EFFECT OF CLIMBING HOLD DEPTH ON BIOMECHANICAL ARM ACTION DURING PULL-UPS

Vigouroux, L., Devise, M. , Cartier, T. , Aubert, C. , Berton, E.

Institute of Movement Sciences, UMR CNRS 7287, Marseille, FRANCE

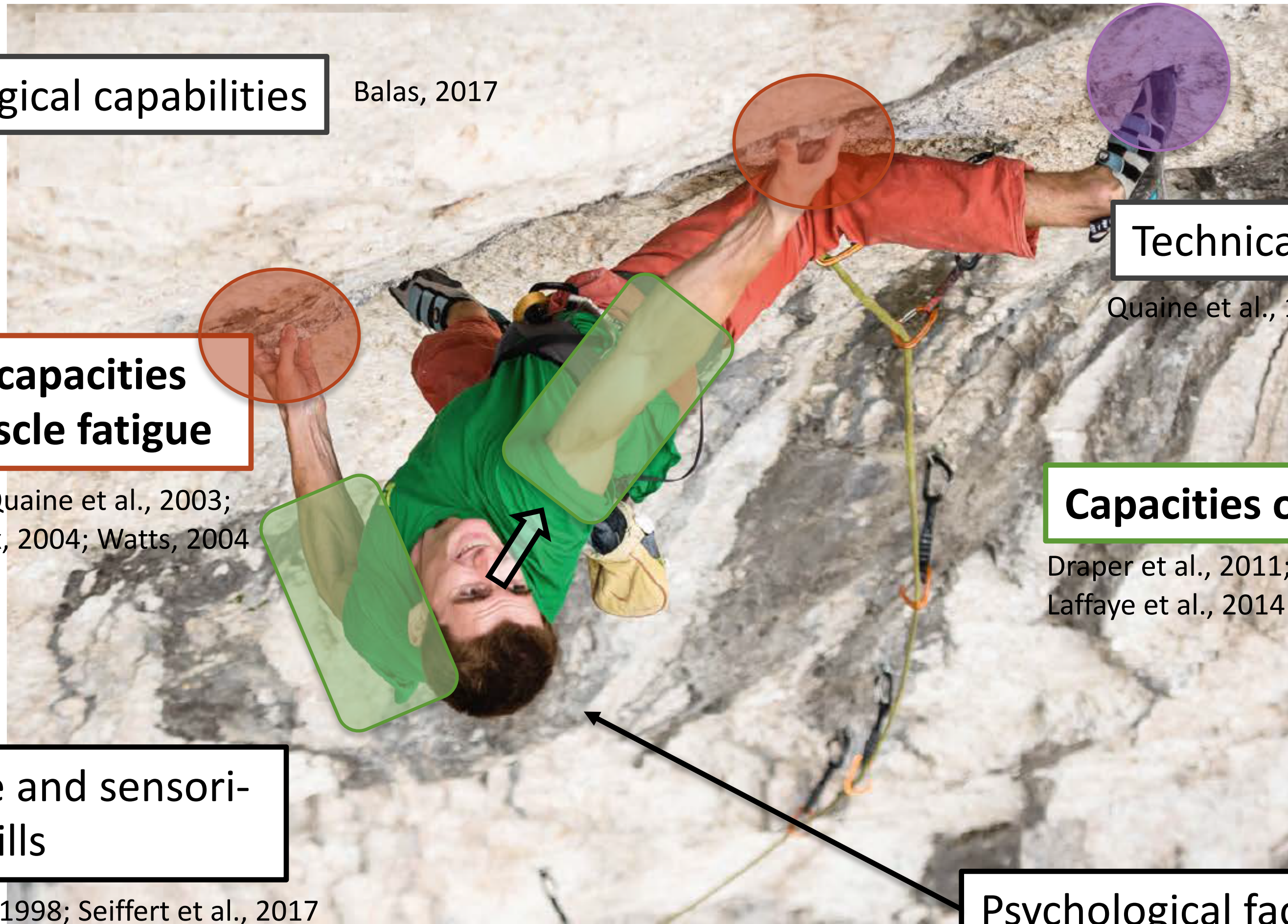
INSTITUT DES SCIENCES DU MOUVEMENT ETIENNE JULES MAREY

cnrs dépasser les frontières

Aix*Marseille université

Introduction

Rock-climbing performance: multi-factorial



Physiological capabilities

Balas, 2017

Technical skills

Quaine et al., 1996; Baláš, et al., 2014

Finger force capacities
Forearm muscle fatigue

Grant et al., 1996; Quaine et al., 2003; Quaine & Vigouroux, 2004; Watts, 2004

Capacities of the arms

Draper et al., 2011; Watts et al., 2004; Laffaye et al., 2014

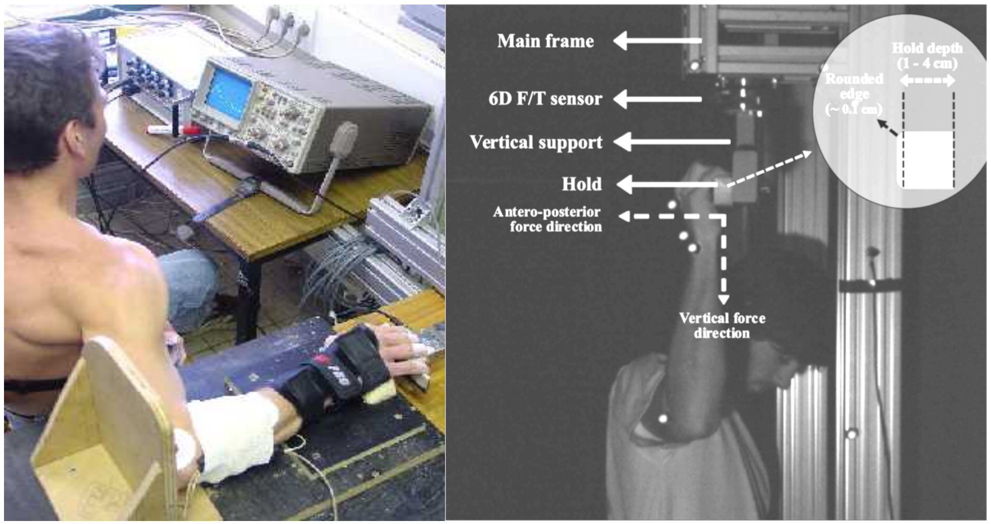
Cognitive and sensori-motor skills

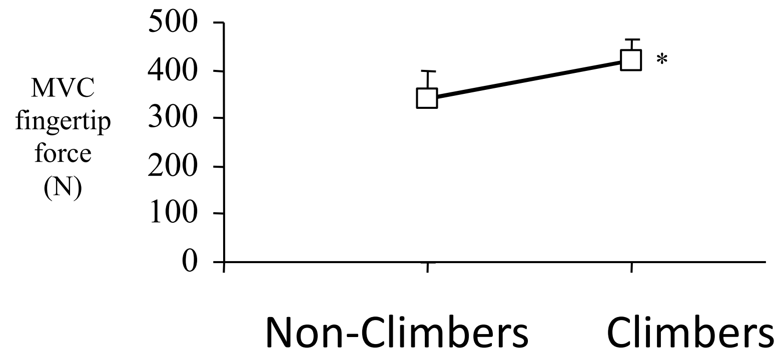
Bourdin et al., 1998; Seiffert et al., 2017

Psychological factors

Sanchez, 2017

Finger force capacities



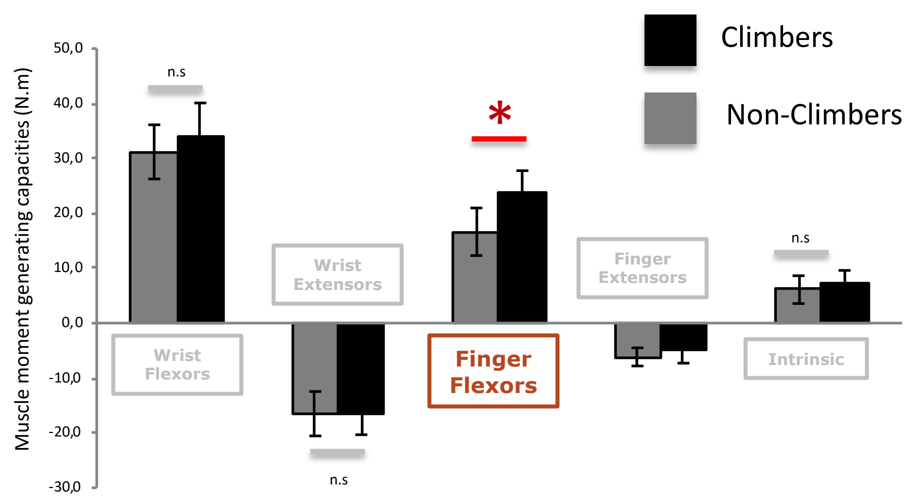


- Climbers are able to generate more force at the fingertips than non-climbers

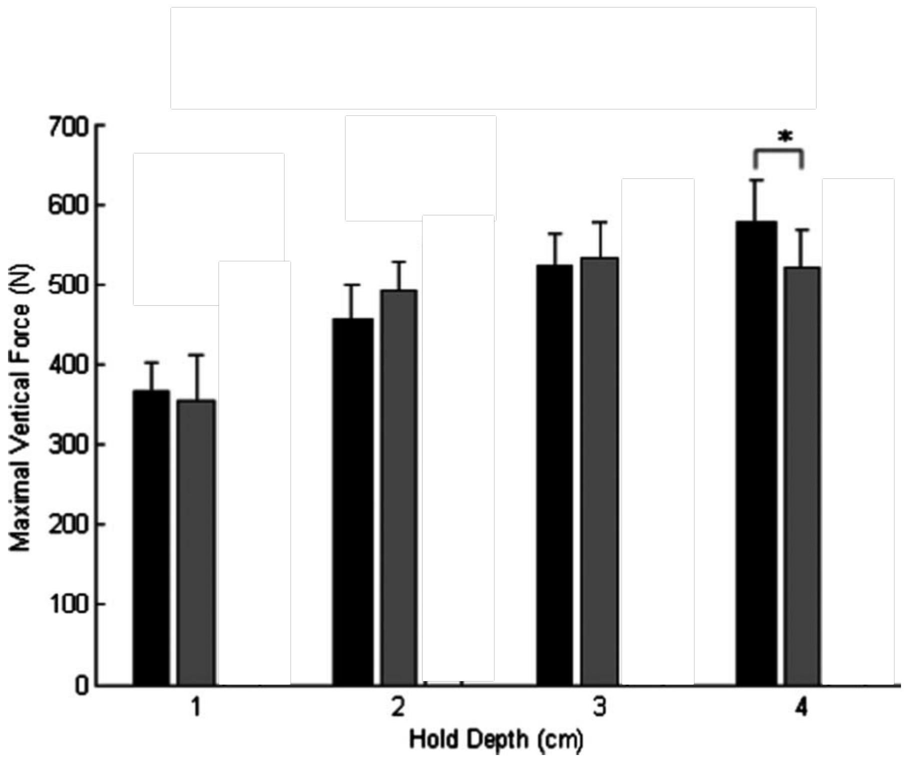
Cutts & Bollen, 1993;Quaine et al., 2003;Vigouroux et al., 2006

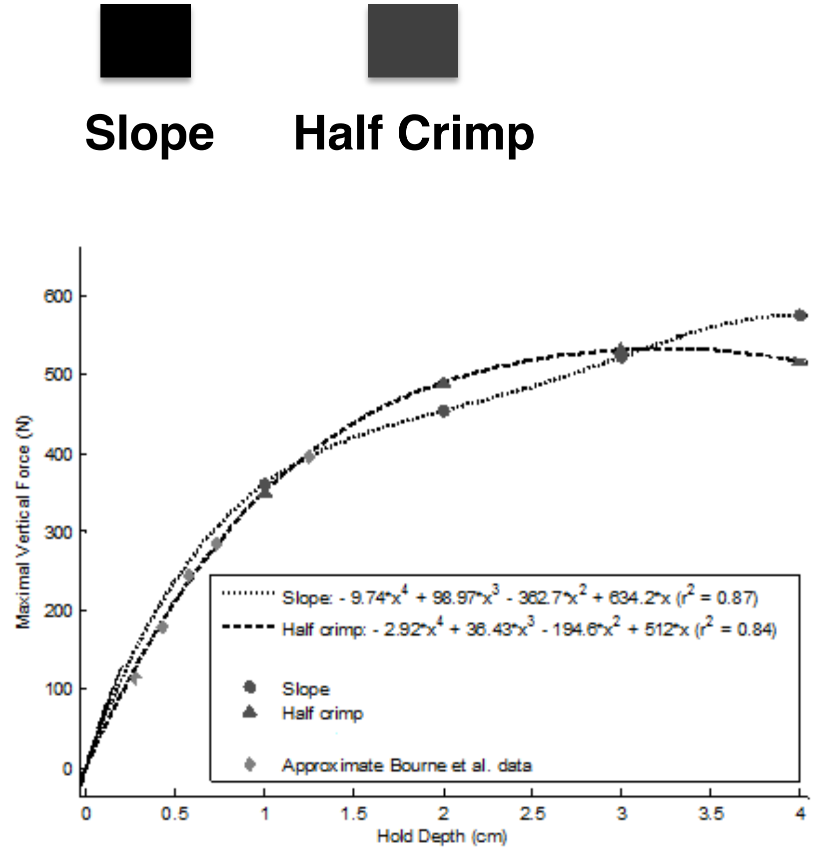
- These higher fingertip force capacities are the result of the improvement of the only finger flexors muscles

Vigouroux et al., 2015



Influence of hold depth





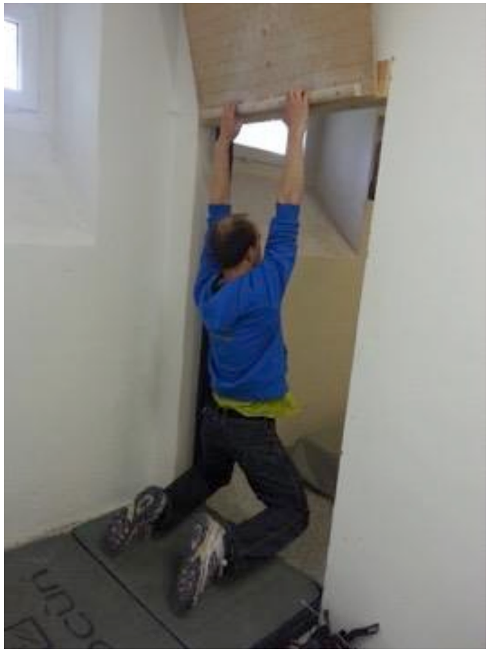
Amca et al., 2012

- The climbing hold depth strongly influences the finger force capacities
- Amca et al. (2012) modelled this relationship using polynomial regression

The capacities of the arms

IRCRA manuel test

Pull-ups



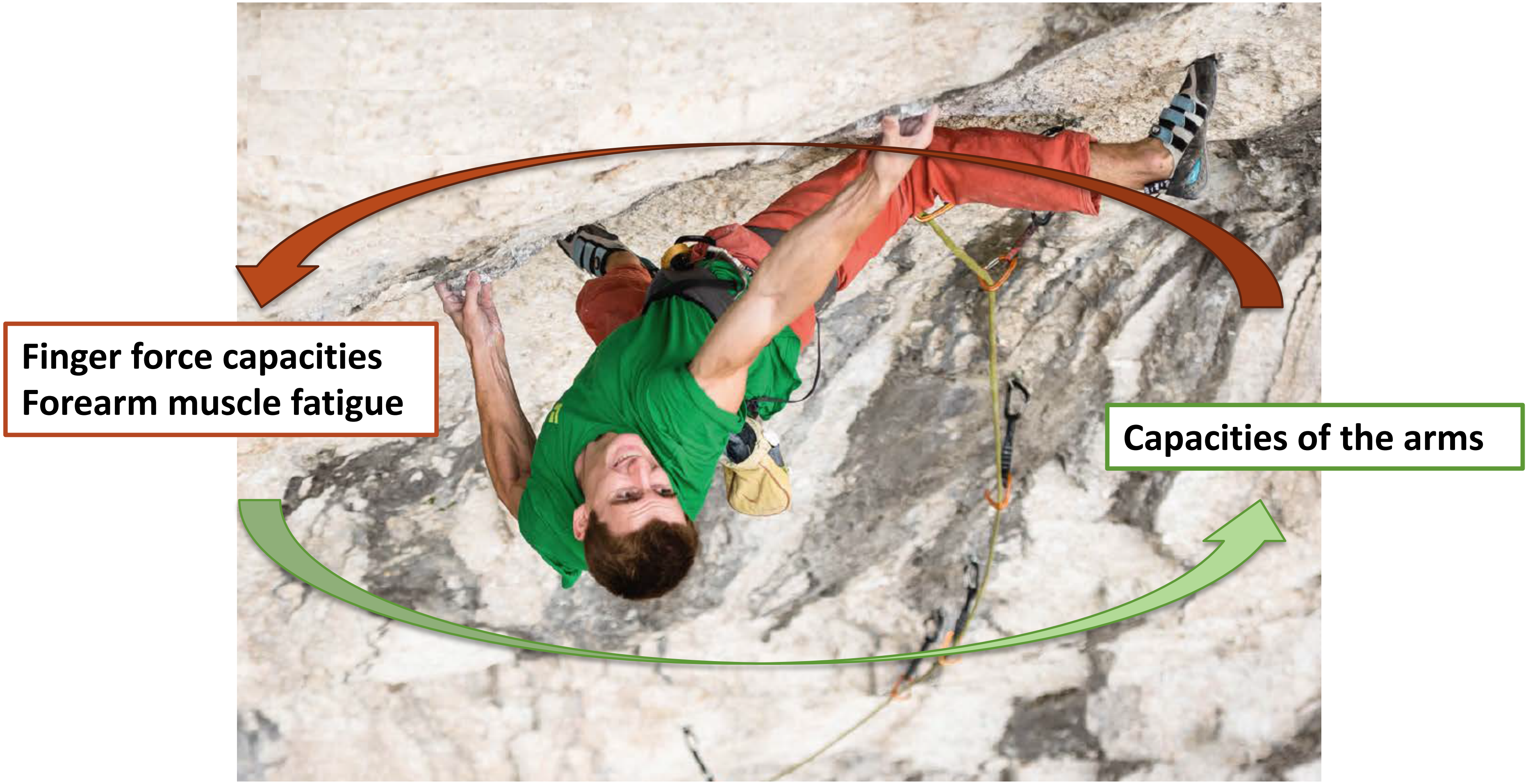
IRCRA manuel test

Power slab test

- Climbers performed more pull-ups than non-climbers
- Climbers developed more power (1350W) than novices (around 40W)

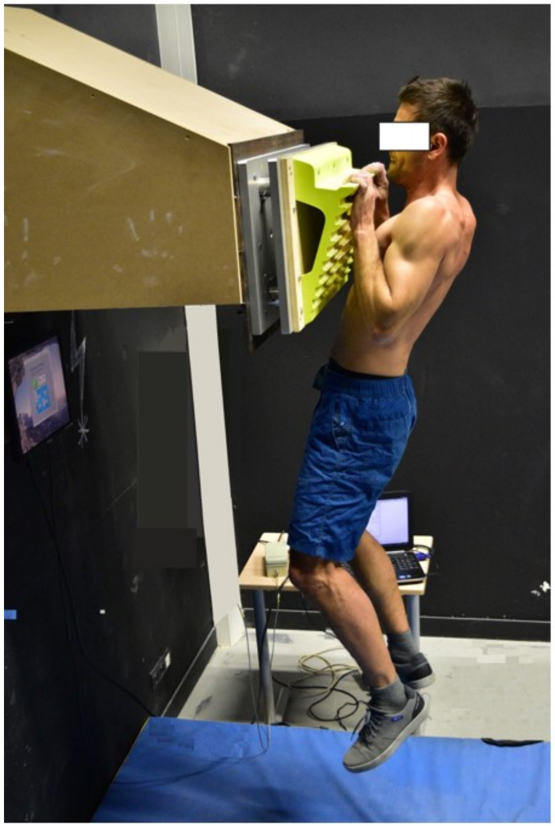
Draper et al., 2011; Watts et al., 2004; Laffaye et al., 2014

The interaction between the grip and the arm movements are still not investigated



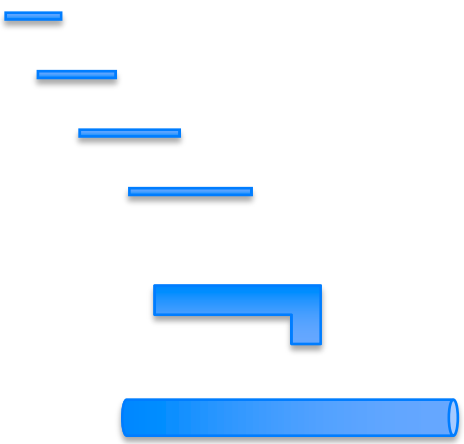
The objective of this study was to investigate this interaction by studying a standardized movement: pull-ups

Material and Methods



(*Hangboard: transgression-Eva Lopez, Spain*)

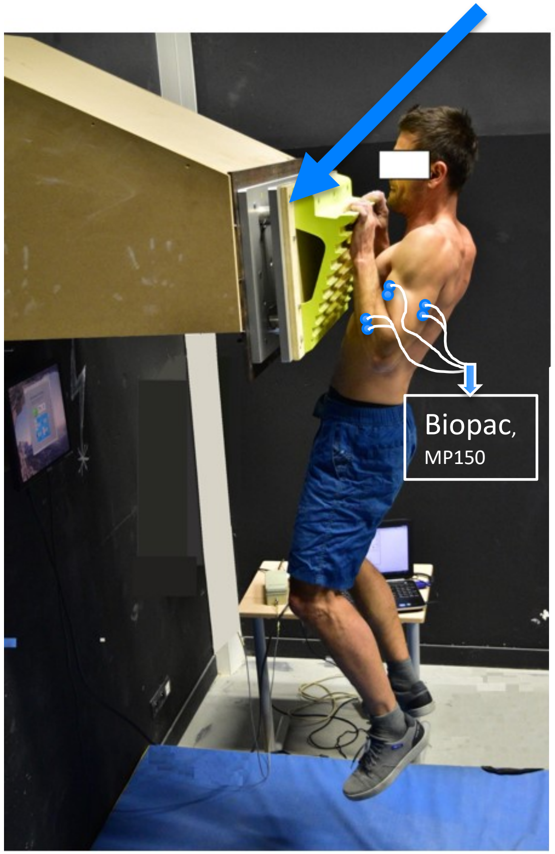
- 10 elite and higher-elite male climbers (from 7c to 8b+)
  21.4±2.6 years 65.95±5.9kg 175.6±4.5cm
- perform a maximum number of pull-ups, "as fast as possible" and "as strongly as possible" until exhaustion.
- Six series: 10mm hold
  14mm hold
  18mm hold
  22mm hold
  Large hold
  Gym bar

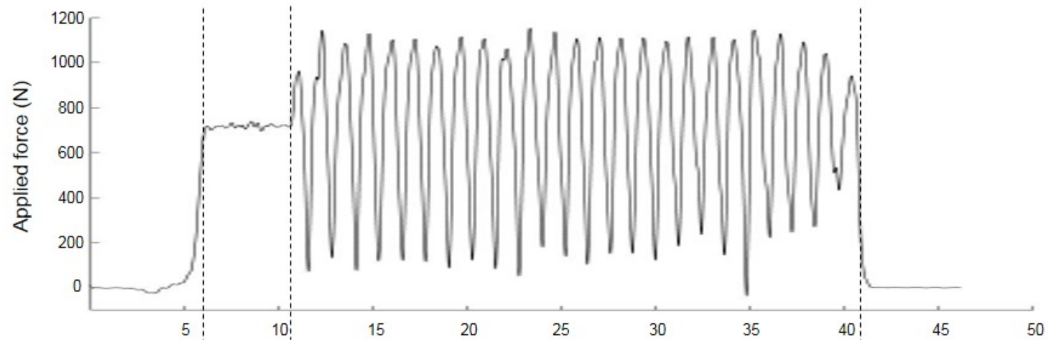


- Randomised, 15 minutes rest, experiment on two days

Material and Methods

Force sensors (Smart Board, Aix-Marseille University), 2000Hz





EMG (2000Hz) of 4 muscles :

Biceps brachii (BB), T*riceps brachii* (TB)

Flexor digitorum superficialis and profundus (FF), *Extensor digitorum communis* (FE)

Data analysis

Force data:
low-pass filtered (Butterworth, fourth-order, cut-off frequency: 3Hz)

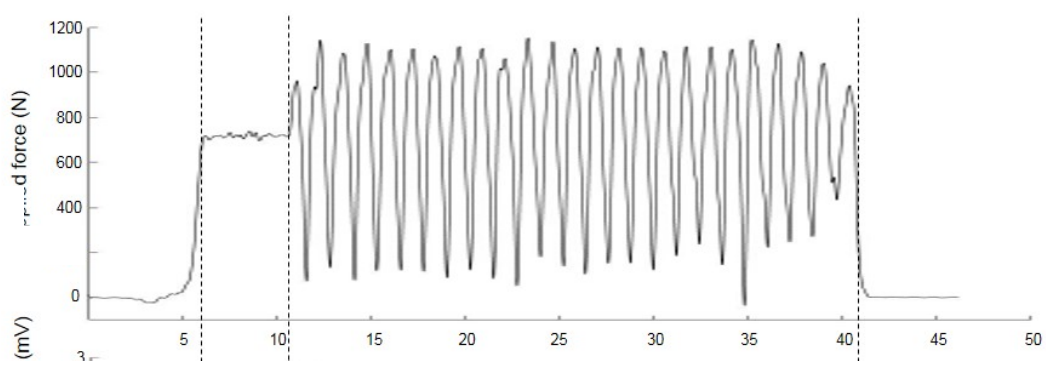
- **Maximal Force (N)**: $\max\left(F(t)\right)$

- **Maximal Power (W)**:

$$\max P(t) = \max\left(F(t).\left(\frac{\Delta t.\,(a(t+\Delta t)+a(t))}{2}\right)\right)$$

- **Summed mechanical work (J)**:

$$\sum W(t) = \sum \frac{\Delta t.\left(P(t+\Delta t)+P(t)\right)}{2}$$

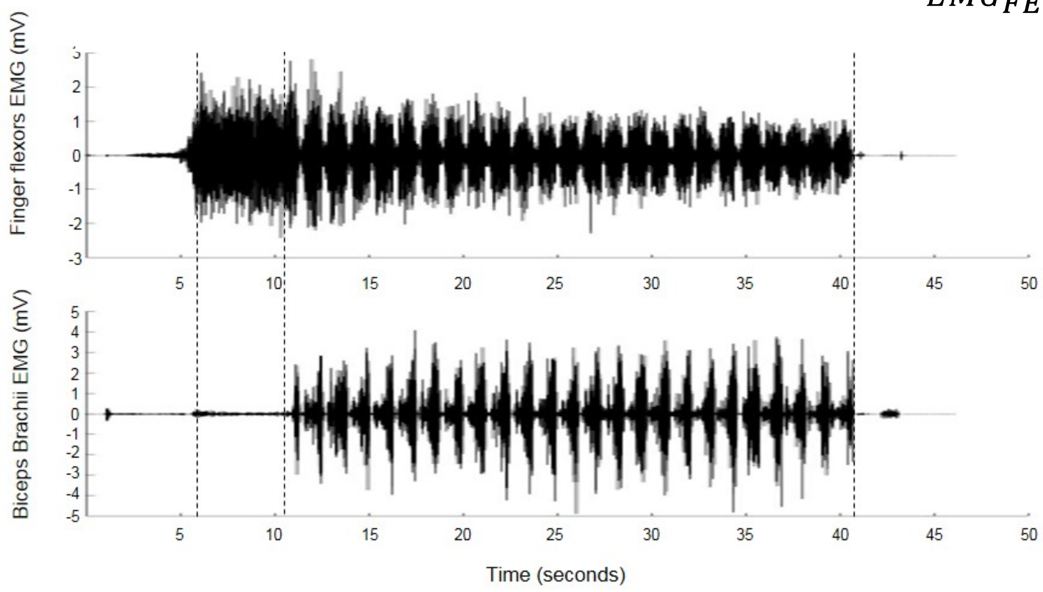


Data analysis

EMG data:
band-pass filtered (Butterworth, fourth-order, cut-off frequency: 20-450Hz)

- **Mean activation of BB muscle** (index of elbow flexors involvement)
- **Evolution of the Mean Power frequency of Finger Flexors** (index of forearm muscle fatigue)
- **Cocontraction index of finger muscles** (index of finger muscle coordination)

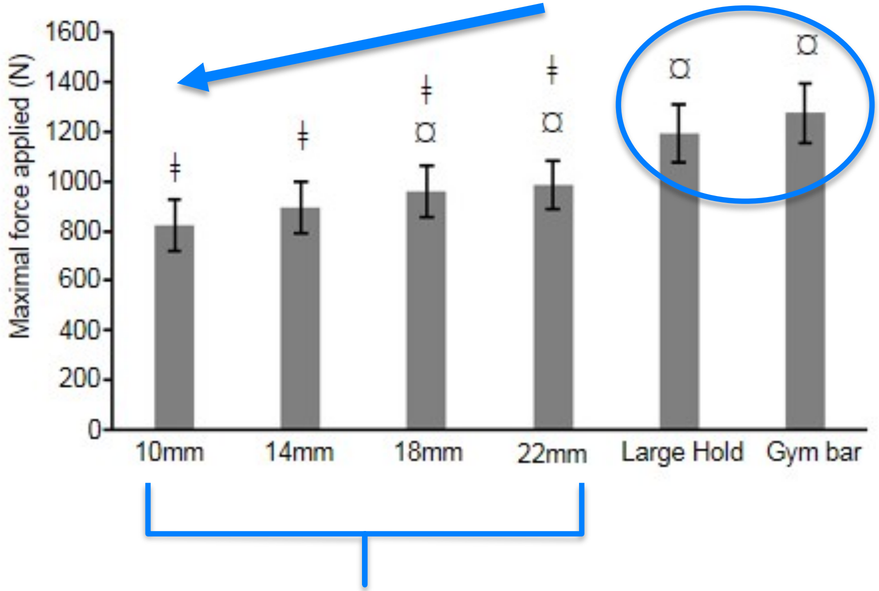
$$cocontraction\ index = \frac{2.EMG_{FE}}{EMG_{FE}+EMG_{FF}}$$

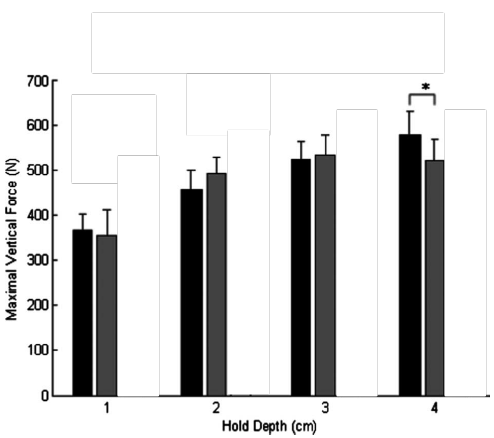


Results

Maximal applied force during pull-ups (N) ($F(5,45)=62.8$; $p<0.001$)

- No difference between Large Hold and Gym bar
- Decrease of maximal force for the small climbing holds





Maximal applied force during pull-ups:

92±8% of the maximal fingertip force capacities

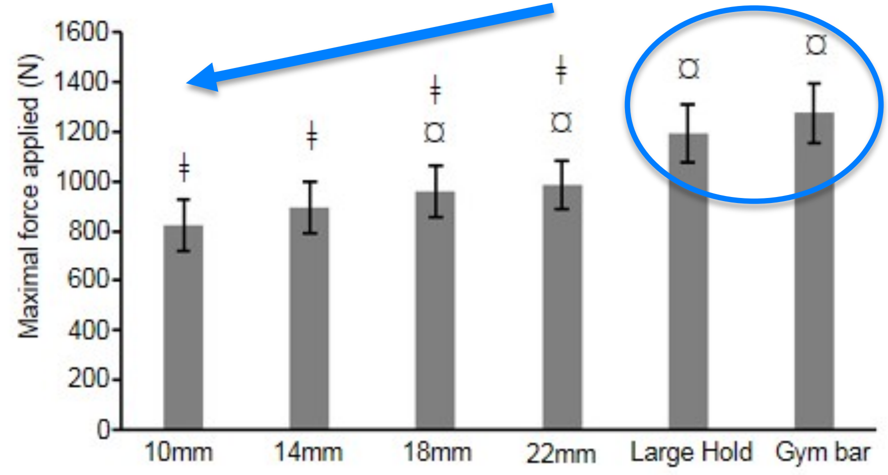
→ decreased finger force capacities

In accordance with Amca et al. (2012)

Results

Maximal applied force during pull-ups (N) (F(5,45)=62.8; p<0.001)

- No difference between Large Hold and Gym bar
- Decrease of maximal force for the small climbing holds



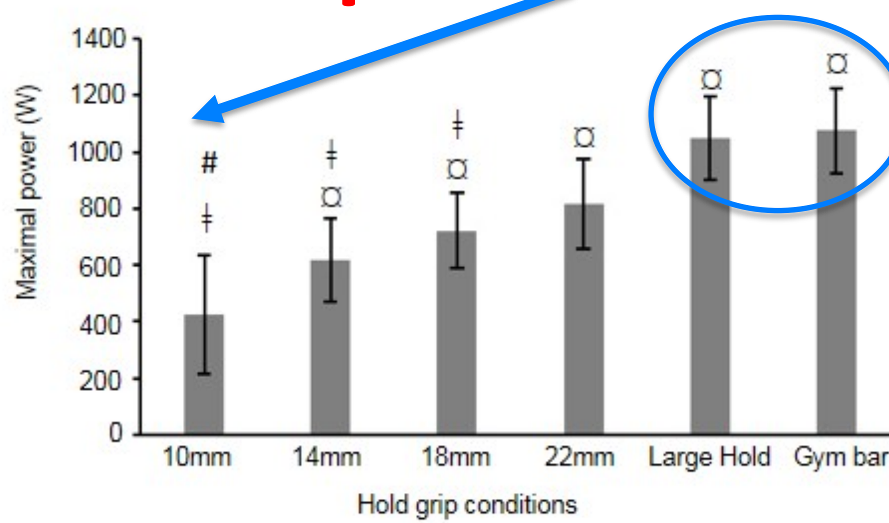
Maximal Power (W)

(F(5,45)=53.9; p<0.001)

- No difference between Large Hold and Gym bar
- Large decrease of Maximal power for the small climbing holds

→ **decreased finger force capacities**

→ **decreased velocity**

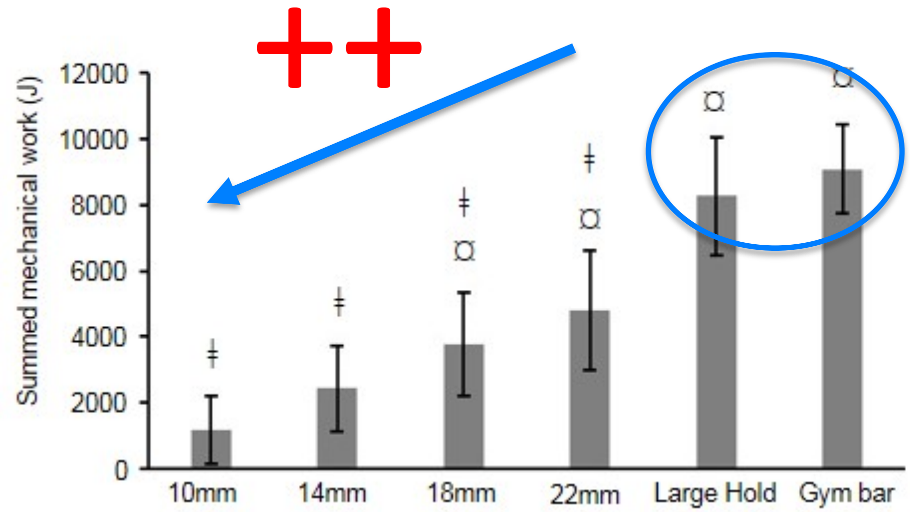


Results

Summed mechanical work (J)

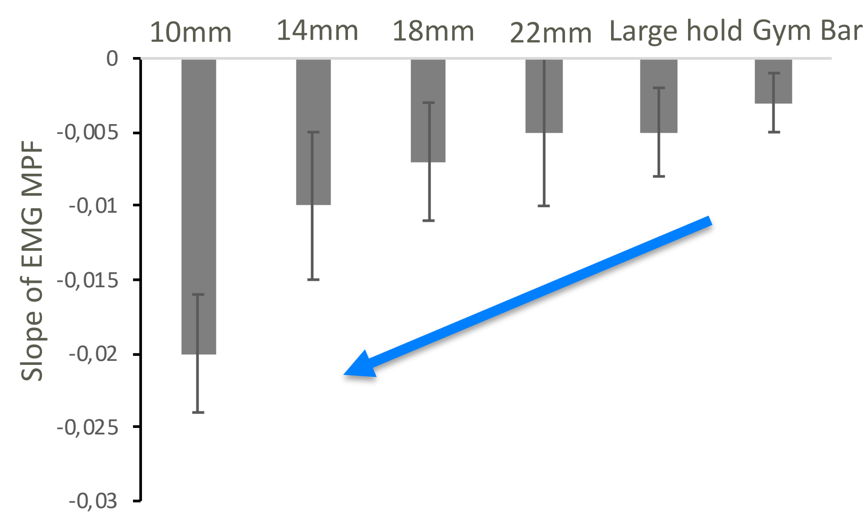
F(5,45)=111.0; p<0.001

- No difference between Large Hold and Gym bar
- Strong decrease of mechanical work for the small climbing holds



MPF of Finger Flexors EMG

(F(5,45)=9.8; p<0.00001)



→ **decreased finger force capacities**

→ **decreased velocity**

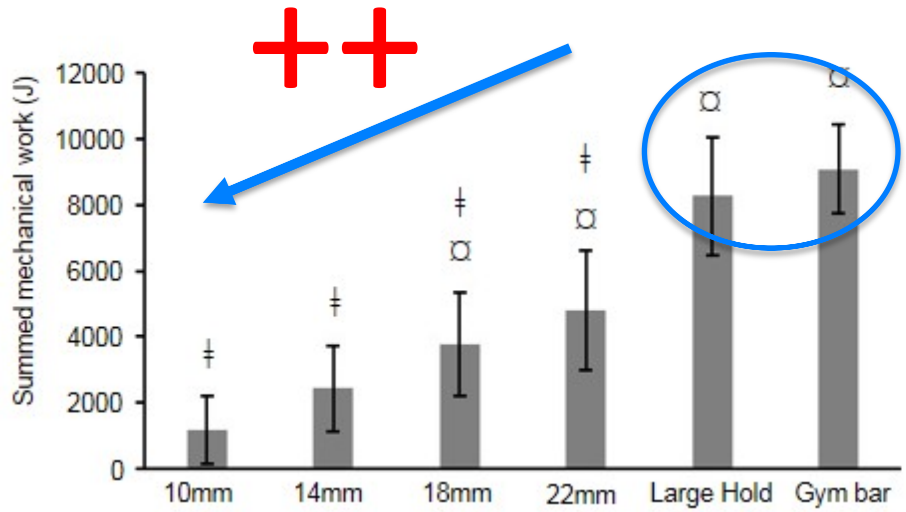
→ **finger muscle fatigue**

Results

Summed mechanical work (J)

F(5,45)=111.0; p<0.001

- No difference between Large Hold and Gym bar
- Strong decrease of mechanical work for the small climbing holds



Activation of Biceps brachii

F(5,45)=4.67; p<0.002

10mm hold: 70%±14%
22mm hold: 87%±12%
Gym bar: 95%±11%

→decreased involvement of elbow flexors

EMG cocontration index of finger muscles (F(5,45)=9.8; p<0.00001)

Large Hold: 0.64±0.13

Gym bar: 0.52±0.11

→ increased wrist stiffness to control body swing with the hold

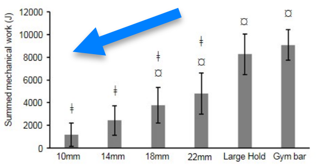
Discussion and Conclusions

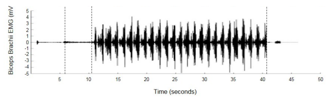
From arms point of view :

Small holds → decreased maximal Power

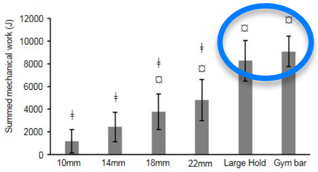
→ decreased expended mechanical energy

→ decreased involvement of elbow flexors





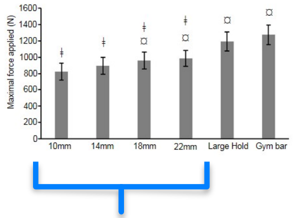
Large hold vs gym bar → similar mechanical arm action



From finger muscles point of view :

Small holds → generate high finger force intensities

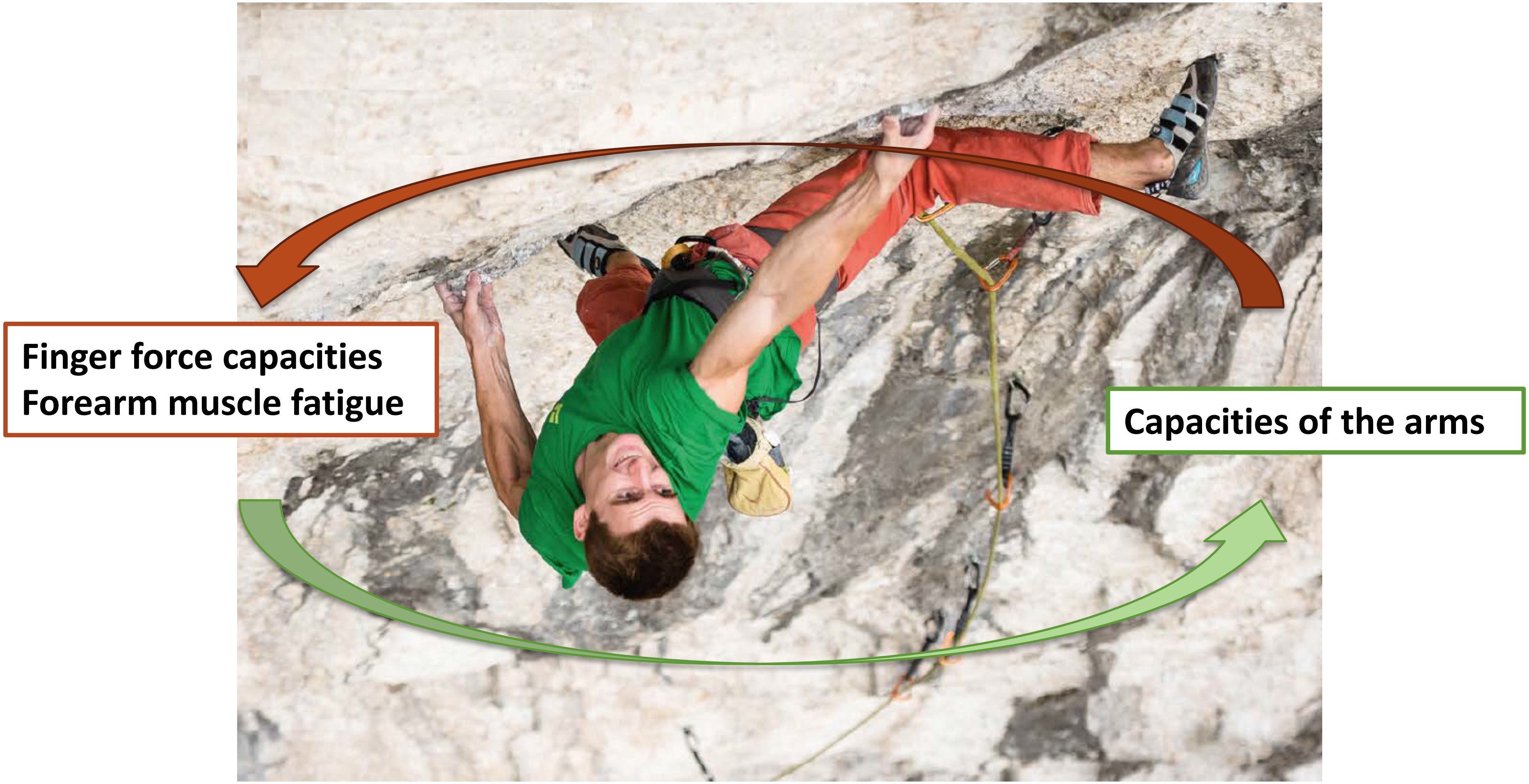
→ generate muscle fatigue



92±8%

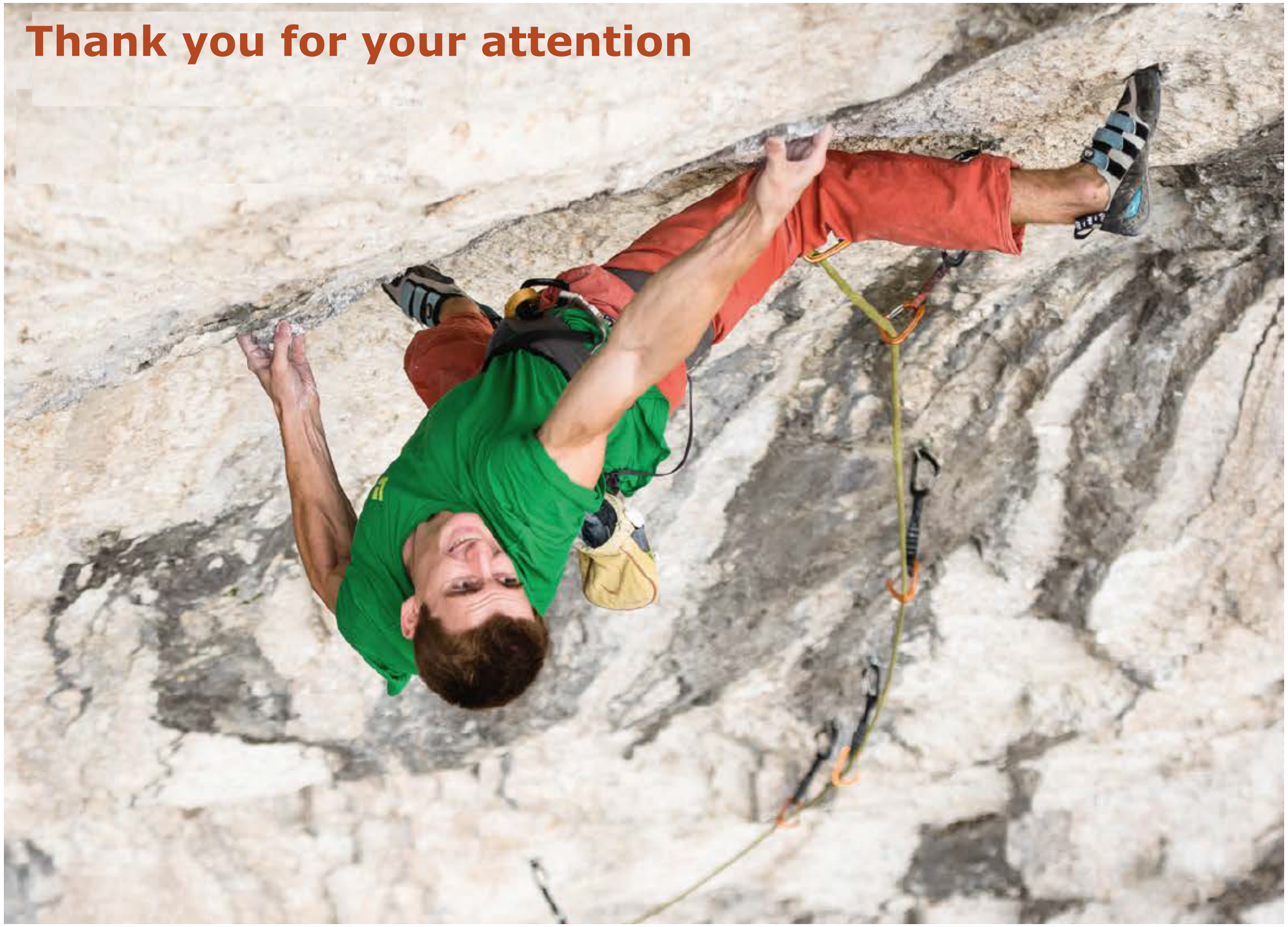
Large hold vs gym bar → generate different finger muscle coordination to control wrist stiffness/body swing

There is a strong interaction between the grip and the arms

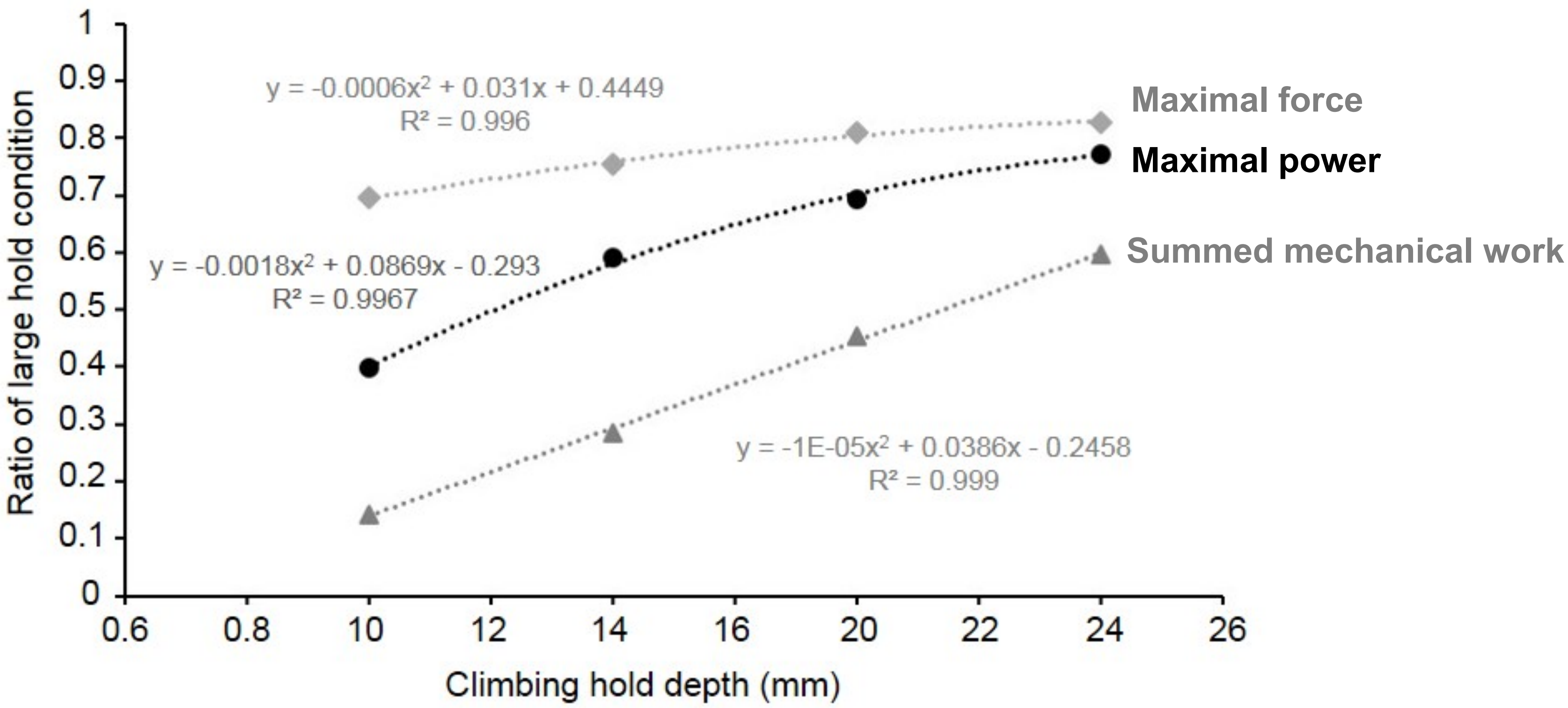


- **Applications for designing pull-up trainings**
- **Should be now conducted during climbing movements**

Thank you for your attention



Polynomial regression models



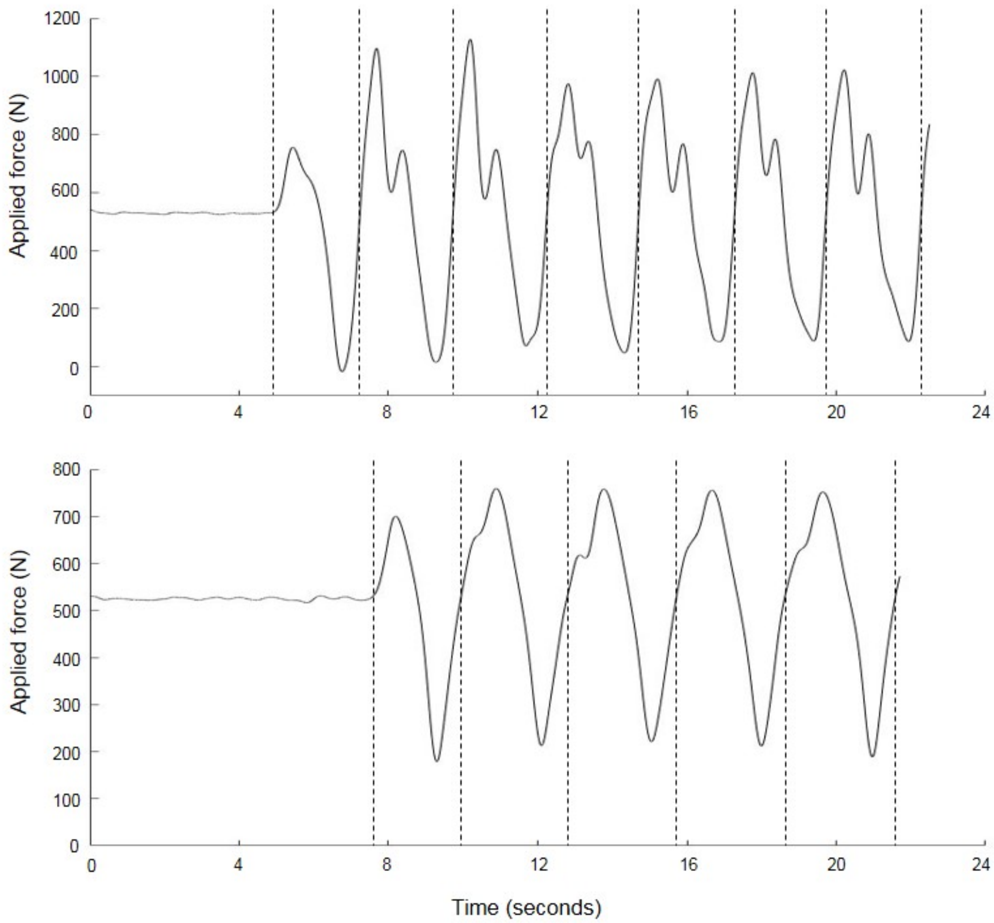

1200
1000
800
600
400
200
0
Applied force (N)
0
4
8
12
16
20
24
800
700
600
500
400
300
200
100
0
Applied force (N)
0
4
8
12
16
20
24
Time (seconds)

Table 1: Mean (±SD) of the number of pull-ups, maximal power to body-mass ratio, maximal force applied to maximal voluntary force ratio, the slope of the finger flexor EMG mean power frequency, and the cocontraction index between finger flexors and extensors.

¤ different (<0.05) from the 10mm hold condition
ǂ different (<0.05) from the gym-bar condition
different from all the other conditions
*** significant effect of grip conditions <0.0001
* significant effect of grip conditions <0.05

Grip conditions	Number of pull-ups (***)	Maximal power / BM (***)	Maximal force / MVF (*)	Slope of the FF EMG mean power frequency (***)	Cocontraction index (***)
10mm	6.6±3.6 ǂ	6.5±3.0 ǂ	0.93±0.09	-0.02±0.02	0.43±0.16
14mm	11.4±4.2 ǂ	9.3±1.8 ǂ¤	0.94±0.05	-0.01 ± 7.10^{-3}	0.45±0.17
18mm	15.6±4.5 ǂ ¤	10.9±1.5 ǂ¤	0.94±0.08	$-5.10^{-3}\pm4.10^{-3}$ ¤	0.46±0.18 #
22mm	18.4±6.2 ǂ ¤	12.3±1.7 ǂ¤	0.88±0.09*	$-7.10^{-3}\pm5.10^{-3}$ ¤	0.52±0.11
Large-hold	27.7±7.7 ¤	16.0±1.9 ¤	/	$-5.10^{-3}\pm3.10^{-3}$ ¤	0.64±0.13
Gym-bar	29.4±5.5 ¤	16.3±2.3 ¤	/	$-3.10^{-3}\pm2.10^{-3}$ ¤	0.44±0.15