



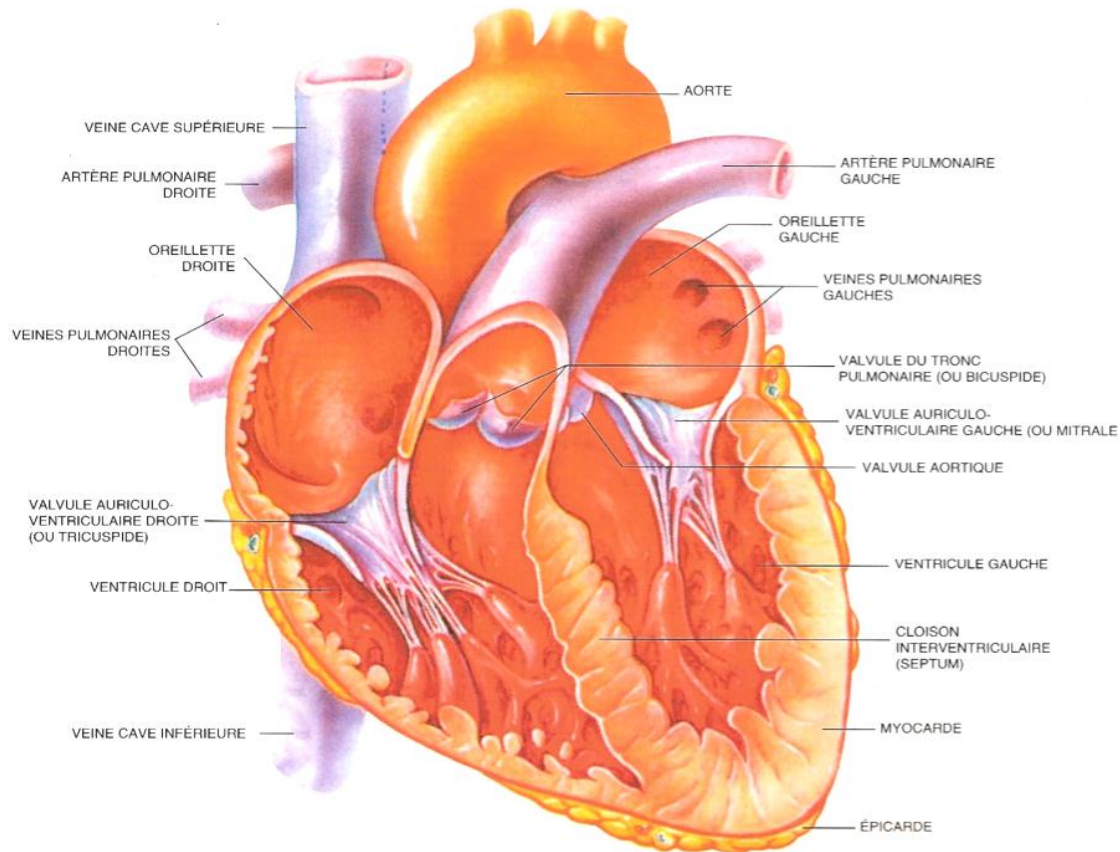
## **Avoir du cœur suffit-il pour être performant ?**

Laurent Bosquet



# Introduction

## Le cœur



*Avoir le cœur gros*

*Le cœur a ses raisons ...*

*Fendre le cœur*

*Ne pas avoir de cœur*

*Être un joli cœur*

*Avoir le cœur sur la main*



# Introduction

## Le cœur



**Le Soldat de Marathon**

Luc Olivier Merson (1869)



**Clarence DeMar**

(1889-1958)

# Introduction

## Le cœur



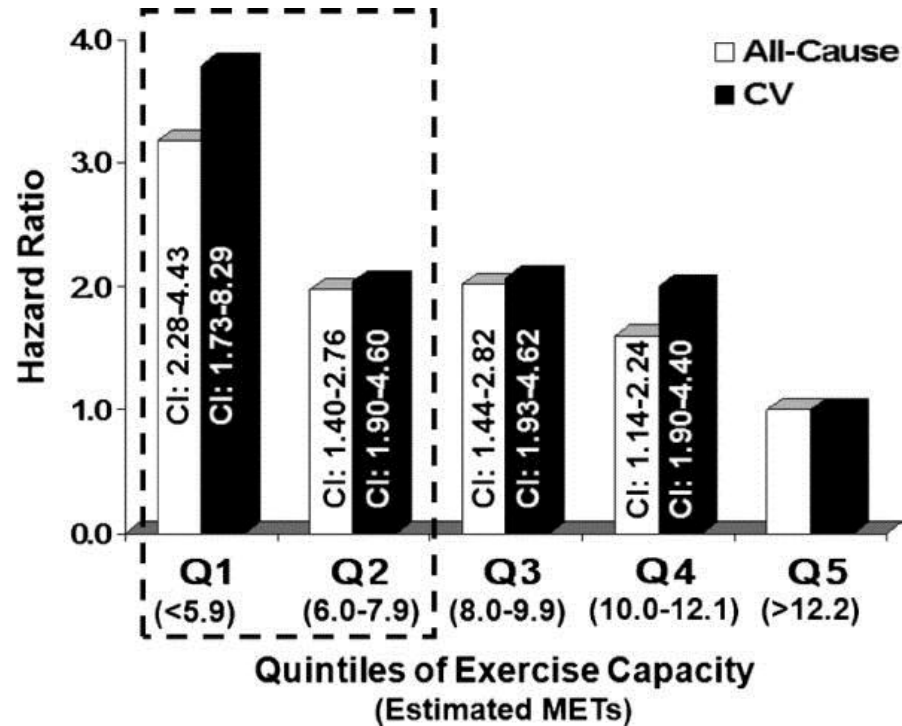
The NEW ENGLAND  
JOURNAL of MEDICINE

## Half a Century of Running — Clinical, Physiologic and Autopsy Findings in the Case of Clarence DeMar (Mr. Marathon)

James H. Currens, M.D.<sup>†</sup>, and Paul D. White, M.D.<sup>‡</sup>  
N Engl J Med 1961; 265:988-993 |

# Introduction

## Aptitude cardio-respiratoire et santé



4384 participants évalués en moyenne tous les 8 ans pendant une période de 20 ans

# Introduction

## Aptitude cardio-respiratoire et santé

L'activité physique est un traitement efficace pour lutter contre :

- Dyslipidémies
- Hypertension artérielle
- Certains cancers
- Diabète de type 2

WJ, M, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, AA, AB, AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, AM, AN, AO, AP, AQ, AR, AS, AT, AU, AV, AW, AX, AY, AZ, BA, BB, BC, BD, BE, BF, BG, BH, BI, BJ, BK, BL, BM, BN, BO, BP, BQ, BR, BS, BT, BU, BV, BW, BX, BY, BZ, CA, CB, CC, CD, CE, CF, CG, CH, CI, CJ, CK, CL, CM, CN, CO, CP, CQ, CR, CS, CT, CU, CV, CW, CX, CY, CZ, DA, DB, DC, DD, DE, DF, DG, DH, DI, DJ, DK, DL, DM, DN, DO, DP, DQ, DR, DS, DT, DU, DV, DW, DX, DY, DZ, EA, EB, EC, ED, EE, EF, EG, EH, EI, EJ, EK, EL, EM, EN, EO, EP, EQ, ER, ES, ET, EU, EV, EW, EX, EY, EZ, FA, FB, FC, FD, FE, FF, FG, FH, FI, FJ, FK, FL, FM, FN, FO, FP, FQ, FR, FS, FT, FU, FV, FW, FX, FY, FZ, GA, GB, GC, GD, GE, GF, GG, GH, GI, GJ, GK, GL, GM, GN, GO, GP, GQ, GR, GS, GT, GU, GV, GW, GX, GY, GZ, HA, HB, HC, HD, HE, HF, HG, HH, HI, HJ, HK, HL, HM, HN, HO, HP, HQ, HR, HS, HT, HU, HV, HW, HX, HY, HZ, IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN, IO, IP, IQ, IR, IS, IT, IU, IV, IW, IX, IY, IZ, JA, JB, JC, JD, JE, JF, JG, JH, JI, JJ, JK, JL, JM, JN, JO, JP, JQ, JR, JS, JT, JU, JV, JW, JX, JY, JZ, KA, KB, KC, KD, KE, KF, KG, KH, KI, KJ, KK, KL, KM, KN, KO, KP, KQ, KR, KS, KT, KU, KV, KW, KX, KY, KZ, LA, LB, LC, LD, LE, LF, LG, LH, LI, LJ, LK, LL, LM, LN, LO, LP, LQ, LR, LS, LT, LU, LV, LW, LX, LY, LZ, MA, MB, MC, MD, ME, MF, MG, MH, MI, MJ, MK, ML, MM, MN, MO, MP, MQ, MR, MS, MT, MU, MV, MW, MX, MY, MZ, NA, NB, NC, ND, NE, NF, NG, NH, NI, NJ, NK, NL, NM, NN, NO, NP, NQ, NR, NS, NT, NU, NV, NW, NX, NY, NZ, OA, OB, OC, OD, OE, OF, OG, OH, OI, OJ, OK, OL, OM, ON, OO, OP, OQ, OR, OS, OT, OU, OV, OW, OX, OY, OZ, PA, PB, PC, PD, PE, PF, PG, PH, PI, PJ, PK, PL, PM, PN, PO, PP, PQ, PR, PS, PT, PU, PV, PW, PX, PY, PZ, QA, QB, QC, QD, QE, QF, QG, QH, QI, QJ, QK, QL, QM, QN, QO, QP, QQ, QR, QS, QT, QU, QV, QW, QX, QY, QZ, RA, RB, RC, RD, RE, RF, RG, RH, RI, RJ, RK, RL, RM, RN, RO, RP, RQ, RR, RS, RT, RU, RV, RW, RX, RY, RZ, SA, SB, SC, SD, SE, SF, SG, SH, SI, SJ, SK, SL, SM, SN, SO, SP, SQ, SR, SS, ST, SU, SV, SW, SX, SY, SZ, TA, TB, TC, TD, TE, TF, TG, TH, TI, TJ, TK, TL, TM, TN, TO, TP, TQ, TR, TS, TT, TU, TV, TW, TX, TY, TZ, UA, UB, UC, UD, UE, UF, UG, UH, UI, UJ, UK, UL, UM, UN, UO, UP, UQ, UR, US, UT, UU, UV, UW, UX, UY, UZ, VA, VB, VC, VD, VE, VF, VG, VH, VI, VJ, VK, VL, VM, VN, VO, VP, VQ, VR, VS, VT, VU, VV, VW, VX, VY, VZ, WA, WB, WC, WD, WE, WF, WG, WH, WI, WJ, WK, WL, WM, WN, WO, WP, WQ, WR, WS, WT, WU, WV, WW, WX, WY, WZ, XA, XB, XC, XD, XE, XF, XG, XH, XI, XJ, XK, XL, XM, XN, XO, XP, XQ, XR, XS, XT, XU, XV, XW, XX, XY, XZ, YA, YB, YC, YD, YE, YF, YG, YH, YI, YJ, YK, YL, YM, YN, YO, YP, YQ, YR, YS, YT, YU, YV, YW, YX, YY, YZ, ZA, ZB, ZC, ZD, ZE, ZF, ZG, ZH, ZI, ZJ, ZK, ZL, ZM, ZN, ZO, ZP, ZQ, ZR, ZS, ZT, ZU, ZV, ZW, ZX, ZY, ZZ.

### Effects Press

**Abstract**—Previous training on b meta-analysis tant cardiovascular endurance tra intervention d journal up to weighting for reductions of 3.3,3.5,5 mm H groups (–6.9) (P<0.05), pla decreased by the homeostat 0.02 mmol/L vascular resist and favorably

### America Sports M Roundta Guidelin Survivor

#### EXPERT PANEL

Kathryn H. Schmitz, Kerry S. Courneya, Charles Matthews, Wendy Demark-Wal Daniel A. Galvão, P Bernardine M. Pinto Melinda L. Irwin, P Kathleen Y. Wolin, J Roanne J. Segal, M Alejandro Lucia, M Carole M. Schneider Vivian E. von Gruen Anna L. Schwartz, P

**R**egular physical activity is associated with a lower risk of cardiovascular disease. This meta-analysis of 19 studies found that regular exercise reduces the risk of cardiovascular disease by 29%. The meta-analysis also found that regular exercise reduces the risk of cardiovascular disease by 29% in people with cardiovascular disease. The meta-analysis also found that regular exercise reduces the risk of cardiovascular disease by 29% in people with cardiovascular disease.

Received May 11, 2010; accepted June 11, 2010. Correspondence: Robert J. Sigal, MD, PhD, Department of Medicine, University of Ottawa, Ottawa, Ontario, Canada (E-mail: sigal@uottawa.ca). © 2010 American Heart Association.

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Diabetologia (2010) 53:1071–1081  
DOI 10.1007/s00125-010-1160-2

### Diabetologia

## Meta-analysis of the effect of structured exercise training on cardiorespiratory fitness in Type 2 diabetes mellitus

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<sup>1</sup>School of Human Kinetics, University of Ottawa, Ottawa, Ontario, Canada  
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<sup>3</sup>Department of Medicine, University of Ottawa, Ottawa, Ontario, Canada  
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#### Abstract

**Aims/hypothesis.** Low cardiorespiratory fitness is a powerful and independent predictor of mortality in people with diabetes. Several studies have examined the effects of exercise on cardiorespiratory fitness in Type 2 diabetic individuals. However, these studies had relatively small sample sizes and highly variable results. Therefore the aim of this study was to systematically review and quantify the effects of exercise on cardiorespiratory fitness in Type 2 diabetic individuals. **Methods.** MEDLINE, EMBASE, and four other databases were searched up to March 2002 for randomized, controlled trials evaluating effects of structured aerobic exercise interventions of 8 weeks or more on cardiorespiratory fitness in adults with Type 2 diabetes. Cardiorespiratory fitness was defined as maximal oxygen uptake ( $\dot{V}O_{2max}$ ) during a maximal exercise test. **Results.** Seven studies, presenting data for nine randomized trials comparing exercise and control groups

(overall  $n=256$ ), met the inclusion criteria. Mean exercise characteristics were as follows: 3.4 sessions per week, 49 min per session for 20 weeks. Exercise intensity ranged from 50% to 75% of  $\dot{V}O_{2max}$ . There was an 11.8% increase in  $\dot{V}O_{2max}$  in the exercise group and a 1.0% decrease in the control group (post intervention standardized mean difference  $\pm$ 0.33,  $p<0.003$ ). Studies with higher exercise intensities tended to produce larger improvements in  $\dot{V}O_{2max}$ . Exercise intensity predicted post-intervention weight of mean difference in  $HbA_{1c}$  ( $r=-0.91$ ,  $p=0.002$ ) to a larger extent than did exercise volume ( $r=-0.46$ ,  $p=0.29$ ). **Conclusions/interpretation.** Regular exercise has a statistically and clinically significant effect on  $\dot{V}O_{2max}$  in Type 2 diabetic individuals. Higher intensity exercise could have additional benefits on cardiorespiratory fitness and  $HbA_{1c}$ . (Diabetologia (2010) 53: 1071–1081)

**Keywords** Meta-analysis, Type 2 diabetes mellitus, exercise, fitness, oxygen consumption.

The maximal amount of oxygen consumed during exercise ( $\dot{V}O_{2max}$ ) has been used for decades by exercise physiologists to determine the maximum exercise ca-

pacities of athletes. In recent decades,  $\dot{V}O_{2max}$  has had a growing importance in clinical settings and has become the gold standard measure of cardiovascular fitness and exercise capacity [1]. There is evidence from large cohort studies that low cardiorespiratory fitness is a powerful and independent predictor of long-term cardiac mortality in people with diabetes [2, 3, 4], even after controlling for traditional risk factors such as age, hypercholesterolemia, smoking, and hypertension and excluding individuals with evidence of coronary ischaemia during testing. Furthermore, in non-diabetic subjects undergoing repeated maximal

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E-mail: sigal@uottawa.ca  
Abbreviations:  $\dot{V}O_{2max}$  maximal oxygen consumption.

# Introduction

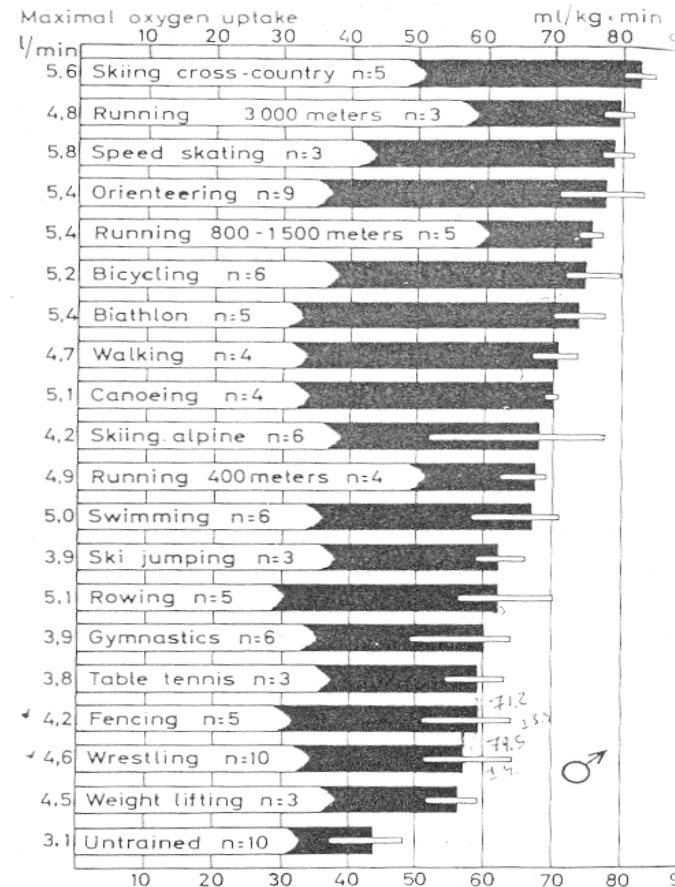
## Aptitude cardio-respiratoire et performance



**Arthur Vivian HILL**

(1886 – 1977)

Prix Nobel de médecine en 1922





# La consommation d'oxygène

## Le principe de Fick

$$\dot{V}O_2 = \dot{Q}c \times (a - \bar{v})O_2$$

# La consommation d'oxygène

## Le principe de Fick

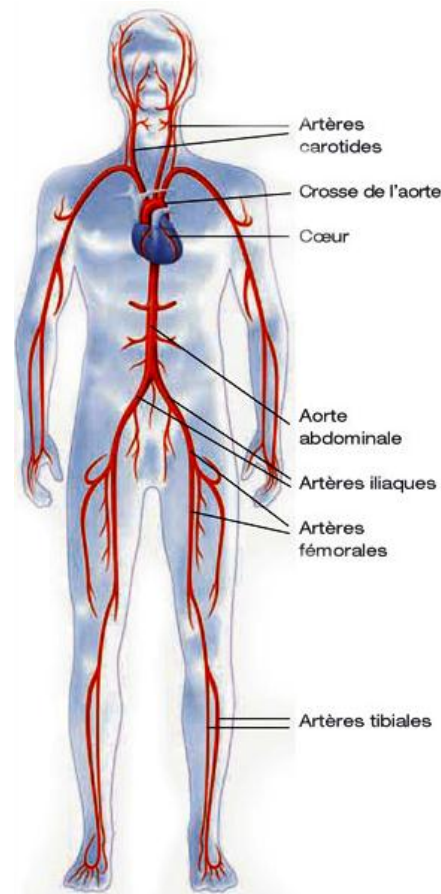
### Quelques valeurs



Variable	Sédentaire	Marathonien
$\text{VO}_2\text{max}$ ( $\text{ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ )	40	80
$Q_c$ ( $\text{l}\cdot\text{min}^{-1}$ )	22	35
$(a-v) \text{O}_2$ ( $\text{ml}\cdot 100 \text{ ml}^{-1}$ )	14	16

# La consommation d'oxygène

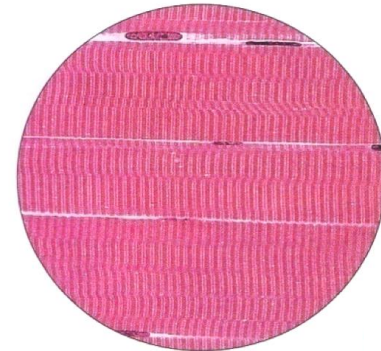
## Le système cardiovasculaire



# La consommation d'oxygène

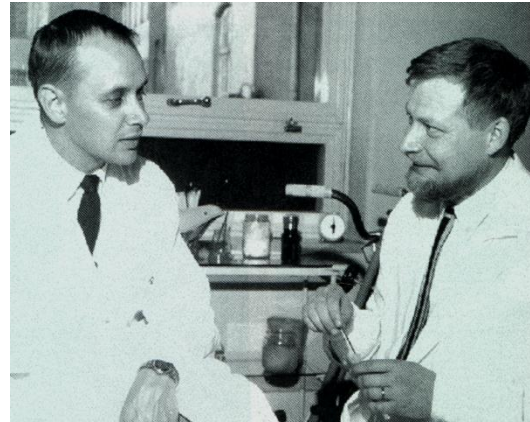
## Le principe de Fick

$$\dot{V}O_2 = \dot{Q}c \times (a - \bar{v})O_2$$

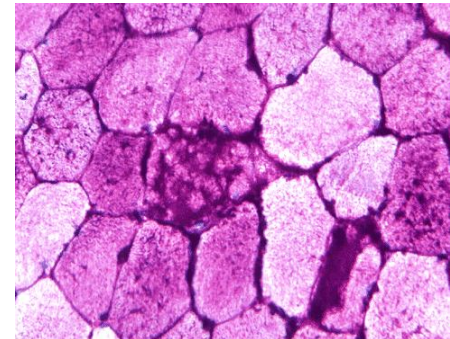
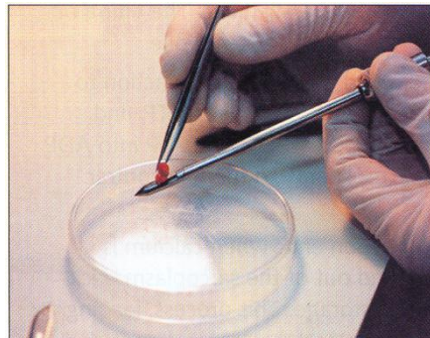
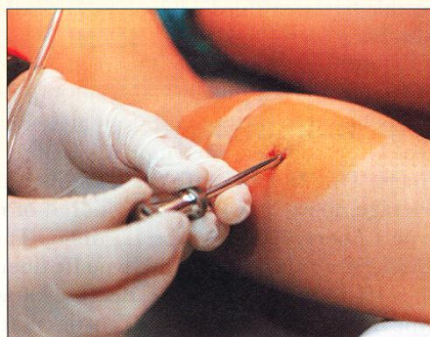


# Caractéristiques du muscle

## Méthodes d'exploration



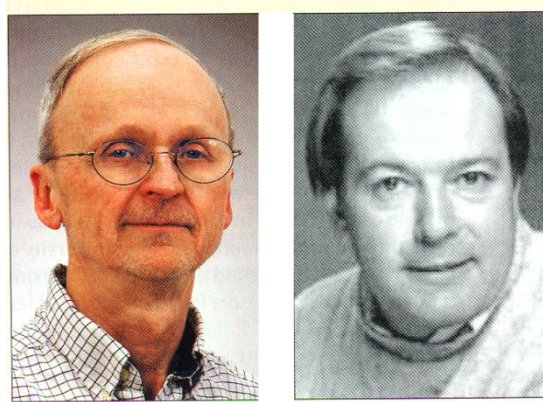
Jonas Bergstrom et Eric Hultman



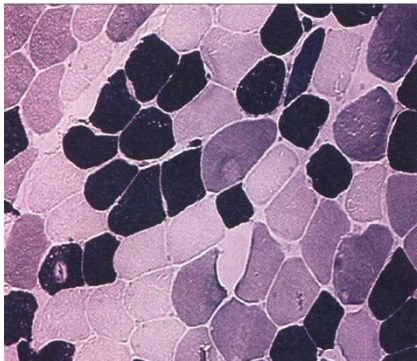


# Caractéristiques du muscle

## Méthodes d'exploration



Franck Booth et Ken Baldwin



**Fibres de type 1 (rouges)**

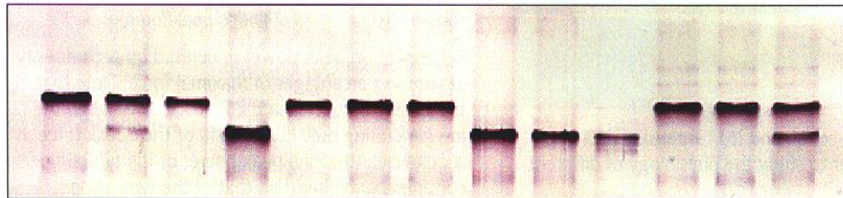
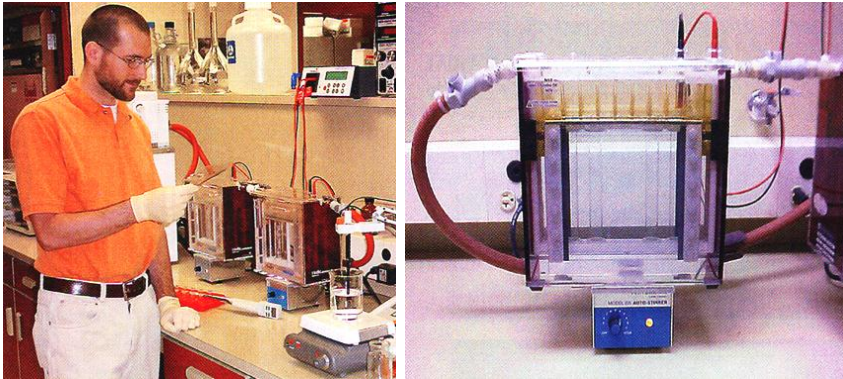
**Fibres de type 2a (grises)**

**Fibres de type 2x (blanches)**

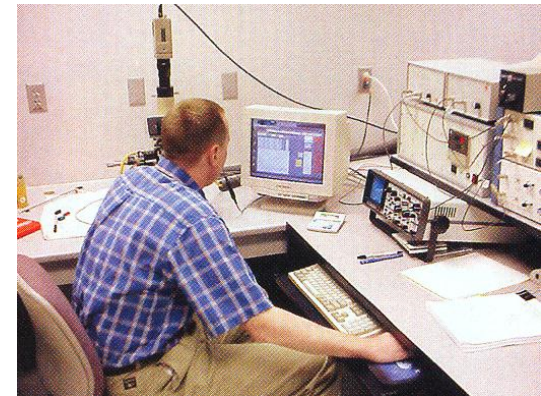
# Caractéristiques du muscle

## Méthodes d'exploration

### L'électrophorèse



### La fibre pelée



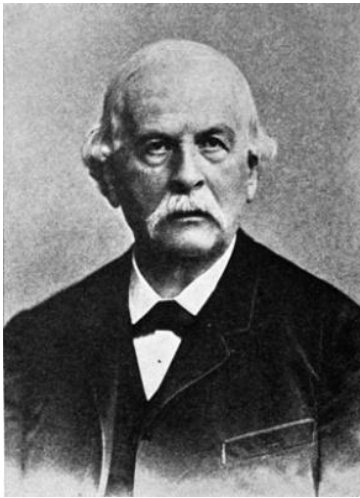
# Caractéristiques du muscle

## Comparaison fonctionnelle

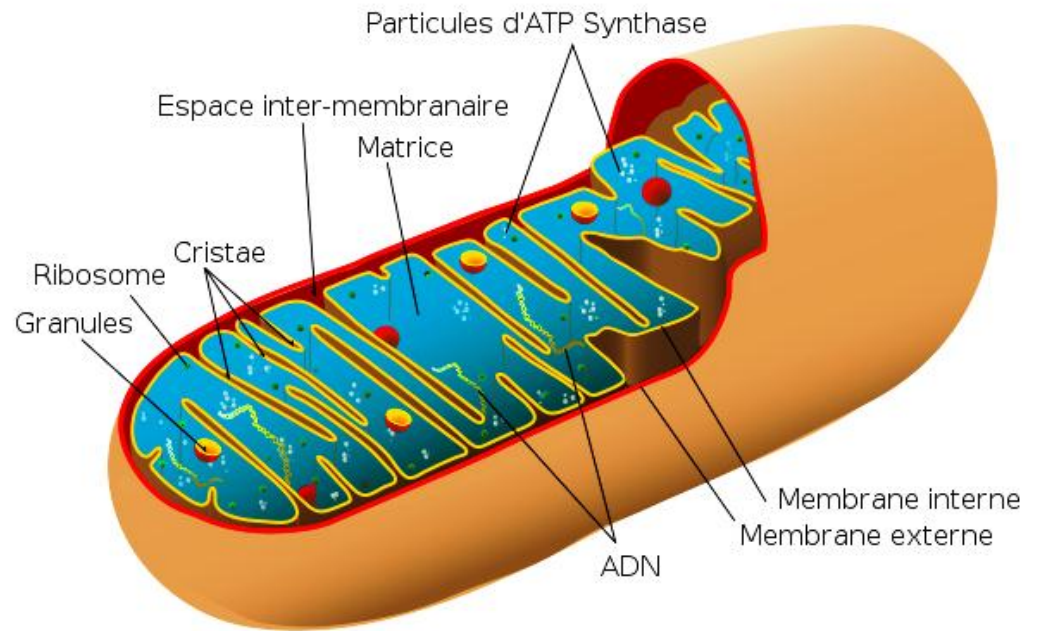
Caractéristique	I	Ila	Iix
Activité de l'ATPase de la myosine	Lente	Rapide	Rapide
Développement du réticulum sarcoplasmique	Faible	Elevé	Elevé
Densité mitochondriale	Elevée	Elevée	Faible
Densité capillaire	Elevée	Elevée	Faible
Concentration de myoglobine	Elevée	Elevée	Faible
Taille des motoneurones	Petite	Grande	Grande
Nombre de fibres par motoneurone	< 300	> 300	> 300
Capacité oxydative	Elevée	Intermédiaire	Faible
Capacité glycolytique	Faible	Elevée	Très élevée

# Caractéristiques du muscle

## La densité mitochondriale



Rudolph Kölliker  
(1857)



# Caractéristiques du muscle

## Performance sportive

Athlète	Sexe	Muscle	% type I	% type II
Sédentaires	M	Vastes latéraux	47	53
	F	Gastrocnémiens	52	48
½ fond - fond	M	Gastrocnémiens	79	21
	F	Gastrocnémiens	69	31
Sprint	M	Gastrocnémiens	24	76
	F	Gastrocnémiens	27	73

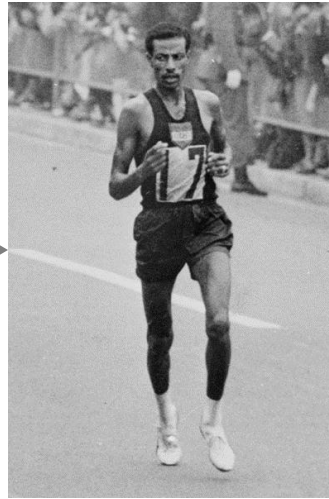


# Facteurs de la performance

## Coût énergétique

$VO_2\text{max}$   
( $\text{ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ )

Coût Énergétique  
( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{m}^{-1}$ )



**Abebe Bikila**

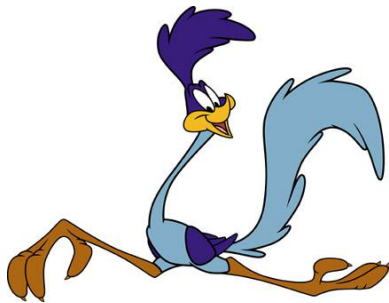
Champion Olympique  
du marathon en 1960 et 1964

# Coût énergétique

## Définition



**Litres d'essence pour parcourir 100 km**

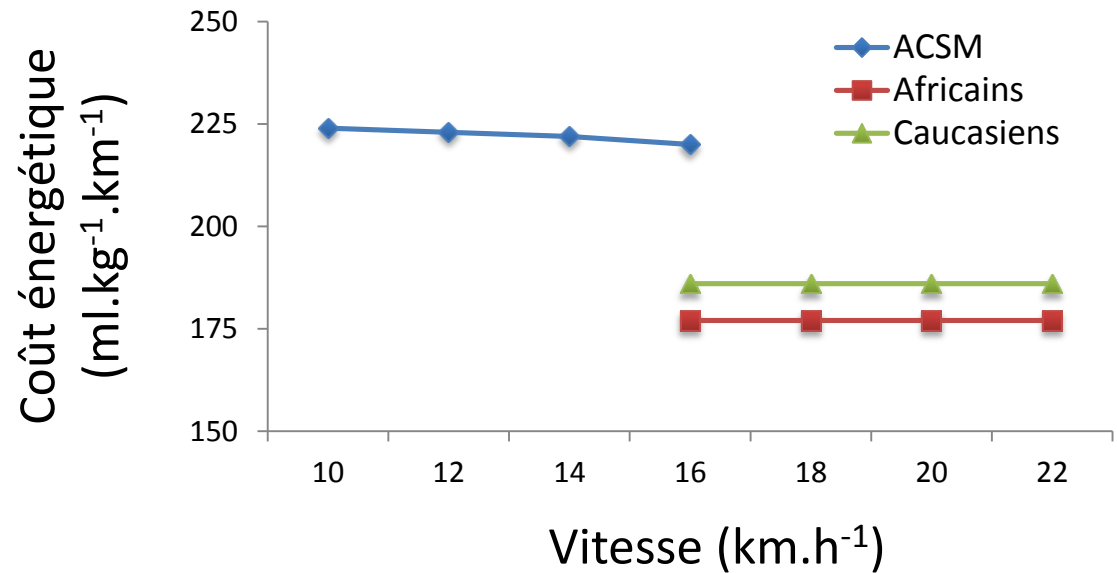


**Millilitres d'O<sub>2</sub> pour parcourir 1 km**

# Coût énergétique

## Définition

### Quelques valeurs



# Coût énergétique

## Facteurs sous-jacents

Composition corporelle

Morphologie

Croissance

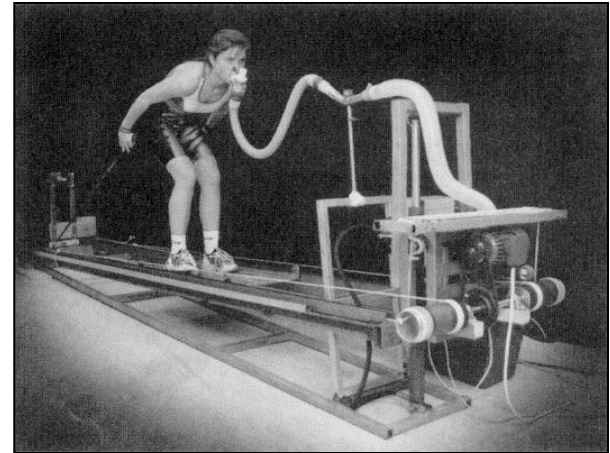
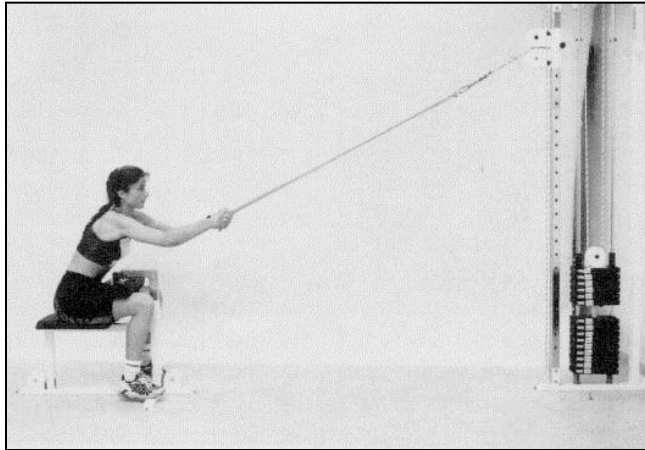
Coût Énergétique  
( $\text{ml.kg}^{-1}.\text{m}^{-1}$ )

**Force musculaire**

**Composante élastique**

# Coût énergétique

## Force maximale





# Coût énergétique

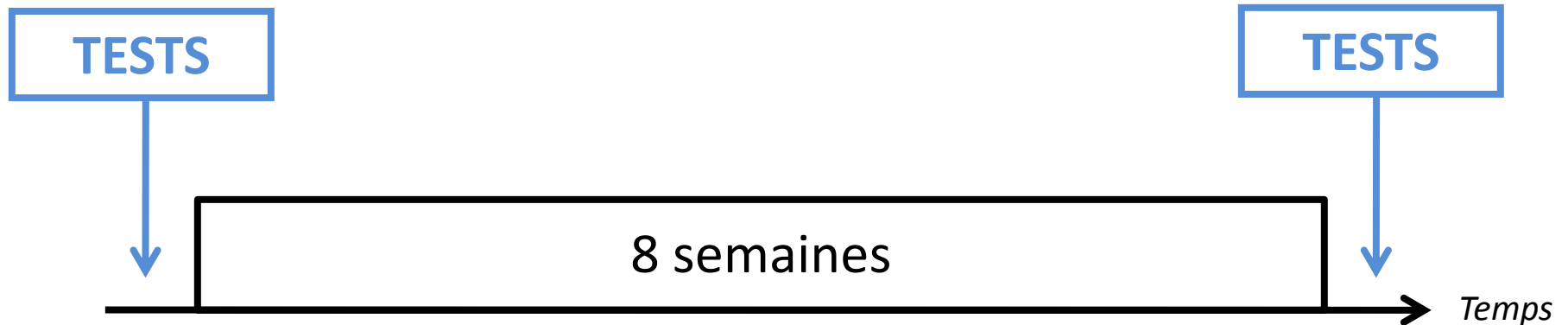
## Force maximale

### Contenus du programme d'entraînement

	Expérimental	Contrôle
Entraînement aérobie	X	X
Entraînement force max	X	

# Coût énergétique

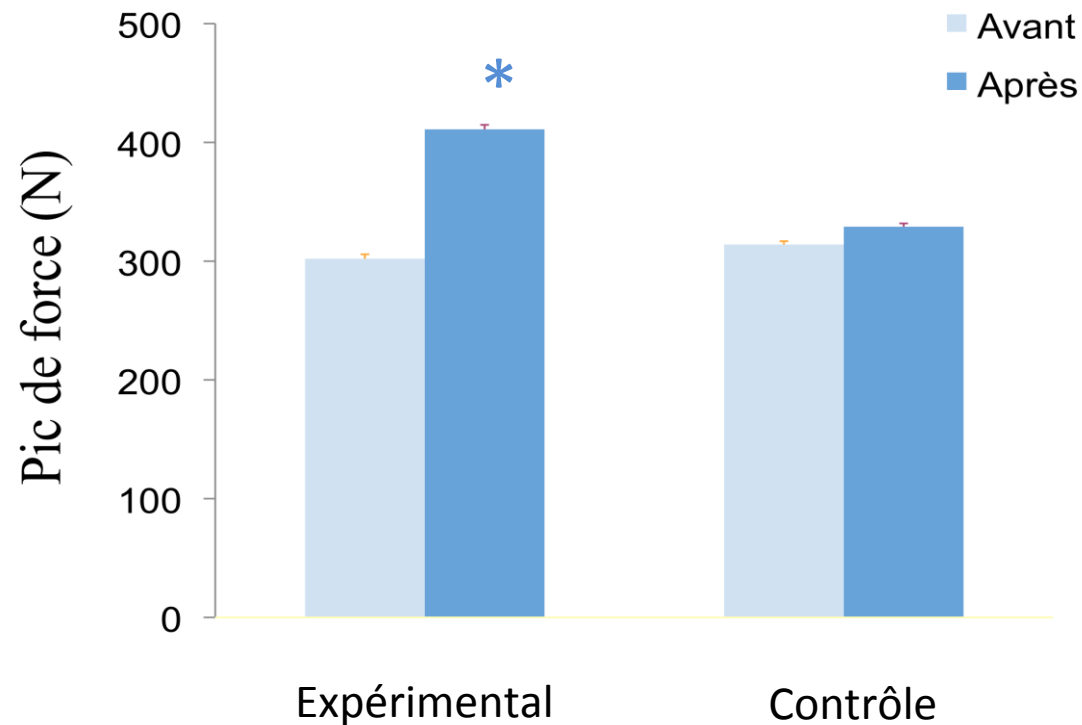
## Force maximale



- **Test incrémenté** : coût énergétique,  $VO_2$ max et PAM
- **Test force maximale** : 1 répétition maximale
- **Test à charge constante** : performance

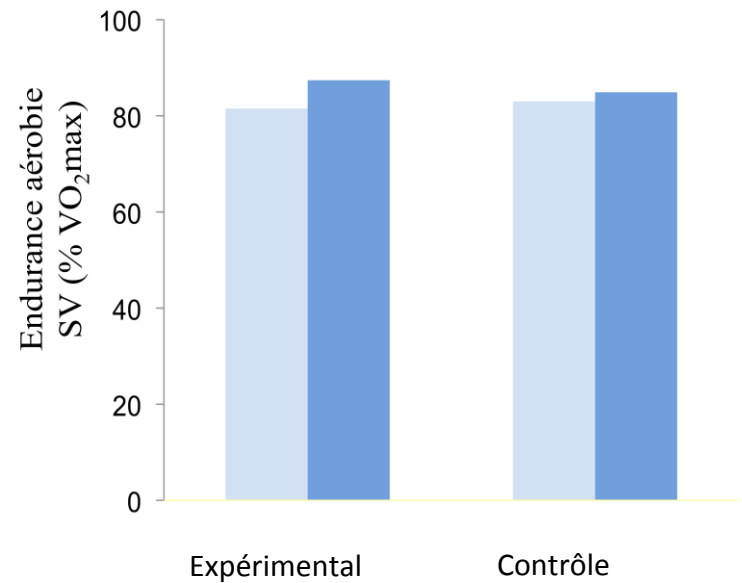
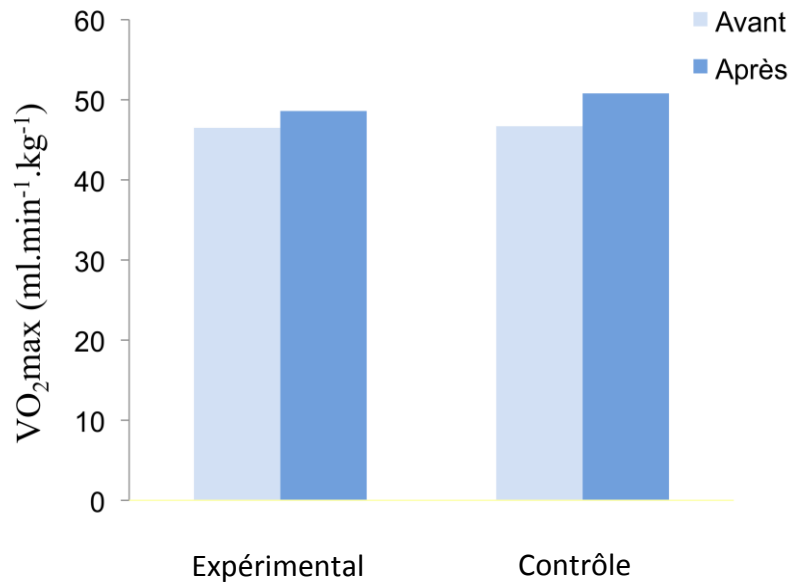
# Coût énergétique

## Force maximale



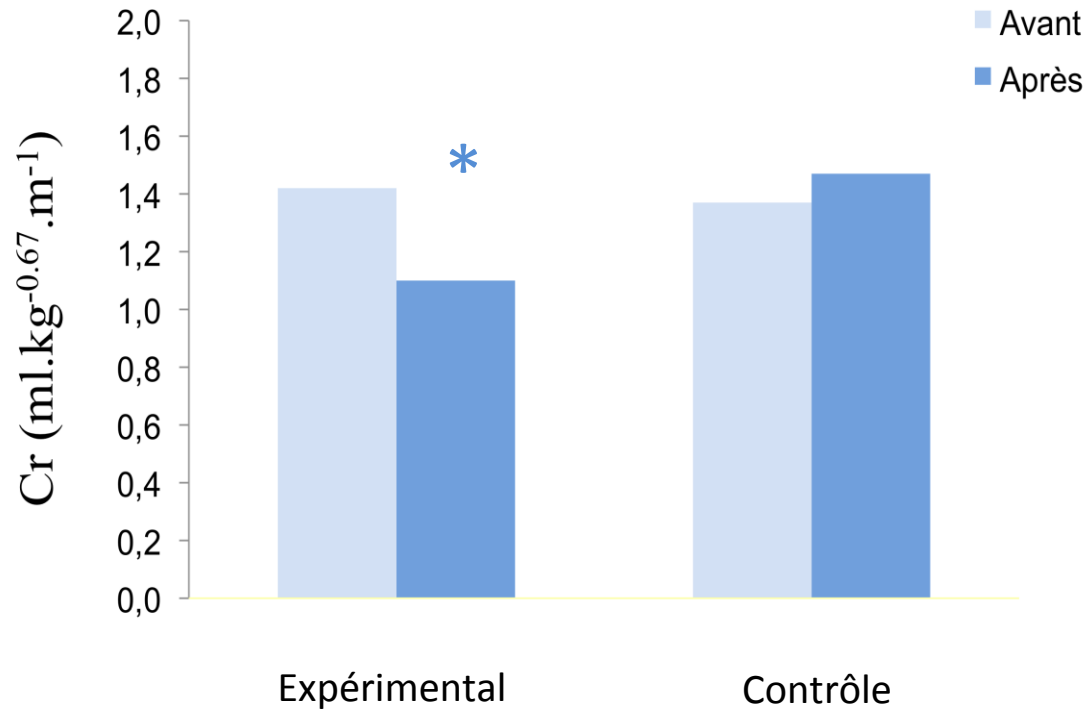
# Coût énergétique

## Force maximale



# Coût énergétique

## Force maximale





# Coût énergétique

## Facteurs sous-jacents

Composition corporelle

Morphologie

Croissance

**Coût Énergétique**  
**(ml.kg<sup>-1</sup>.m<sup>-1</sup>)**

**Force musculaire**

**Composante élastique**

# La contraction musculaire

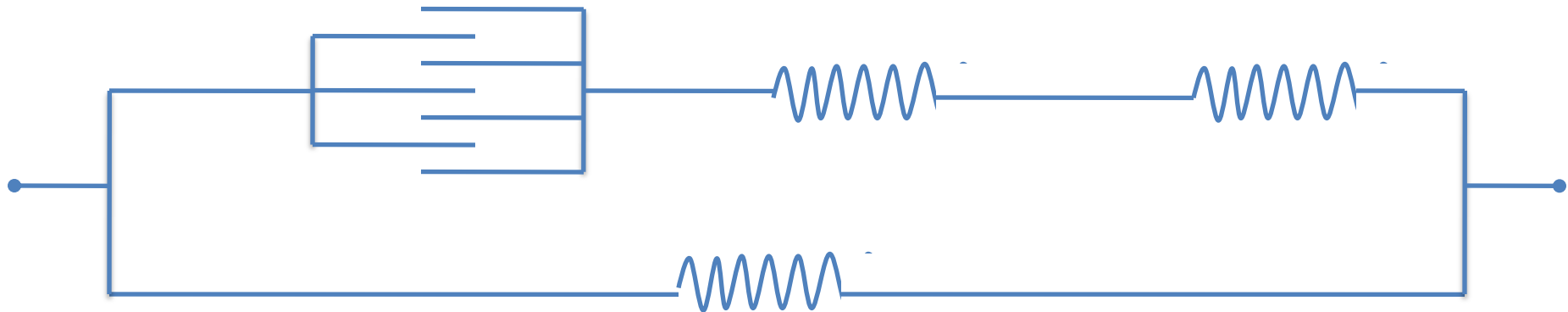
## Modèle de Huxley-Simmons

**Composante contractile**  
(filaments actine et myosine)

**Composante élastique série**

**Active**  
(ponts actine-myosine)

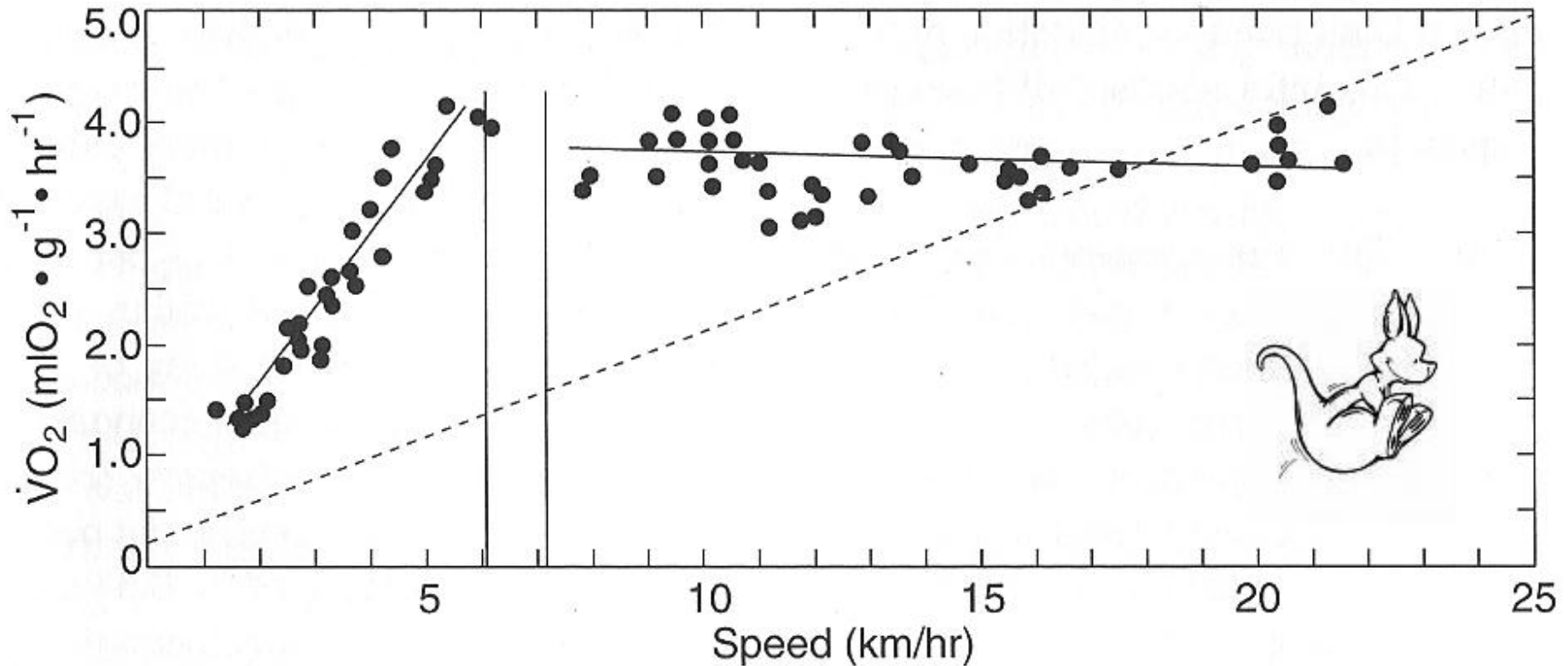
**Passive**  
(tendons)



**Composante élastique parallèle**  
(tissu conjonctif)

# Coût énergétique

## Composante élastique



# Coût énergétique

## Composante élastique

### EFFECT OF PLYOMETRIC VS. DYNAMIC WEIGHT TRAINING ON THE ENERGY COST OF RUNNING

NICOLAS BERRYMAN,<sup>1</sup> DELPHINE MAUREL,<sup>2</sup> AND LAURENT BOSQUET<sup>1,2</sup>

<sup>1</sup>Department of Kinesiology, Exercise Physiology Laboratory, University of Montreal, Montreal, Canada; and  
<sup>2</sup>Faculty of Sport Sciences, University of Poitiers, Poitiers, France

#### ABSTRACT

Berryman, N, Maurel, D, and Boquet, L. Effect of plyometric vs. dynamic weight training on the energy cost of running. *J Strength Cond Res* 24(7): 1818–1825, 2010—The purpose of this study is to compare the effects of 2 strength training methods on the energy cost of running ( $C_r$ ). Thirty-five moderately to well-trained male endurance runners were randomly assigned to either a control group (C) or 2 intervention groups. All groups performed the same endurance-training program during an 8-week period. Intervention groups added a weekly strength training session designed to improve neuromuscular qualities. Sessions were matched for volume and intensity using either plyometric training (PT) or purely concentric contractions with added weight (dynamic weight training [DWT]). We found an interaction between time and group ( $p < 0.05$ ) and an effect of time ( $p < 0.01$ ) for  $C_r$ . Plyometric training induced a larger decrease of  $C_r$  ( $218 \pm 16$  to  $203 \pm 13$   $\text{ml}\cdot\text{kg}^{-1}\cdot\text{km}^{-1}$ ) than DWT ( $207 \pm 15$  to  $199 \pm 12$   $\text{ml}\cdot\text{kg}^{-1}\cdot\text{km}^{-1}$ ), whereas it remained unchanged in C. Pre-post changes in  $C_r$  were correlated with initial  $C_r$  ( $r = -0.57$ ,  $p < 0.05$ ). Peak vertical jump height ( $\text{VJH}_{\text{max}}$ ) increased significantly ( $p < 0.01$ ) for both experimental groups (DWT =  $33.4 \pm 6.2$  to  $34.9 \pm 6.1$  cm, PT =  $33.3 \pm 4.0$  to  $35.3 \pm 3.6$  cm) but not for C. All groups showed improvements ( $p < 0.05$ ) in  $\text{Perf}_{3000}$  (C =  $711 \pm 107$  to  $690 \pm 109$  seconds, DWT =  $755 \pm 87$  to  $724 \pm 77$  seconds, PT =  $748 \pm 81$  to  $712 \pm 76$  seconds). Plyometric training were more effective than DWT in improving  $C_r$  in moderately to well-trained male endurance runners showing that athletes and coaches should include explosive strength training in their practices with

a particular attention on plyometric exercises. Future research is needed to establish the origin of this adaptation.

**KEY WORDS** concurrent training, half squat, drop jump, running performance

#### INTRODUCTION

Successful running performance in long duration events is directly influenced by maximal oxygen uptake ( $\dot{V}O_{2\text{max}}$ ), fractional use of  $\dot{V}O_{2\text{max}}$  (End), and the energy cost of running ( $C_r$ ) (10). Although we have been aware of its importance since the 1970s, the state of knowledge about  $C_r$  is low compared to our understanding of  $\dot{V}O_{2\text{max}}$  or End (10,13).  $C_r$  is the  $O_2$  equivalent of the energy required to run through a given distance at a submaximal speed (32). It is particularly relevant to predict performance in individuals with similar  $\dot{V}O_{2\text{max}}$  (9) and has been acknowledged as one of the multiple determinants of East African runners' domination in international competitions (21).  $C_r$  depends on a complex interplay of factors including training, environment, physiology, biomechanics, anthropometry, and training (32). Recent research suggests that strength training is one of the most powerful interventions for improving  $C_r$  (17,28,34,36,37). However, because muscular hypertrophy has been shown to interfere with some peripheral aerobic adaptations, (5,23) it has been suggested that implementations should use strength training methods that emphasize on neural adaptations (11).

Plyometric and dynamic weight training (PT and DWT) fulfill this requirement (14,20,40). Plyometric training involves an eccentric contraction immediately followed by a concentric contraction to allow the muscle to store and recoil elastic energy (6,24,38). Jumps and rebounds are typically used to induce this muscle stretch shortening cycle. Dynamic weight training involves concentric contractions leading to the maximal power output (40). It generally consists in moving relatively light loads (between 30 and 50% of 1 repetition maximum) as fast as possible (40).

The effectiveness of plyometric and DWT (either alone or in combination) to decrease  $C_r$  has been highlighted in several convergent reports (28,35,37). In a recent study (35), 8 moderately trained endurance runners improved  $C_r$  after

### Travail pliométrique



### Travail concentrique



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# Coût énergétique

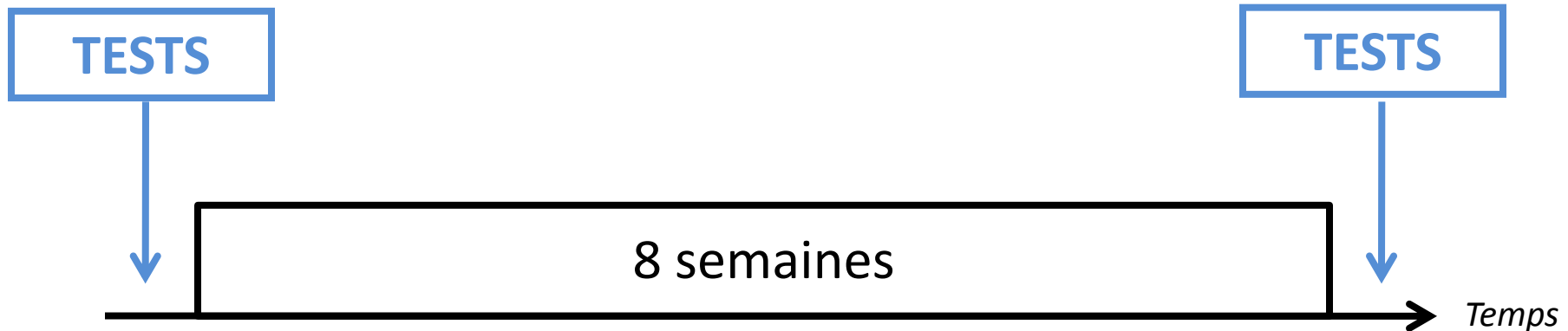
## Composante élastique

### Contenus du programme d'entraînement

	Pliométrique	Concentrique	Contrôle
Entraînement aérobie	X	X	X
Entraînement puissance	X	X	

# Coût énergétique

## Composante élastique

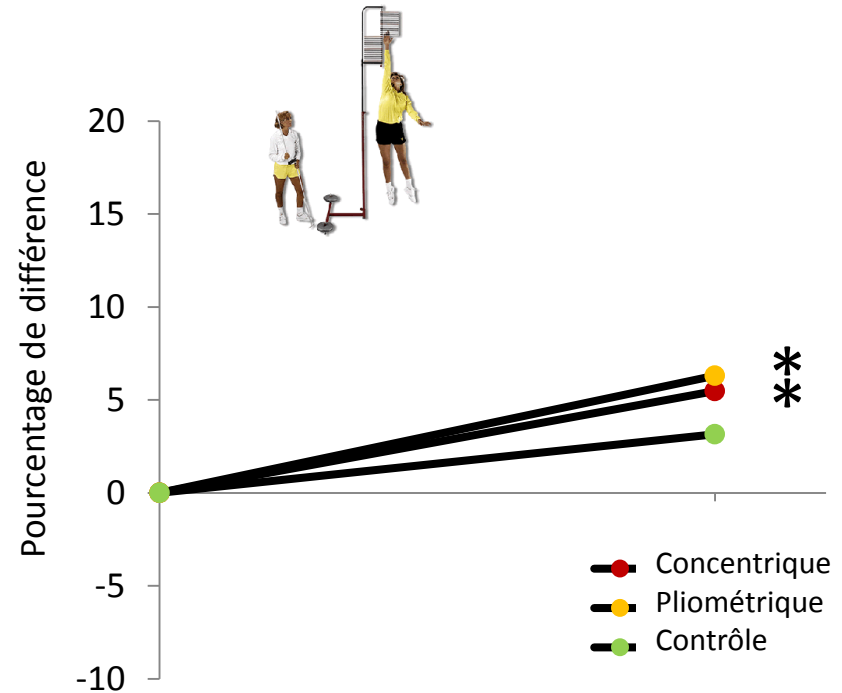
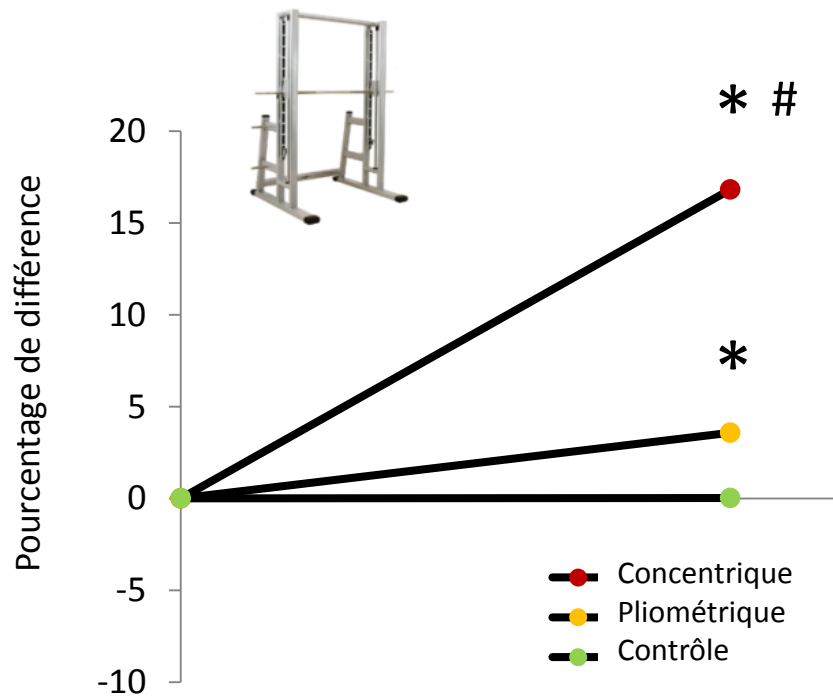


- **Test incrémenté** : coût énergétique,  $VO_2$ max et VAM
- **Test force-vitesse** : puissance maximale concentrique
- **Test de sauts** : puissance maximale pliométrique
- **Test à travail constant** : performance et endurance



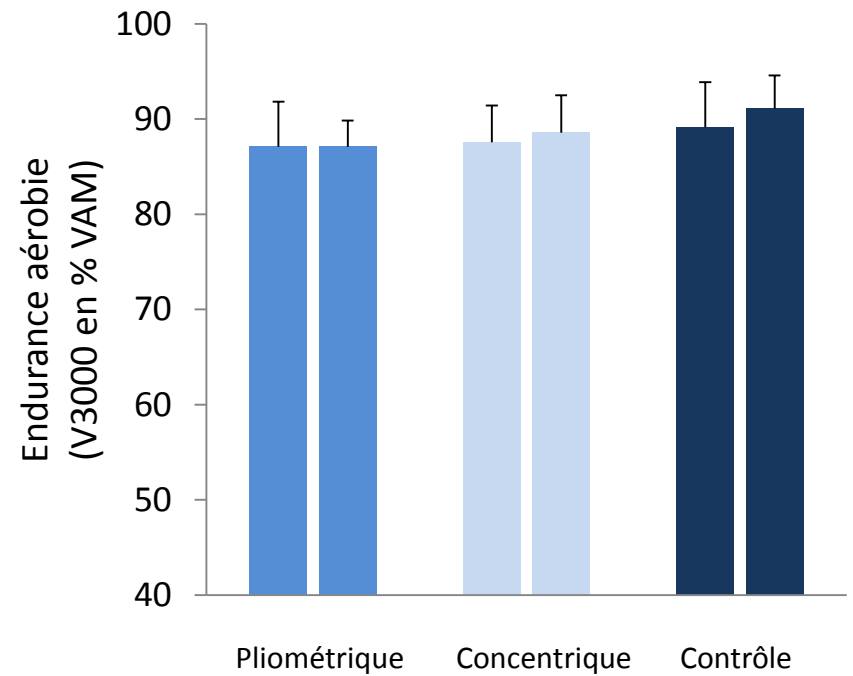
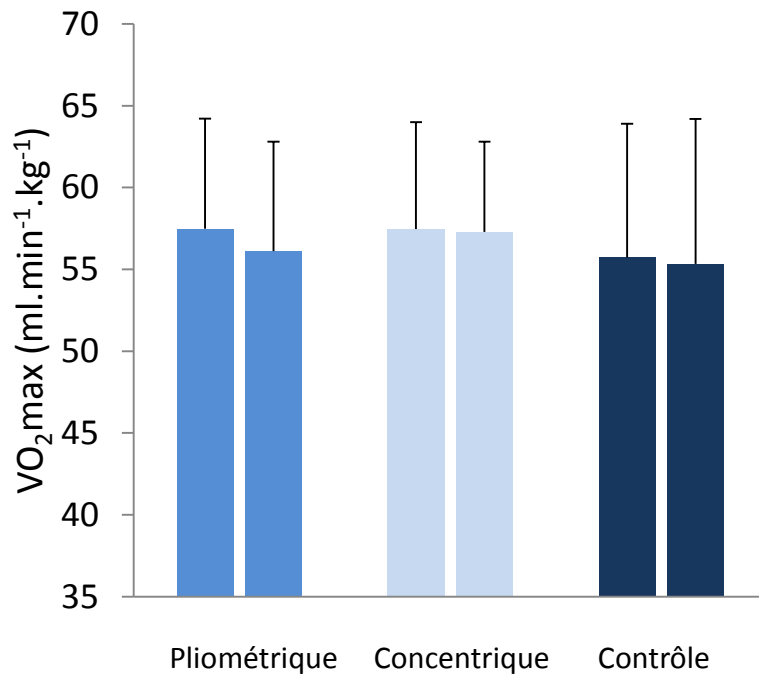
# Coût énergétique

## Composante élastique



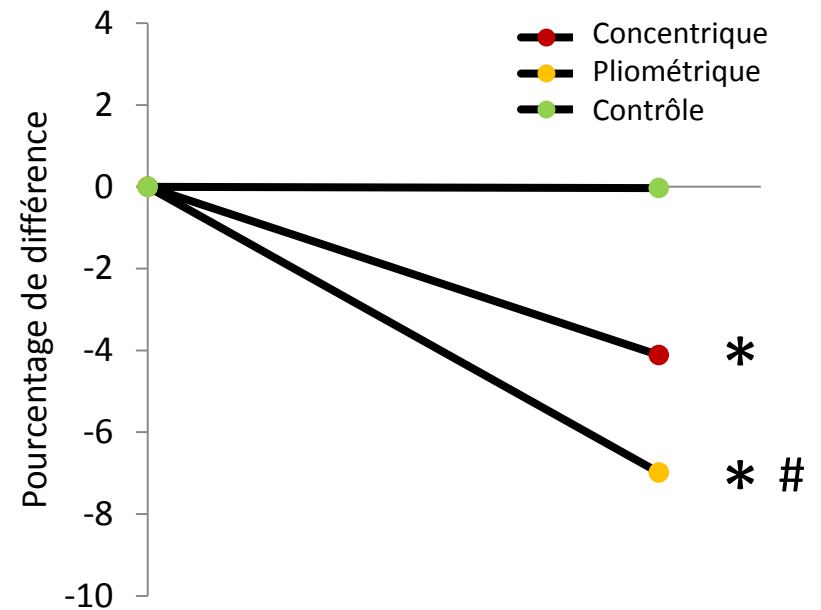
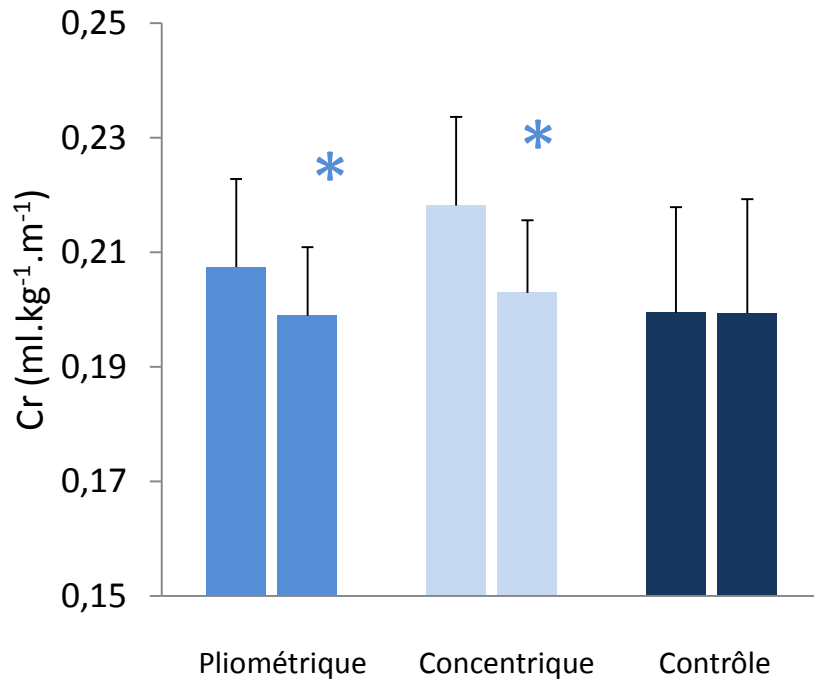
# Coût énergétique

## Composante élastique



# Coût énergétique

## Composante élastique



# Coût énergétique

## Facteurs sous-jacents

Composition corporelle

Morphologie

Croissance

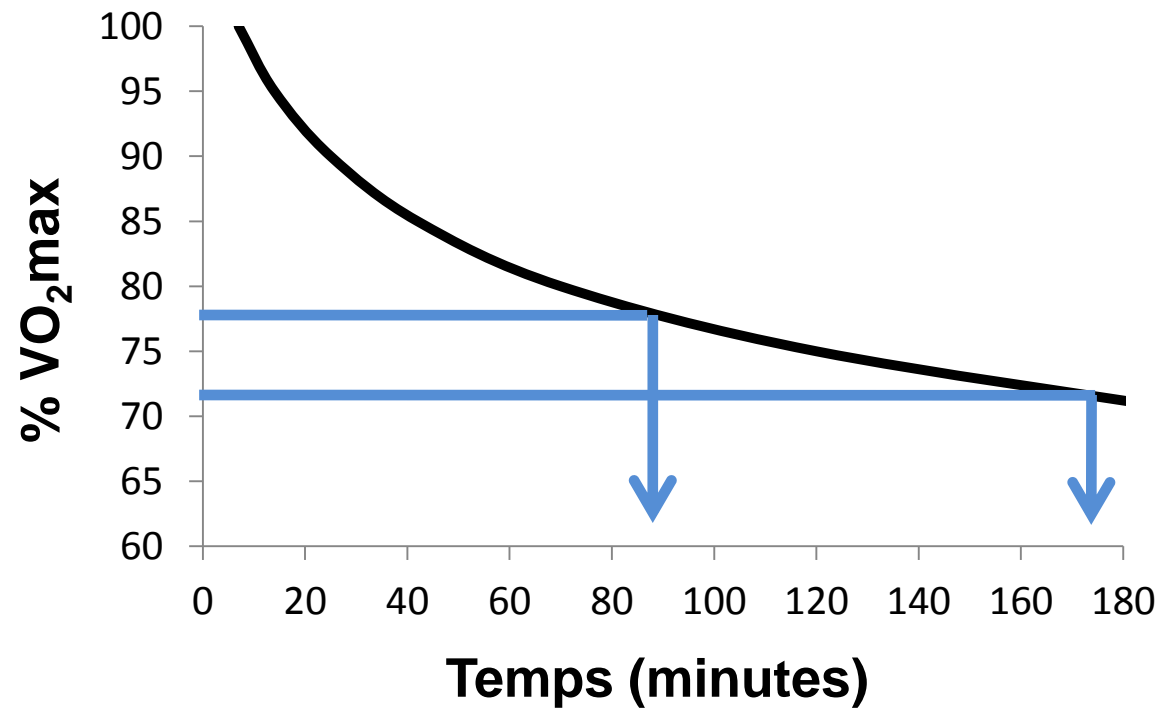
Coût Énergétique  
( $\text{ml.kg}^{-1}.\text{m}^{-1}$ )

Force musculaire

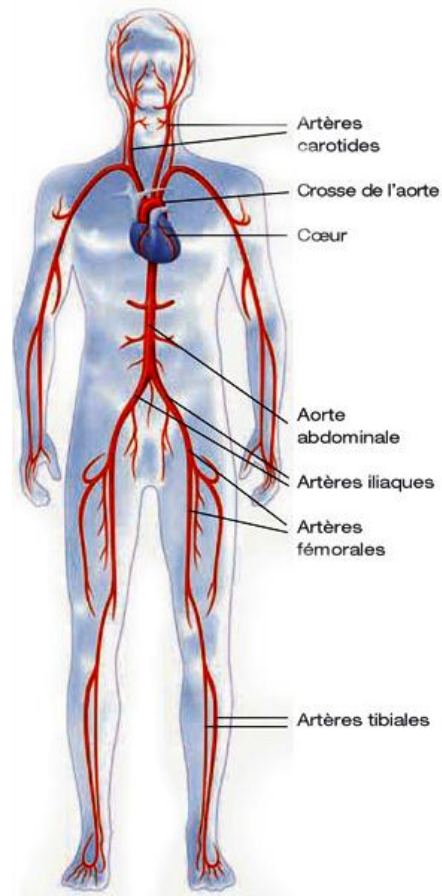
Composante élastique

# Coût énergétique

## Relation avec la performance



# Conclusion



Le **cœur** occupe une fonction centrale dans la performance humaine

Le rôle du **muscle** est souvent sous-estimé. Pourtant ses caractéristiques structurelles et fonctionnelles jouent un rôle clé dans la capacité à se mouvoir

Un élément clé est la coordination de tous les acteurs. Le chef d'orchestre est le **cerveau**.

# Avoir du cœur suffit-il pour être performant ?



## Merci de votre attention

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