# *Psychobiological limitations to exercise performance*

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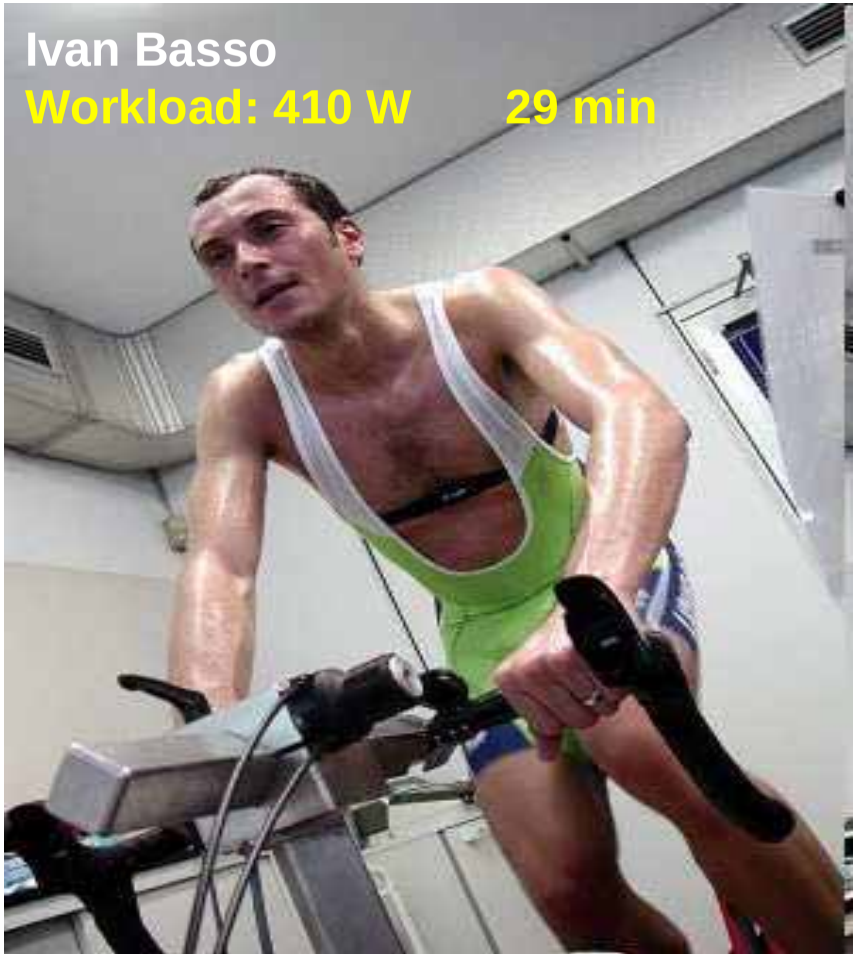
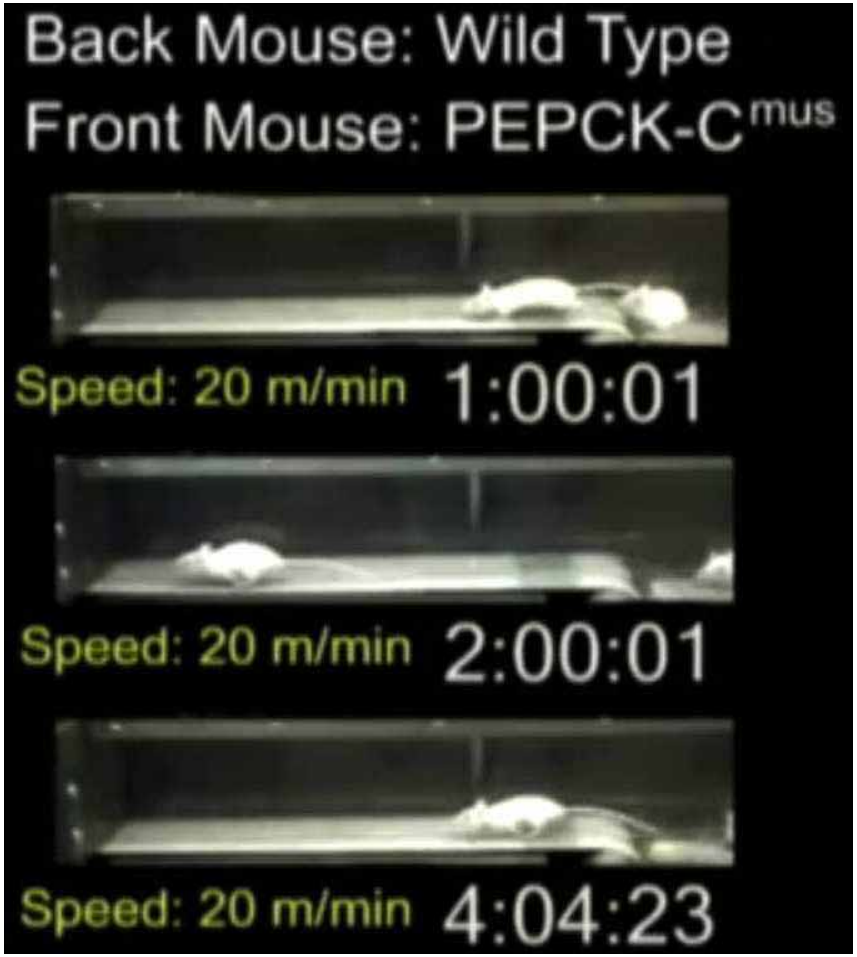
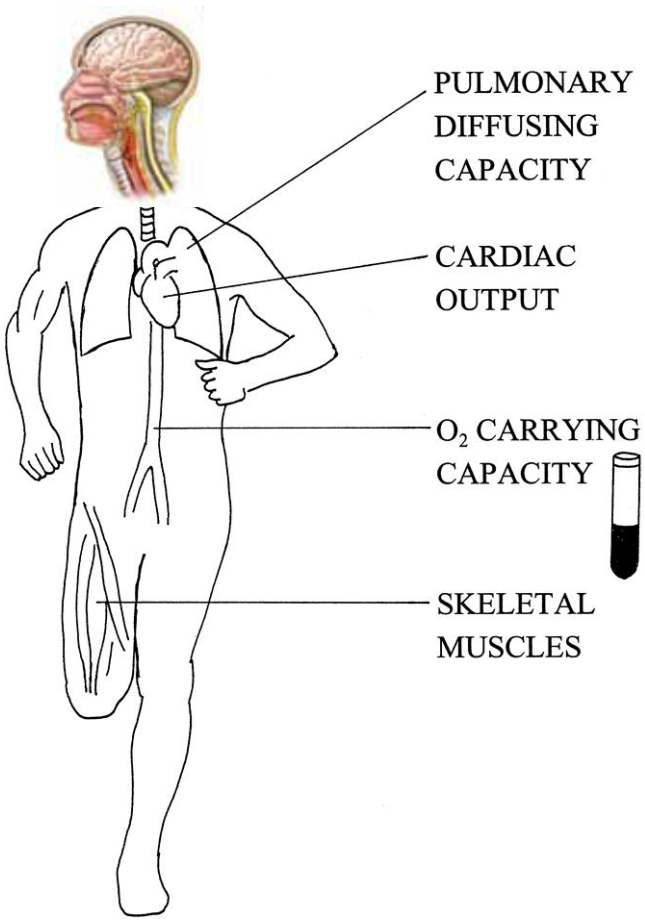
# Endurance Exercise Performance



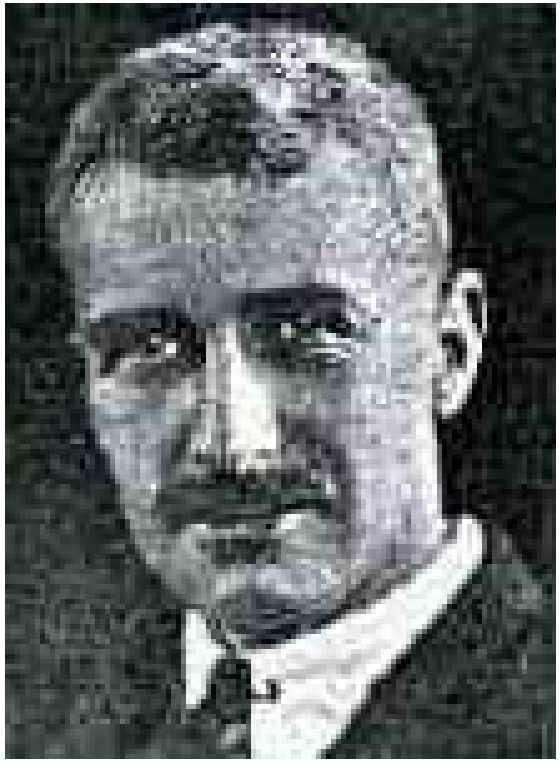
# Levels of explanation

- Psychology
- Physiology (whole-body, systems, organs)
- Cellular biology
- Molecular biology



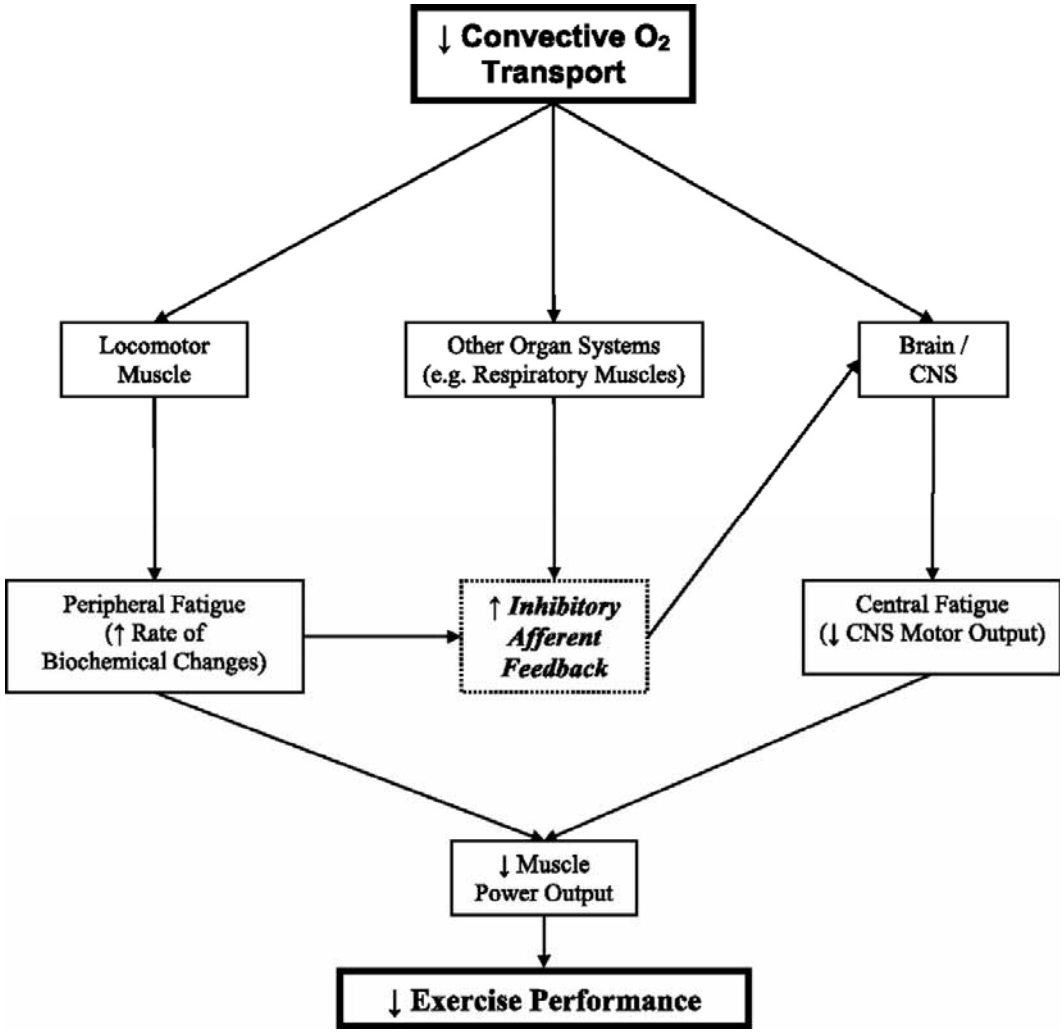
# Traditional Paradigm

- **With young athletic people one may be sure that they really have gone "all out"**, moderately certain of not killing them, and practically certain that their **stoppage is due to oxygen-want and to lactic acid in their muscles**. [...]
- [...] you can experiment with your athlete; you can "try out" on him the facts and theories which you have reached with **frogs**. There I must leave it, and be grateful if the young athletes in their turn can suggest further experiments on frogs.
- AV Hill. *Muscular Activity*. Williams & Wilkins, Baltimore, **1926**.



**AV Hill**

**Fig. 5. Hypothetical scheme linking convective O2 transport and exercise performance via its effects on fatigue**

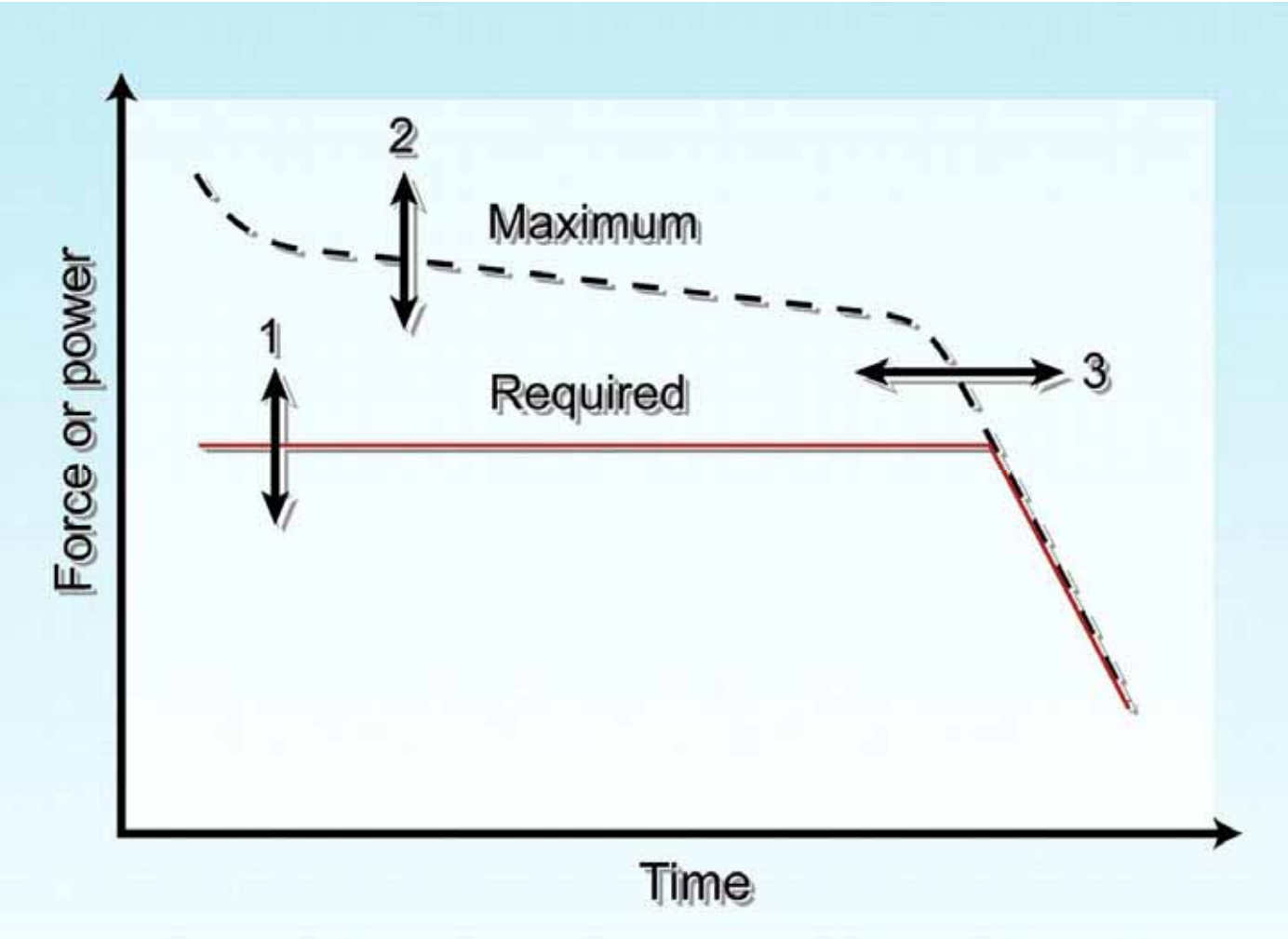



**Amann, M. et al. J Appl Physiol 104: 861-870 2008; doi:10.1152/japplphysiol.01008.2007**



Journal of Applied Physiology

**FIG. 9. Schematic to illustrate different mechanisms leading to exhaustion [...] Exhaustion (failure to produce the required force or power) occurs at the intersection of the two lines.**




**Allen, D. G. et al. Physiol. Rev. 88: 287-332 2008;**
**doi:10.1152/physrev.00015.2007**



Physiological Reviews

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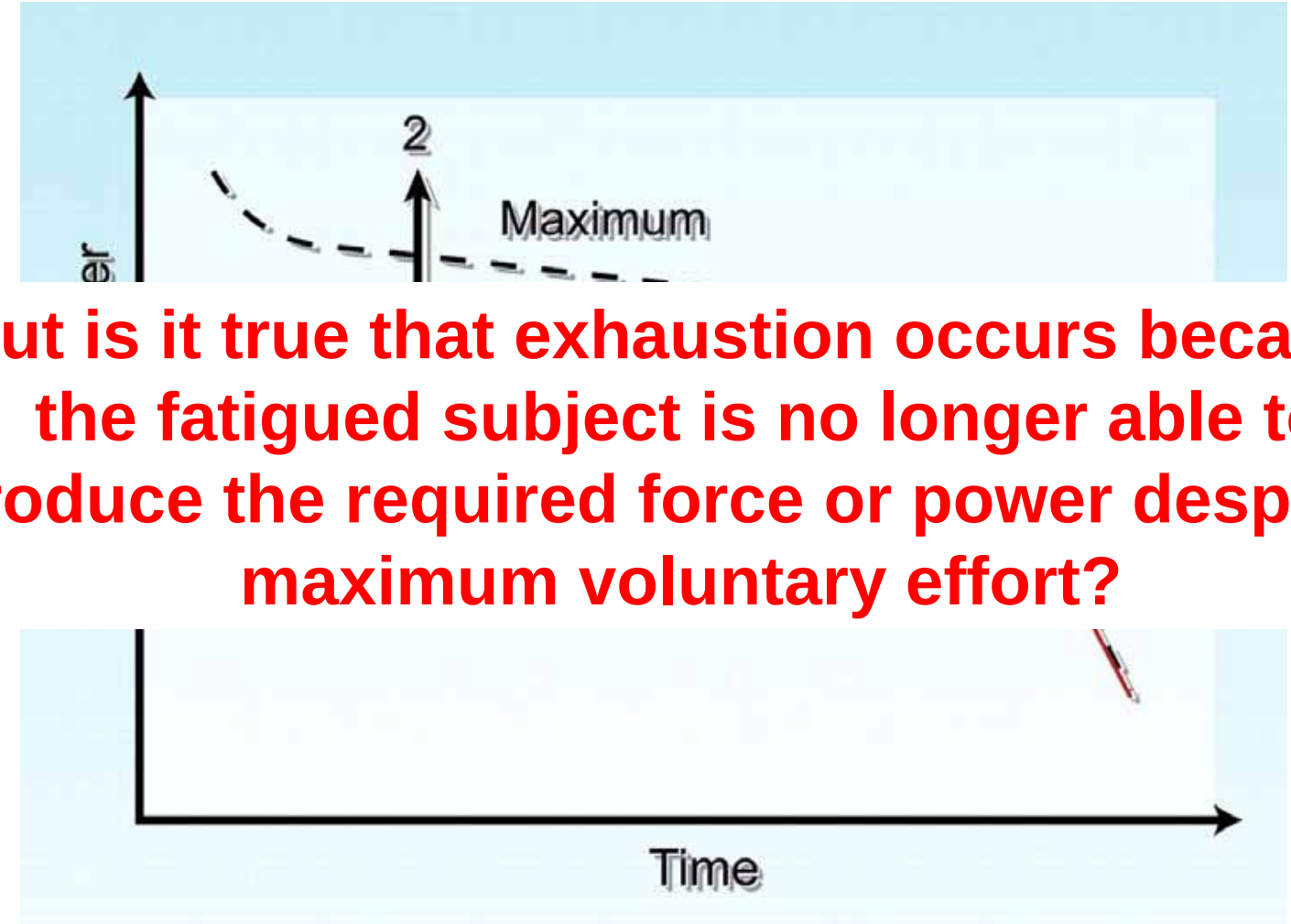


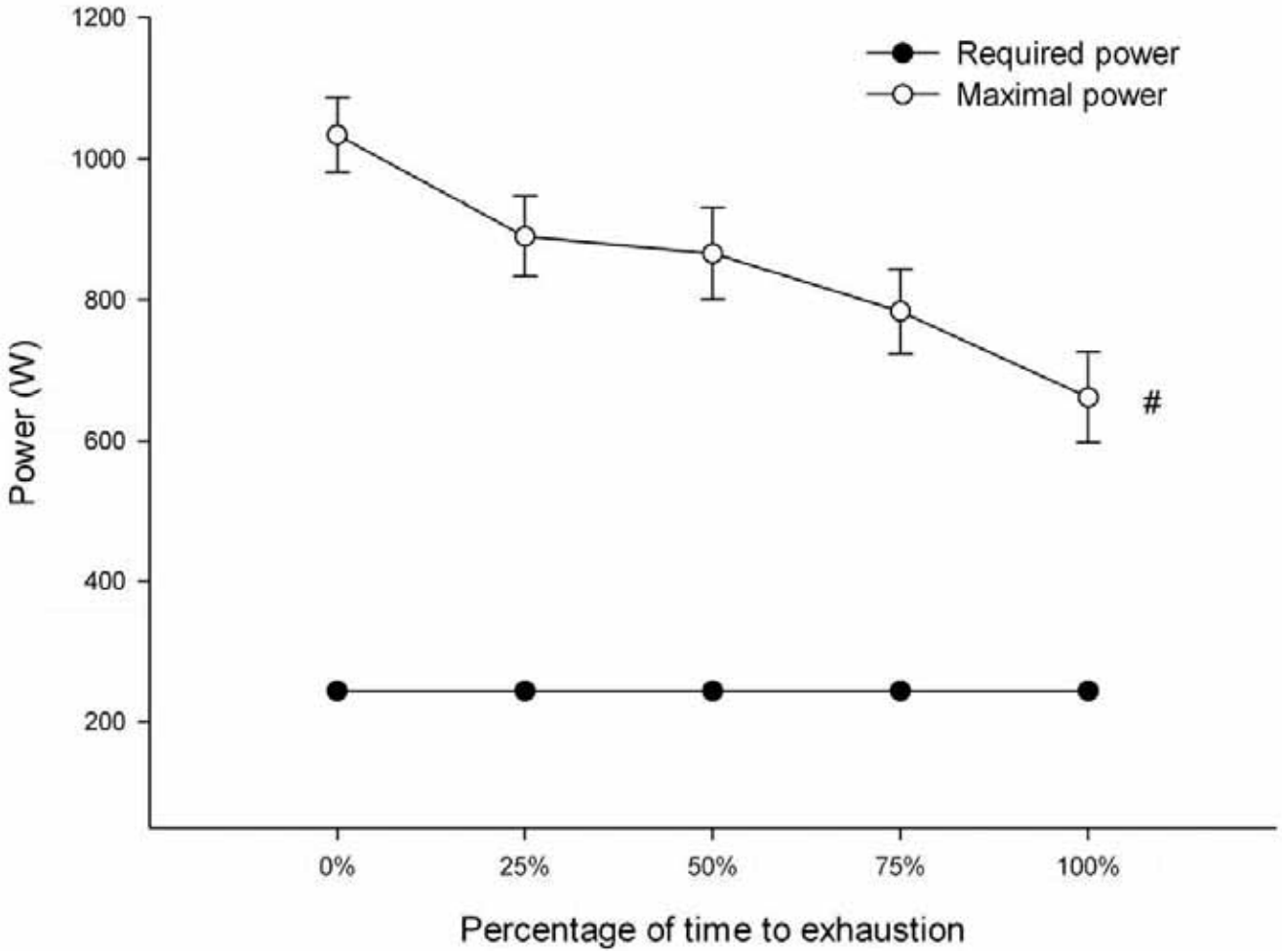

**But is it true that exhaustion occurs because the fatigued subject is no longer able to produce the required force or power despite a maximum voluntary effort?**

**Allen, D. G. et al. Physiol. Rev. 88: 287-332 2008;**
**doi:10.1152/physrev.00015.2007**



Physiological Reviews

# The answer is no!



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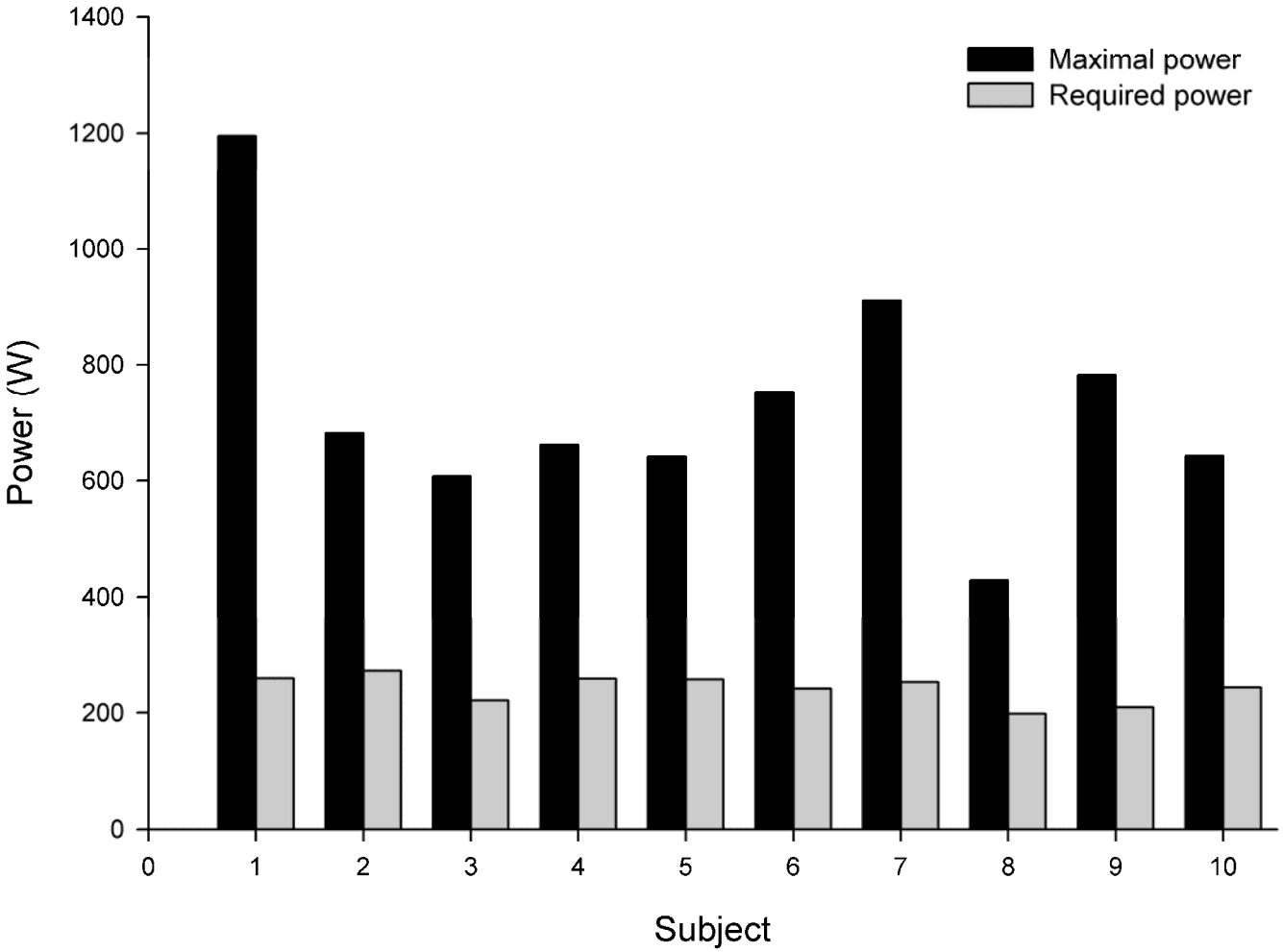
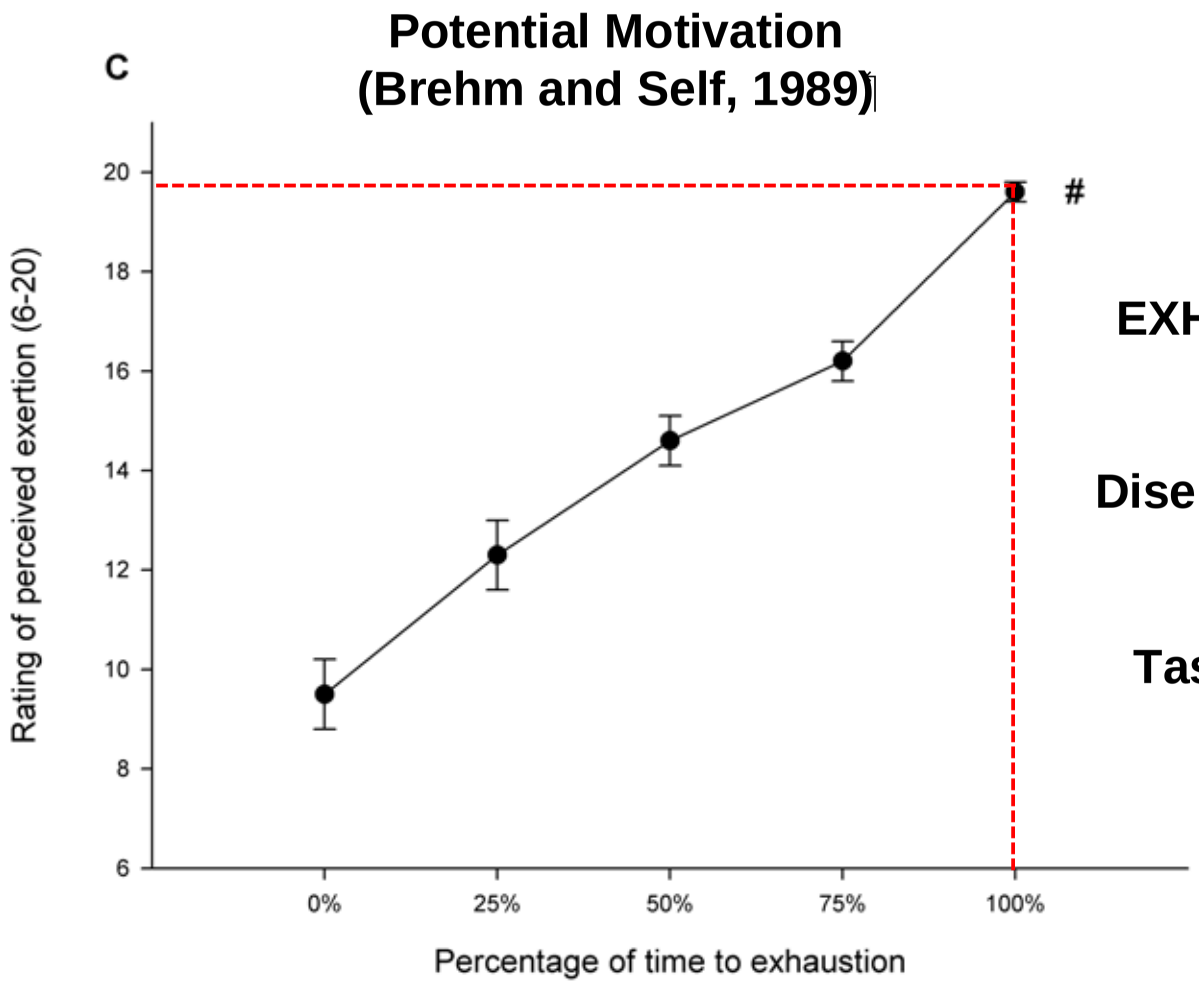


# So what limits exercise performance?

- For the one who is tired, **the feelings experienced are the fatigue**. In spite of this, the experience is taken as merely incidental when attempts are made to analyse and understand what it is called “fatigue”.
- The very **individual** who experiences fatigue and **regulates** his life in accordance with it changes his whole outlook when he steps **into the laboratory** supposedly to study fatigue. **He forgets what he knows about fatigue from personal experience and attempts to measure human activity solely as the product of a physiochemic machine**.
- Bartley SH and Chute E. *Fatigue and impairment in man*. McGraw-Hill, New York, **1947**.

# Perception of effort during prolonged exercise




**EXHAUSTION**
**=**
**Task Disengagement**

**NOT**

**Task Failure**

# Exercise intensity and RPE

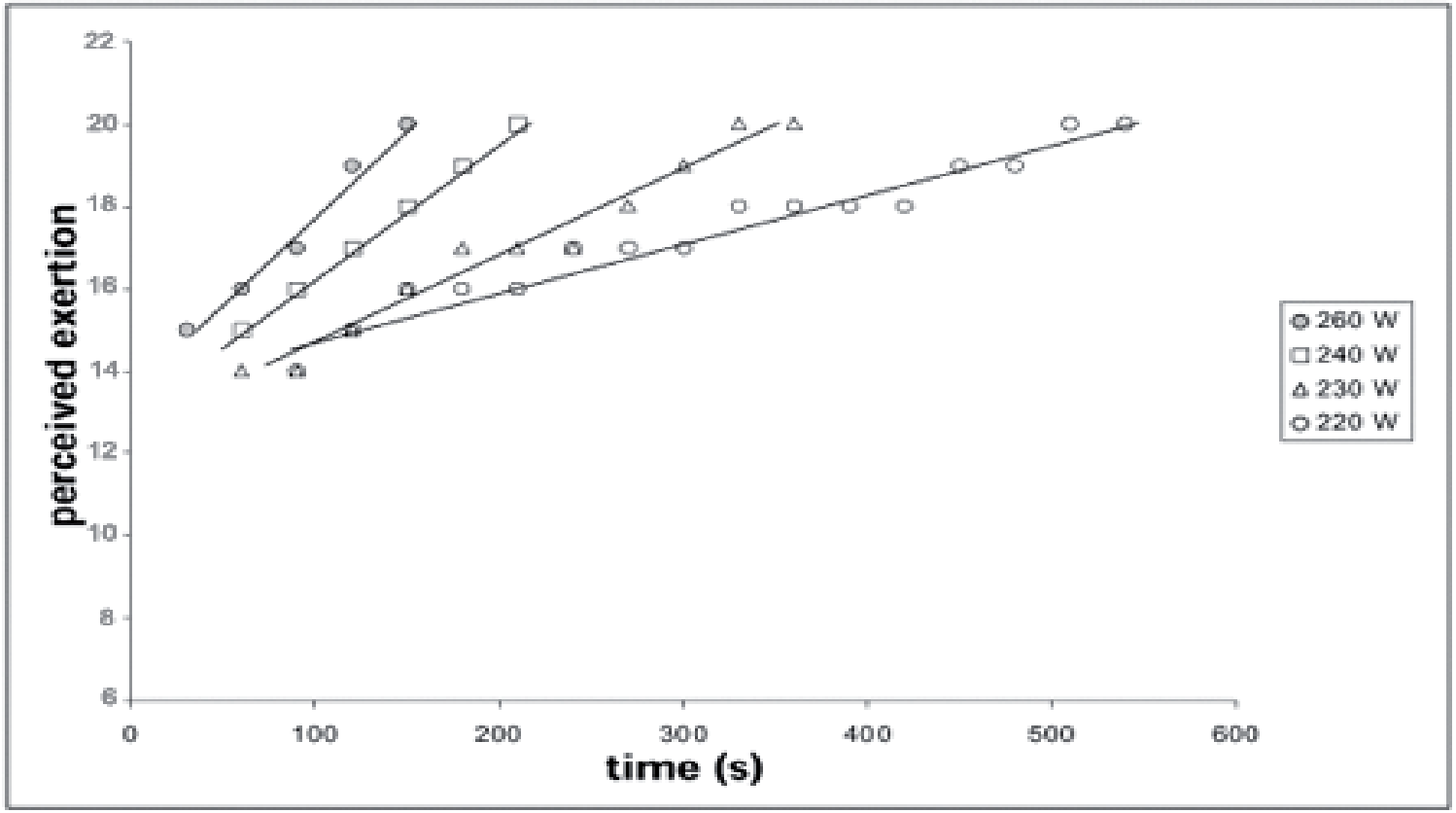
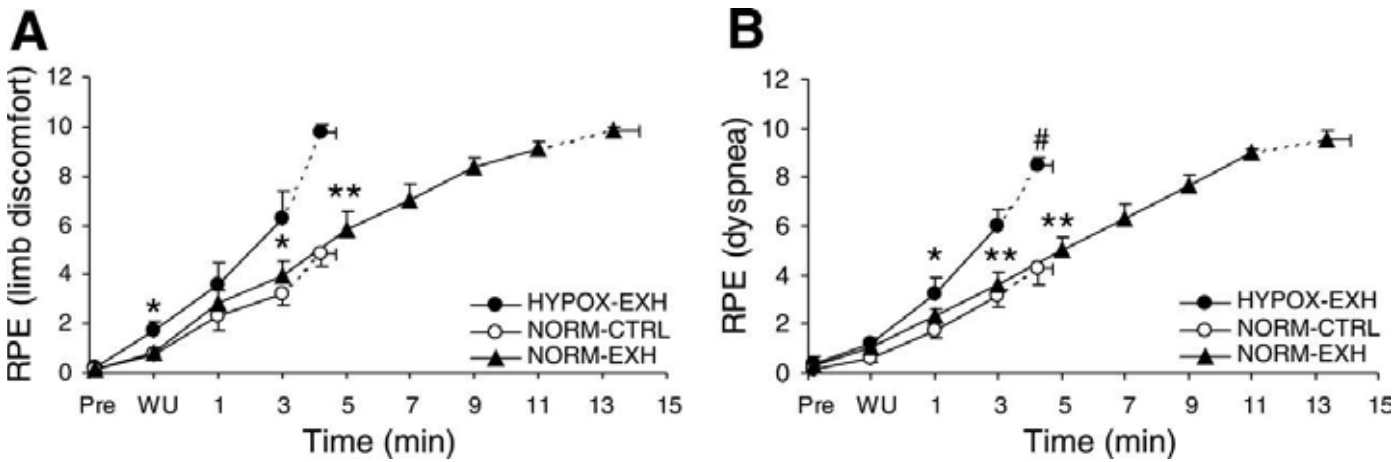



***Fig. 2*** *– Increase on the perceived exertion along time in exhaustive rectangular tests of a representative subject*

# HYPOXIA and RPE

**Fig. 6. Ratings of perceived exertion (RPE) for limb discomfort (A) and dyspnea (B) in HYPOX-EXH, NORM-CTRL, and NORM-EXH**

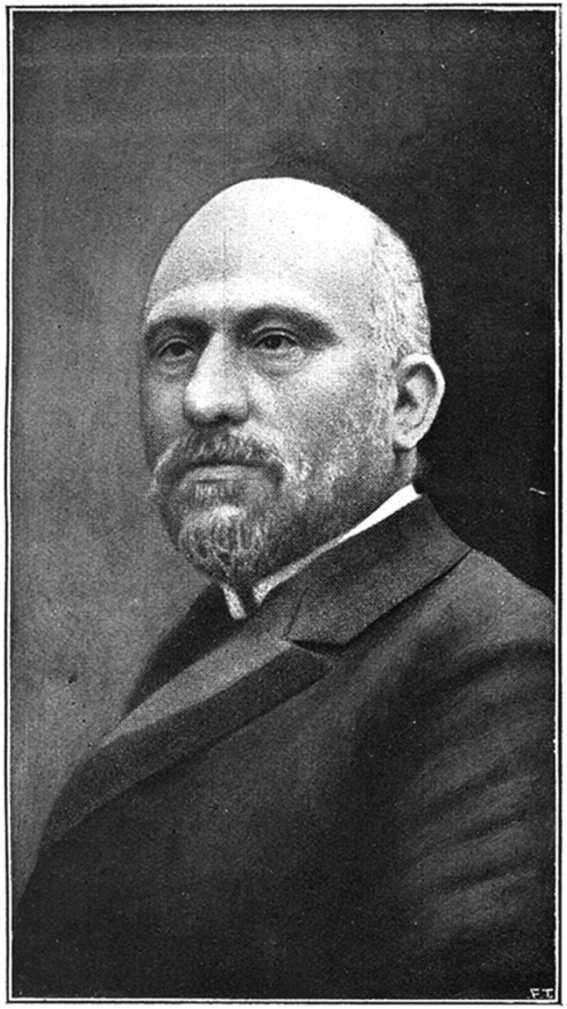


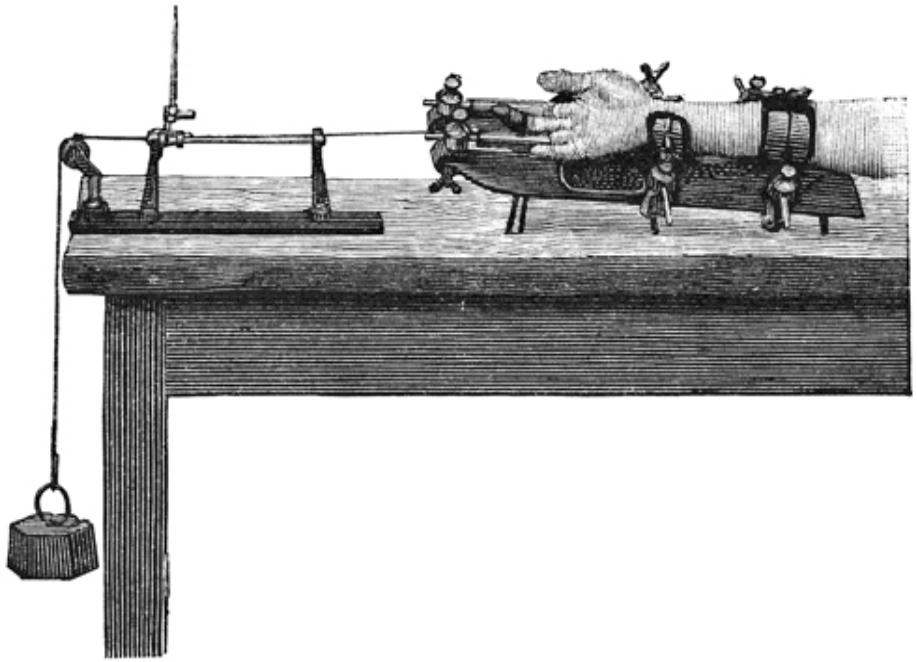

**Romer, L. M. et al. Am J Physiol Regul Integr Comp Physiol 292: R598-R606 2007; doi:10.1152/ajpregu.00269.2006**



AJP - Regulatory, Integrative and Comparative Physiology

# Mental Fatigue and Physical Performance

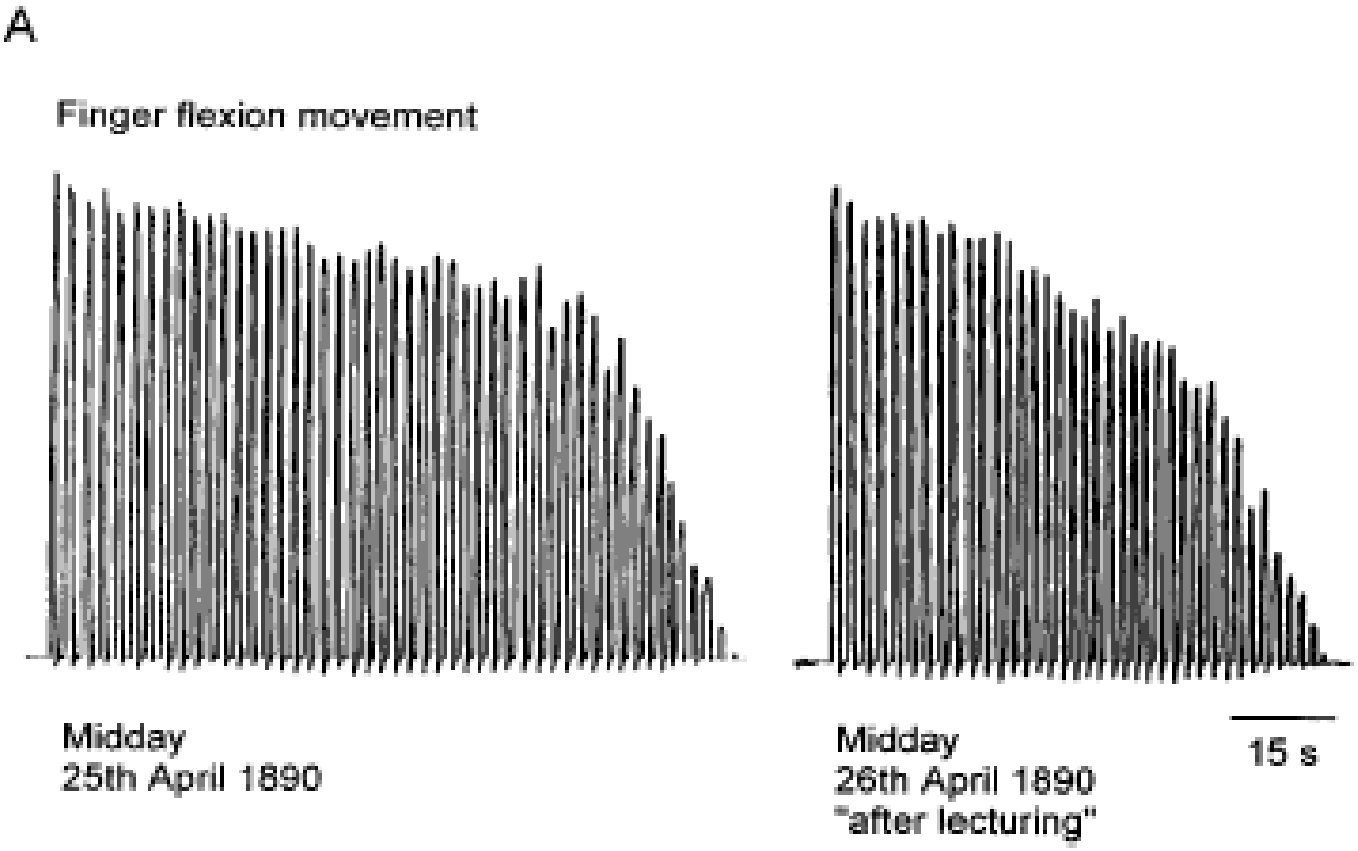




Italian Physiologist Angelo Mosso

(1846–1910)

# Mental Fatigue and Physical Performance

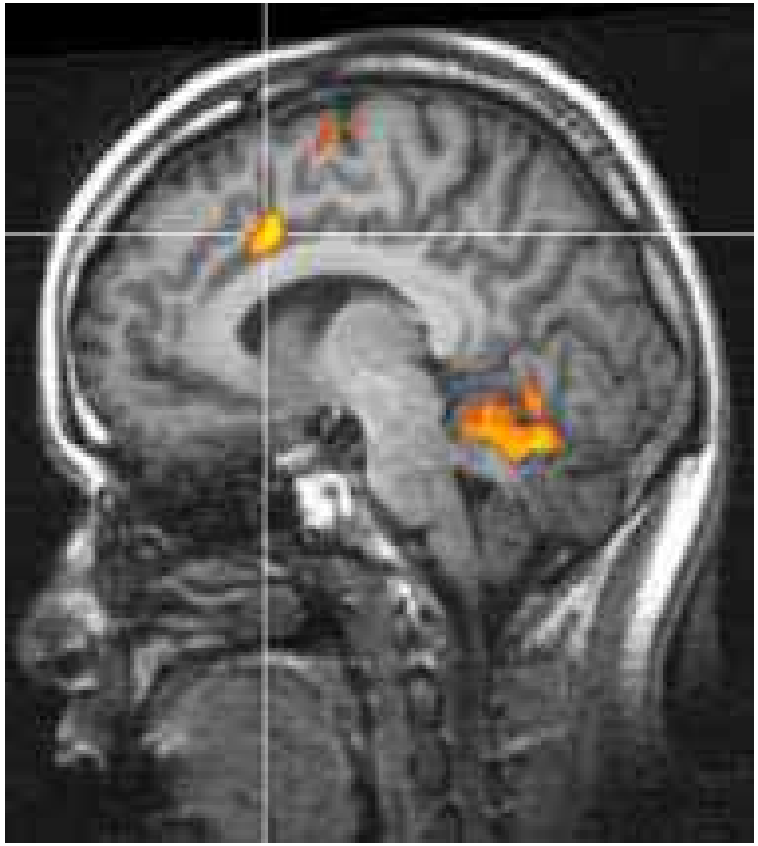



In Gandevia (2001)

# Mental Fatigue and Physical Performance

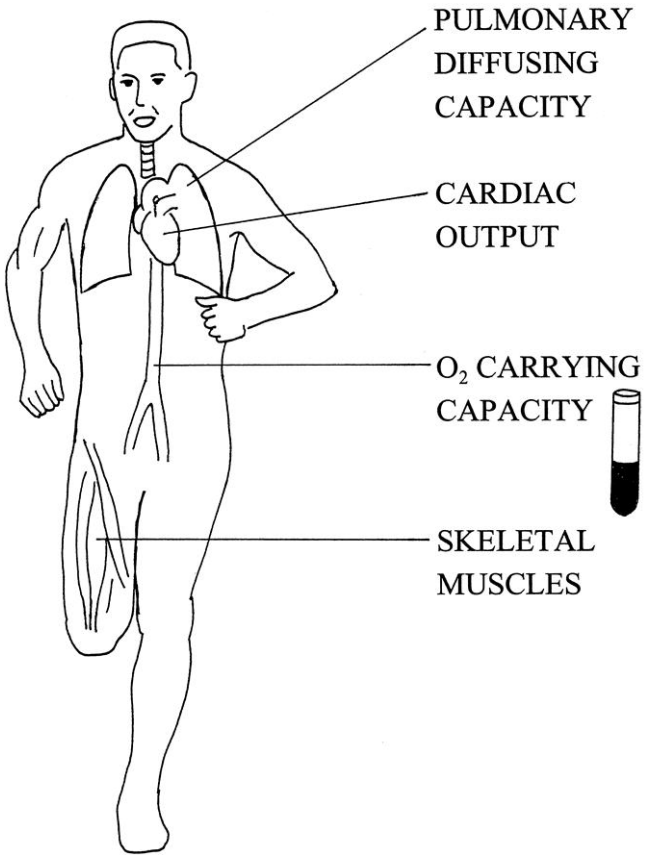
# AX-Continuous Performance Test

- **AX-CPT task strongly activates the ACC** (Carter et al., 1998)
- **ACC activity is correlated with perceived exertion during exercise in humans** (Williamson et al., 2001)
- **ACC lesions affect effort-based decision making in rats** (Walton et al., 2006)
- **ACC activity is associated with autonomic cardiovascular control** (Critchley et al., 2003)

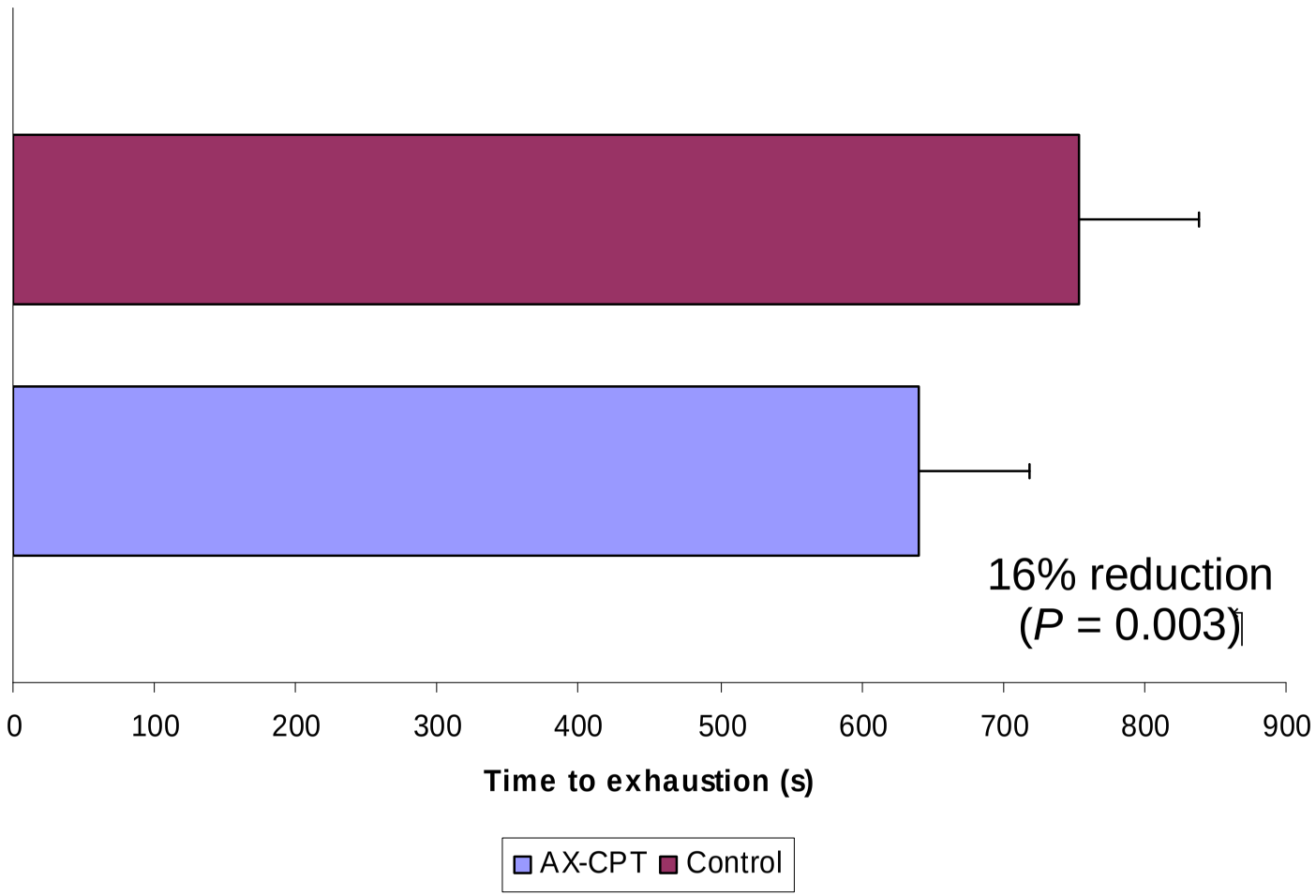


**Anterior Cingulate Cortex (ACC)**

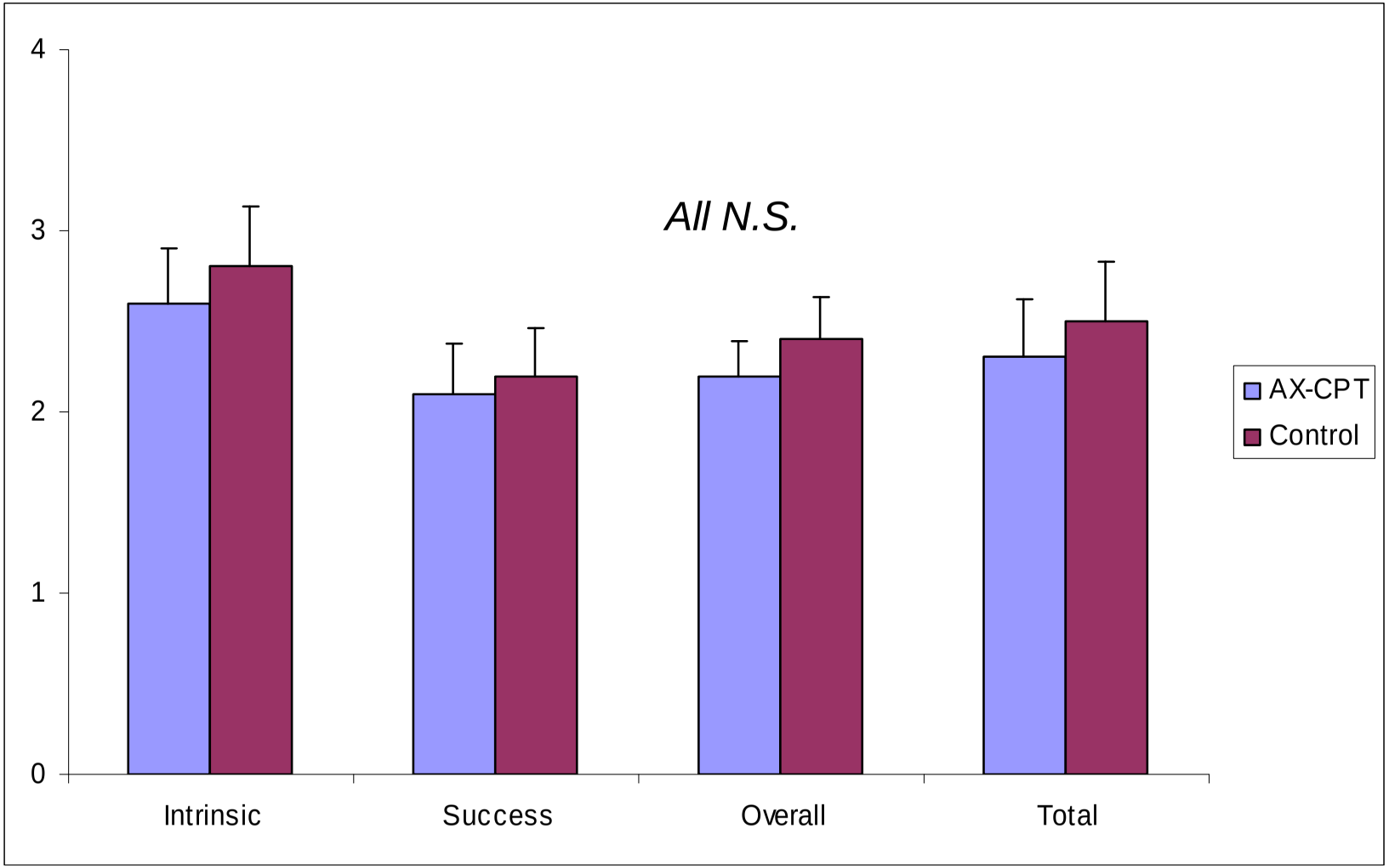
# Time to Exhaustion Test at 90% $VO_{2max}$

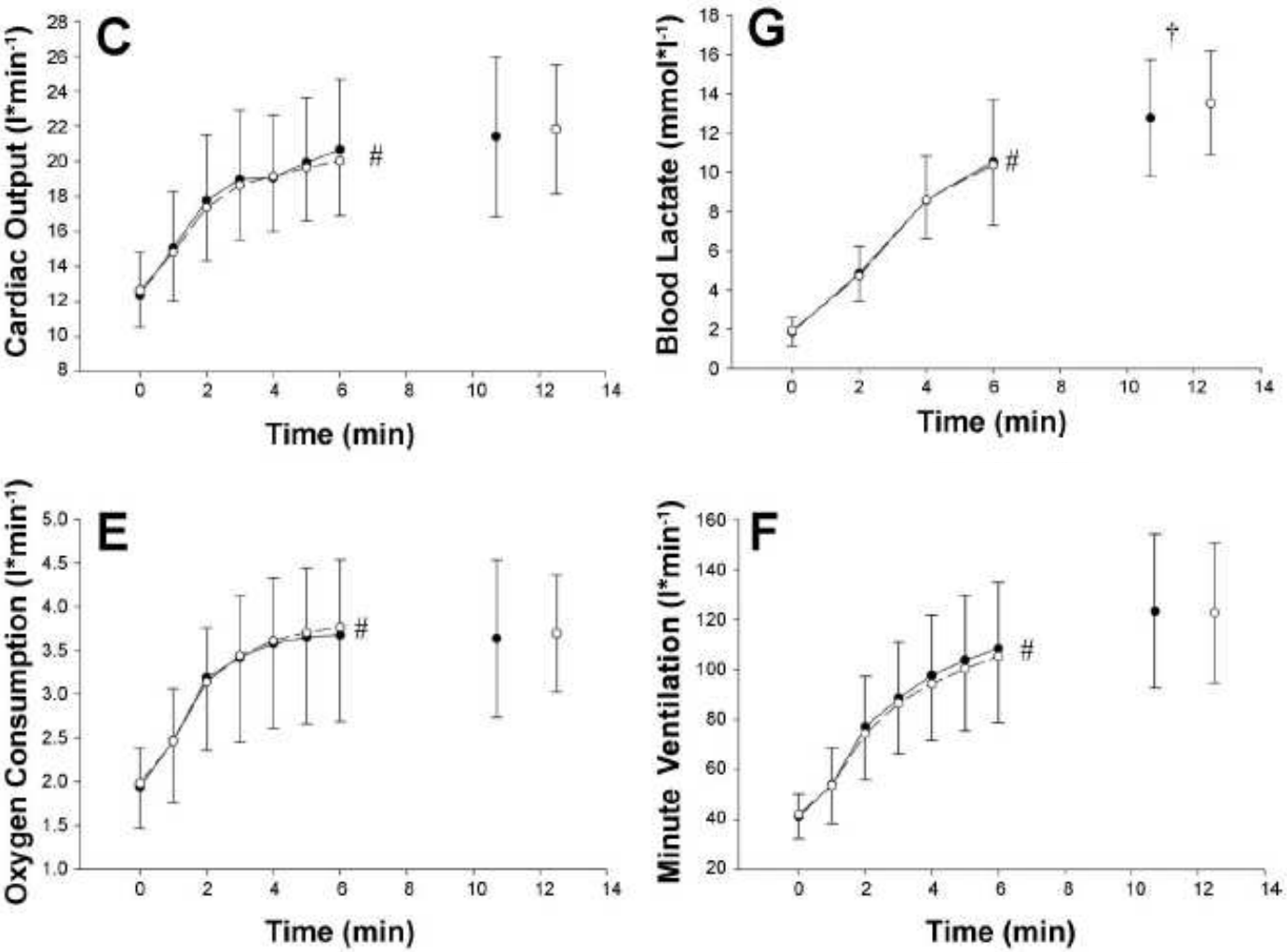
# Effect on Endurance Performance



# Effects on Task-Related Motivation

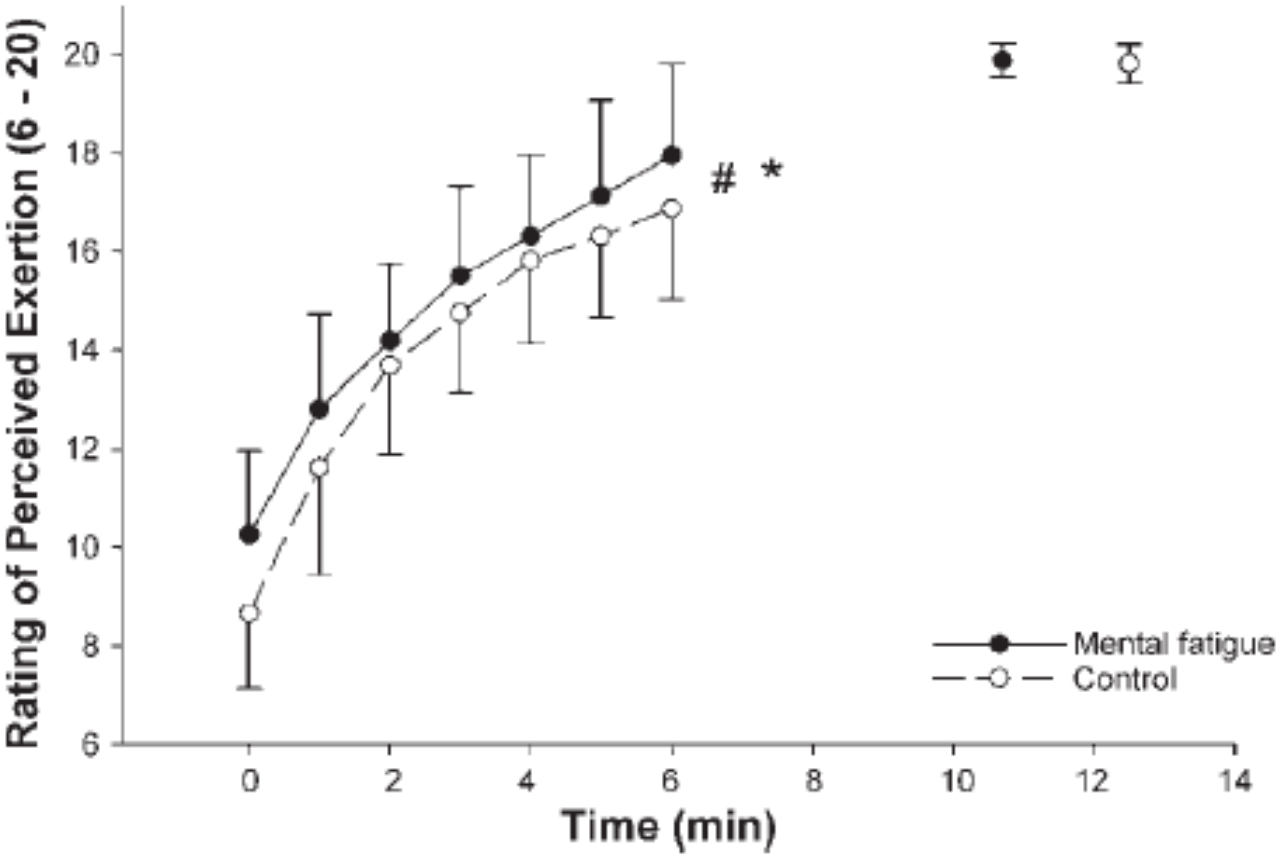


# Effects on Physiological Responses




# significant difference at exhaustion; † significant main effect of treatment at isotime

# Effect on Perception of Effort




# significant difference at exhaustion; † significant main effect of treatment at isotime

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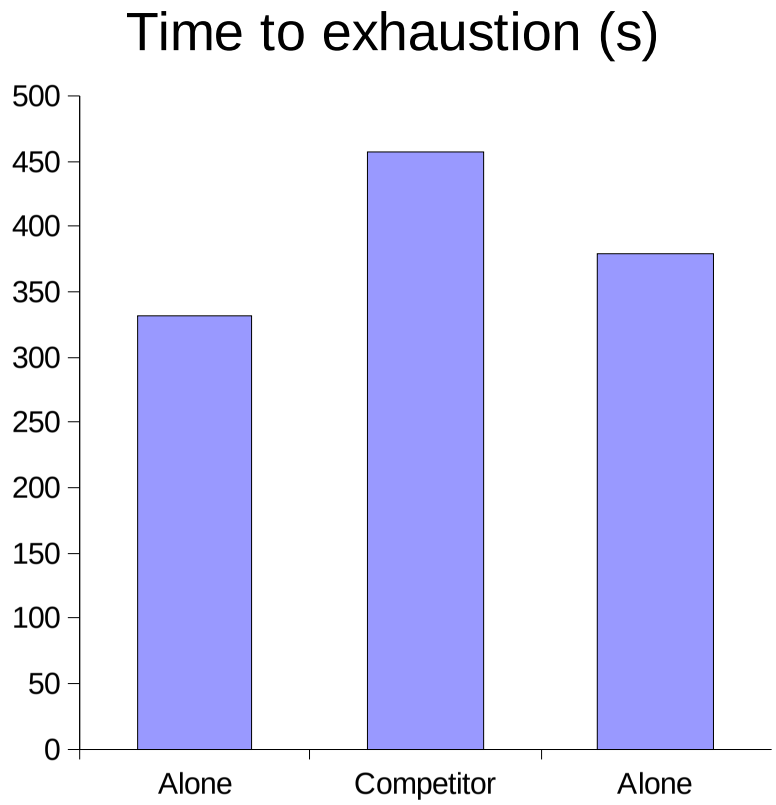
Vol. 24, No. 4, April 1968. *Printed in U.S.A.*

# Influence of motivation on physical work capacity and performance[1]

JACK H. WILMORE



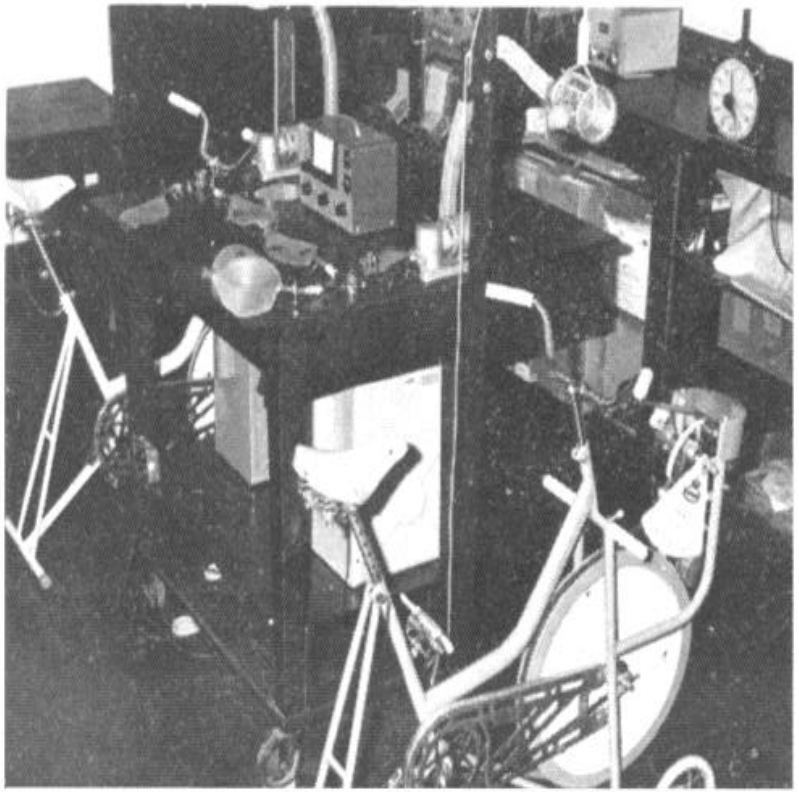
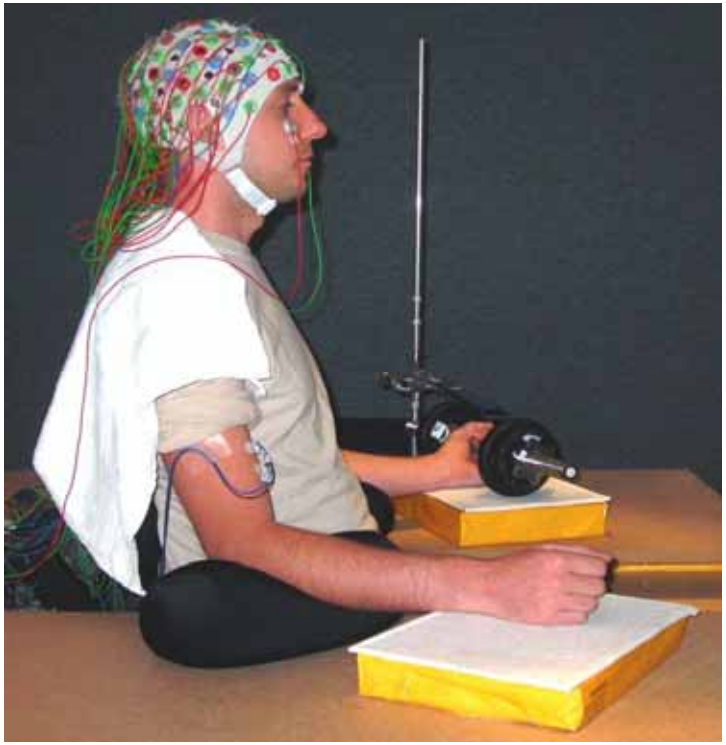



FIG. 1. Physical arrangement which permitted the simultaneous testing of endurance capacity of two paired subjects under condition E. It should be noted that the subjects were placed side by side, each having an independent but identical system for monitoring and collecting expired air and each having an unhindered view of the timer which indicated the duration of the test.

# Neural Correlates of Effort



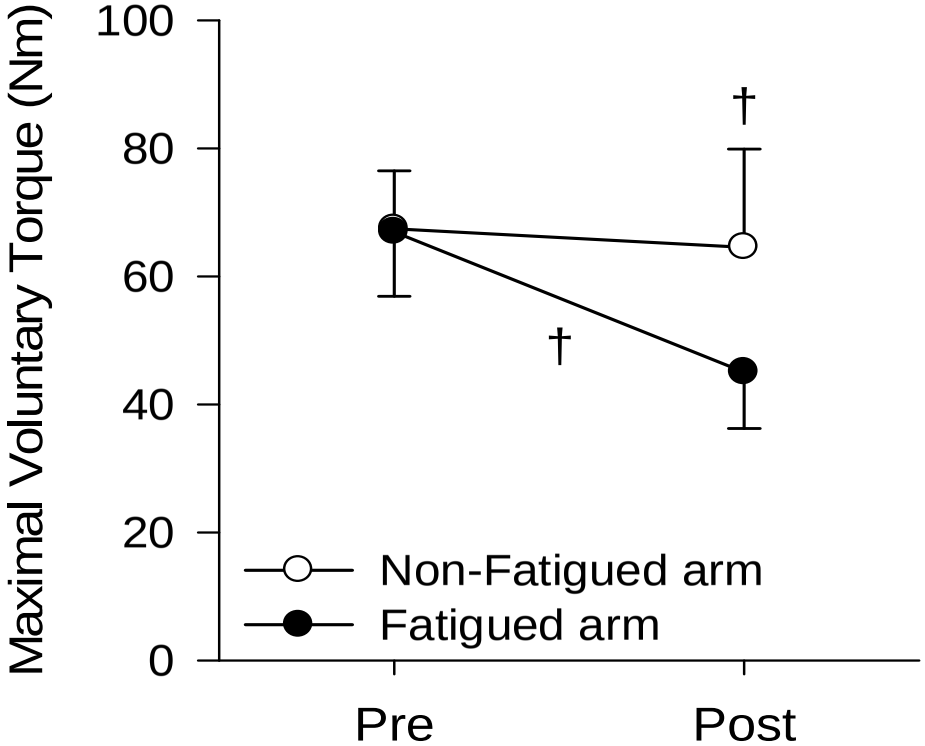
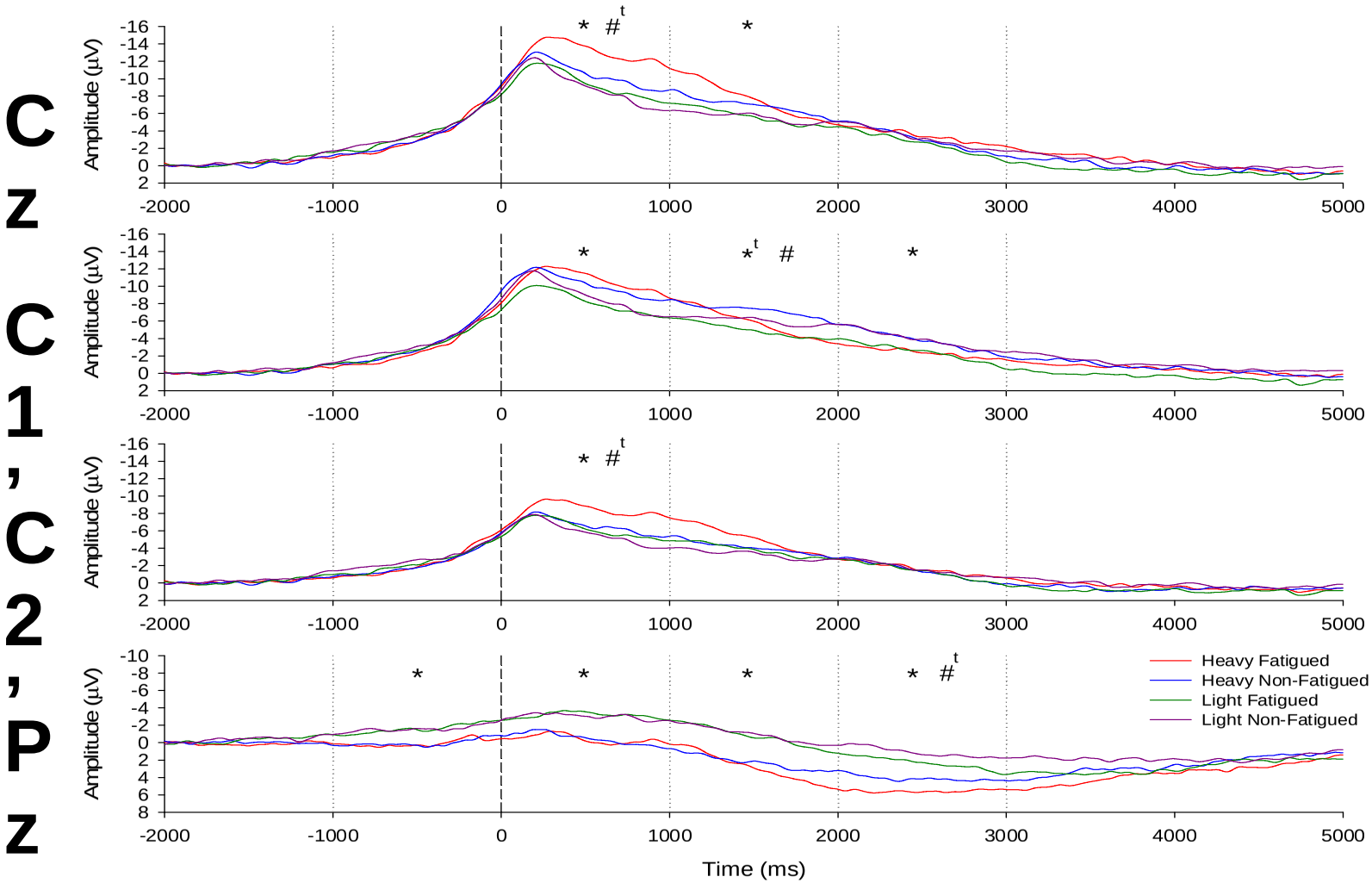



**Figure 1.** *Left.* Experimental set-up. *Right.* Strength loss after fatiguing protocol. † significant paired difference.

# Neural Correlates of Effort



# New Interventions to Improve Endurance Performance

- Cognitive behavioural therapy
- Self-talk
- Goal-setting
- Etc.
- Nutrition


**2007**

# New Interventions to Improve Endurance Performance

- Brain training
- Transcranial Magnetic/Electric Stimulation
- Psychoactive drugs
- Neurofeedback
- Combinations