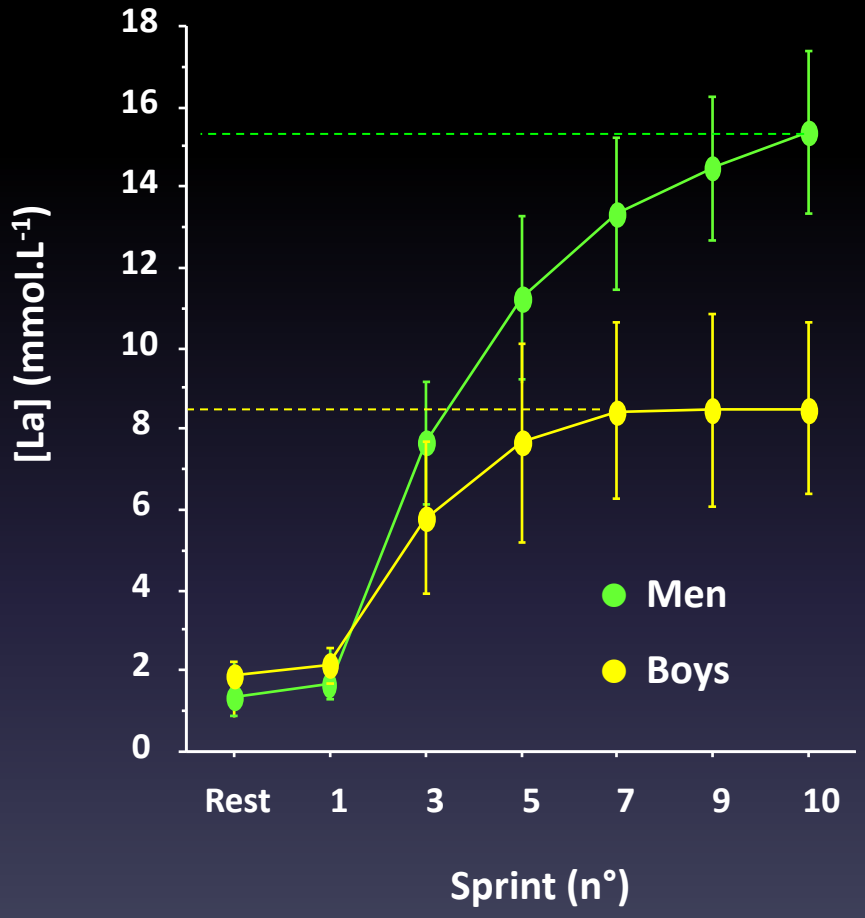


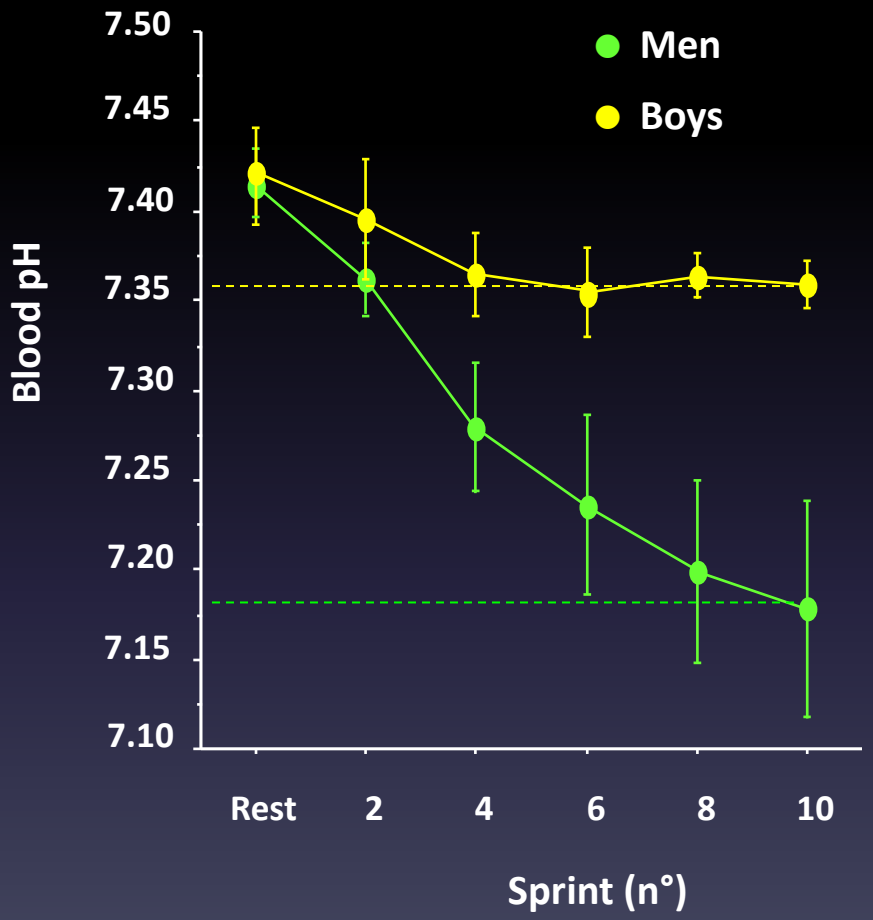


Ratel et al., J. Appl. Physiol., 92: 479-85, 2002

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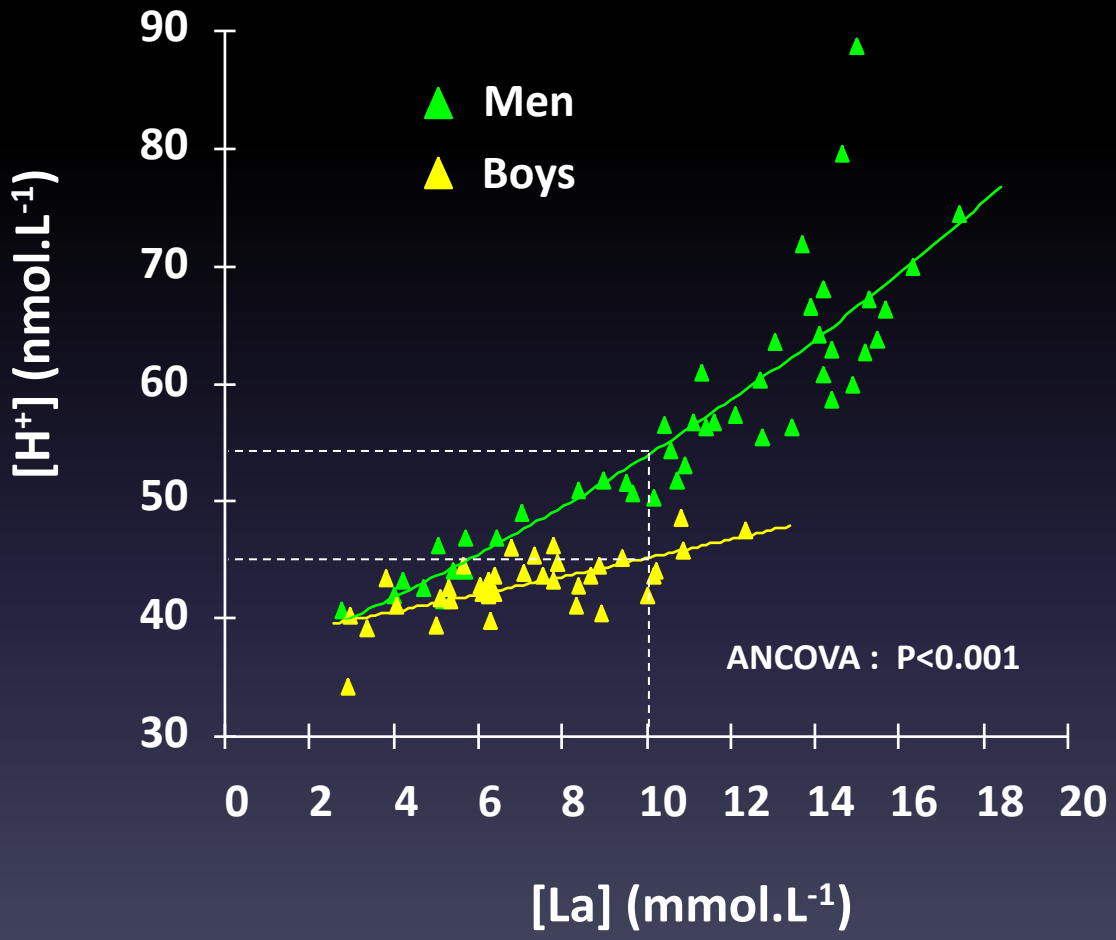


Ratel et al., J. Appl. Physiol., 92: 479-85, 2002

# Cycling

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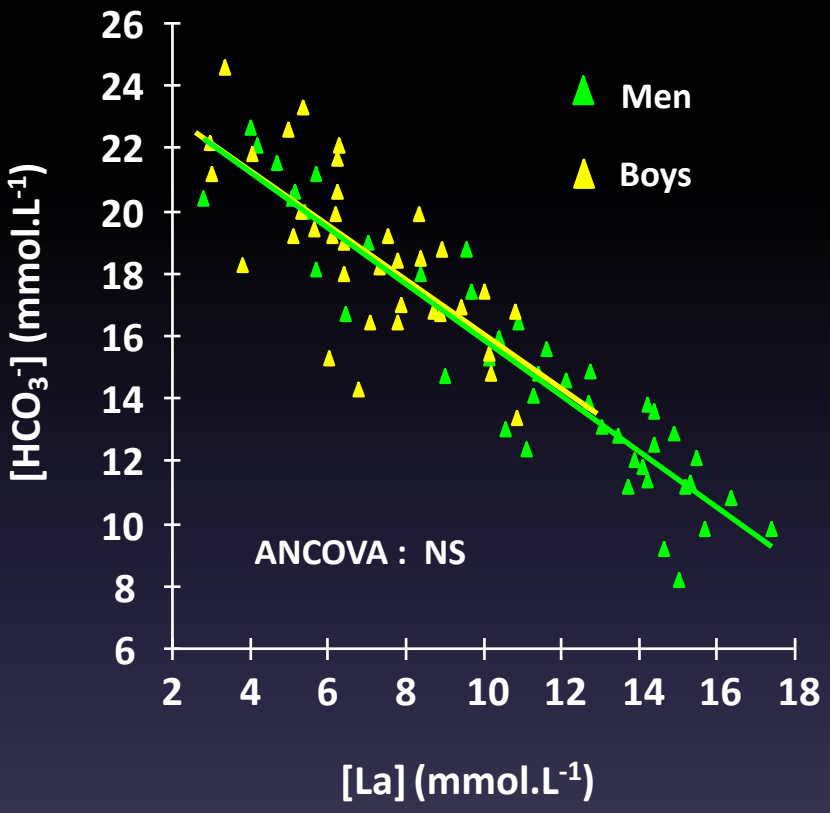
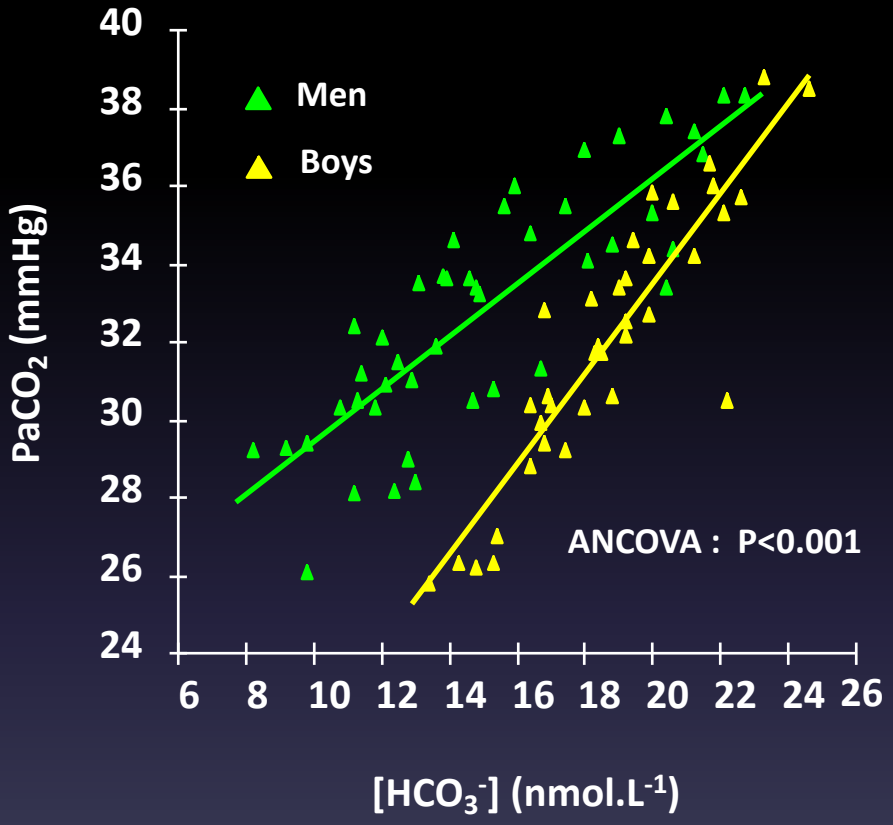
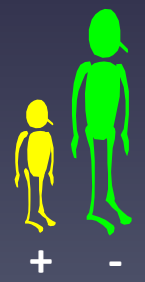



Ratel et al., J. Appl. Physiol., 92: 479-85, 2002

$$pH = pKa + \log \frac{[HCO_3^-]}{\alpha\, PaCO_2}$$



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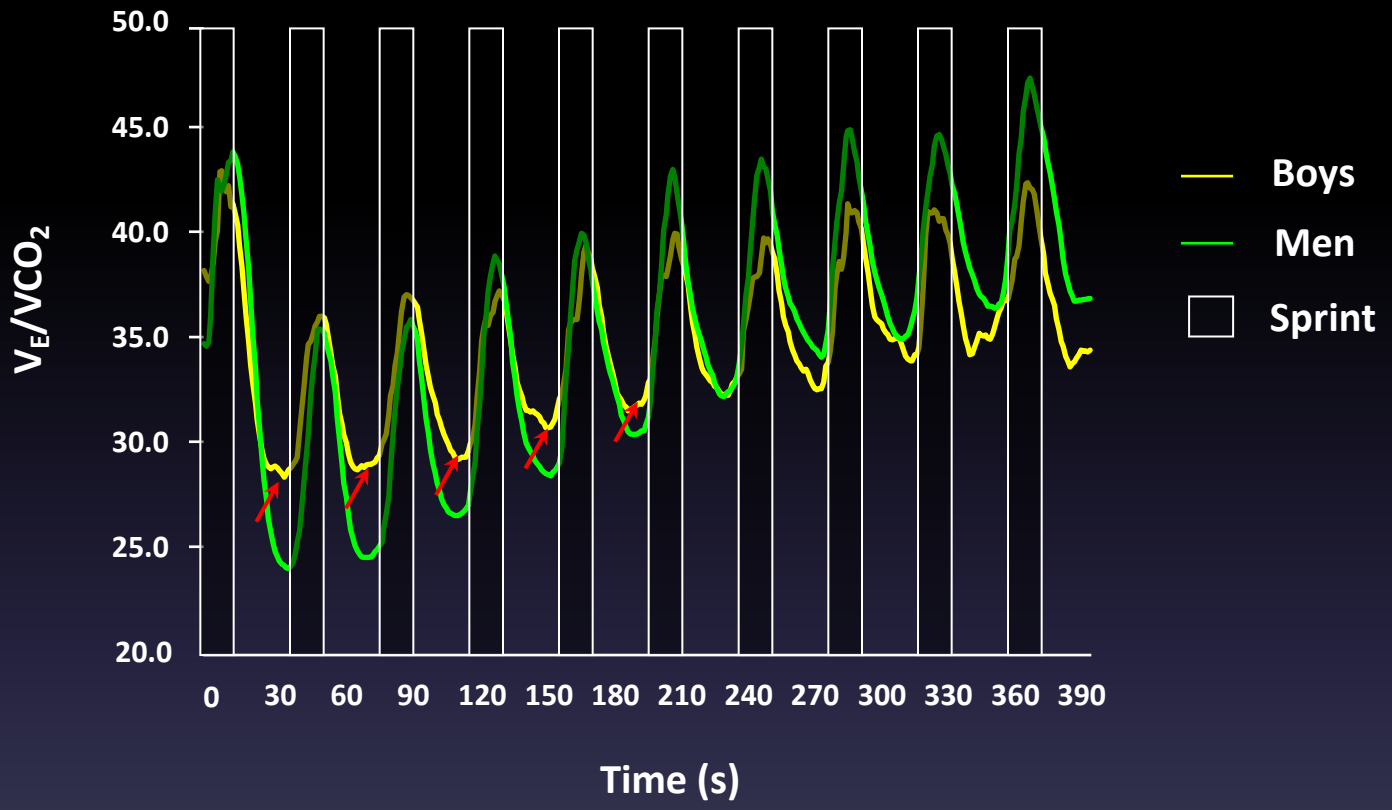


➔The regulation of blood acid-base balance during high-intensity intermittent exercise is more effective in children than adults

Ratel et al., J. Appl. Physiol., 92: 479-85, 2002

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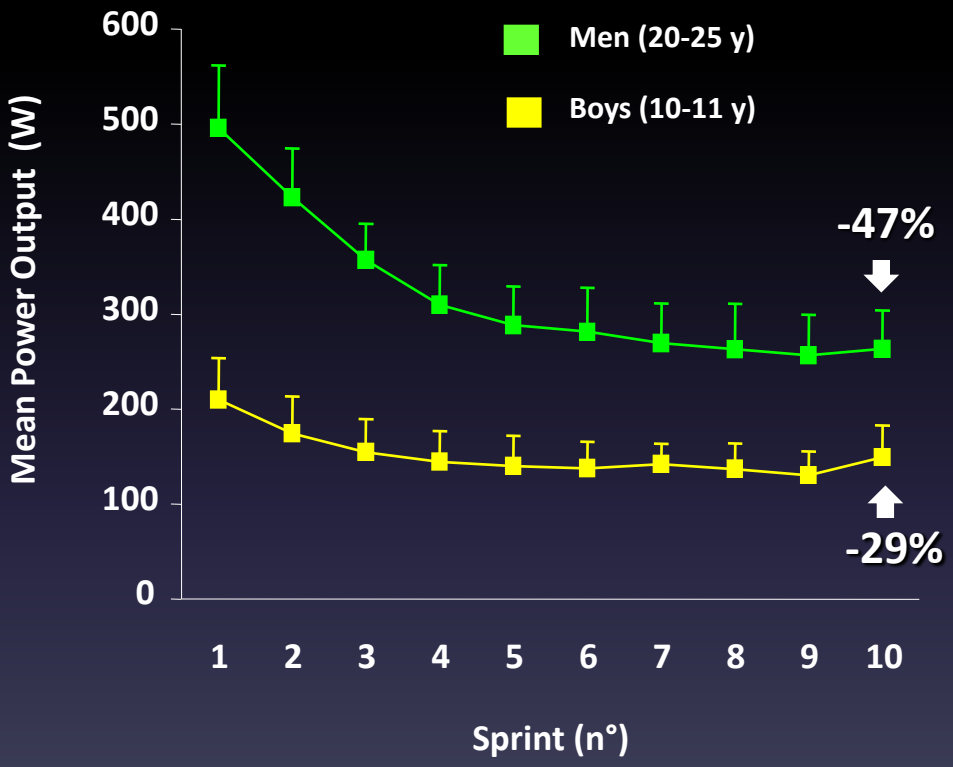
# Running

## Ten 10 s sprints R = 15 s

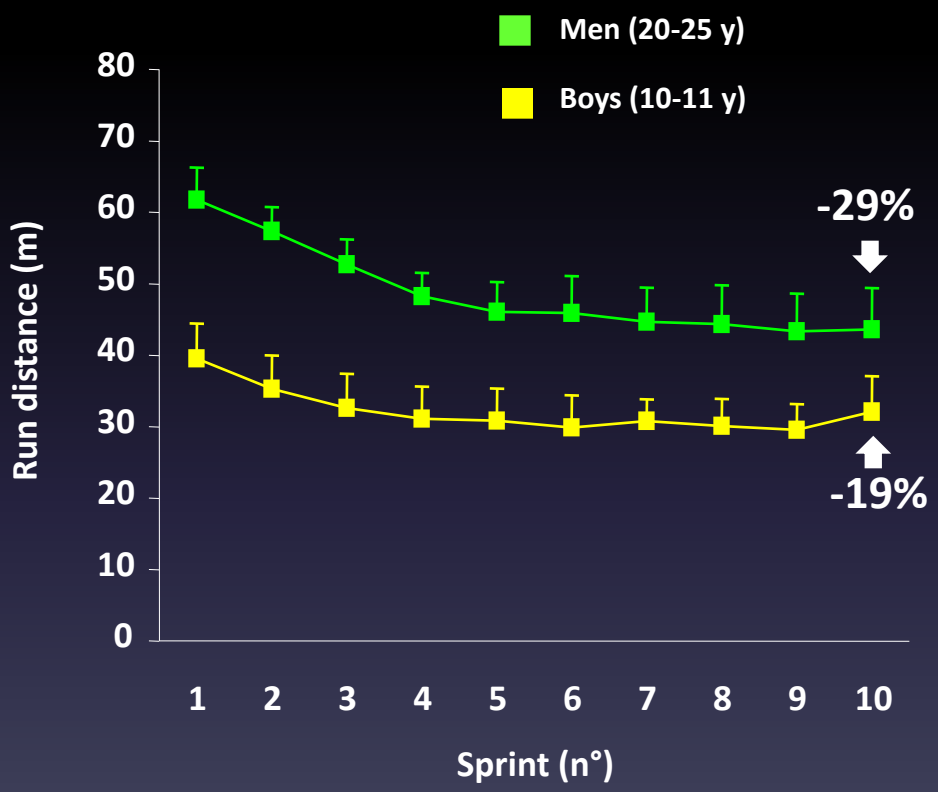



Non-motorized treadmill

Ratel et al., Int. J. Sports Med., 27: 1-8, 2006

# Running

## Ten 10 s sprints R = 15 s

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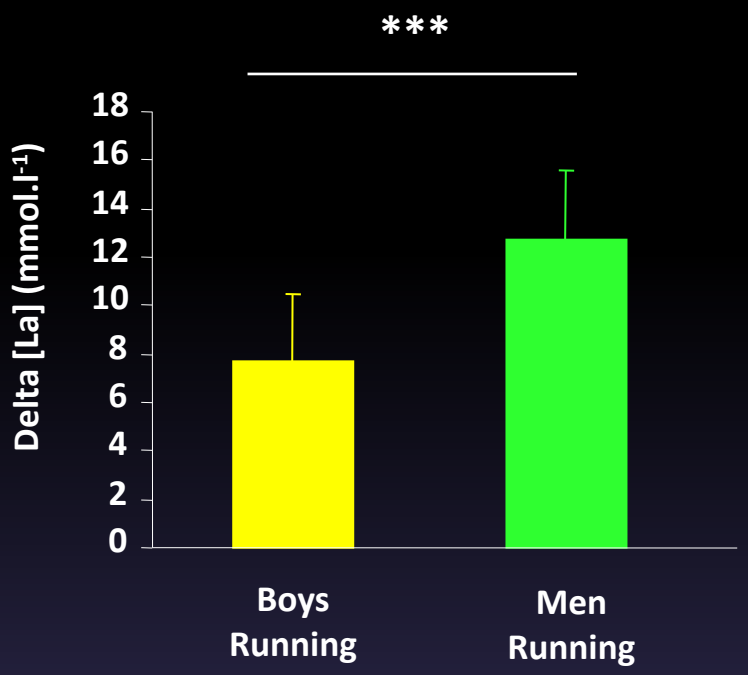


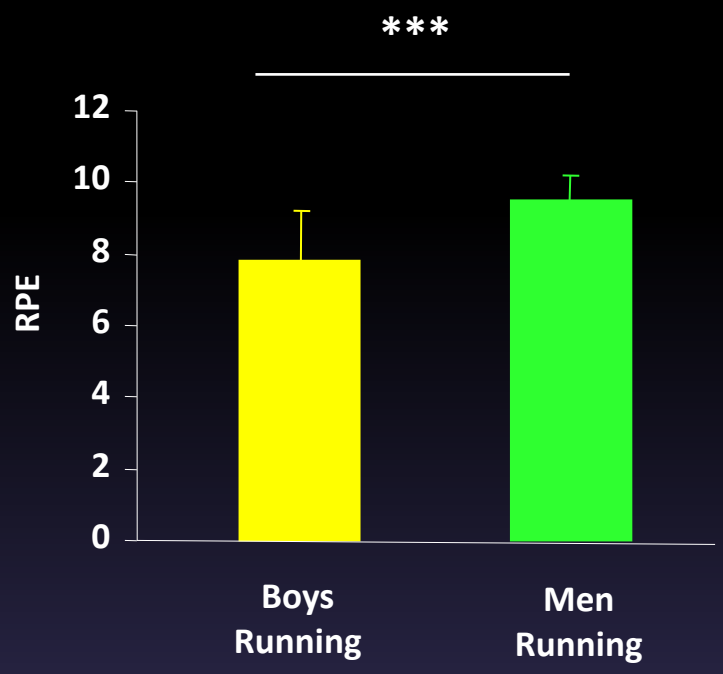

Delta [La] = 3 min post-exercise – rest

➔Lower blood lactate accumulation in children

➔Lower glycolytic activity in children?

Ratel et al., Eur. J. Appl. Physiol., 92: 204-10, 2004

# Ten 10 s sprints R = 15 s



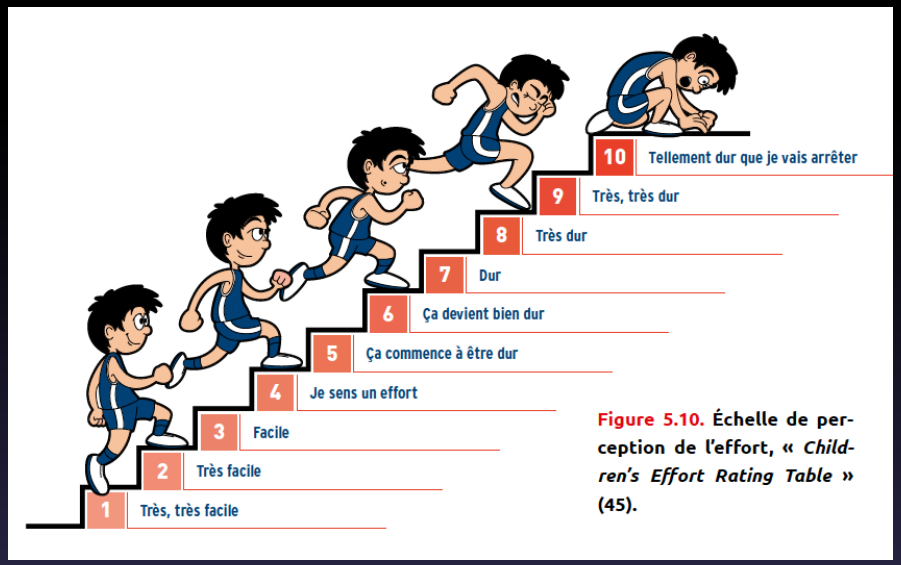




**Figure 5.10.** Échelle de perception de l'effort, « *Children's Effort Rating Table* » (45).

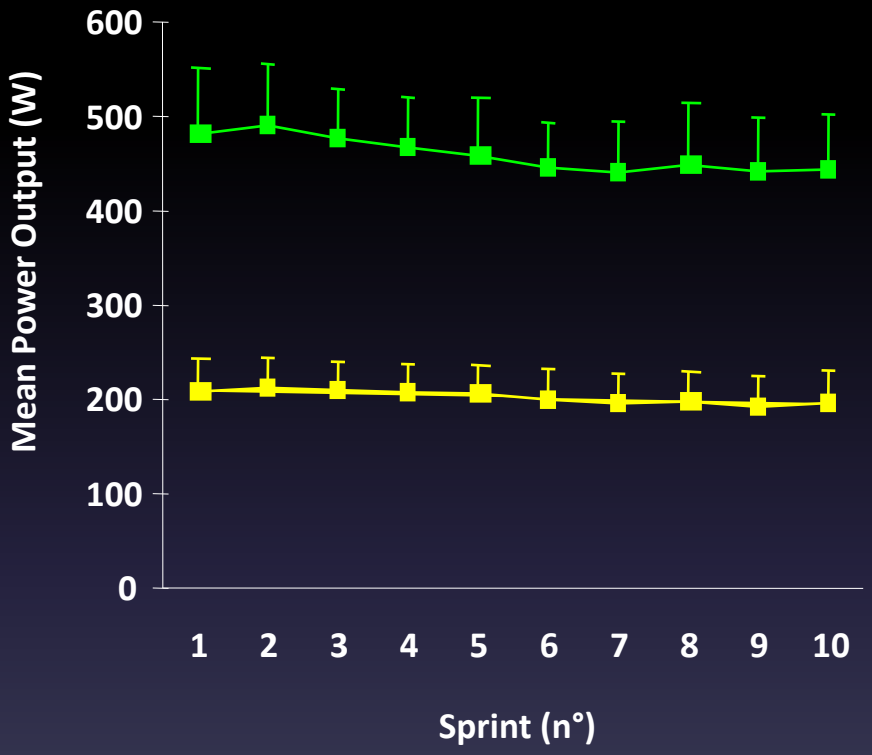
RPE from the Children's Effort Rating Table

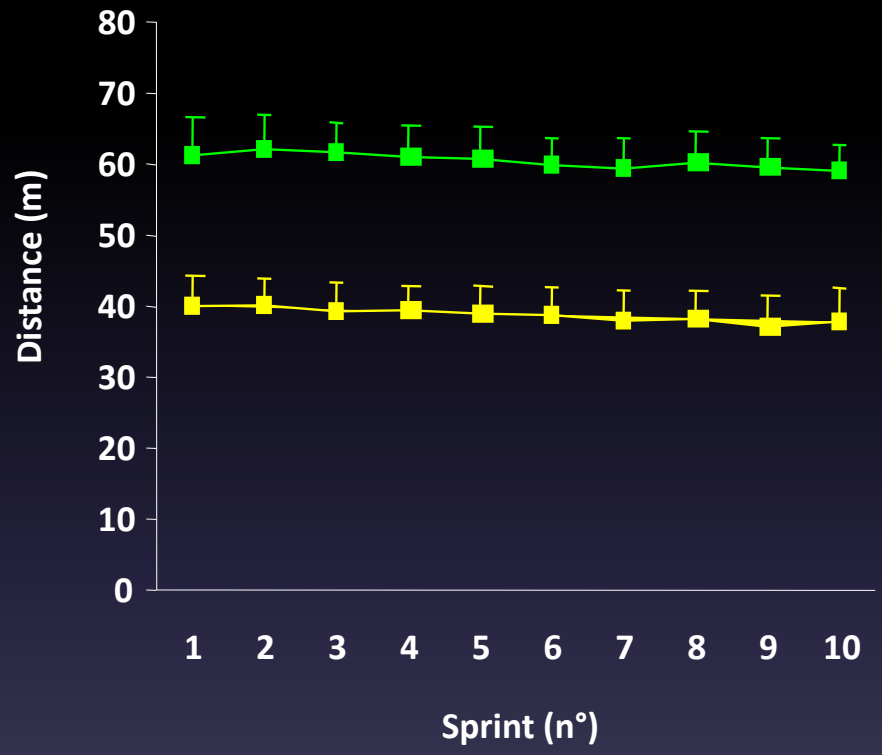
➔Lower RPE in children

Ratel et al., Eur. J. Appl. Physiol., 92: 204-10, 2004

# Running

## Ten 10 s sprints R = 3 min




Men Boys

Ratel et al., Int. J. Sports Med., 27: 1-8, 2006

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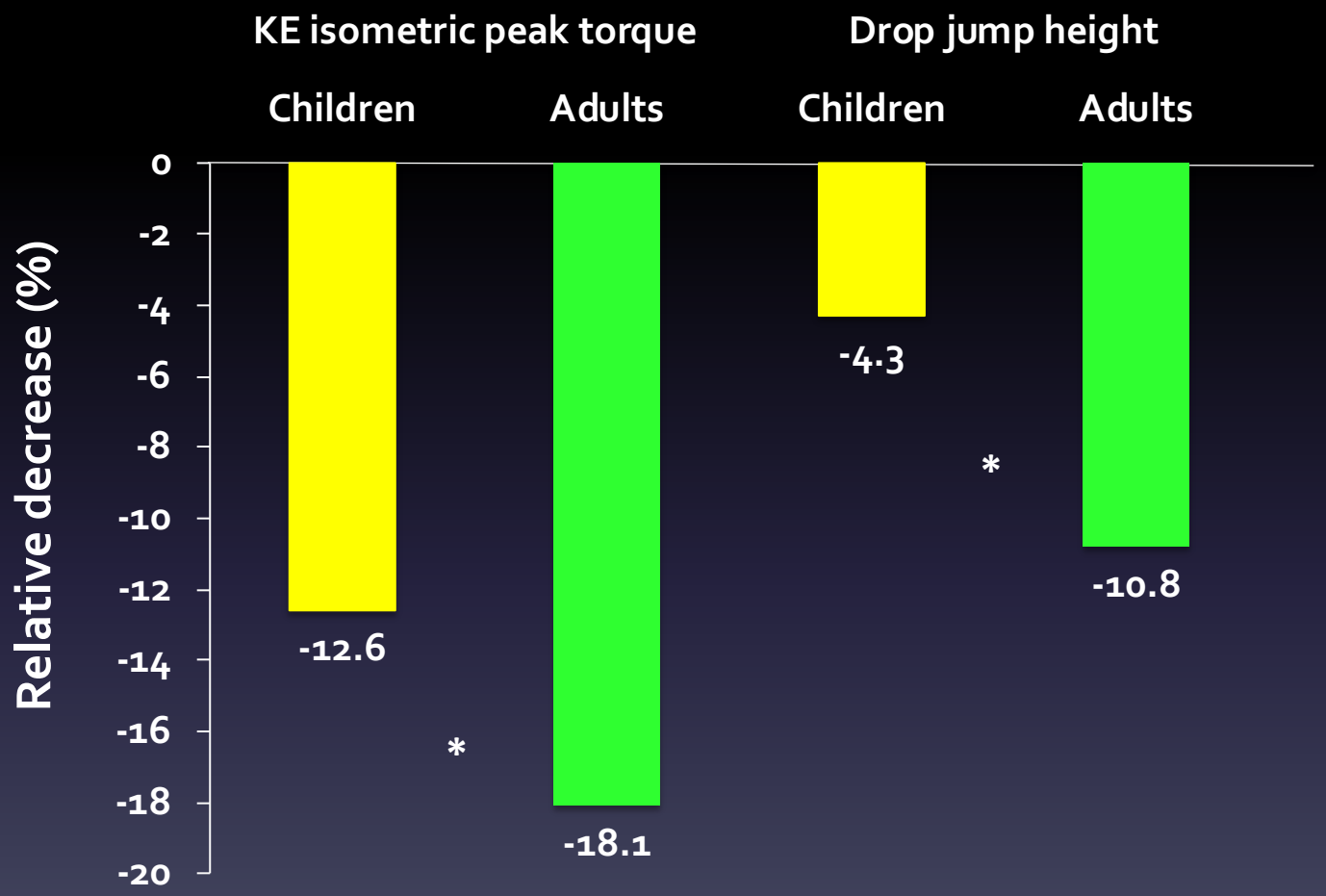
# Hopping

## 10 sets of 10 CMJs R = 30 s




Lazaridis et al., J. Sports Sci., 36: 131-9, 2018

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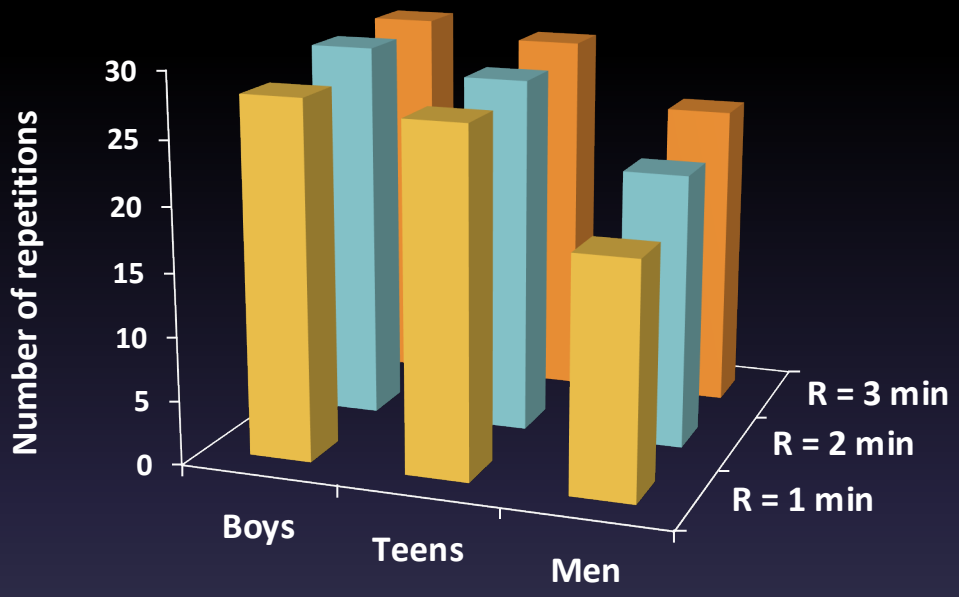
# Bench press

**3 sets with a 10 repetition maximum load with 1, 2 or 3 min RIs on bench press**




➔ **Boys and teens are able to maintain easier their lifting performance on bench press than men during intermittent resistance exercise**

Faigenbaum et al., Pediatr. Exerc. Sci., 20:457-469, 2008

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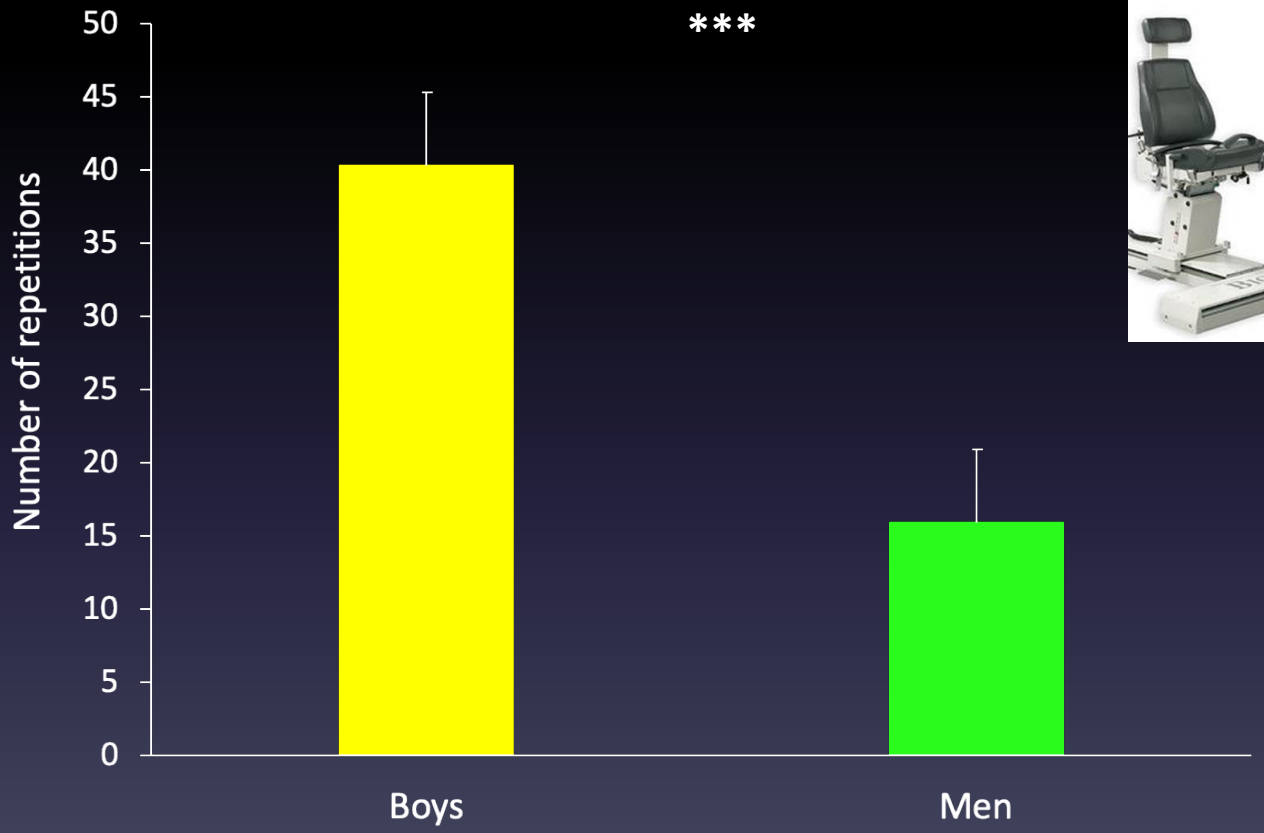
# Boys fatigue less than men during repeated KE MVCs

**Repeated 5-s MVCs of the KE muscles until the torque reached 60% of initial value**

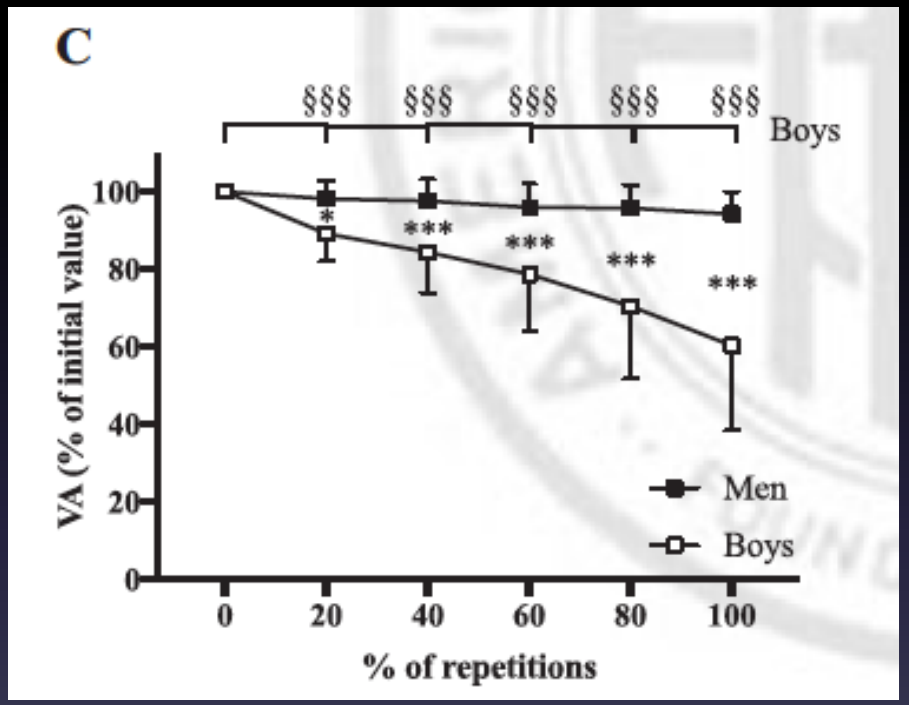



Piponnier et al., J. Appl. Physiol., in press

# Boys fatigue less than men during repeated KE MVCs

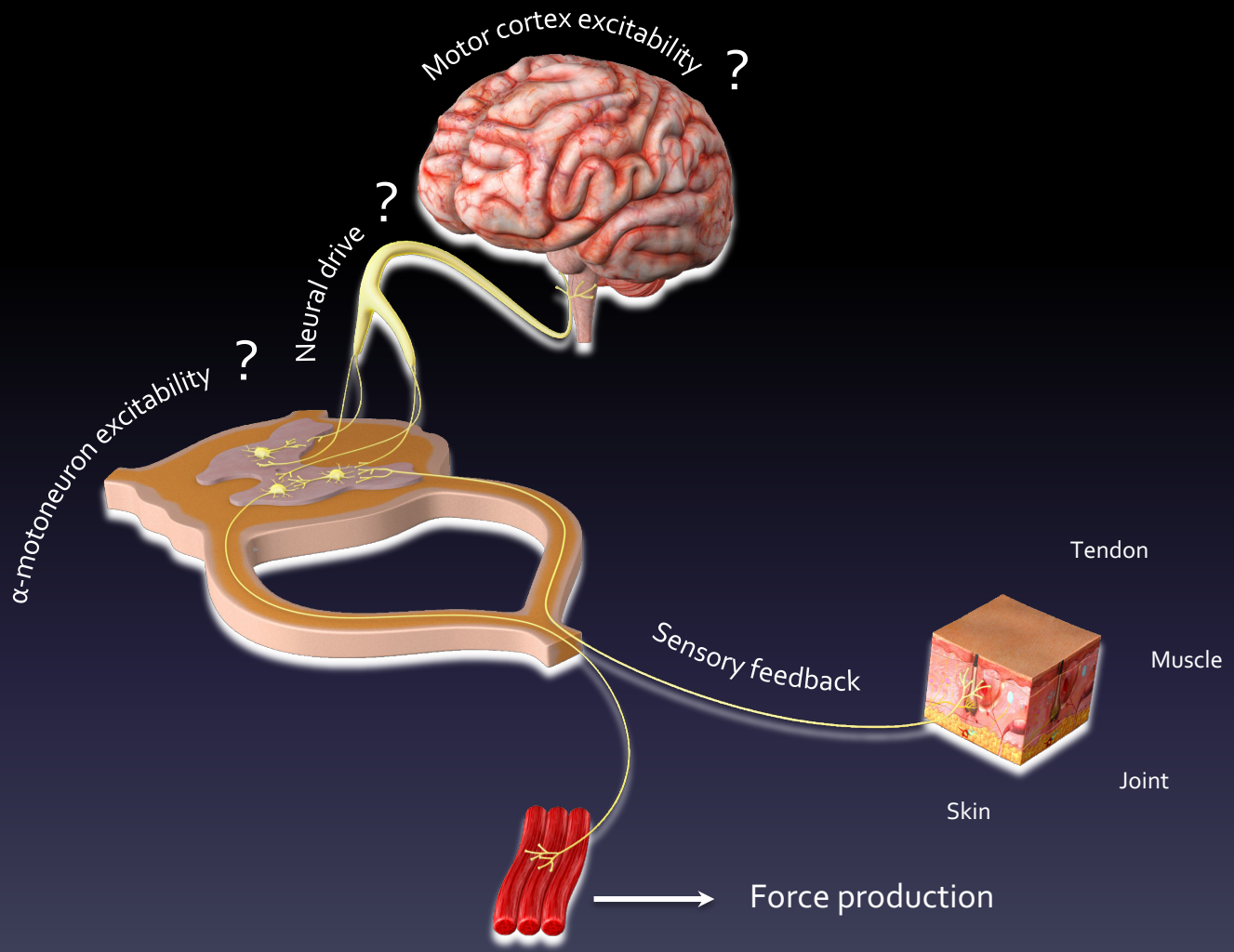
**Boys > Central fatigue > Men**

**Boys > Voluntary activation (VA) deficit > Men**




Ratel et al., Med. Sci. Sports Exerc., 47: 2319-28, 2015; Piponnier et al., J. Appl. Physiol., in press

# Boys > Central fatigue > Men

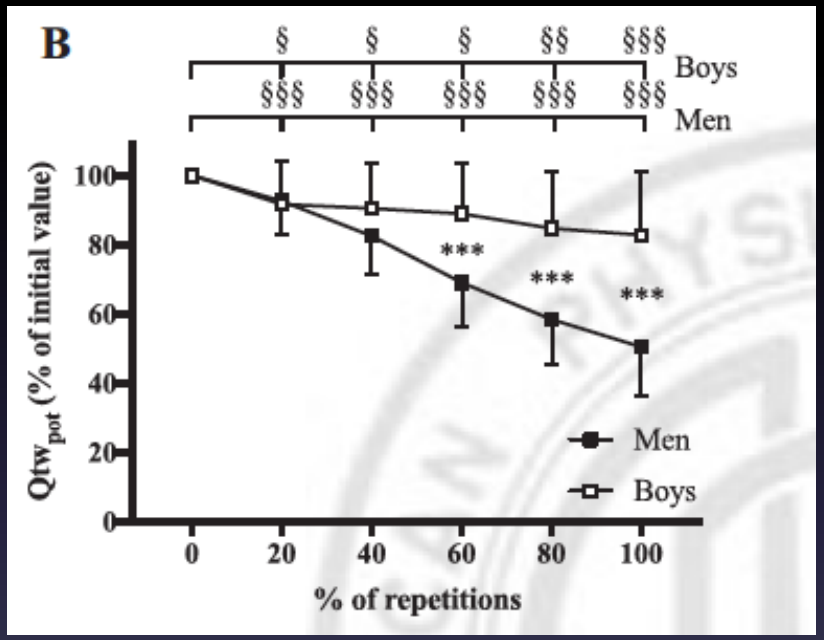



Patikas et al., Eur. J. Appl. Physiol., 118: 899-910, 2018

# Boys fatigue less than men during repeated KE MVCs

**Boys < Peripheral fatigue < Men**

**Boys < Twitch torque alteration (Qtw) < Men**



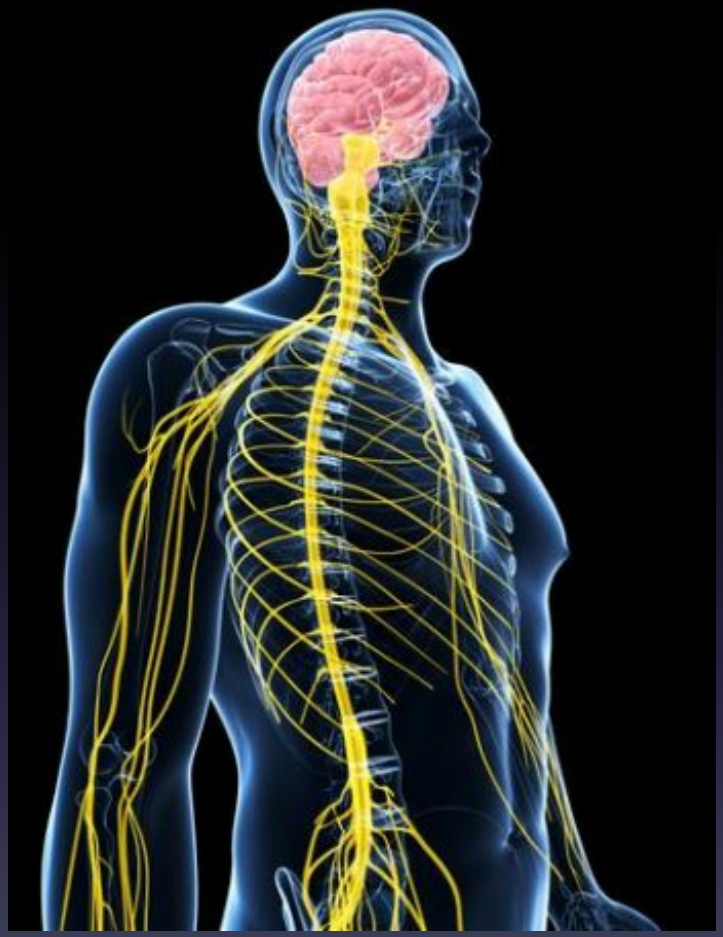

**Boys < low-frequency fatigue < Men**

➥ lower alteration of E-C coupling and/or contractile activity in boys

**Boys = M-wave = Men**

➥ no change of excitability of the sarcolemma

Ratel et al., Med. Sci. Sports Exerc., 47: 2319-28, 2015; Piponnier et al., J. Appl. Physiol., in press



## Interplay between central vs. peripheral fatigue???

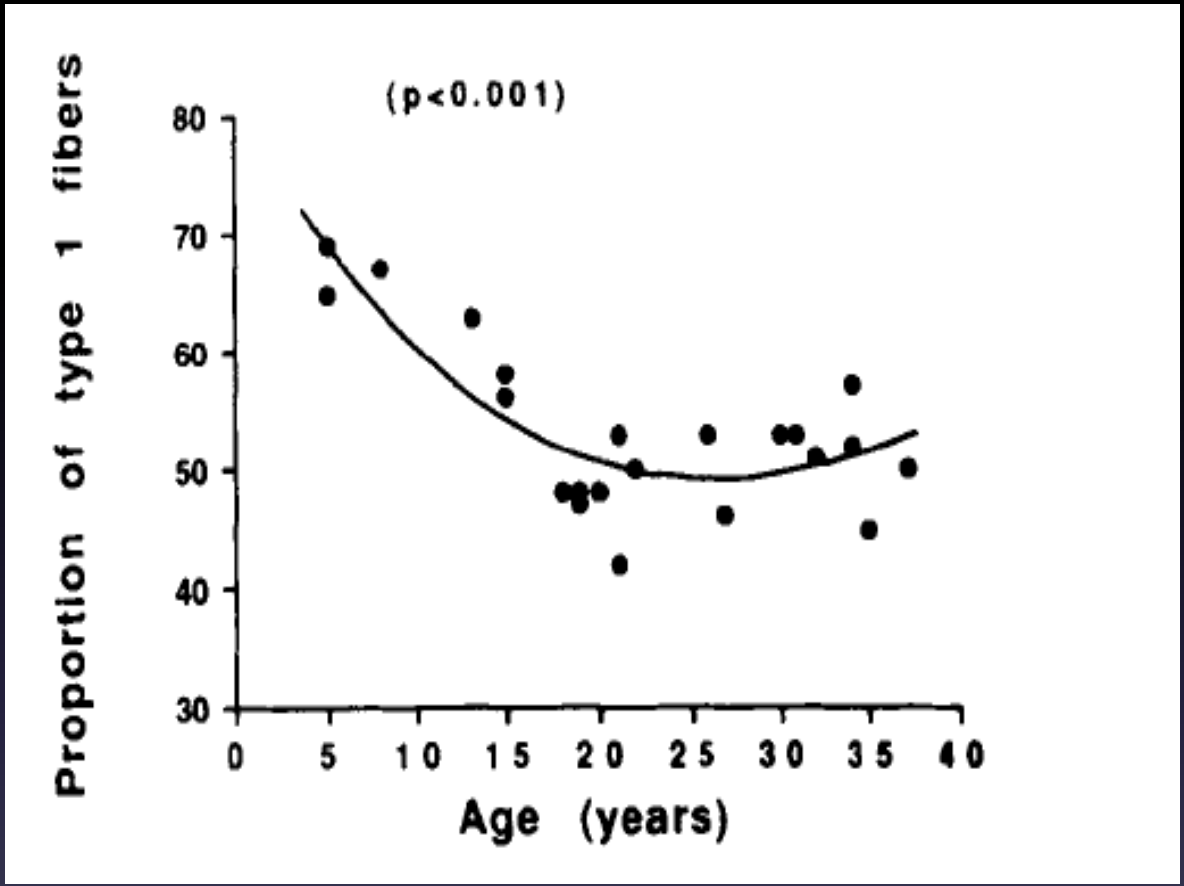
Children > Central fatigue > Adults

Central governor theory

Preemptive mechanism to prevent any excessive peripheral fatigue and muscle damage (protective mechanism) in children ?

Noakes et al., Br. J. Sports Med., 39:120-124, 2005

# Why children produce Less peripheral fatigue?

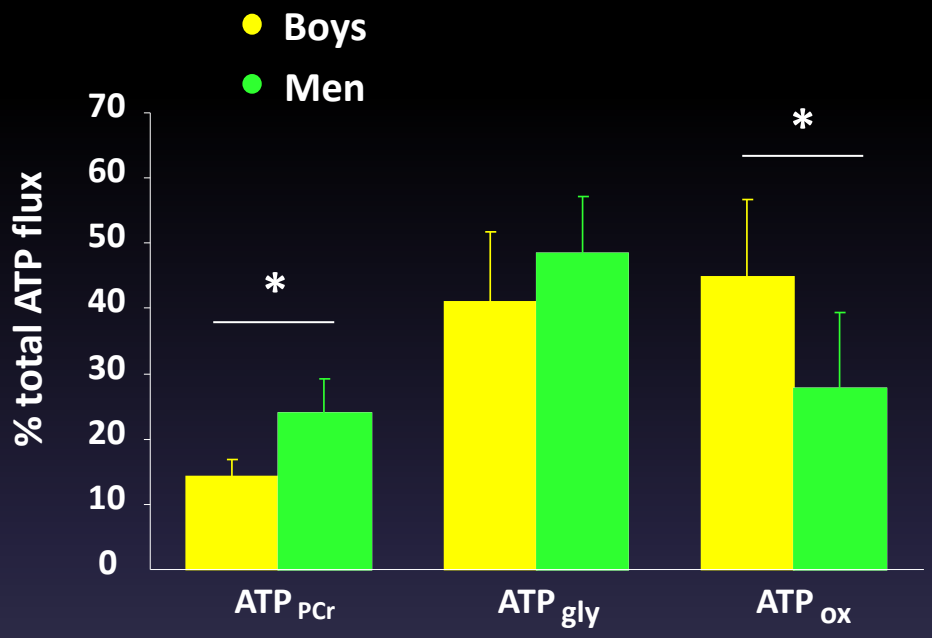



➔Higher proportion of less fatigable fibres (slow-twitch) in children

Lexell et al., Muscle & Nerve, 15:404-409, 1992

# Why children produce Less peripheral fatigue?

During 3 min of finger flexions at 15% of MVC ($^{31}$P-MRS)



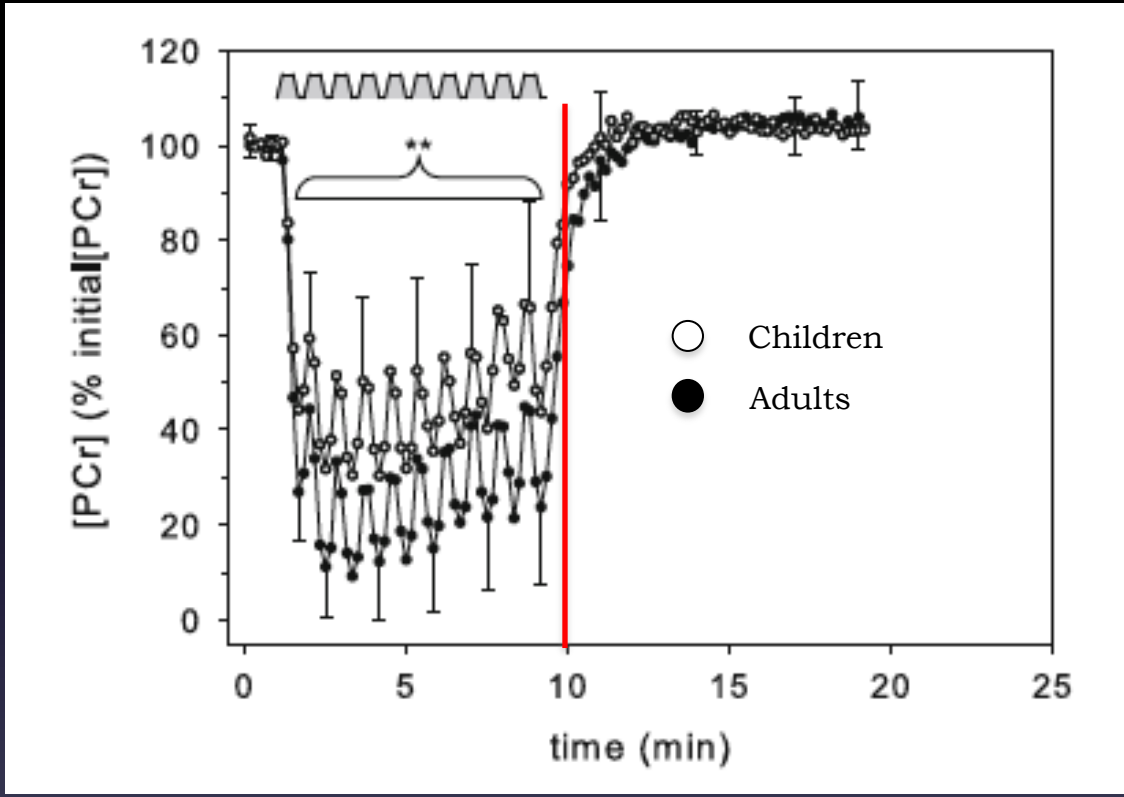

4.7 T Bruker magnet ($^{31}$P-MRS)

➔ Children use more their oxidative than anaerobic metabolism during exercise than adults

Tonson, Ratel et al., J. Appl. Physiol., 109: 1769-1778, 2010

# Why children produce Less peripheral fatigue?

**Ten bouts of 30-s plantar flexion interspersed by 20-s recovery followed by 10 min of recovery**




➔ **Lesser phosphocreatine depletion in children**

**Kappenstein et al., Eur. J. Appl. Physiol., 113: 2769-79, 2013**

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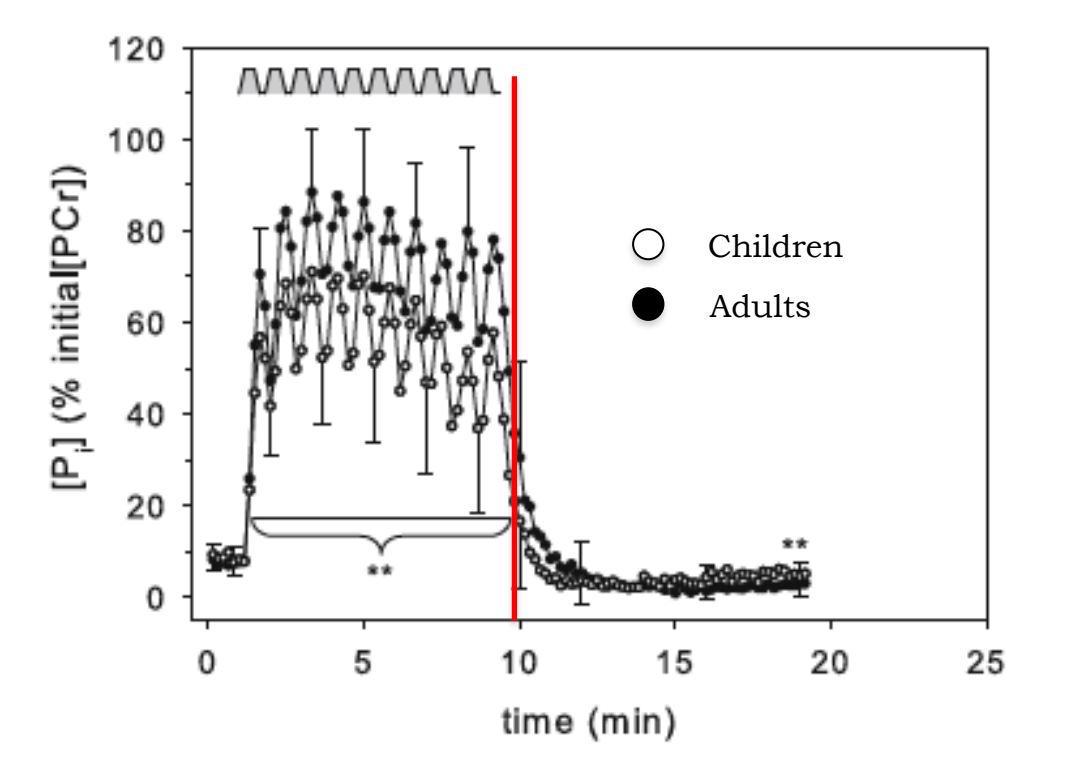


➔ **Lower muscle Pi accumulation in children**

➔ **Lower low-frequency fatigue in children**

Kappenstein *et al.*, Eur. J. Appl. Physiol., 113: 2769-79, 2013

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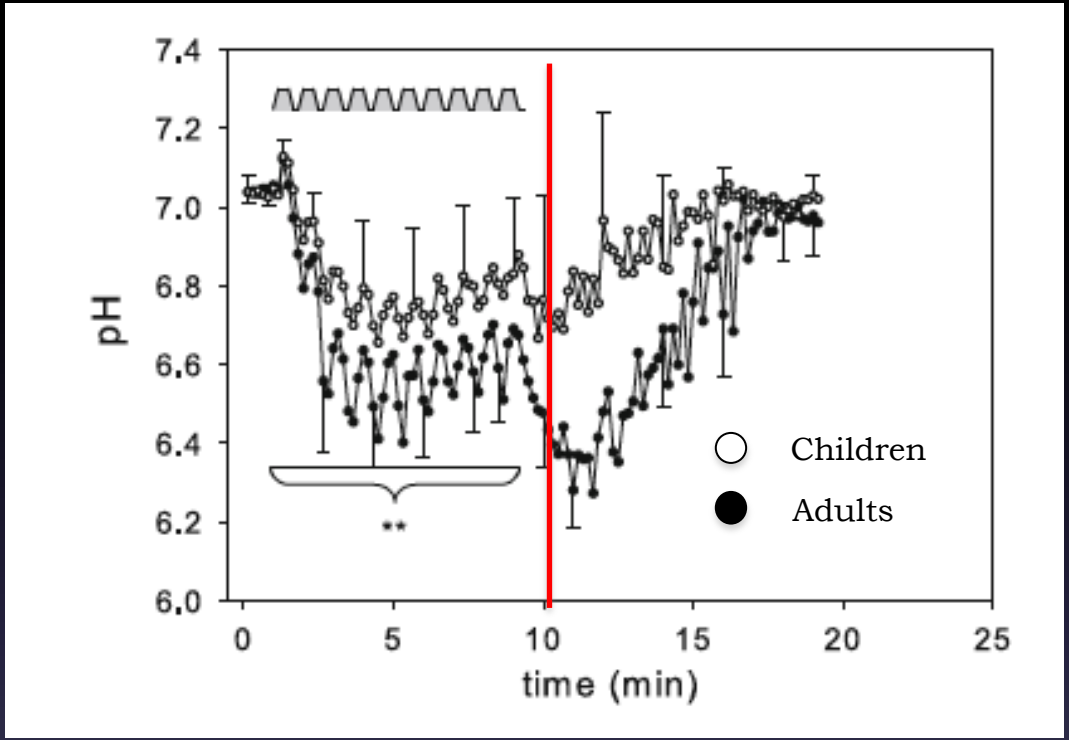



➔ **Lower decrement in muscle pH in children**

➔ **Preservation of contractile properties in children**

➔ **Delayed muscle fatigue in children**

Kappenstein *et al.*, Eur. J. Appl. Physiol., 113: 2769-79, 2013

# Why children produce Less peripheral fatigue?

| Study | Age | Muscle | Enzyme | Comparison |
|---|---|---|---|---|
| Haralambie (1982) | Ado: 13-15<br>Adu: 22-42 | Vastus Lateralis | CS | Child = Adu |
| Berg et al. (1986) | Child: 6,4<br>Ado: 17,1 | Vastus Lateralis | CS | Child = Ado |
| Eriksson et al. (1973) | Child: 11,2 | Vastus Lateralis | SDH | Child > Adu |
| Haralambie (1982) | Ado: 13-15<br>Adu: 22-42 | Vastus Lateralis | Fumarase | Ado > Adu |
| Berg et al. (1986) | Child: 6,4<br>Ado: 17,1 | Vastus Lateralis | Fumarase | Child > Ado |

CS: citrate synthase, SDH: succinate deshydrogenase

➔Greater oxidative enzyme activity in children

# Why children produce Less peripheral fatigue?

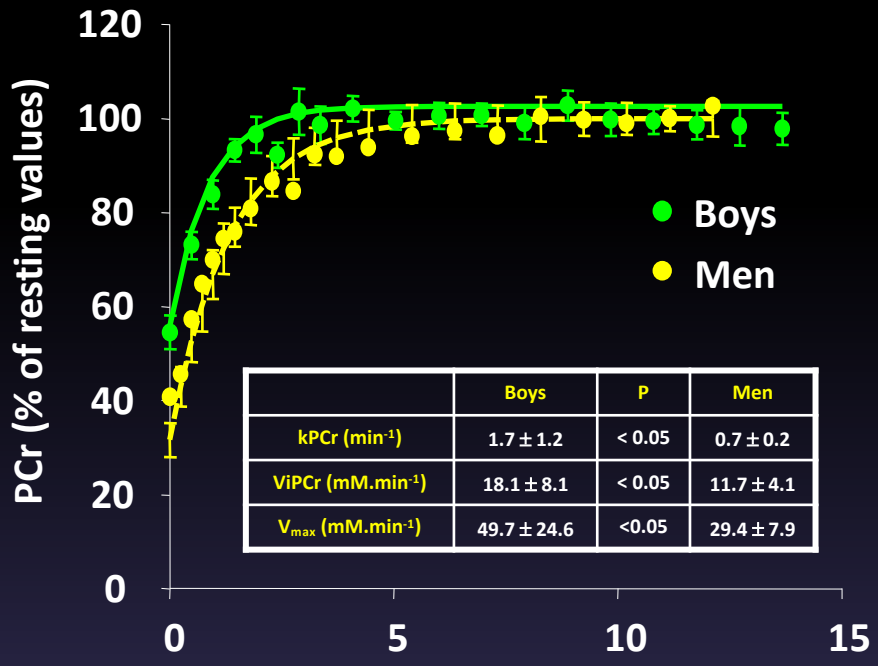
| Study | Muscle | Enzyme | Comparison |
|---|---|---|---|
| **Haralambie (1982)** | **Vastus Lateralis** | **LDH** | **Child* = Adu**<br>* 13-15-y-old |
| **Berg *et al.* (1986)** | **Vastus Lateralis** | **LDH** | **Child < Adu** |
| **Kaczor *et al.* (2005)** | **Obliquus internus abdominis** | **LDH** | **Child < Adu** |
| **Eriksson *et al.* (1973)** | **Vastus Lateralis** | **PFK** | **Child < Adu***<br>* Gollnick et al. (1972) |
| **Fournier *et al.* (1982)** | **Vastus Lateralis** | **PFK** | **Child* < Ado**<br>*Eriksson *et al.* (1973) |

**LDH: lactate dehydrogenase, PFK: phosphofructokinase**

**➔Lesser glycolytic enzyme activity in children**

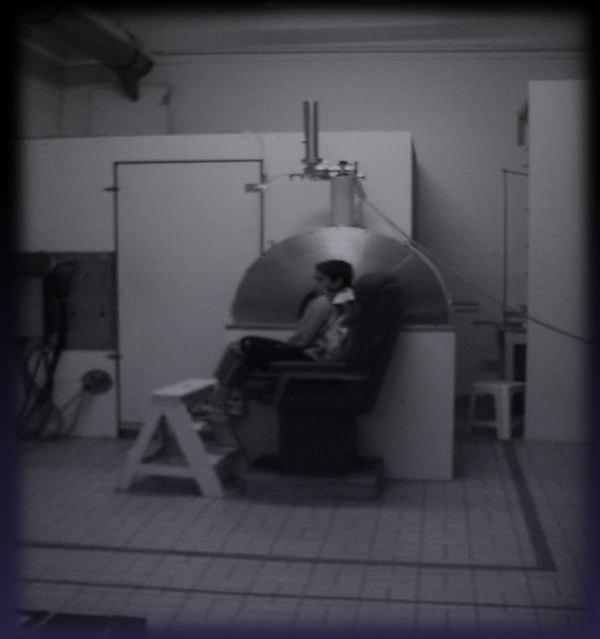
# Why children produce Less peripheral fatigue?

Following 3 min of finger flexions at 15% MVC




| | Boys | P | Men |
|---|---|---|---|
| kPCr ($min^{-1}$) | 1.7 ± 1.2 | < 0.05 | 0.7 ± 0.2 |
| ViPCr ($mM.min^{-1}$) | 18.1 ± 8.1 | < 0.05 | 11.7 ± 4.1 |
| $V_{max}$ ($mM.min^{-1}$) | 49.7 ± 24.6 | <0.05 | 29.4 ± 7.9 |

Post-exercise recovery time (min)



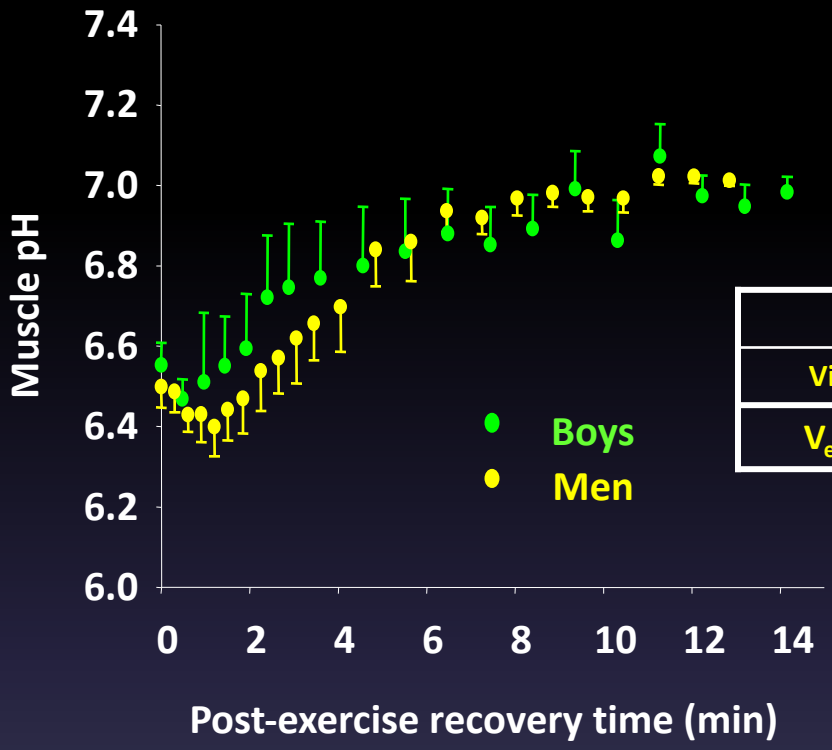
4.7 T Bruker magnet ($^{31}$P-MRS)

➔The greater muscle oxidative capacity in children could facilitate phosphocreatine resynthesis rate following exercise

Ratel et al., Appl. Physiol. Nutr. Metab., 33: 720-727, 2008

# Why children produce Less peripheral fatigue?

Following 3 min of finger flexions at 15% MVC




| | Boys | P | Men |
|---|---|---|---|
| VipH (pHunit.min$^{-1}$) | 0.03 ± 0.09 | < 0.05 | -0.04 ± 0.04 |
| $V_{eff}$ max (mM.min$^{-1}$) | 6.2 ± 2.3 | < 0.05 | 3.9 ± 1.9 |

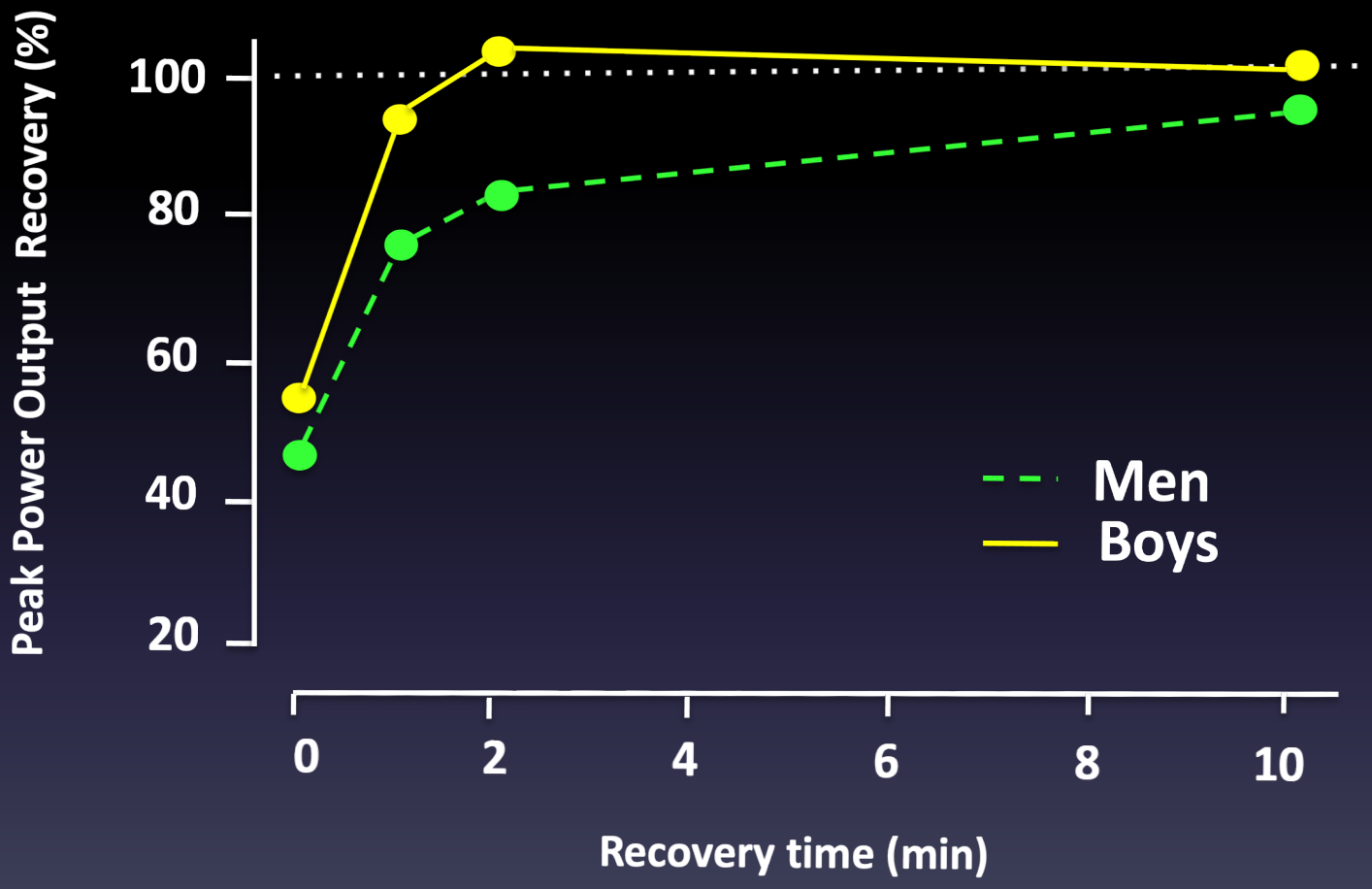
➔The capacity to remove $H^+$ ions from muscles is higher in children

➔Muscle proton efflux rate is higher in children

Ratel et al., Appl. Physiol. Nutr. Metab., 33: 720-727, 2008

# Why children produce Less peripheral fatigue?

Following 30 s of maximal exercise (after a Wingate test)




➔Faster recovery of peak power output in children

Hebestreit et al., J. Appl. Physiol., 74(6): 2875-80, 1993

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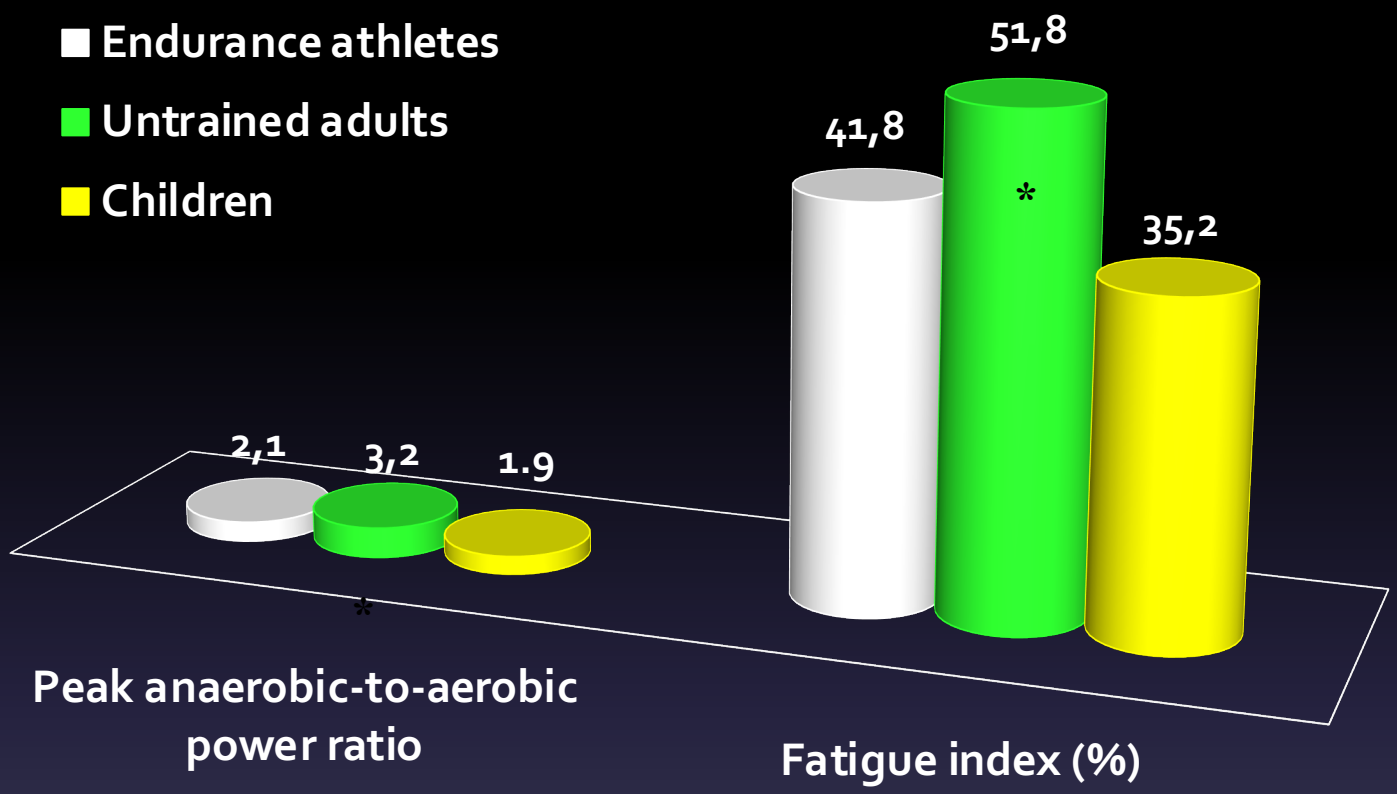
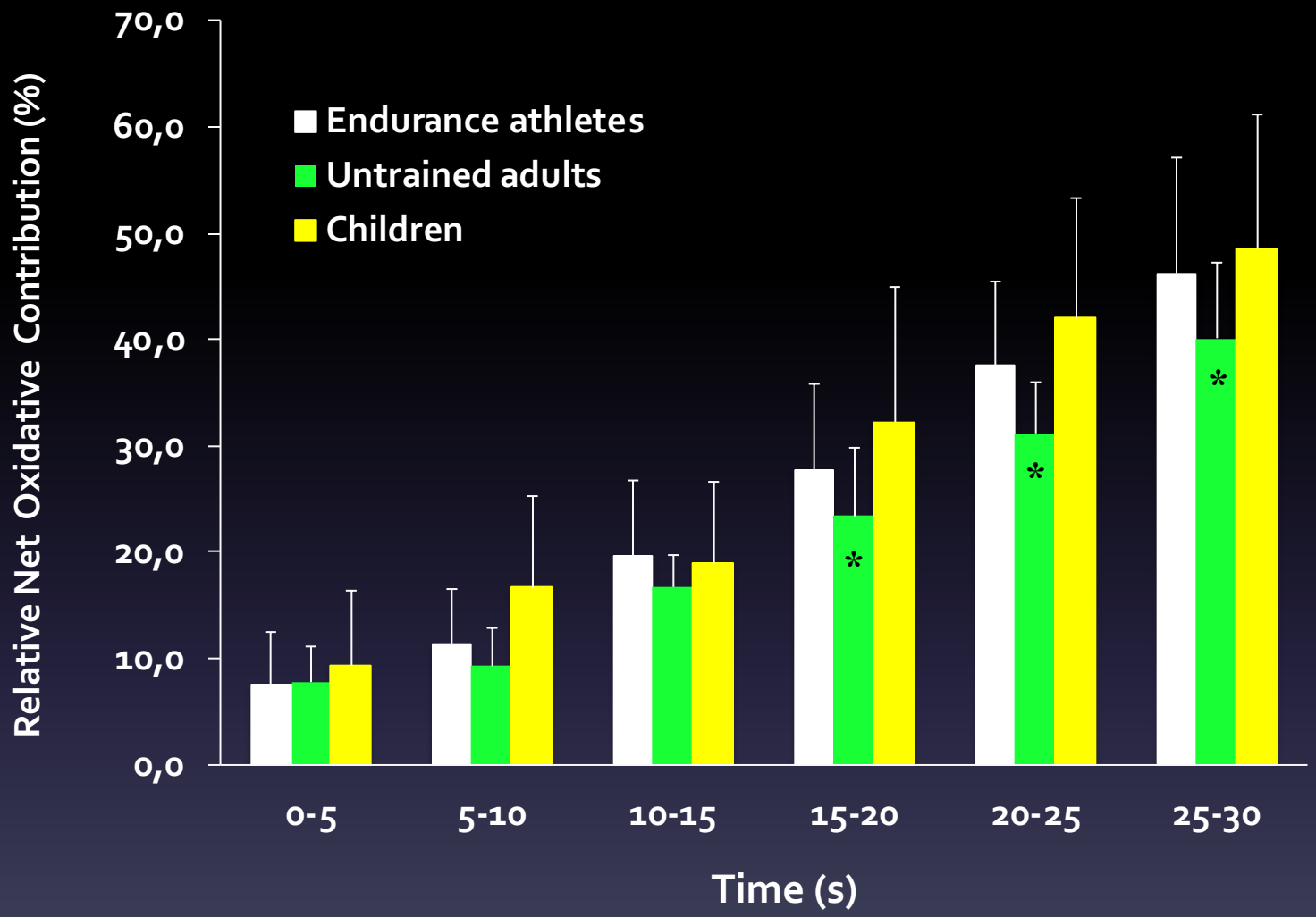
# 30-s all-out cycle sprint (Wingate test)




➔Fatigue index (power decline) is similar in children and endurance athletes and lower than untrained adults

Birat et al., Front. Physiol., Apr 24;9:387, 2018

# 30-s all-out cycle sprint (Wingate test)




➔Comparable relative oxidative contribution (%) in children and endurance athletes

Birat et al., Front. Physiol., Apr 24;9:387, 2018

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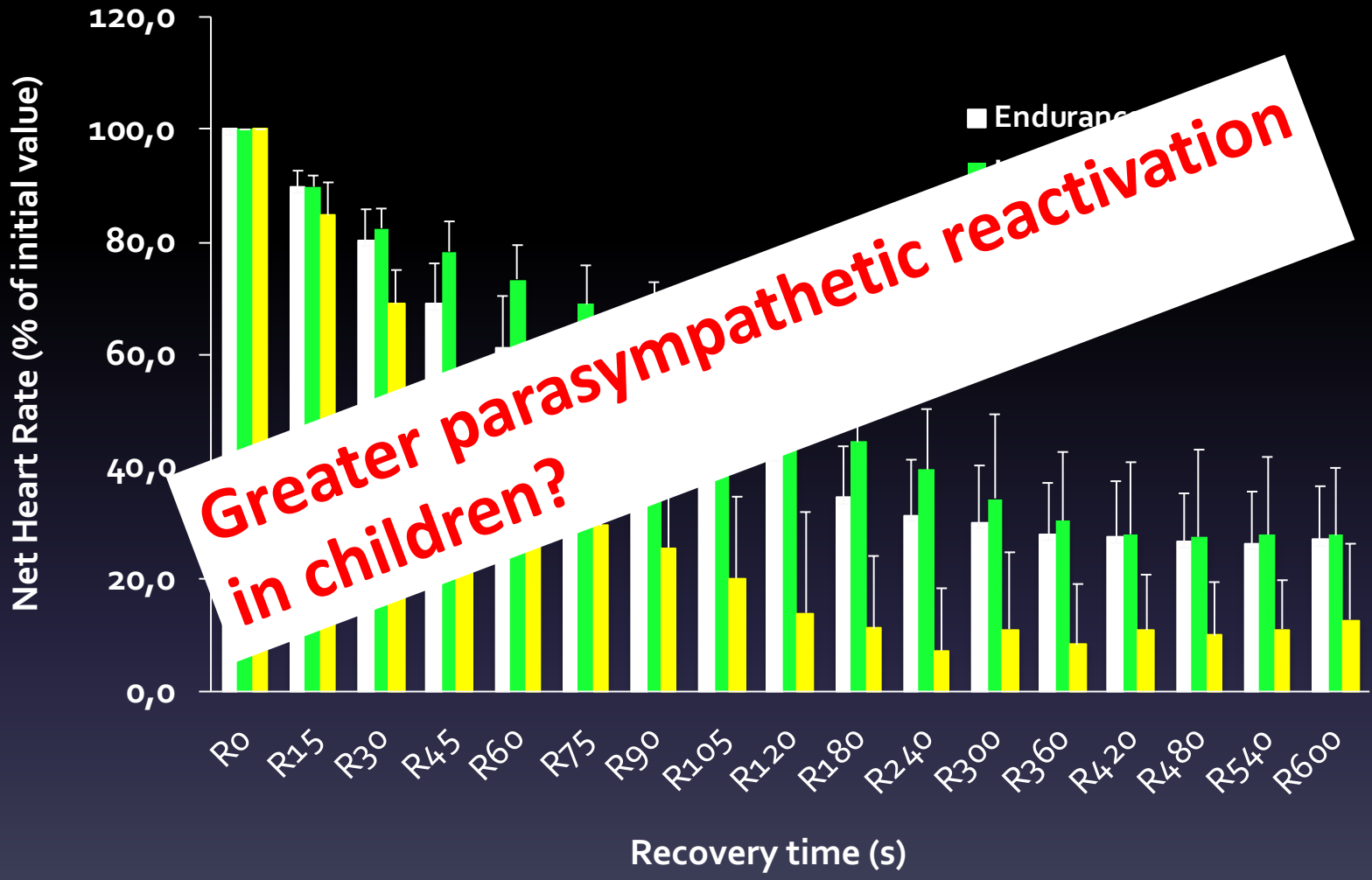
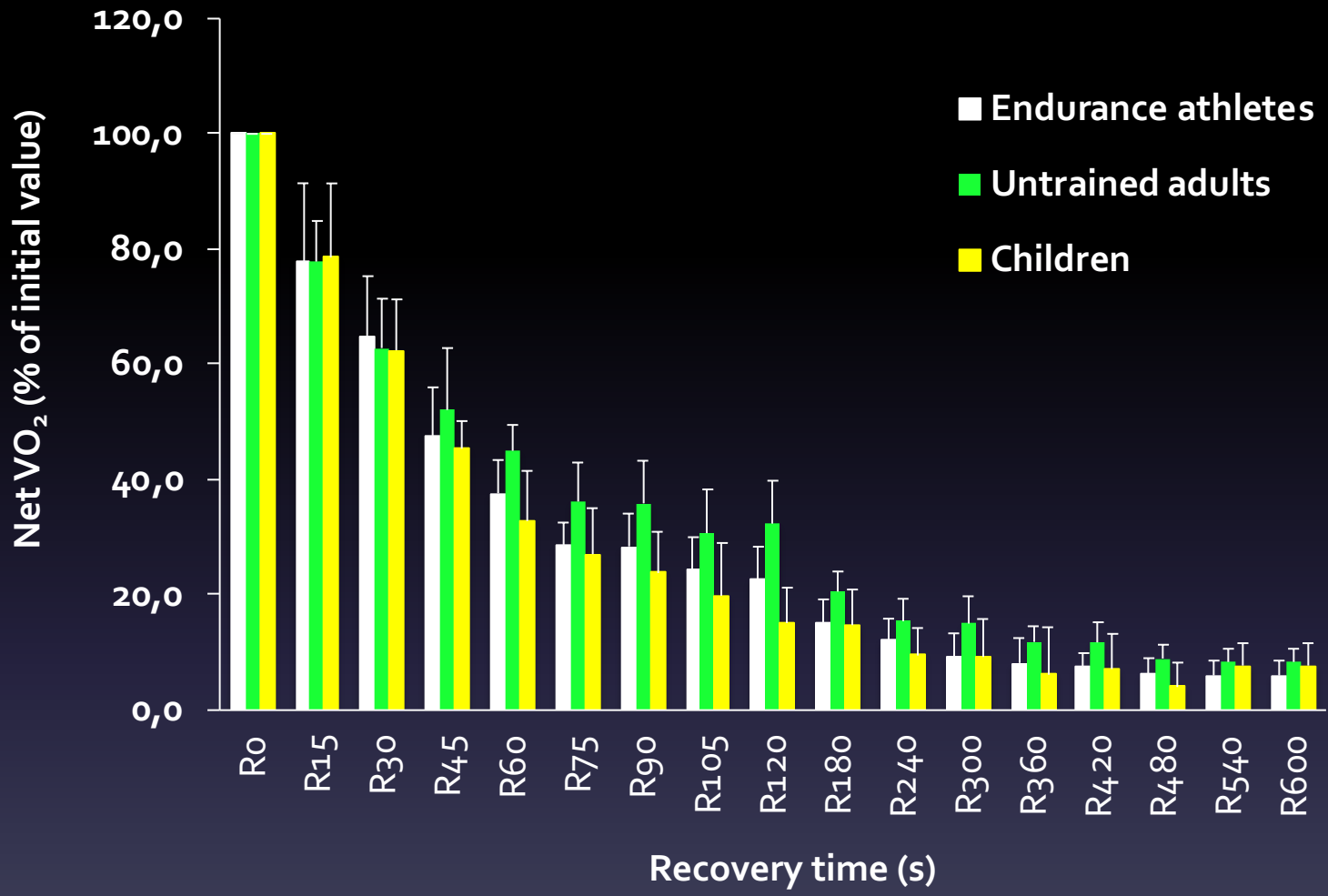



➔Heart rate recovery rate is faster in children than endurance athletes

Birat et al., Front. Physiol., Apr 24;9:387, 2018

# Following a 30-s all-out cycle sprint (Wingate test)

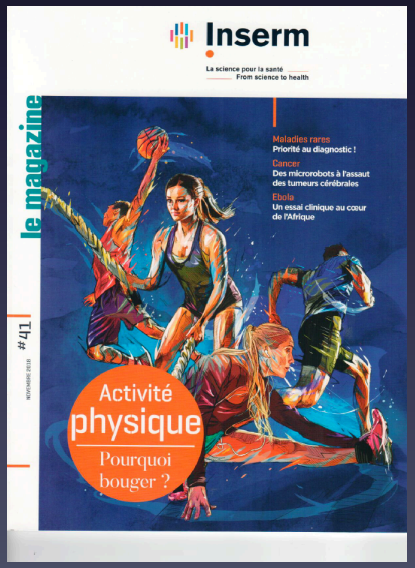



➔ $VO_2$ recovery rate is similar in children and endurance athletes

Birat et al., Front. Physiol., Apr 24;9:387, 2018








Le Monde

SCIENCES

# Les enfants sont plus endurants que des athlètes

**Les enfants prépubères sont aussi résistants à un effort physique intense que des adultes avec un niveau national en course de fond, triathlon ou cyclisme.**

Par Sandrine Cabut • Publié le 07 mai 2018 à 17h00 - Mis à jour le 07 mai 2018 à 17h00

# What does science say?

- Growth- and maturation-related differences
  - Whole body dynamic activities
    - Cycling
    - Running
    - Hopping
    - Bench press
  - Maximal voluntary muscle contraction

- Comparison children/endurance athletes
  - Whole body dynamic activities
  - Maximal voluntary muscle contraction

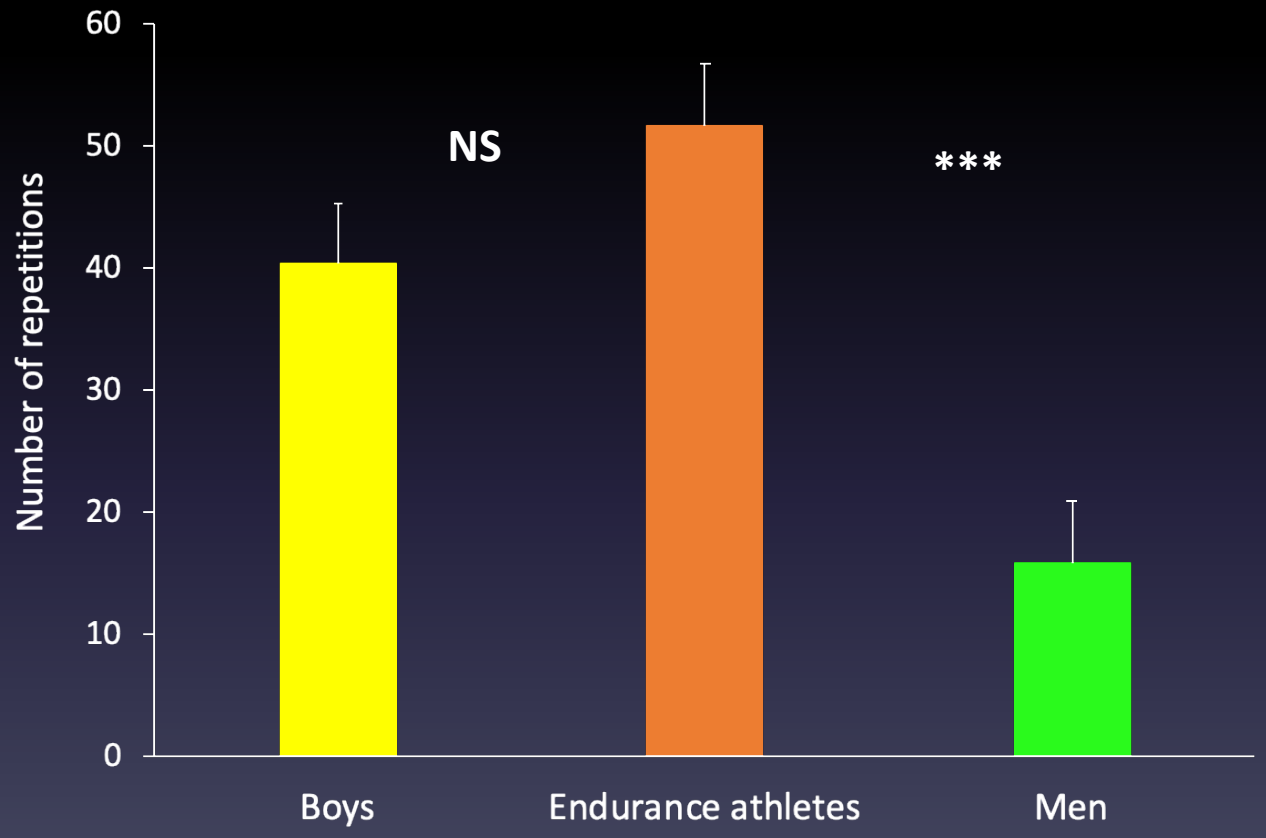
- Sex-related differences during growth

- Effect of exercise modality

- Conclusions

# Boys fatigue as much as endurance athletes during repeated MVCs

**Repeated 5-s MVCs of the KE muscles until the torque reached 60% of initial value**

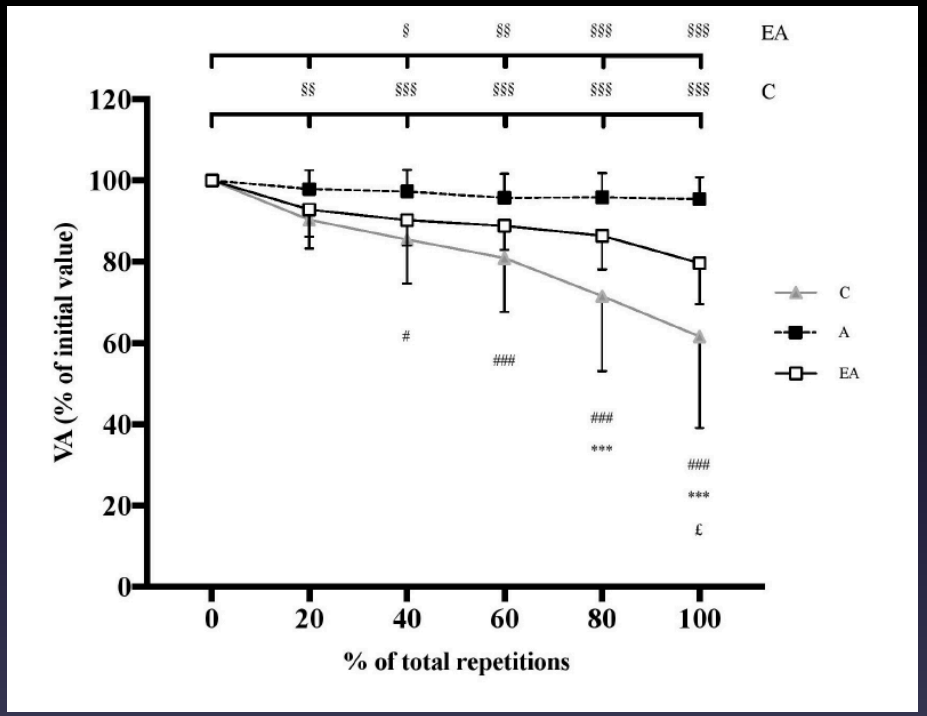



Bontemps et al., Front. Physiol., 15;10:119, 2019

# Boys fatigue as much as endurance athletes during repeated MVCs

**Boys > Central fatigue > Endurance athletes**

**Boys > Voluntary activation (VA) deficit > Endurance athletes**

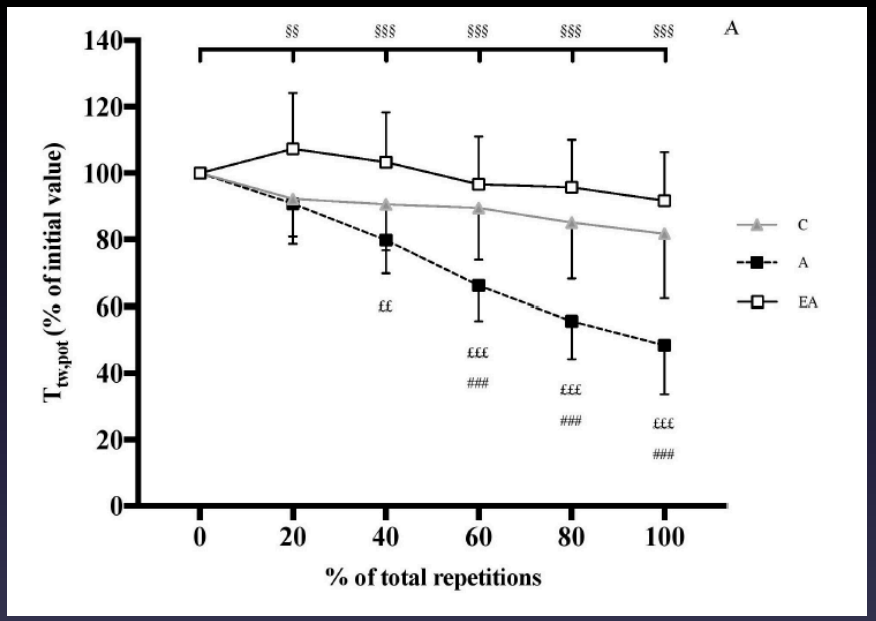



Bontemps et al., Front. Physiol., 15;10:119, 2019

# Boys fatigue as much as endurance athletes during repeated MVCs

**Boys = Peripheral fatigue = Endurance athletes**

**Boys = Twitch torque alteration (Tw) = Endurance athletes**




**Boys = low-frequency fatigue = Endurance athletes**

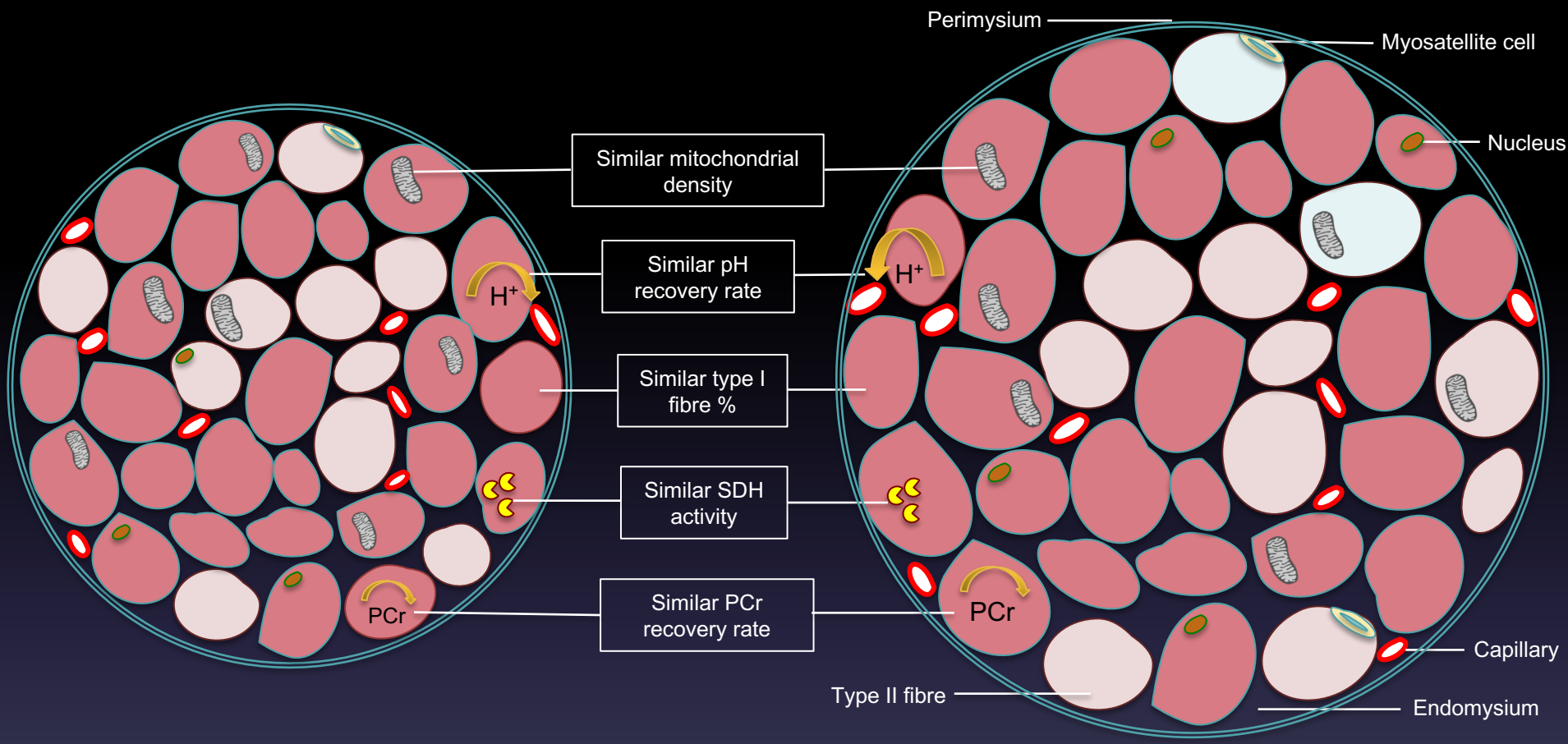
➥ similar alteration of E-C coupling and/or contractile activity

**Boys = M-wave = Endurance athletes**

➥ no change of excitability of the sarcolemma

Bontemps et al., Front. Physiol., 15;10:119, 2019

# Children = peripheral fatigue = Endurance athletes ?




Muscle fascicle
(cross-sectional area)

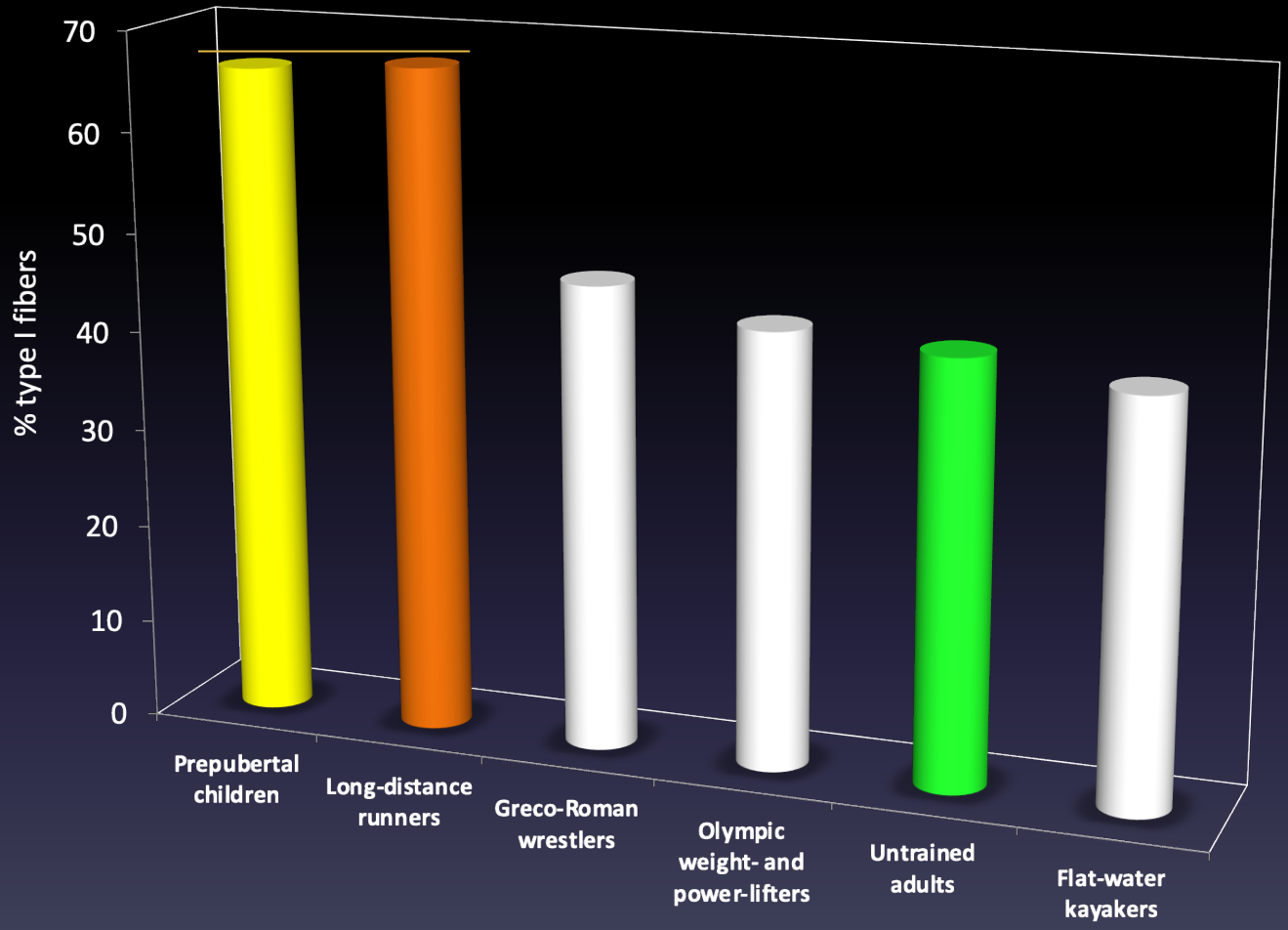
Prepubertal children

Muscle fascicle
(cross-sectional area)

Well-trained adult endurance athletes

**Ratel and Blazevich, Sports Med., 47: 1477-85, 2017**

# Children = peripheral fatigue = Endurance athletes ?




Ratel and Blazevich, Sports Med., 47: 1477-85, 2017

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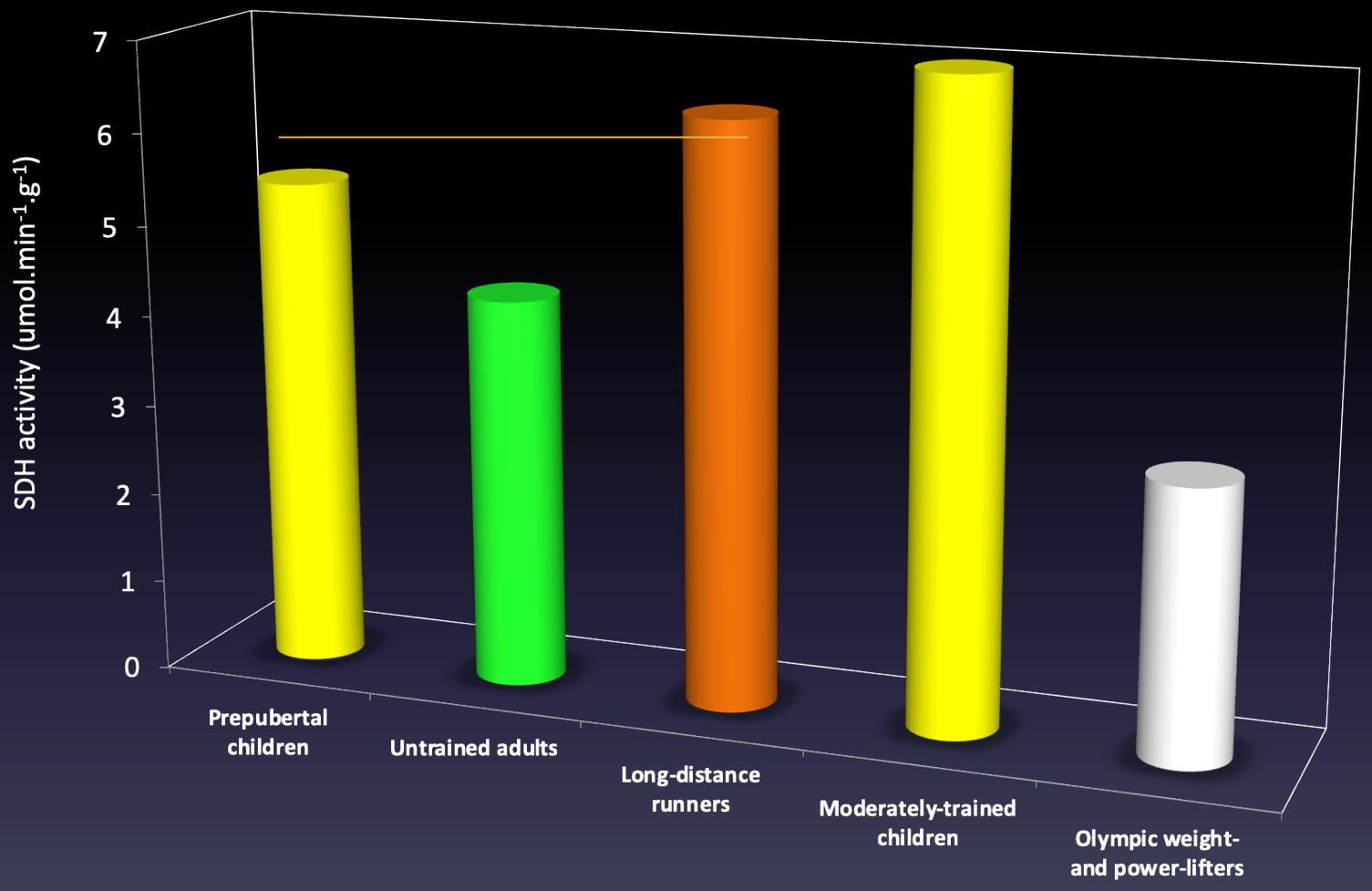


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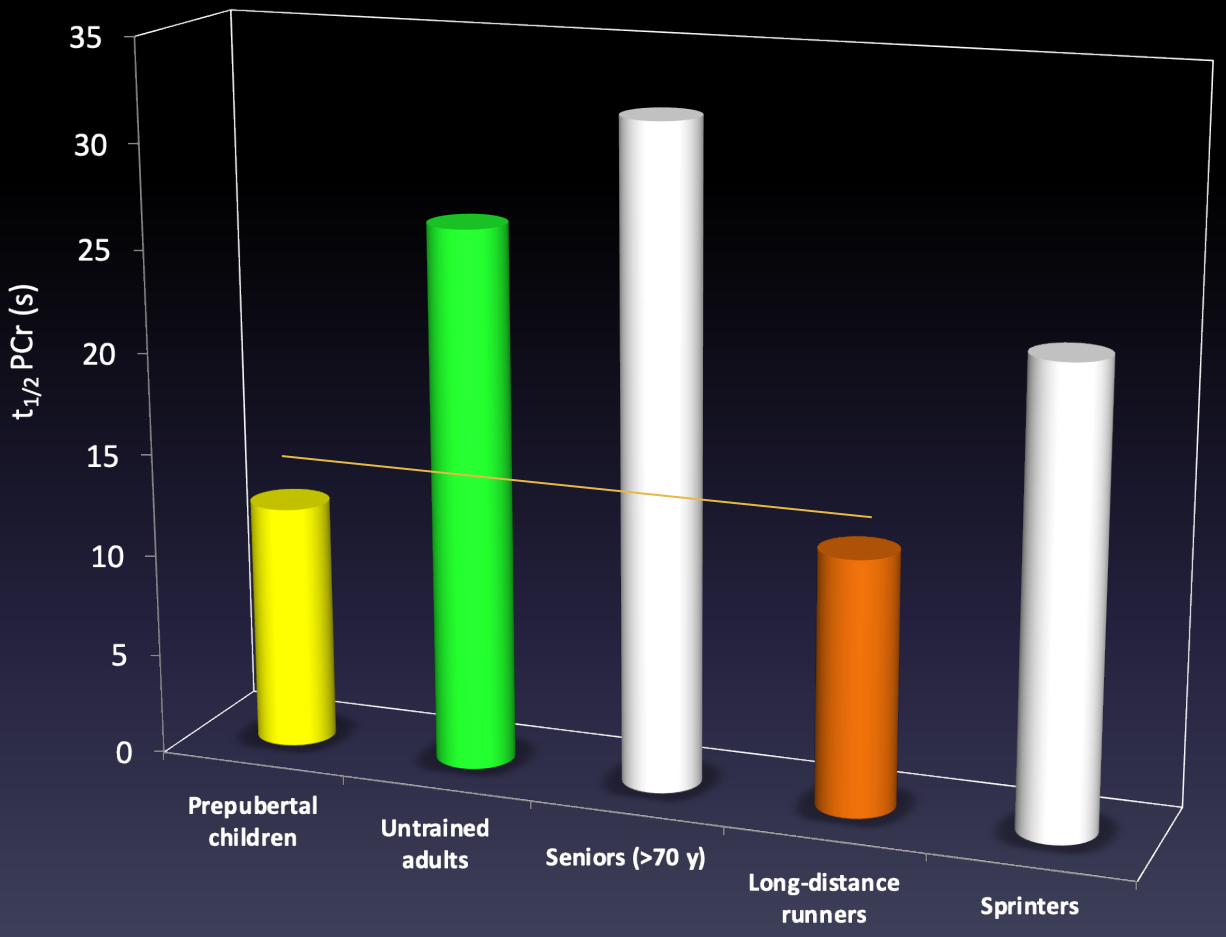


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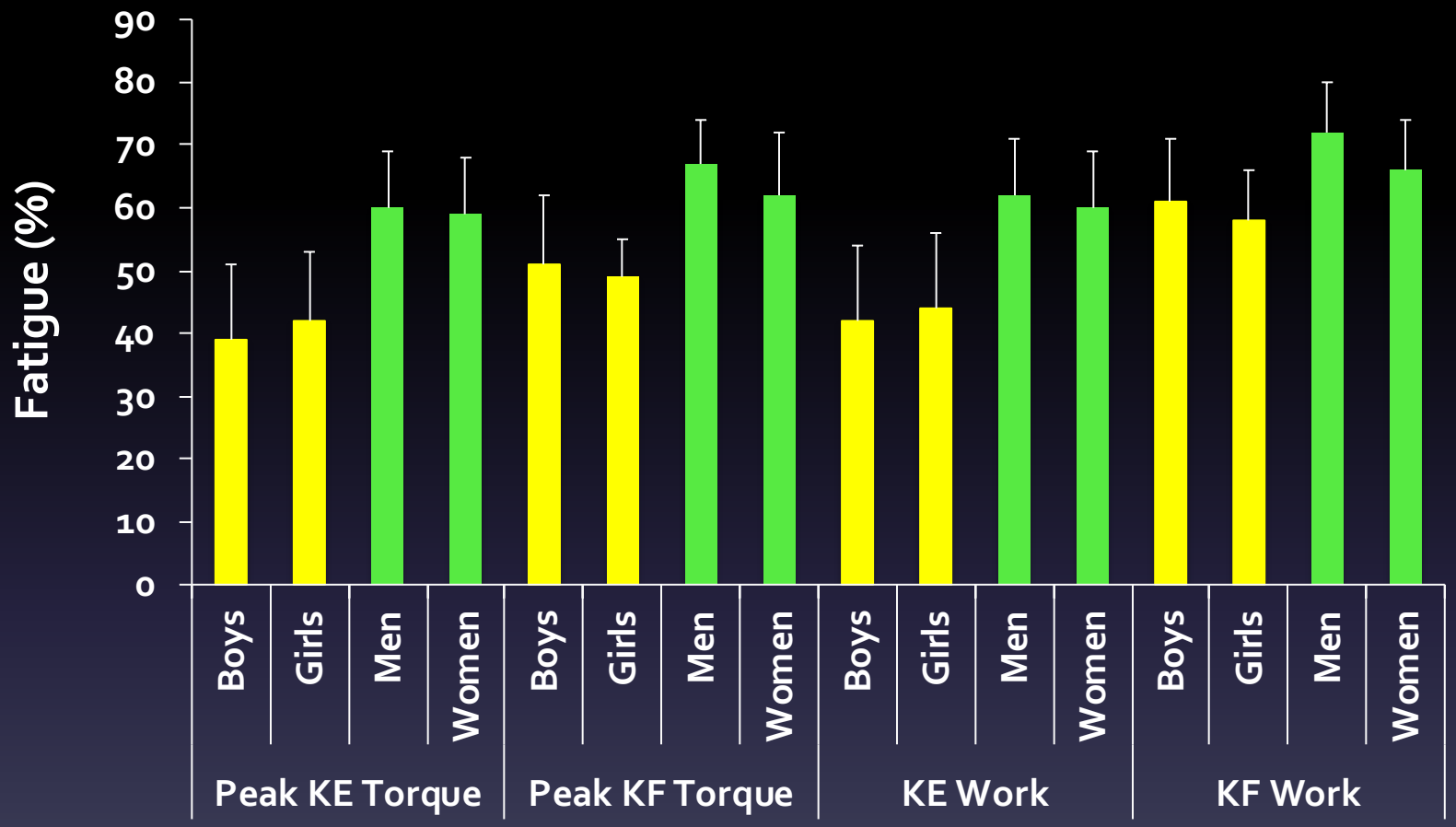
# Isokinetic device (Biodex)

## 50 maximal knee flexions/extensions (90° /s)



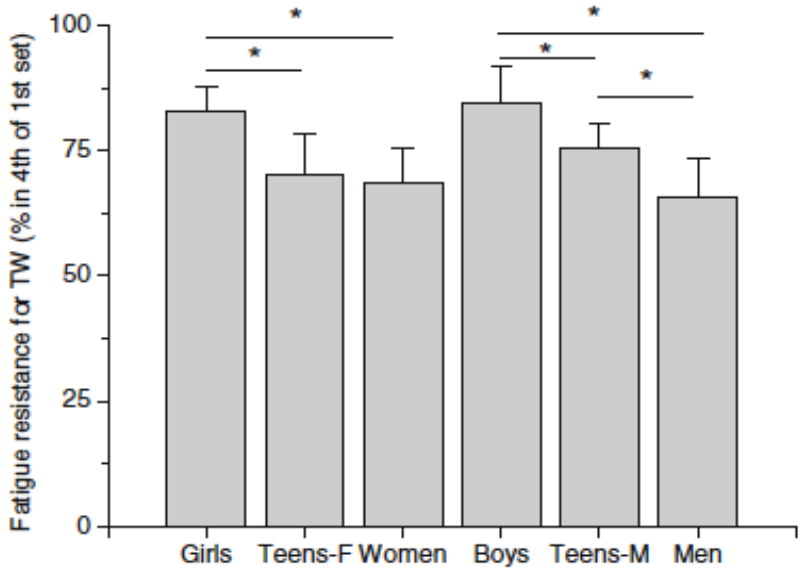

➔Age effect; no sex x age interaction effect

De Ste Croix, Deighan, Ratel et al., Appl. Physiol. Nutr. Metab. 34: 725-31, 2009

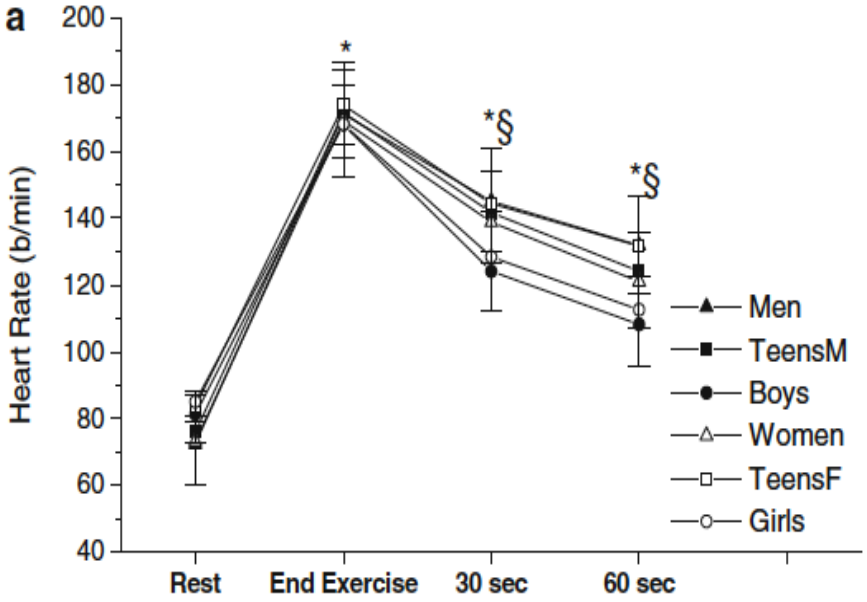
# Isokinetic device (Cybex Norm)

## 4 x 18 maximal knee flexions/extensions R = 60 s (120° /s)

| Variable | Boys ($n$ = 10) | Teen-males ($n$ = 10) | Men ($n$ = 10) | Girls ($n$ = 10) | Teen-females ($n$ = 10) | Women ($n$ = 10) |
|---|---|---|---|---|---|---|
| Age (years) | 11.3 ± 0.5 | 14.7 ± 0.3 | 24.0 ± 2.1 | 10.9 ± 0.6 | 14.4 ± 0.7 | 25.2 ± 1.4 |
| Tanner stage | 2 | 4 | 5 | 2 | 4–5 | 5 |




Fatigue resistance (%)




Heart rate recovery

➔Maturation effect ; no sex x maturation interaction effect

Dipla et al., Eur. J. Appl. Physiol., 106: 645-653, 2009

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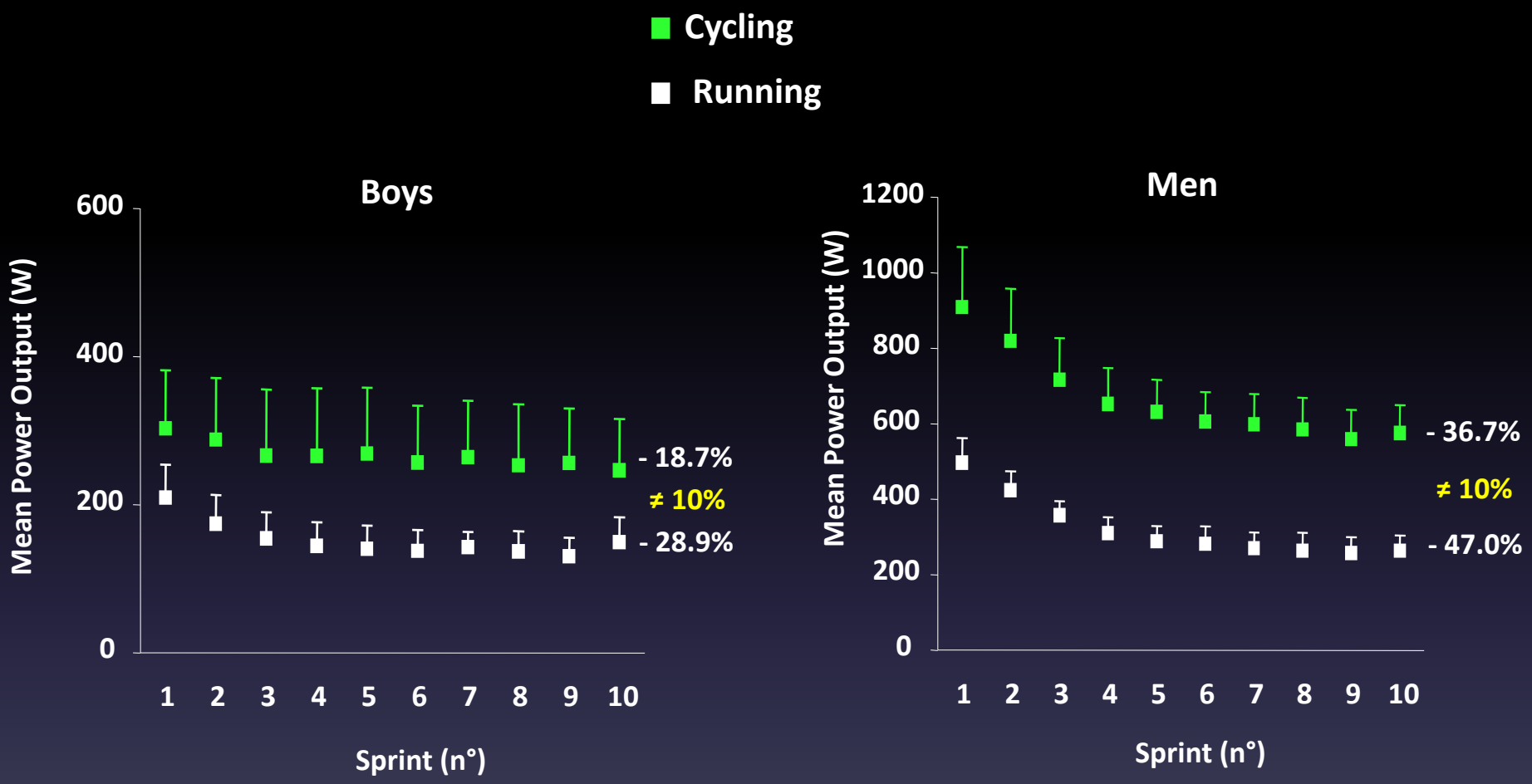
# Cycling vs. Running

## (Non weight- vs. weight-bearing exercises)


Ratel et al., Eur. J. Appl. Physiol., 92: 204-10, 2004

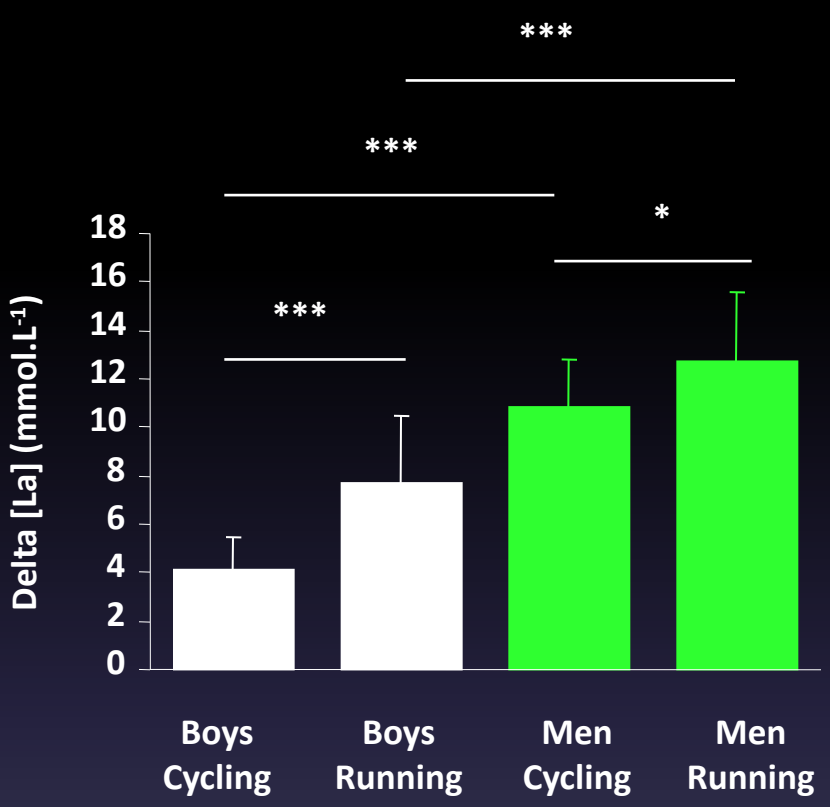
# Ten 10 s sprints R = 15 s



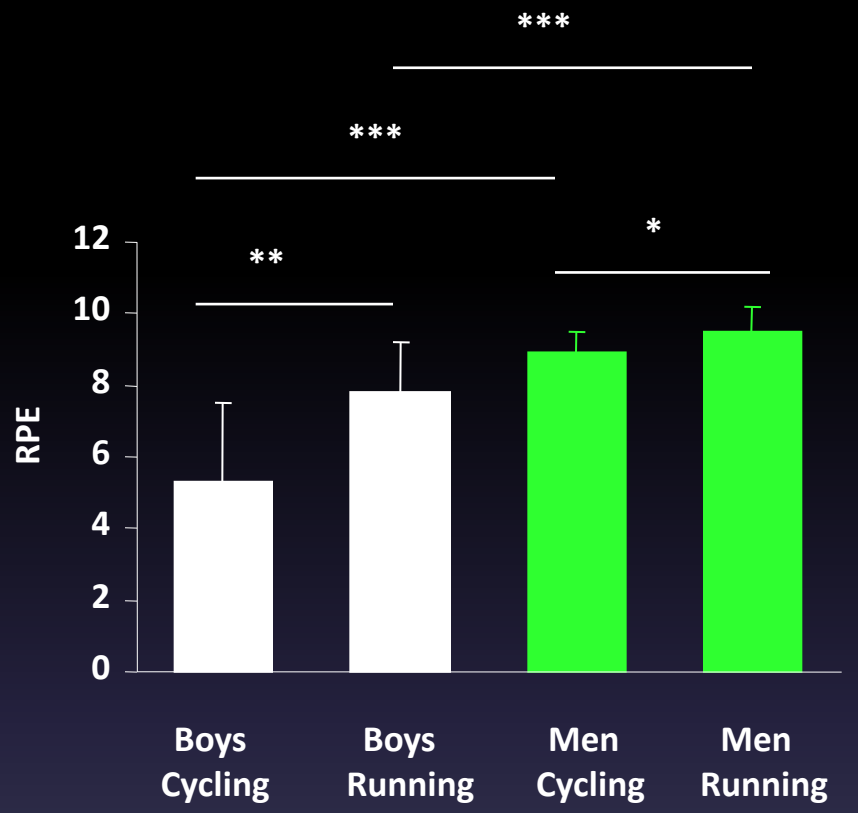

➔ Fatigue is higher during running than cycling

Ratel et al., Eur. J. Appl. Physiol., 92: 204-10, 2004

# Ten 10 s sprints R = 15 s




Delta [La] = 3 min post-exercise – rest




RPE from the Children's Effort Rating Table

➔Blood lactate and RPE are higher during running than cycling

Ratel et al., Eur. J. Appl. Physiol., 92: 204-10, 2004

# Hypothesis

**Greater fatigue during sprint running in children and adults**

**Additional muscle recruitment during sprint running ?**

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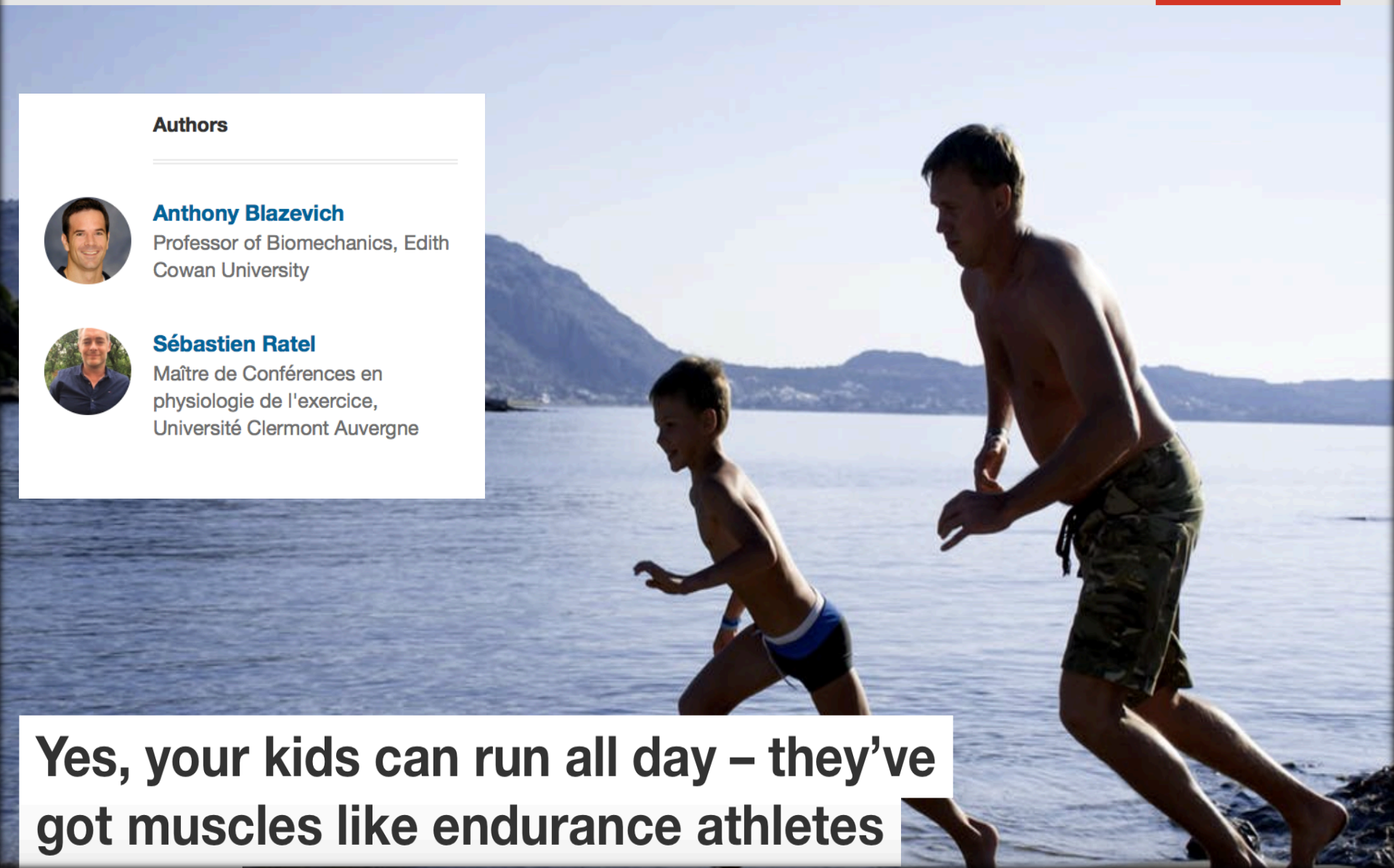

**Authors**



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**Sébastien Ratel**
Maître de Conférences en physiologie de l'exercice, Université Clermont Auvergne

# Yes, your kids can run all day – they've got muscles like endurance athletes

Children tire less quickly than adults during experimental tests of cycling, running and vertical jumping.

**METABOLISM** · 24 APRIL 2018

# Kids beat elite runners in fitness tests

*Children can surpass competitive athletes on assessments of exercise-induced fatigue.*

Maturation

Fatigue

# Aerobic training

**Aerobic training is required during and after puberty:**

- To offset the decrement in muscle oxidative capacity over this period
- To delay the development of exercise-induced fatigue and maintain the post-exercise recovery capacity in pubertal and post pubertal children
- To avoid the development of metabolic diseases associated with reduced mitochondrial function (type 2 diabetes, insulin-resistance, etc.)

Ratel et al., J. Sports Med. Phys. Fitness, 44:272-80, 2004; Ratel et al., Sports Med., 12:1031-65, 2006

Ratel and Blazevich, Sports Med., 47: 1477-85, 2017

# Acknowledgements


Pascale Duché

Vincent Martin

Enzo Piponnier

Virginie Kluka

Anthony Birat

Pierre Bourdier

Neil Armstrong

Craig Williams

Mark De Ste Croix

David Bendahan

Anne Tonson

Anthony Blazevich

Ken Nosaka

Christos Kotzamanidis

Dimitrios Patikas

Ronei Pinto

# Thank you for your attention

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