Psychobiology of Physical Activity Behaviour:

Theory and Innovative Strategies to Increase Exercise Adherence

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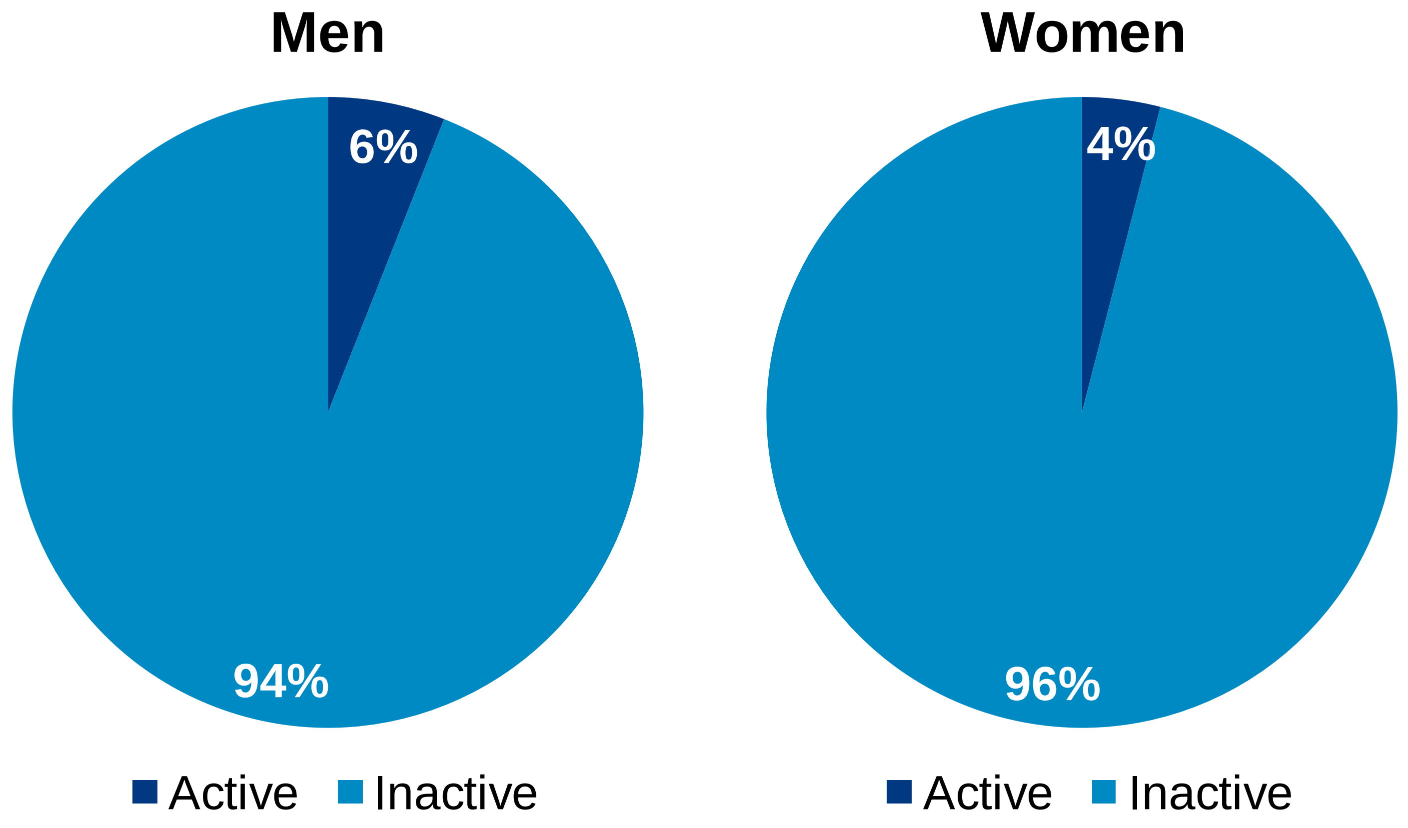
The Problem

Professor Lieberman (2015): “Many lines of evidence indicate that **humans evolved to be adapted for regular, moderate amounts of endurance physical activity** into late age. However, because energy from food was limited, humans also were selected to avoid unnecessary exertion.”

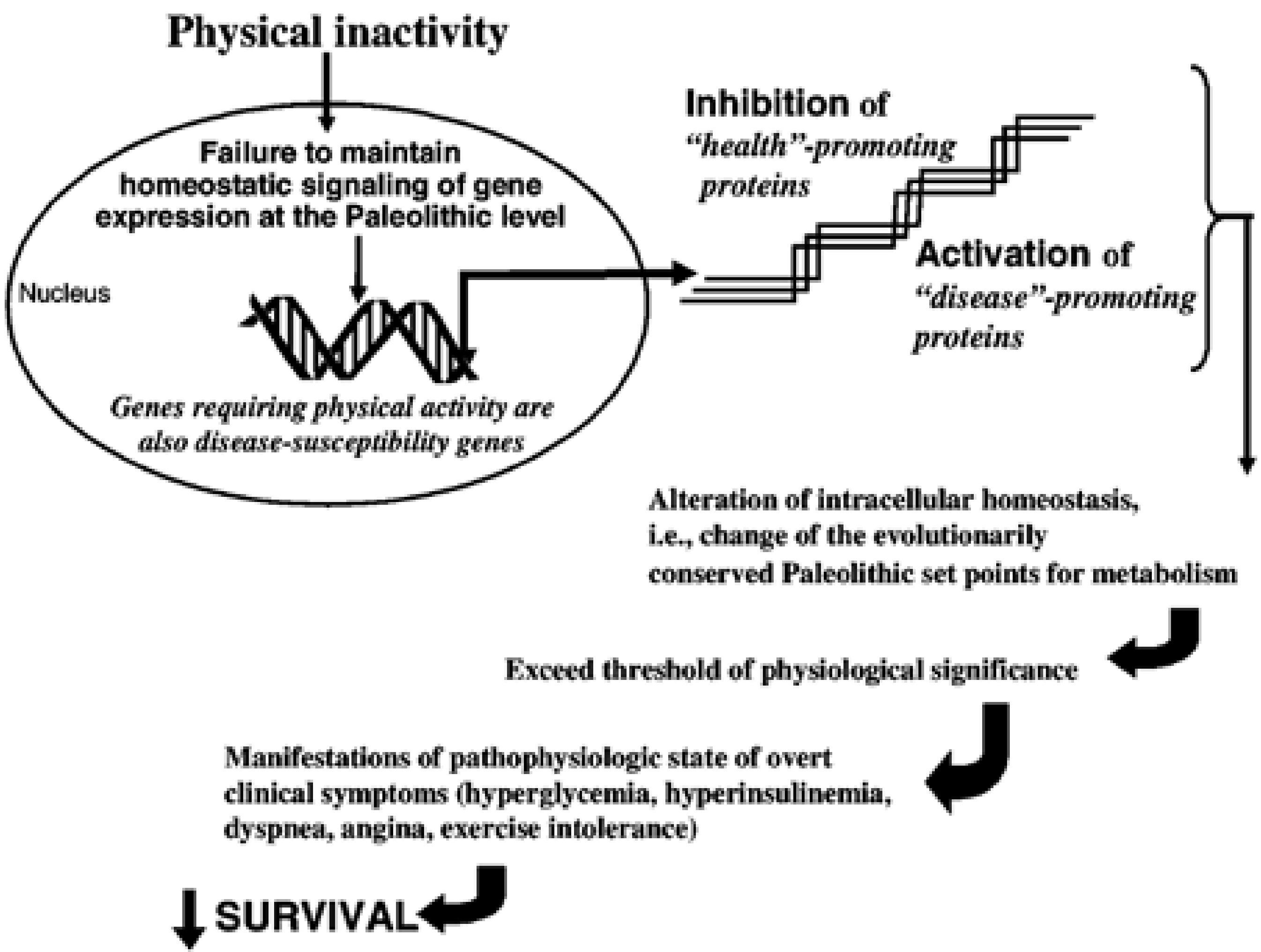
Adults performing ≥150 min/week of moderate intensity aerobic activity



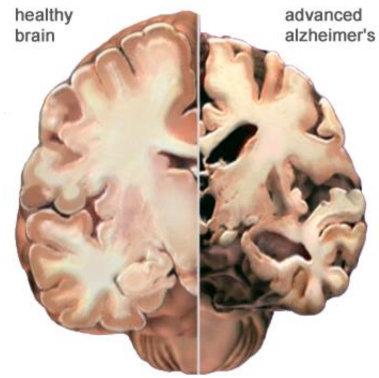
Based on accelerometry data from the 2008 Health Survey of England

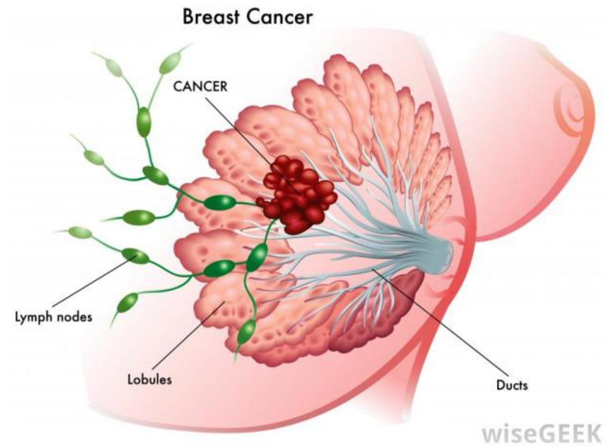
Exercise and gene expression: physiological regulation of the human genome through physical activity

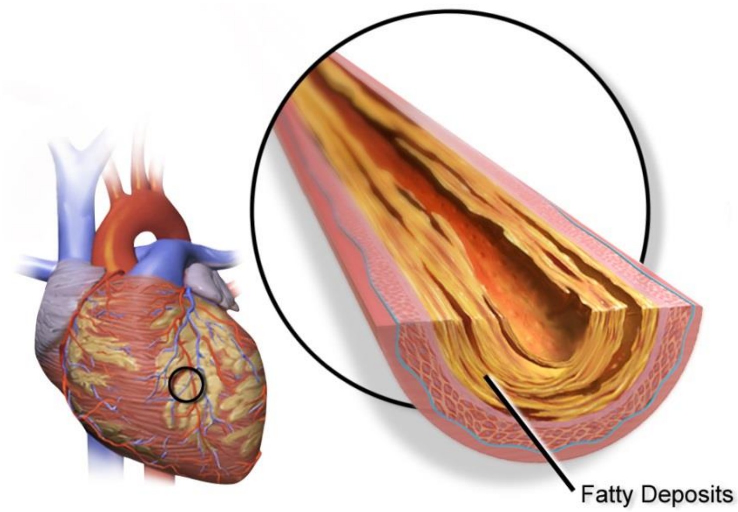
Frank W. Booth *, Manu V. Chakravarthy † and Espen E. Spangenburg *Journal of Physiology* (2002), **543.2**, *pp.* 399–411



Health Consequences of Physical Inactivity







Correlates of physical activity: why are some people physically active and others not?

Lancet 2012; 380: 258–71

*Adrian E Bauman, Rodrigo S Reis, James F Sallis, Jonathan C Wells, Ruth J F Loos, Brian W Martin, for the Lancet Physical Activity Series Working Group**

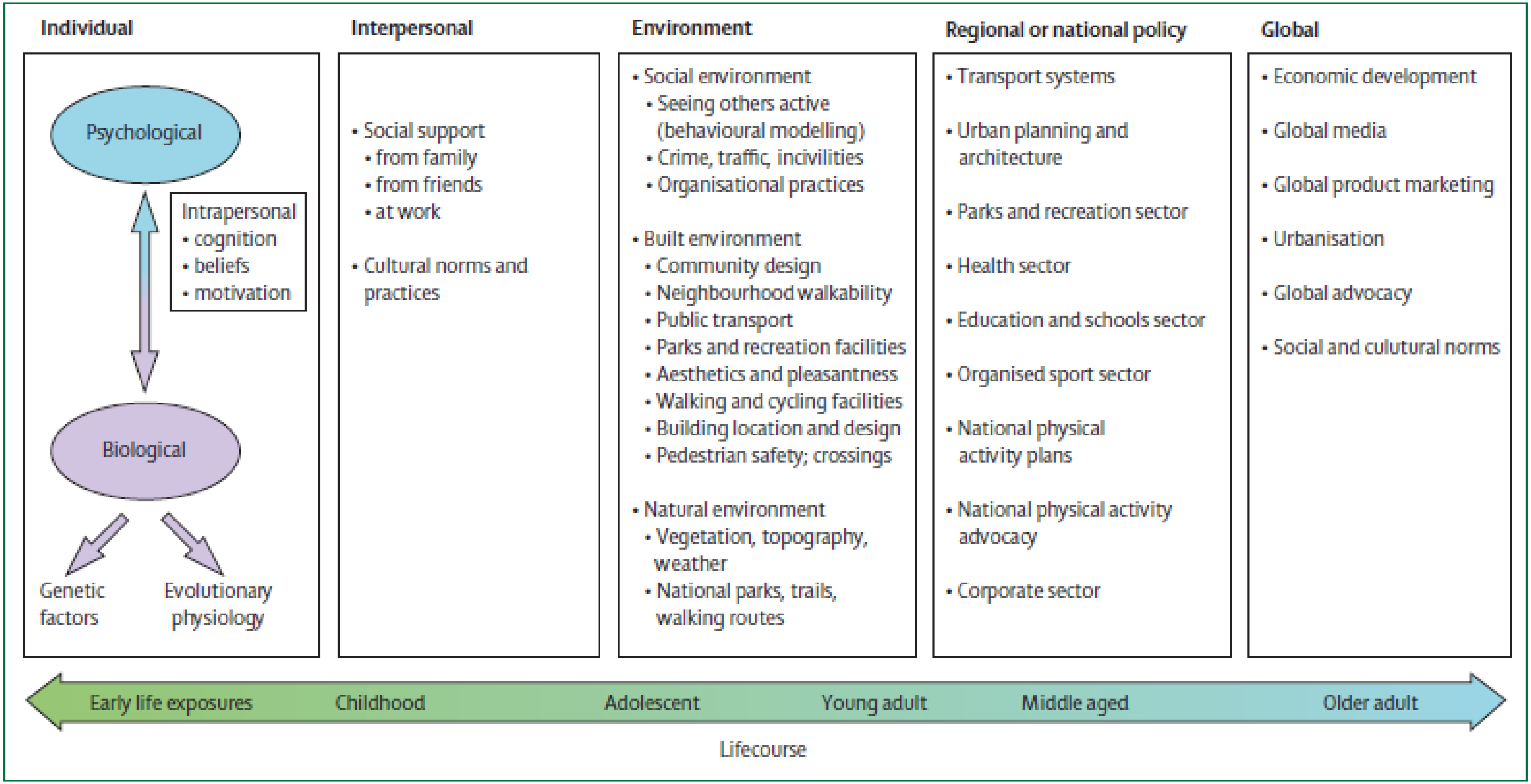


Figure 1: Adapted ecological model of the determinants of physical activity

Evolutionary Theory and the Ultimate–Proximate Distinction in the Human Behavioral Sciences

Perspectives on Psychological Science
6(1) 38–47

DOI: 10.1177/1745691610393528
http://pps.sagepub.com
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"To properly understand behaviour, we must obtain both ultimate and proximate explanations. Put briefly, **ultimate explanations** are concerned with why a behaviour exists, and **proximate explanations** are concerned with how it works."

Ultimate Explanations:

Why are humans lazy?

Because it is good to be fat

Body Fat = 3.6%

Body Fat = 22.0%

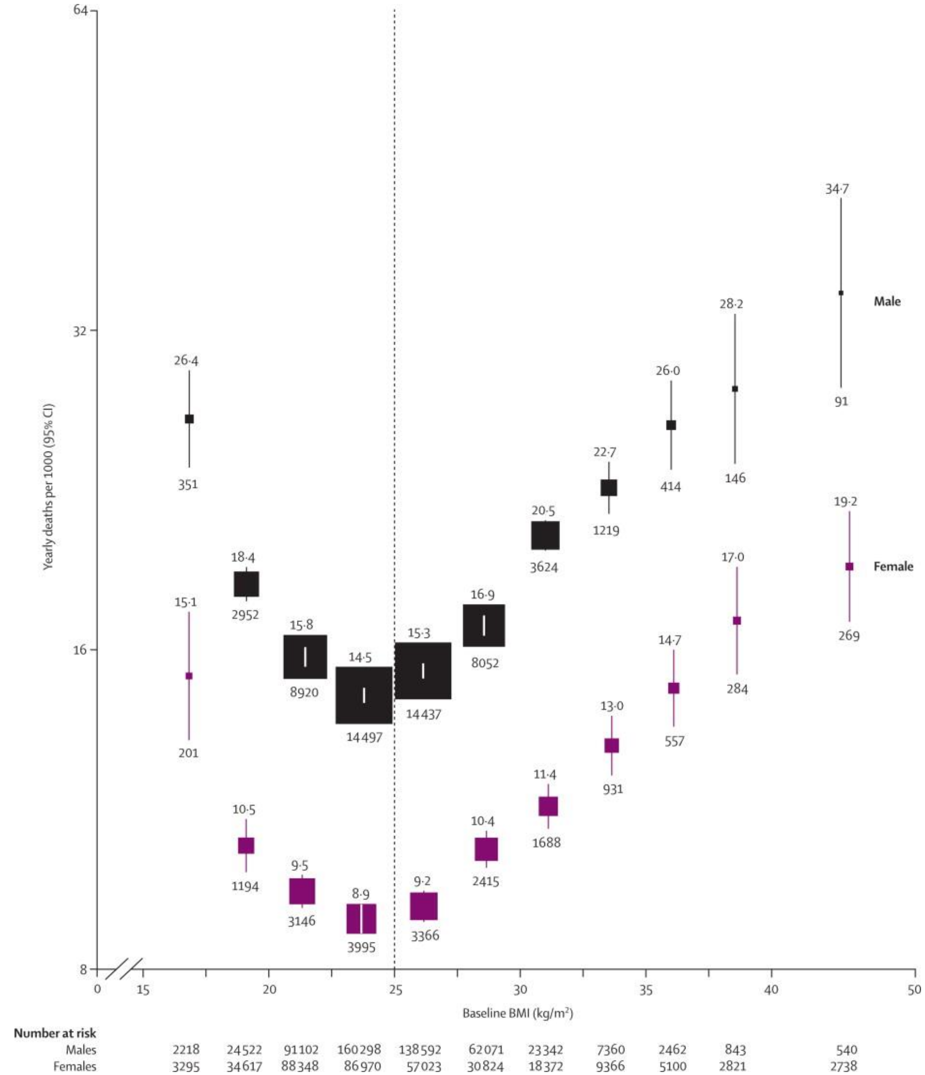
Bonobo Female

Fit Human Female

(Gallagher et al., 2000; Zihlman and Bolter, 2015)

Fitness Functions of Body Fat

- Buffering starvation
- Buffering stochasticity
- Adaptation to the cold
- Growth
- Buffering the brain
- Reproduction
- Immune function
- Psychosocial stress
- Sexual selection



(Prospective Studies Collaboration, 2009; West, 2012)

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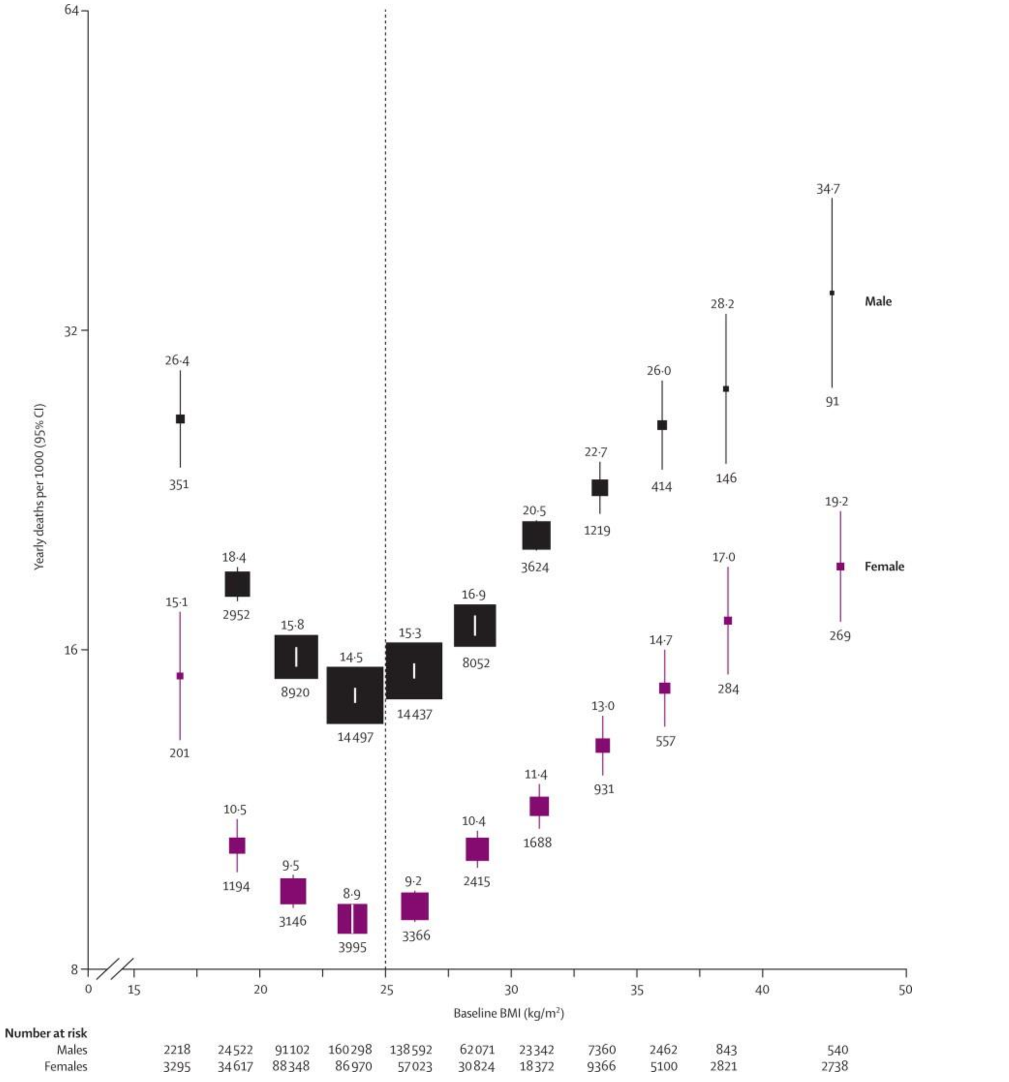

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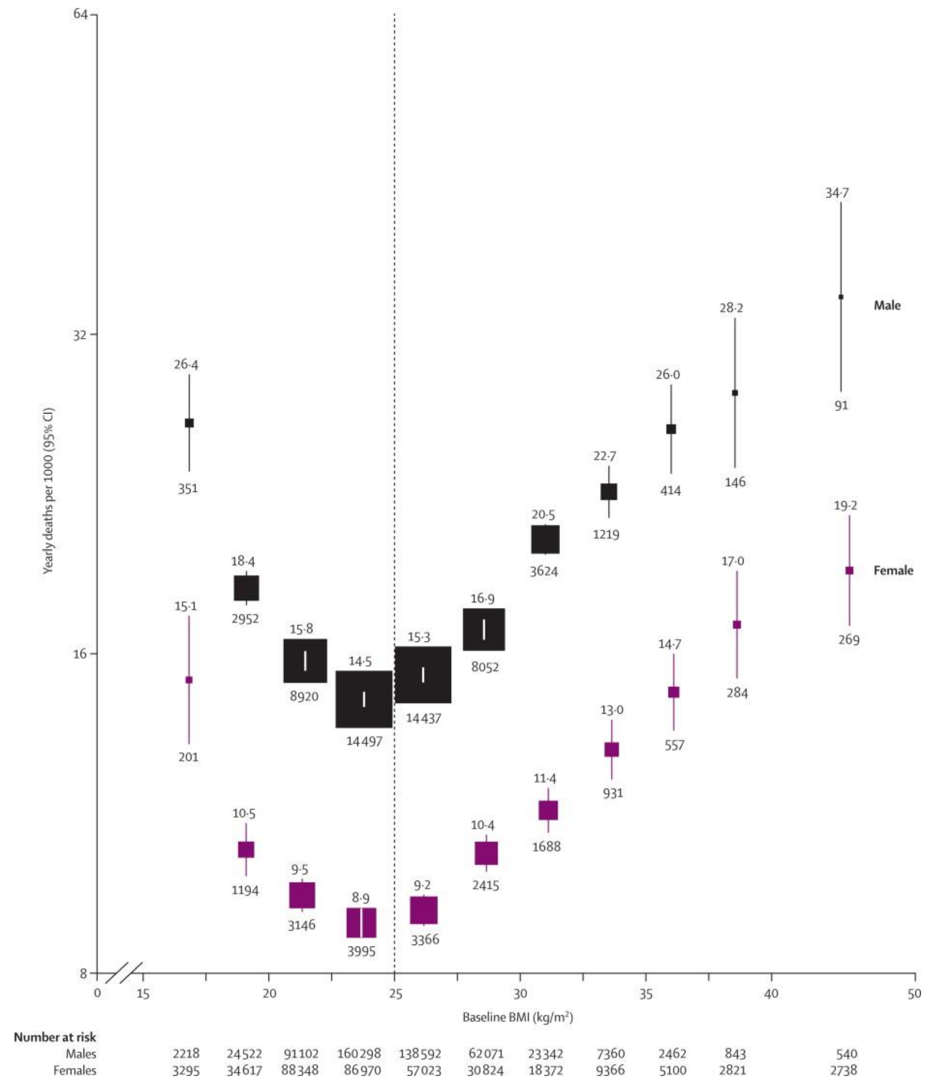

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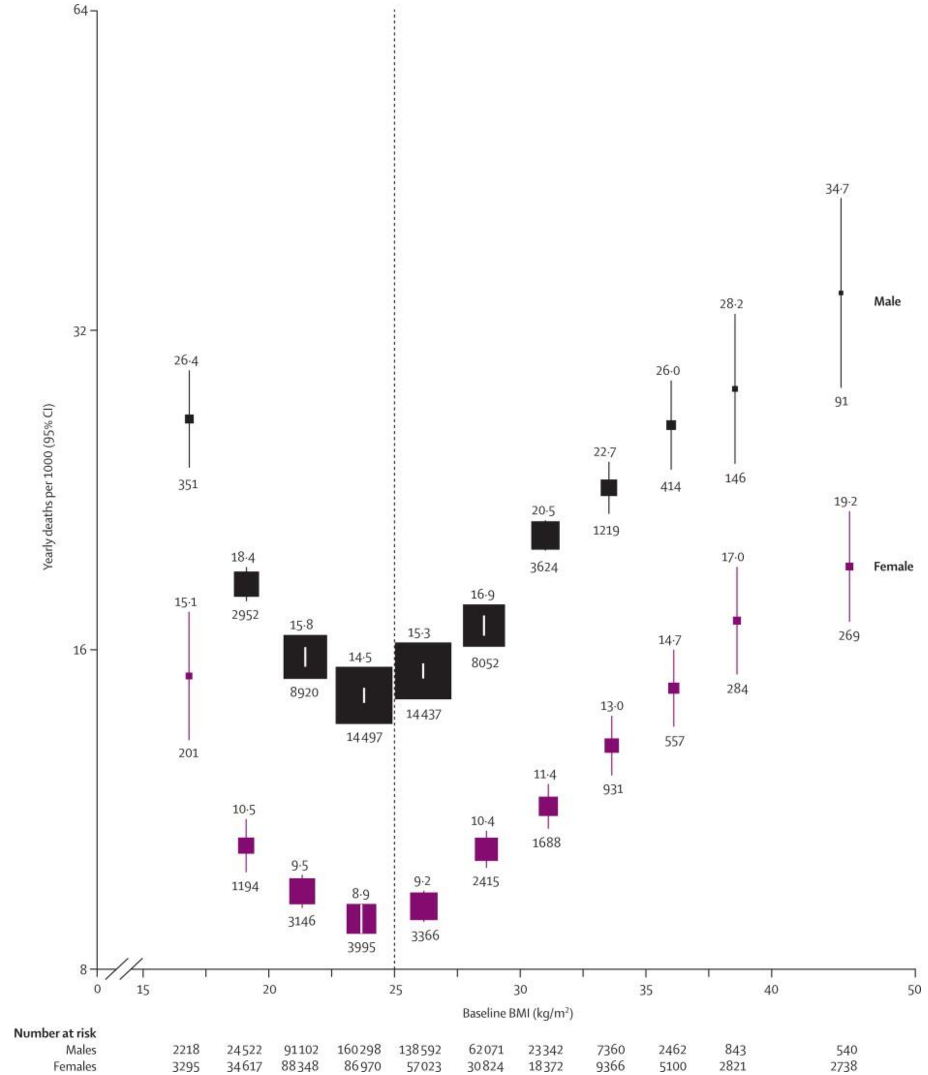

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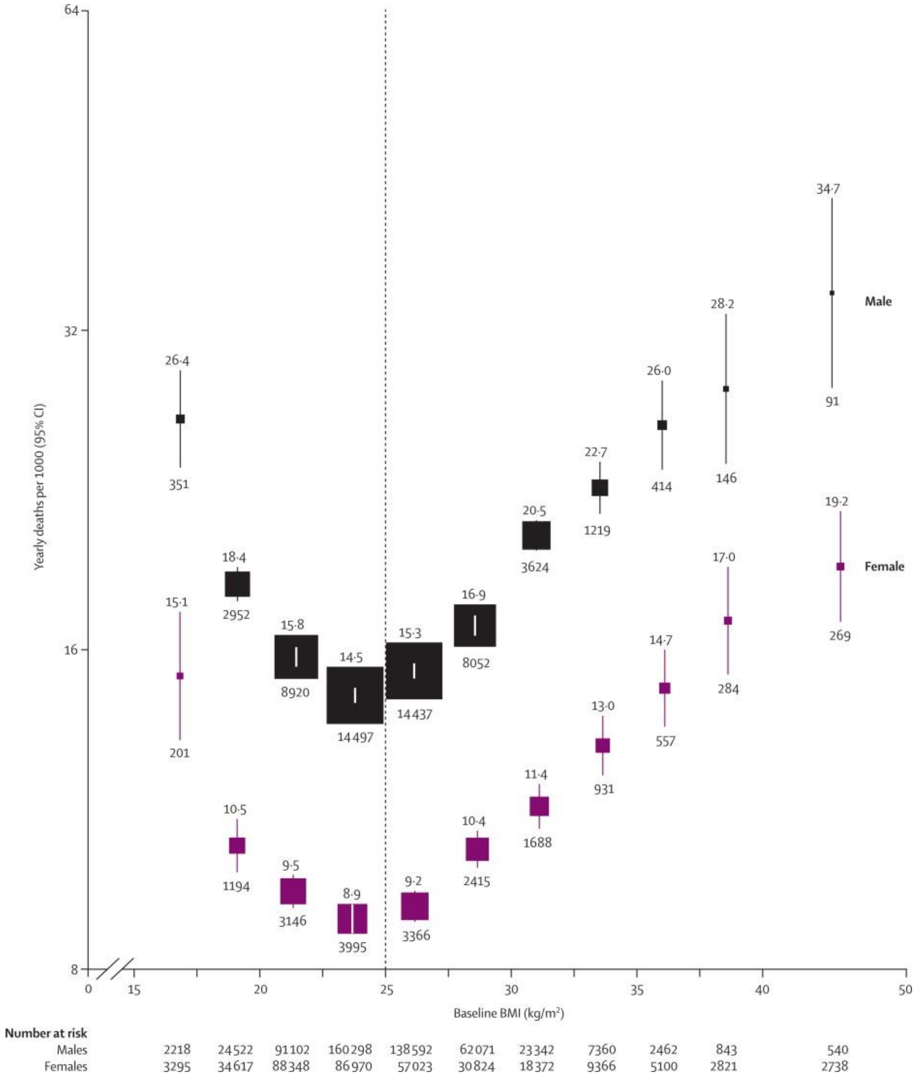
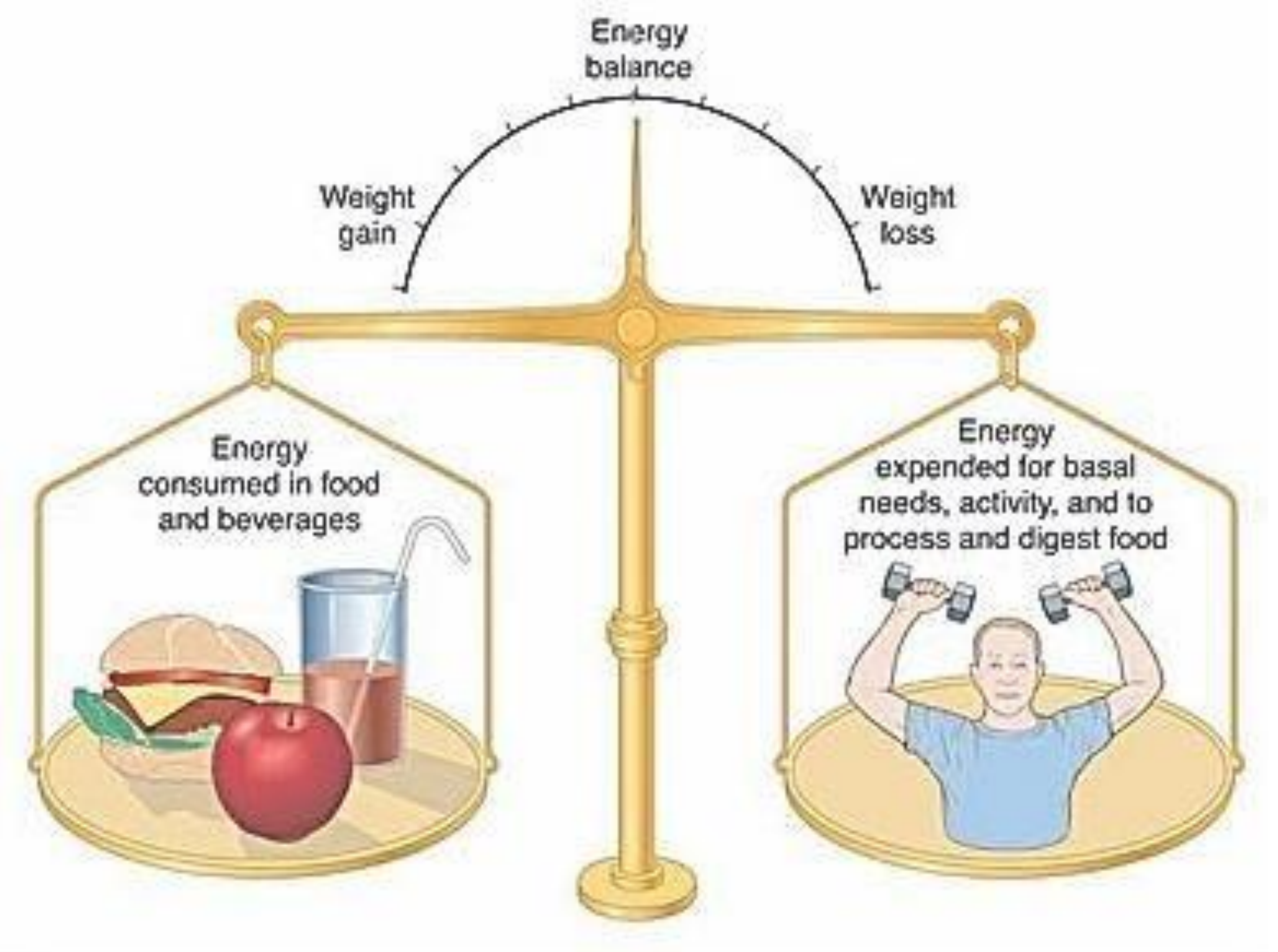
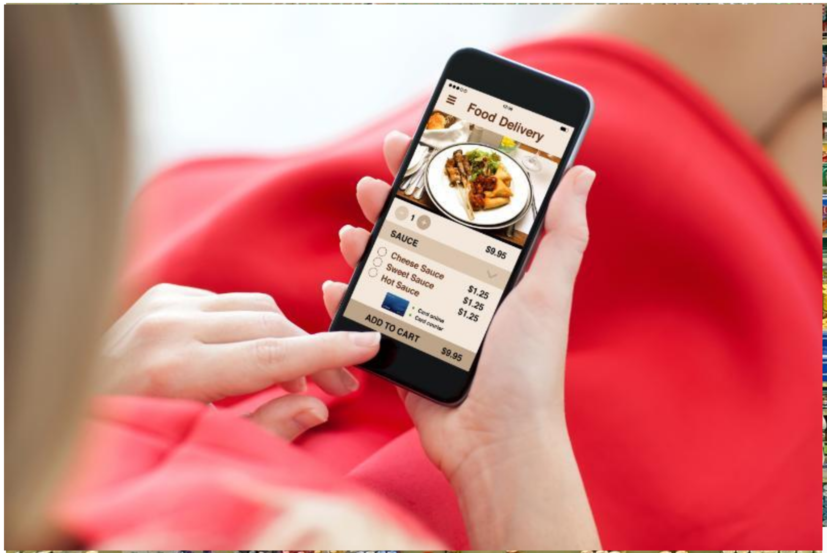


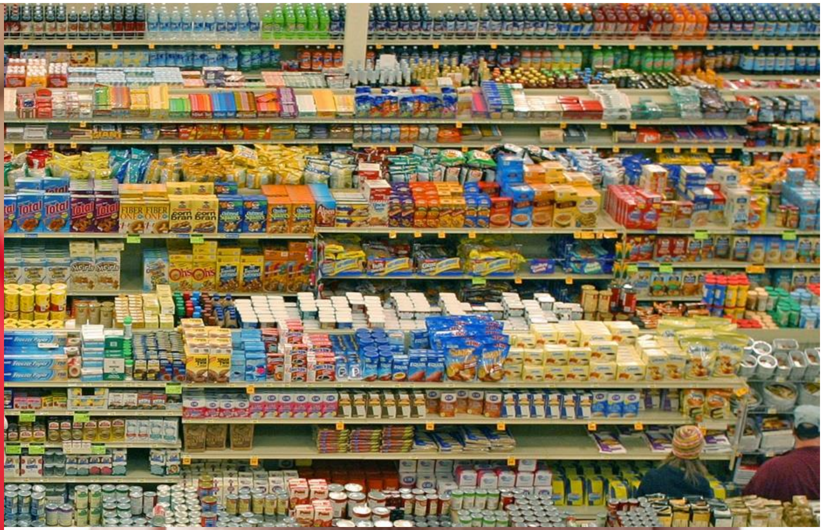
(Prospective Studies Collaboration, 2009; West, 2012)

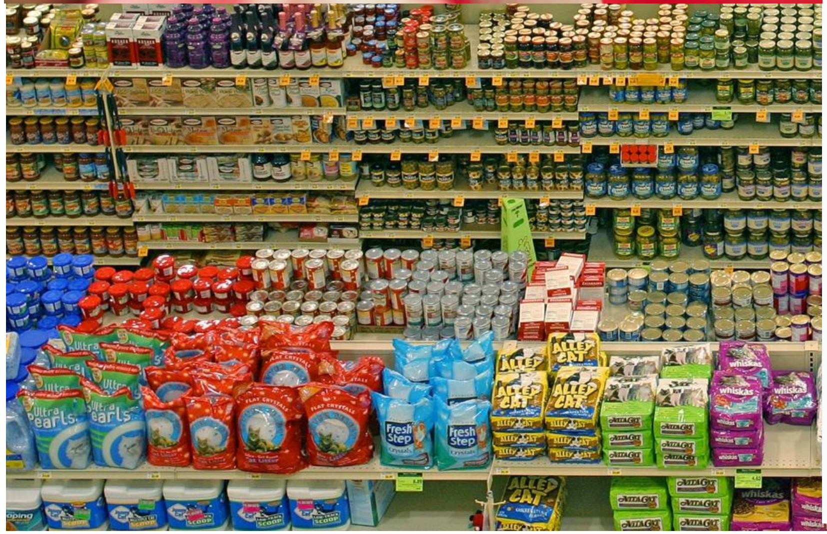
Energy Balance



Food Landscape Now



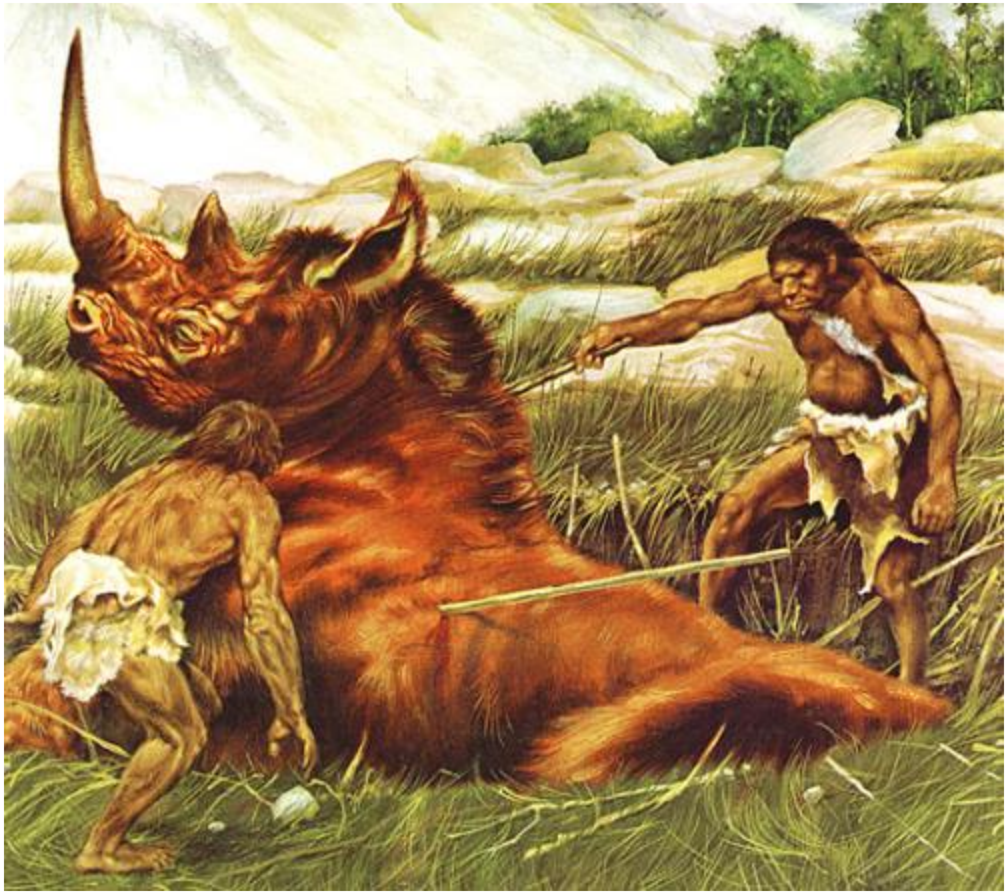


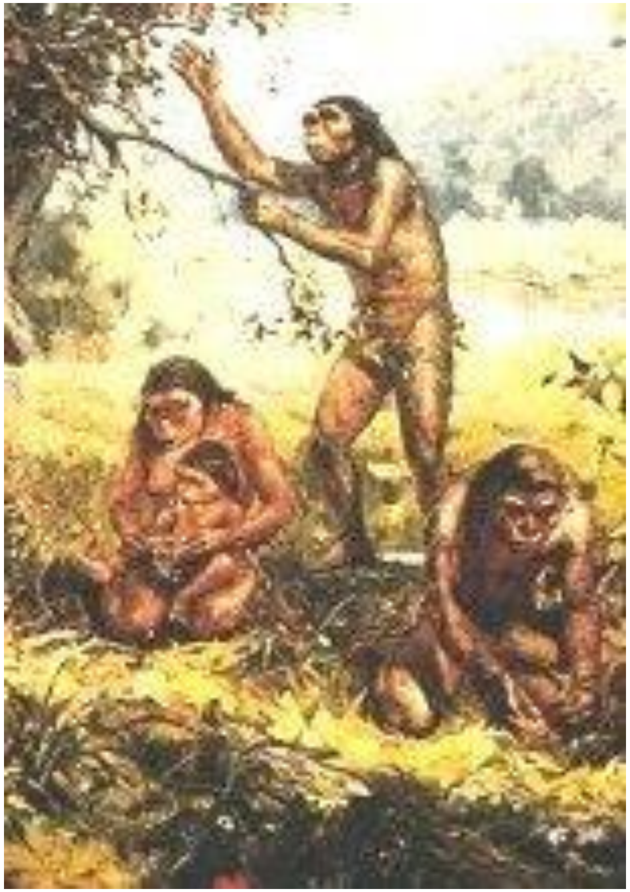


Food Landscape Then

Hunting

Gathering





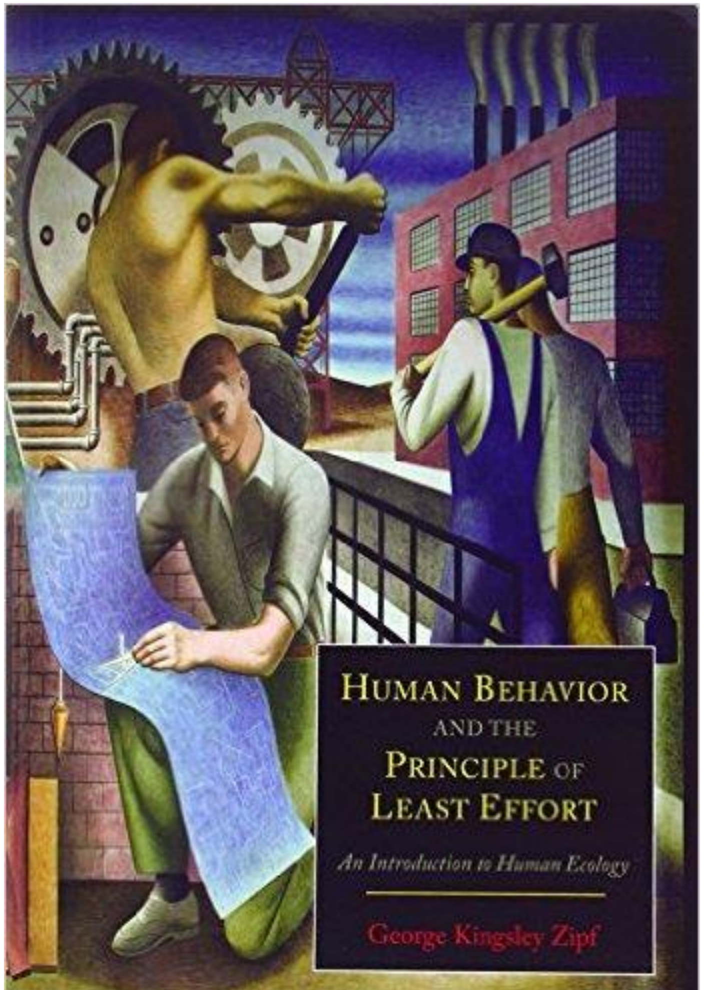
Physical activity was essential for food intake but requires energy, e.g. males would spend 1798 kcal in a persistence hunt at optimal running speed (Steudel-Numbers and Wall-Scheffler, 2009)

Physical Labour + Little Food

Five starving men in German concentration camp at time of liberation by U.S. Army

Professor Lieberman (2015): "Many lines of evidence indicate that **humans evolved to be adapted for regular, moderate amounts of endurance physical activity** into late age. However, because energy from food was limited, **humans also were selected to avoid unnecessary exertion**."

Principle of Least Effort



People minimize the amount of effort they exert in order to obtain desirable outcomes (Ferrero, 1894; Hull, 1943; Zipf, 1949).

In the economy of action, effort is a cost. Laziness is built deep into our nature (Kaheneman, 1973).

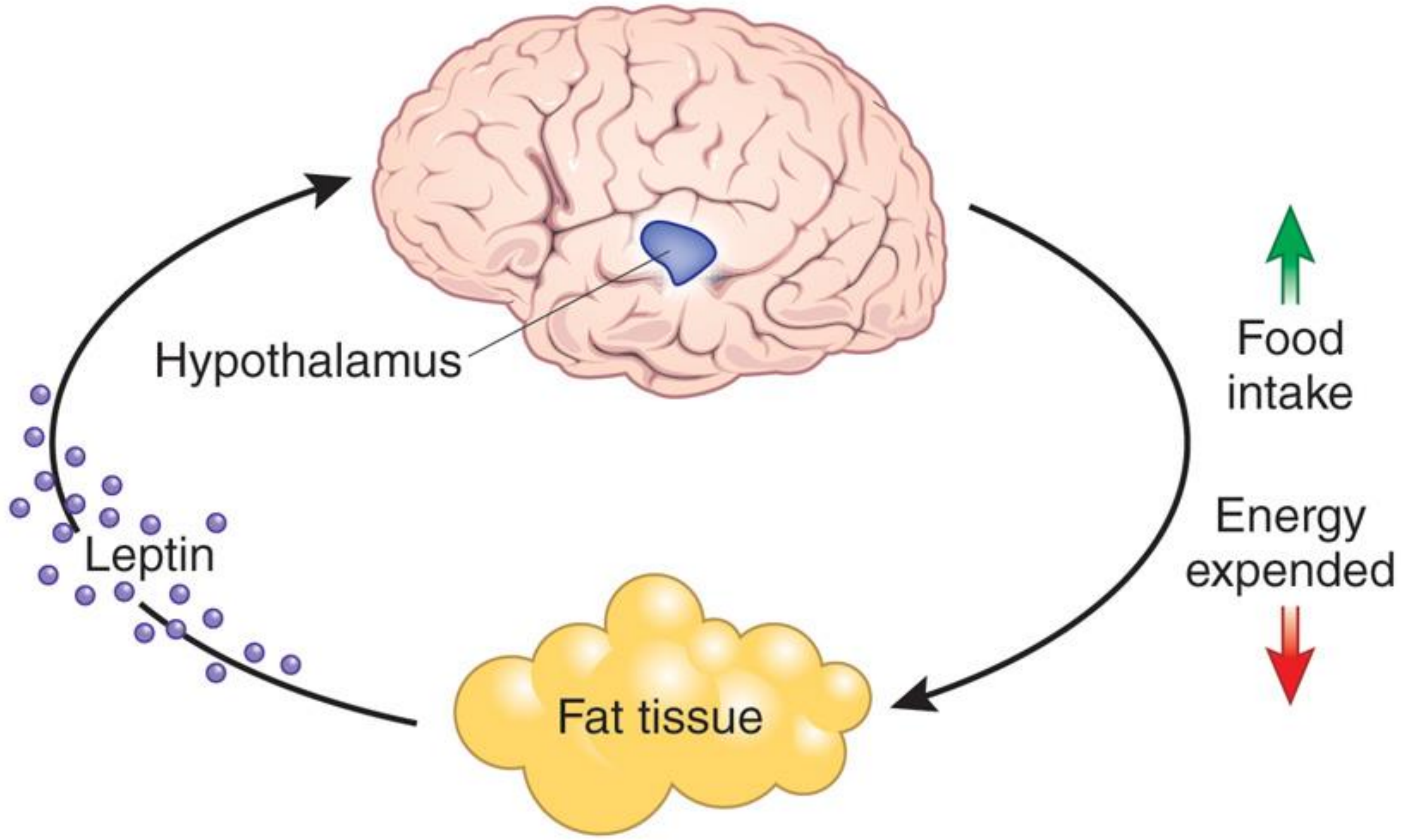
Principle of Least Effort

Principle of Least Effort

Self-reported % of normal-weight women meeting CDC guidelines for moderate intensity LTPA (Ariazza-Jones et al., 1998)

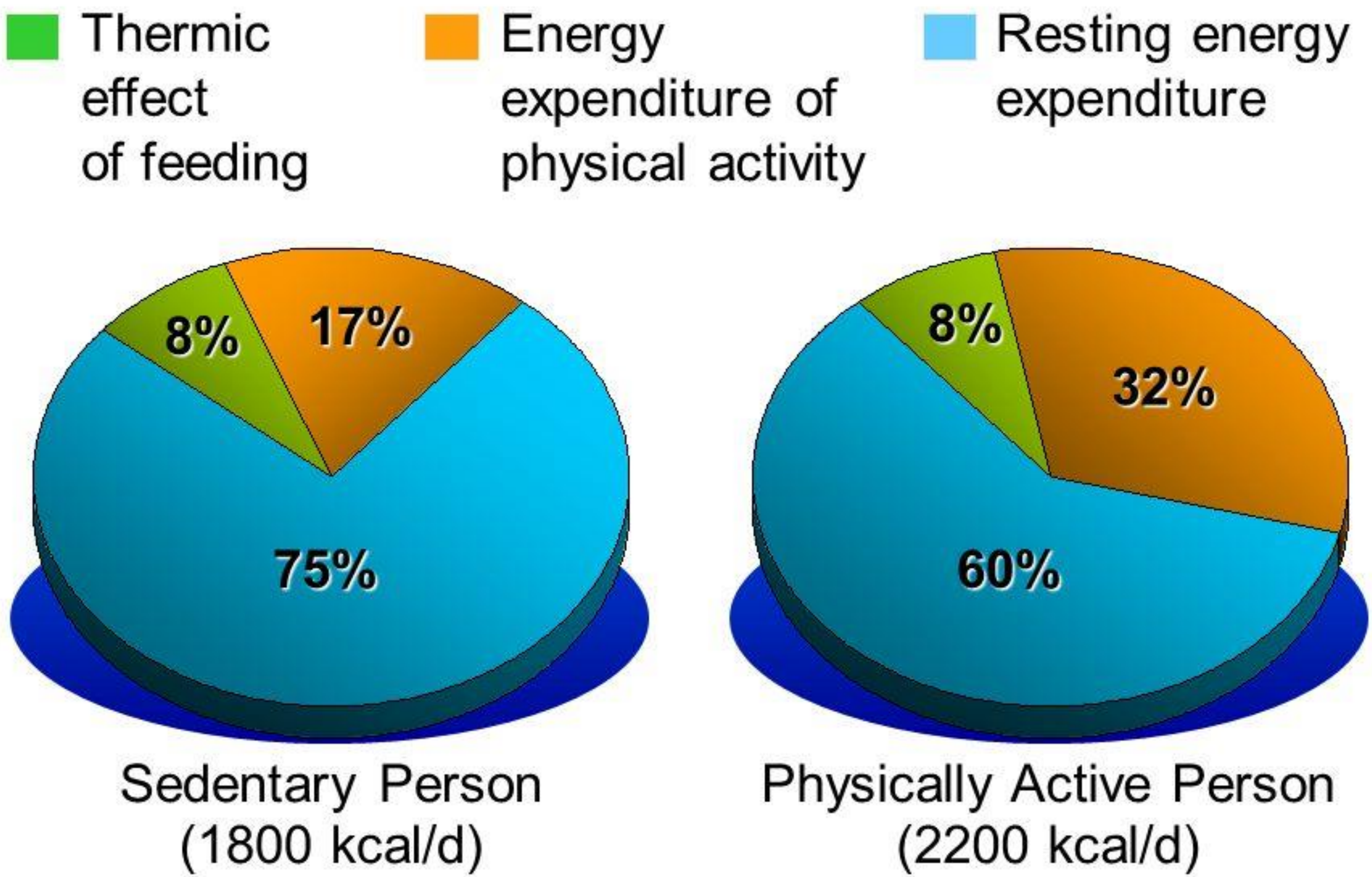
Proximate Explanations

Brain Regulation of Body Fat



(Friedman, 2010)

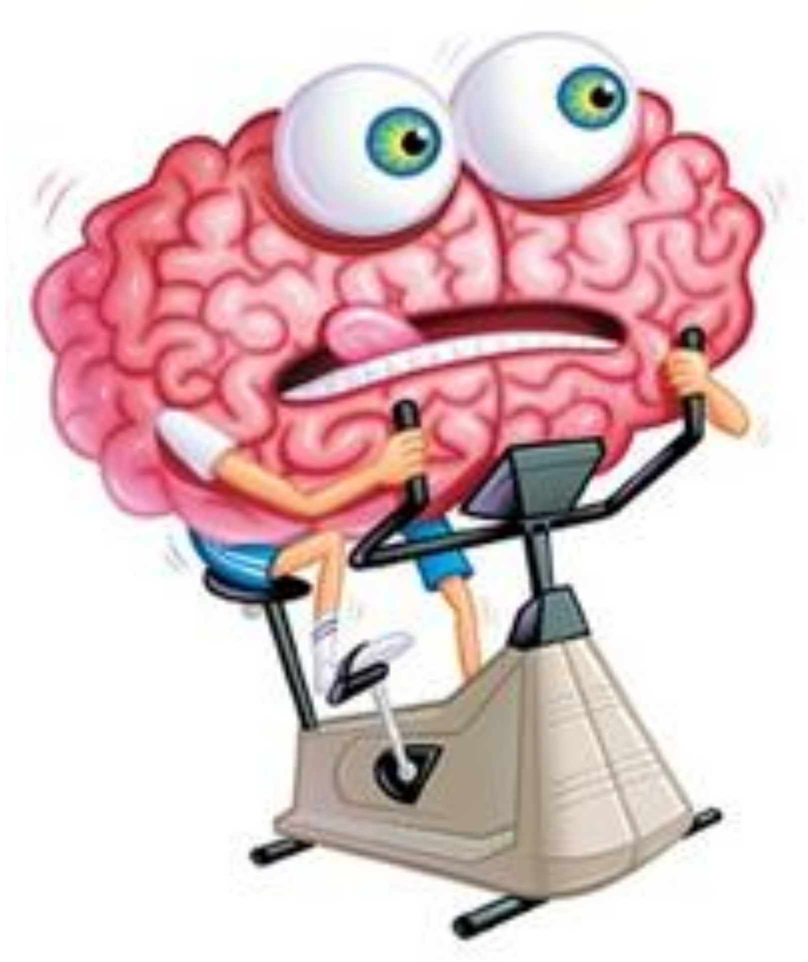
Components of Daily Energy Expenditure



Segal KR et al. *Am J Clin Nutr*. 1984;40:995-1000.

Slide Source: www.obesityonline.org

Brain regulation of PA behaviour in humans



PHYSICAL ACTIVITY BEHAVIOUR

PSYCHOLOGICAL LEVEL OF EXPLANATION
Psychological Constructs and Theories

BIOLOGICAL LEVEL OF EXPLANATION
Neural Correlates, Neurobiology, Genetics

Psychological Level

Perception of Effort

- It is a **conscious sensation of strain and labour, a feeling that intensifies the harder a person tries**.
- Unlike the strain felt from some external force (like having one's arm pulled), **effort feels mustered from within**.
- Feelings of effort are experienced during:
- **Physical exertion** (e.g., lifting weights);
- **Mental concentration** (e.g., studying statistics);
- **Self-restraint** (e.g., dieting).
- From **Preston and Wagner (2009)**.

Rating of Perceived Exertion (Borg, 1965)

Physical Stimulus

Perceptual Response

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Leg Effort and Respiratory Effort

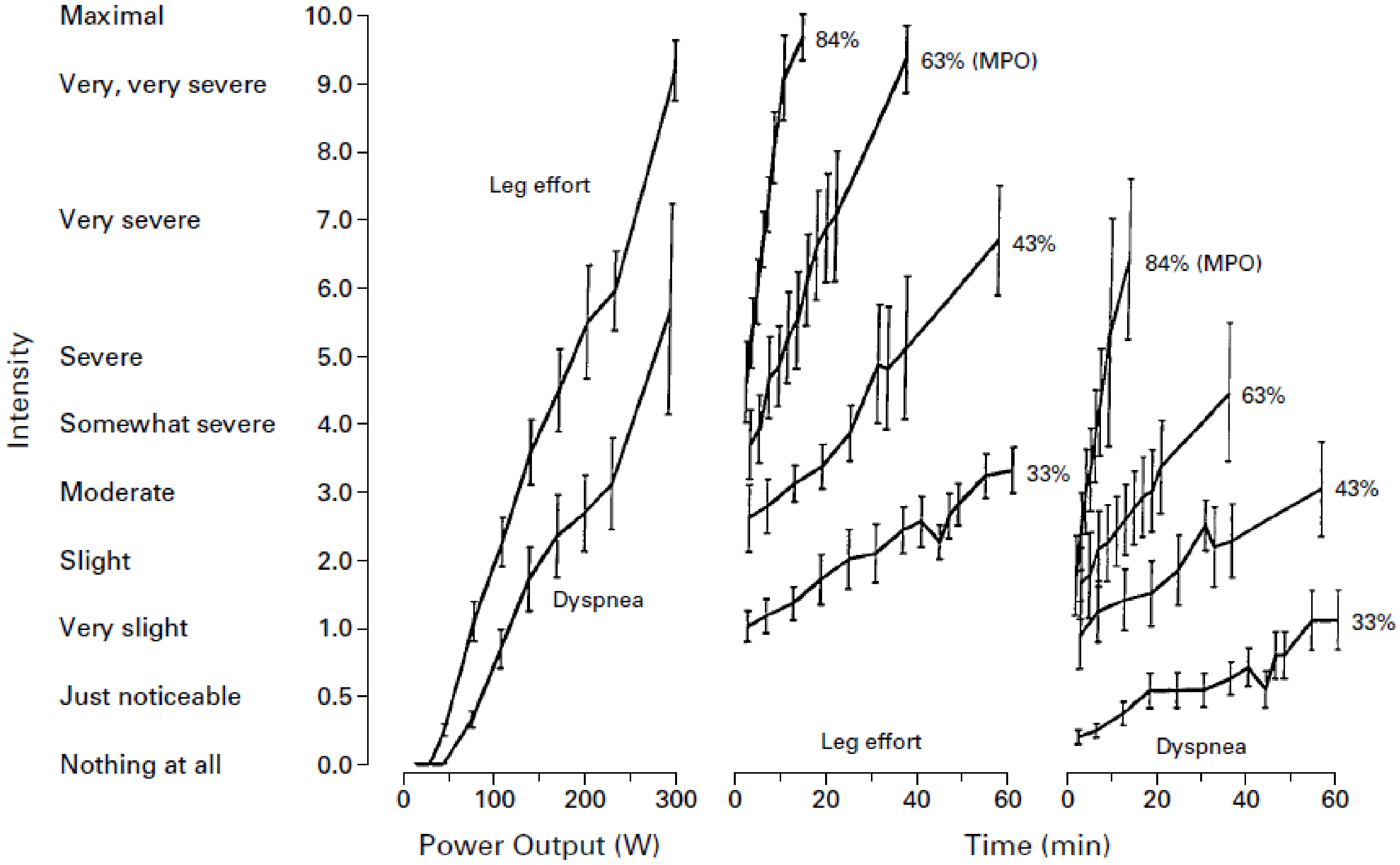
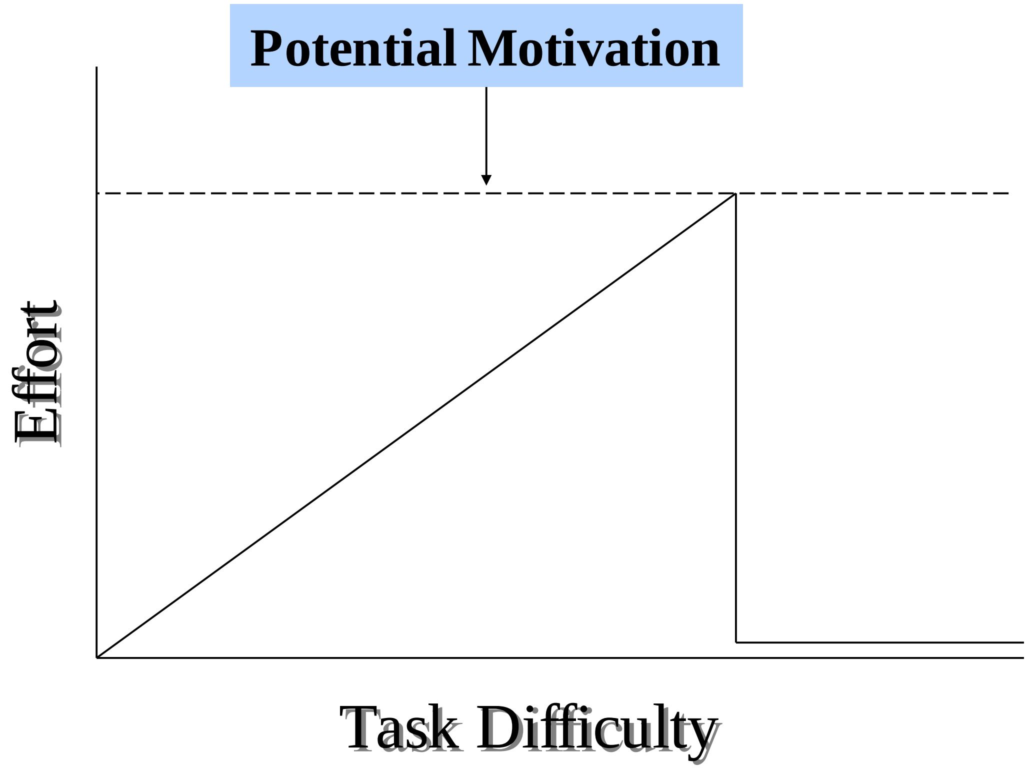


Figure 3. Intensity of Leg-Muscle Effort and Dyspnea Measured by the Borg Scale during Cycle-Ergometer Exercise in Fit Young Men. The left-hand panel shows leg effort and the degree of dyspnea during incremental exercise; the middle and right-hand panels show leg effort and the degree of dyspnea, respectively, during constant exercise at several levels, expressed as percentages of peak oxygen consumption ($\dot{V}_{O_2max}$). MPO denotes maximal power output. Adapted from Kearon et al.,[8] with the permission of the publisher.

(Jones and Killian, 2000)

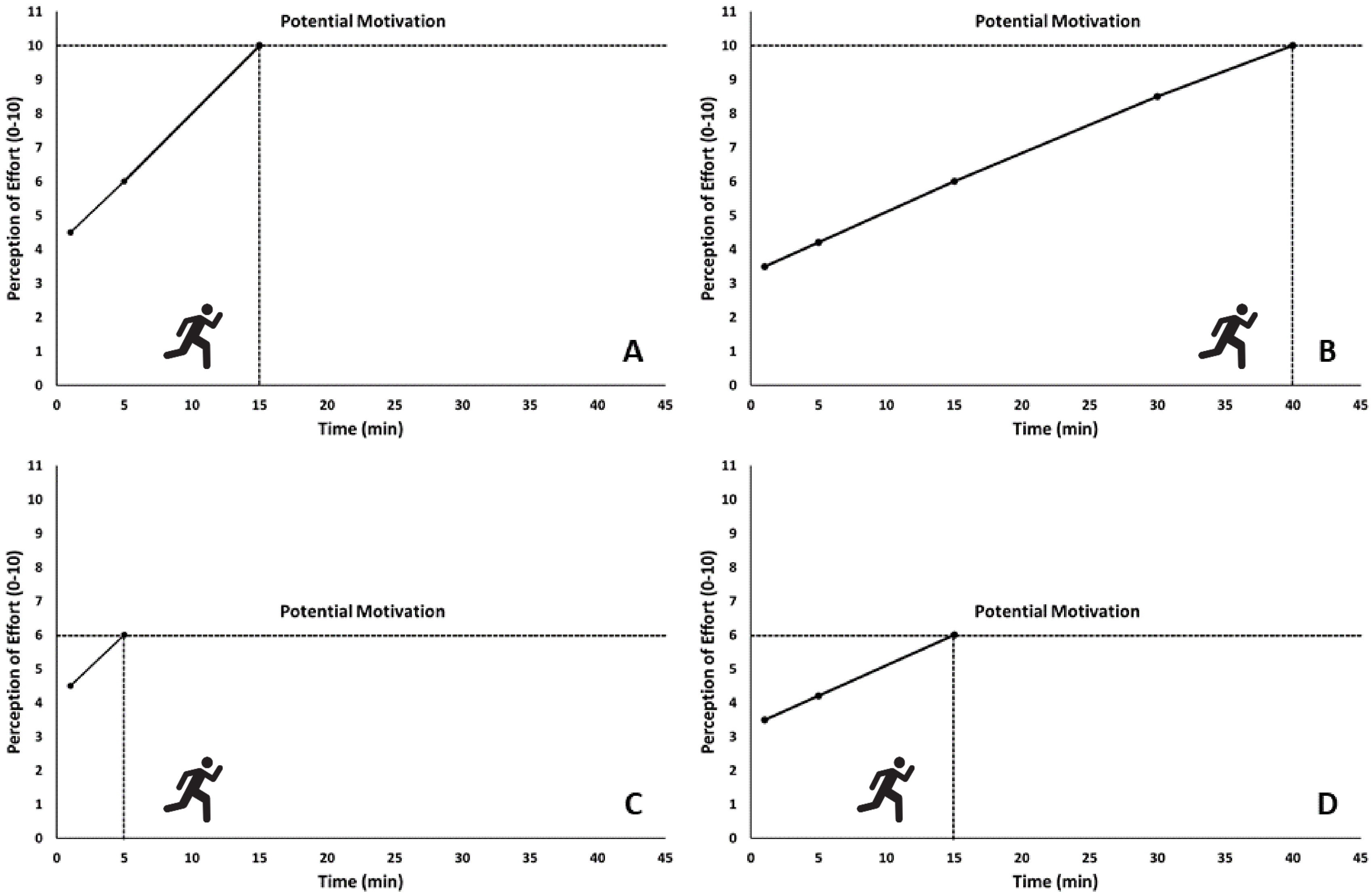
THE INTENSITY OF MOTIVATION

Jack W. Brehm and Elizabeth A. Self **Ann. Rev. Psychol. 1989. 40:109–31**



Potential motivation is the maximum effort an individual would be willing to exert to satisfy a motive

Unfit/Fatigued/Placebo Fit/Non Fatigued/Caffeine



Running at 12 km/h

Determinants of Potential Motivation

- **Reward** value
- **Need** for the reward
- **Contingency** of the reward upon completion of the task (instrumental behaviour)

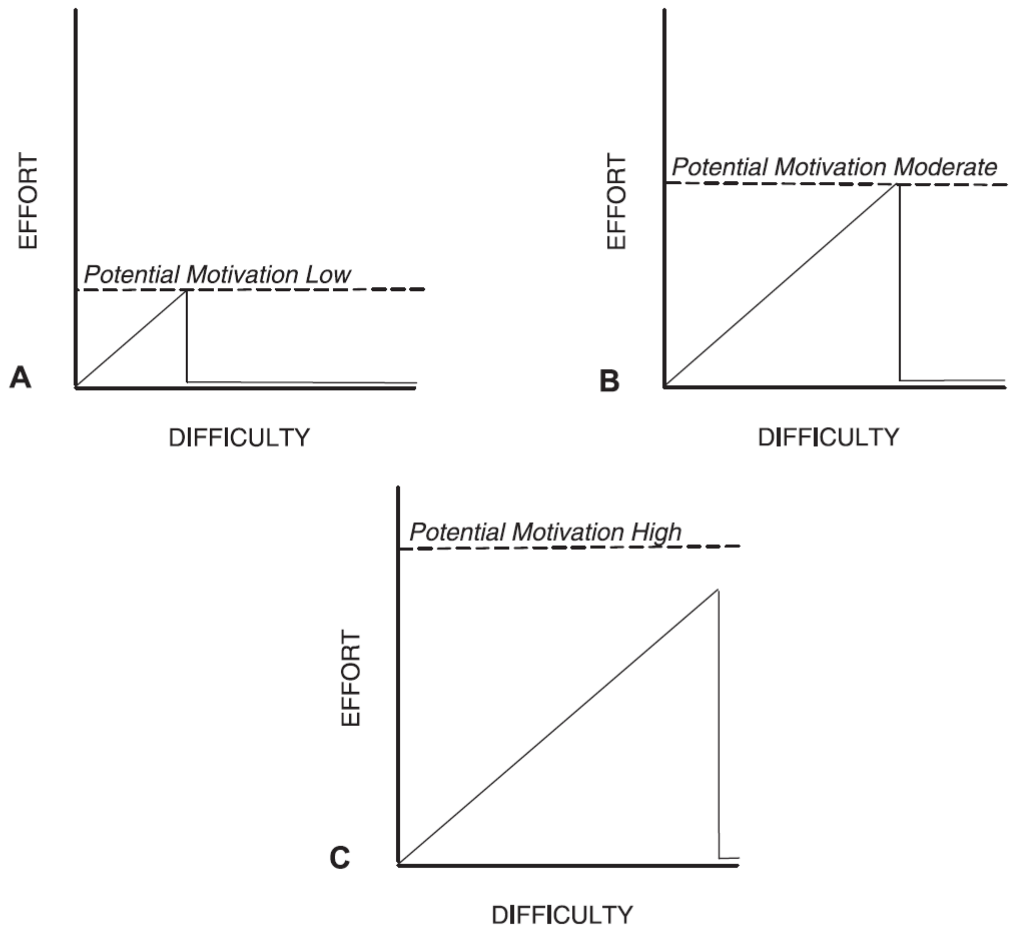
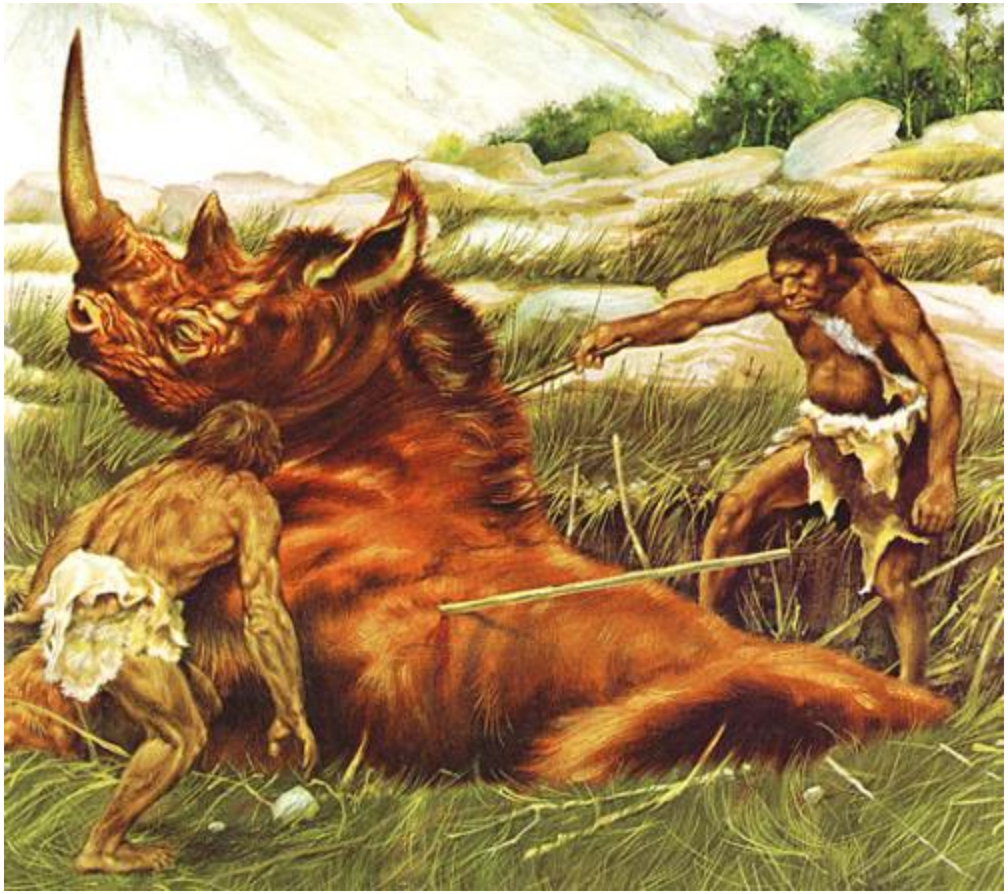


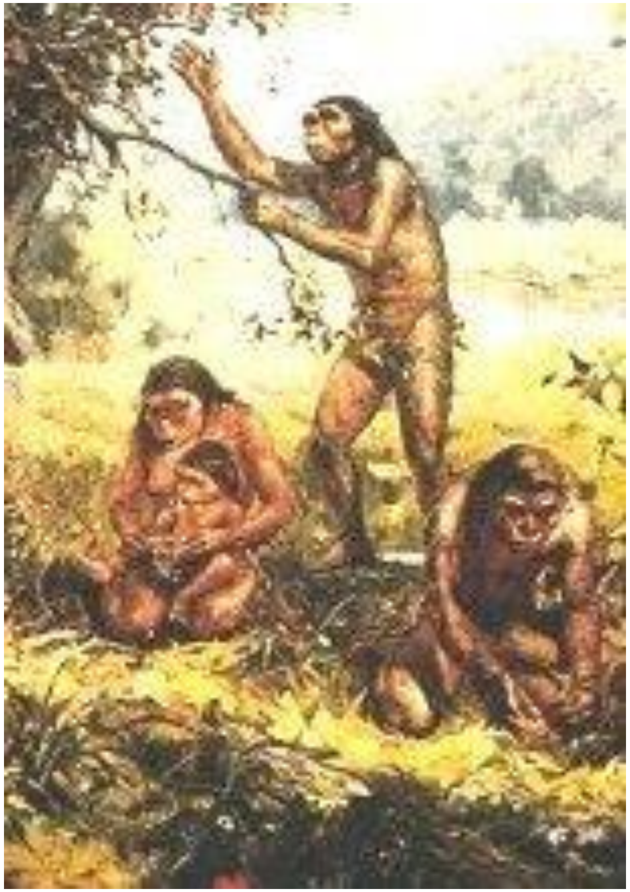
Figure 1 Effort as a function of challenge difficulty at low, moderate, and high levels of potential motivation.

(Wright, 2008)

Hunting

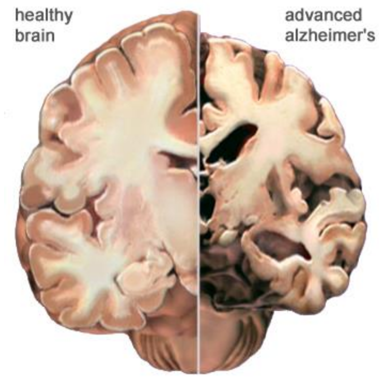


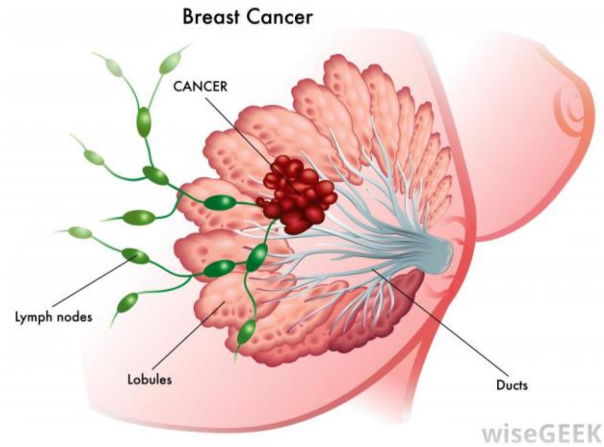
Gathering

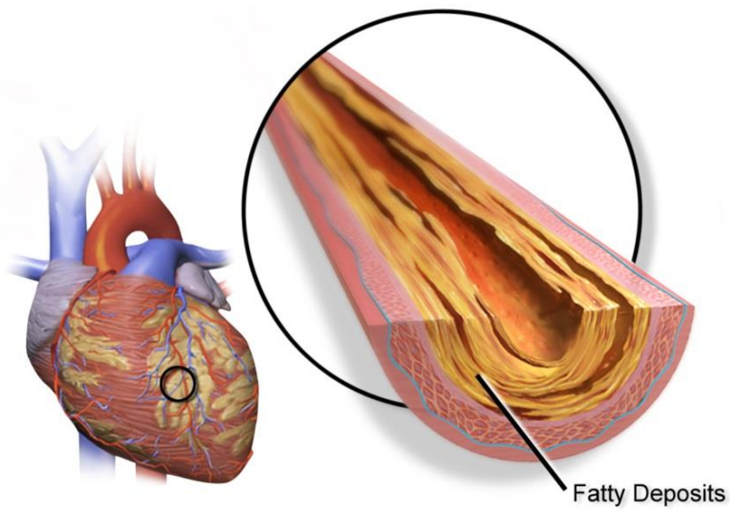


In the past, food was main reward of PA

Now main reward of PA for health is to avoid

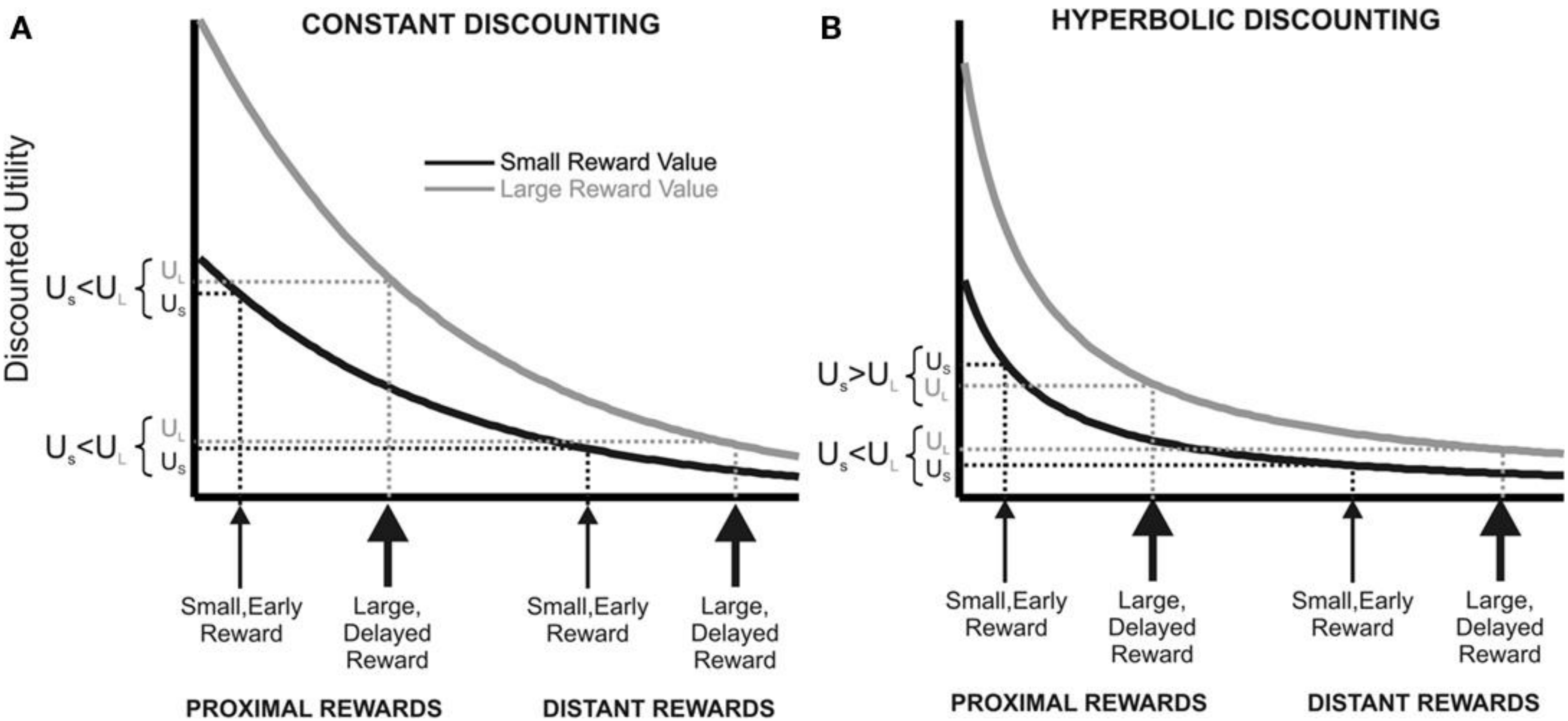






Public Health Campaigns

Discounting of Future Events

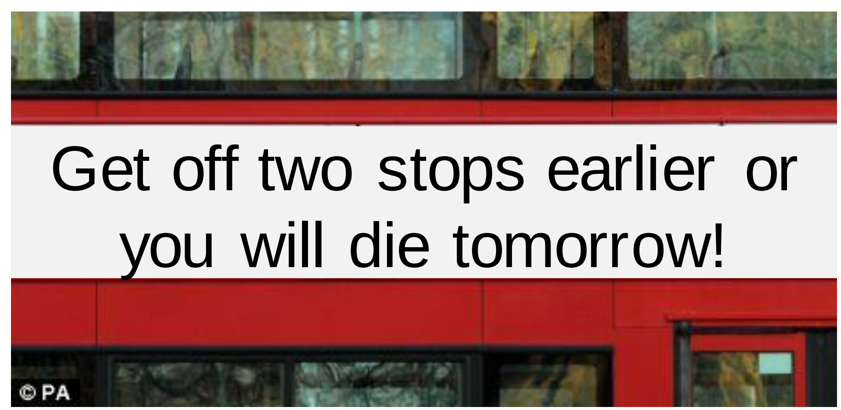


(Kalenscher and Windergen, 2011)

Most Effective Public Health Campaign Ever

Take the stairs every day

or you will get cancer



Financial Incentives for Exercise Adherence in Adults

Systematic Review and Meta-Analysis

Study or subgroup	Incentive Mean	Incentive SD	Incentive Total	Control Mean	Control SD	Control Total	Weight (%)	Mean difference IV, Fixed, 95% CI	Year
Epstein (1980)[21]	76.5	20.75	7	57.5	26.05	8	6.3	19.00 (-4.71, 42.71)	1980
Epstein (1980)[21]	79	21.6	5	57.5	26.05	8	5.2	21.50 (-4.66, 47.66)	1980
Wing (1996)[18]	60.7	29.2	21	52.2	30.7	16	9.2	8.50 (-11.05, 28.05)	1996
Courneya (1997)[28]	45.42	40.83	100	31.42	30.25	100	35.6	14.00 (4.04, 23.96)	1997
Jeffery (1998)[19]	44.4	27.6	37	34.67	27.7	42	23.7	9.73 (-2.49, 21.95)	1998
Charness (2009)[16]	108.89	40.83	40	33.33	30.25	40	0.0	75.56 (59.81, 91.31)	2009
Charness (2009)[16]	145	40.83	60	18.75	30.25	60	0.0	126.25 (113.39, 139.11)	2009
Daryanto (2010)[31]	148.88	21.6	25	143	26.05	25	20.1	5.88 (-7.39, 19.15)	2010
Total (95% CI)			**195**			**199**	**100.0%**	**11.55 (5.61, 17.50)**	

Heterogeneity: Chi² = 2.05, df = 5 ($p = 0.84$); $I^2 = 0\%$

Test for overall effect: $z = 3.81$ ($p = 0.0001$)

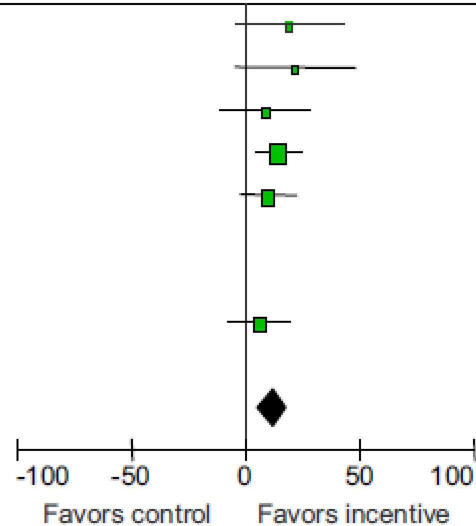
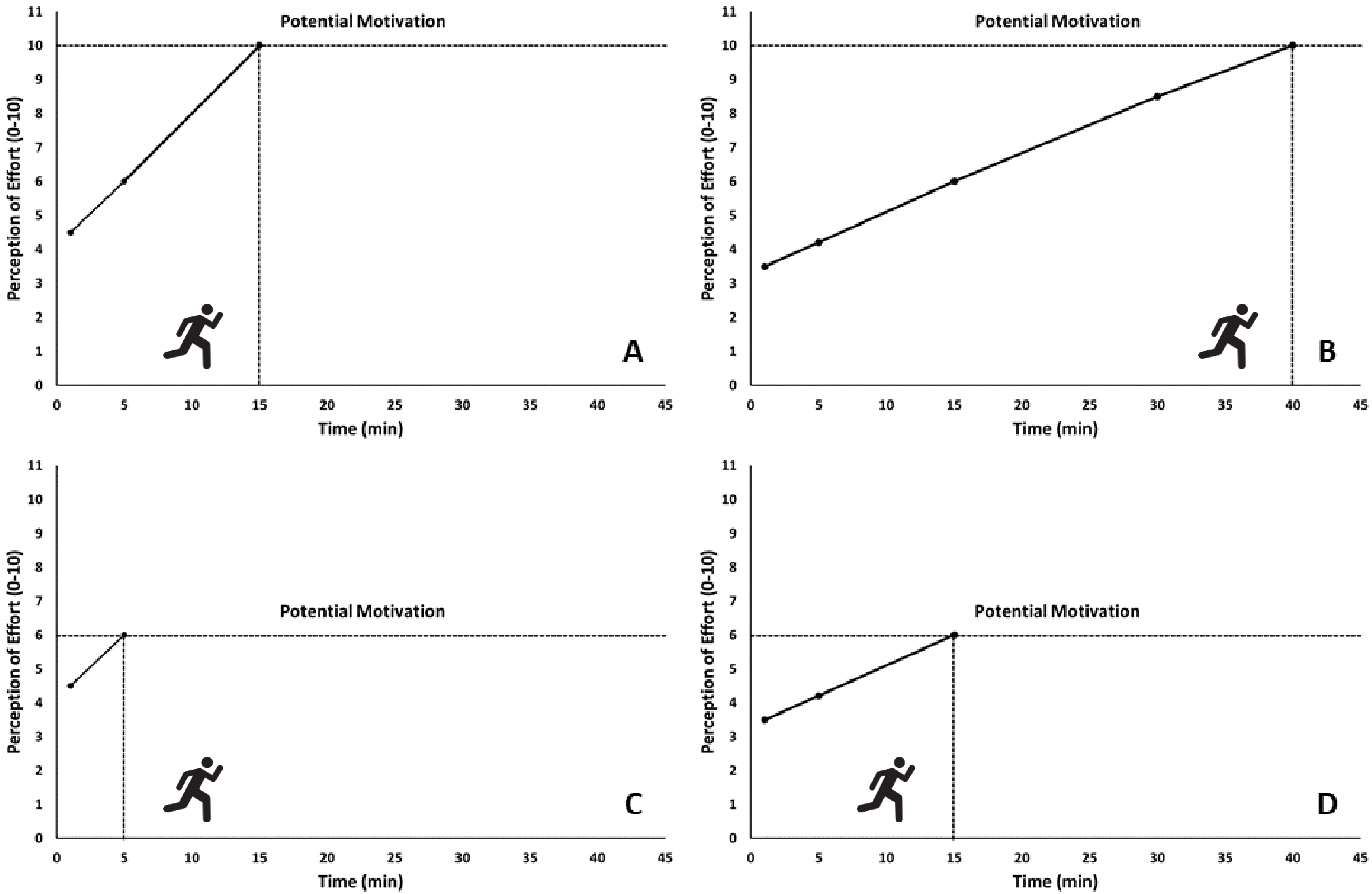


Figure 2. Exercise session attendance (%; 4–26 weeks) comparing use of incentives versus no incentives

Note: The Charness 2009 paper reported on two studies, so results are given for each.


Potential Motivation
Perception of Effort (0-10)
Time (min)
A
Potential Motivation
Perception of Effort (0-10)
Time (min)
B
Potential Motivation
Perception of Effort (0-10)
Time (min)
C
Potential Motivation
Perception of Effort (0-10)
Time (min)
D

Barriers to Exercise

- Factor analysis of responses from 650 adults gave four main barriers:
- **Physical Exertion** (e.g., exercise is hard work for me)
- **Exercise Milieu** (e.g., places for me to exercise are too far away)
- **Time Expenditure** (e.g., exercise takes too much of my time)
- **Family Discouragement** (e.g., my spouse does not encourage exercising)

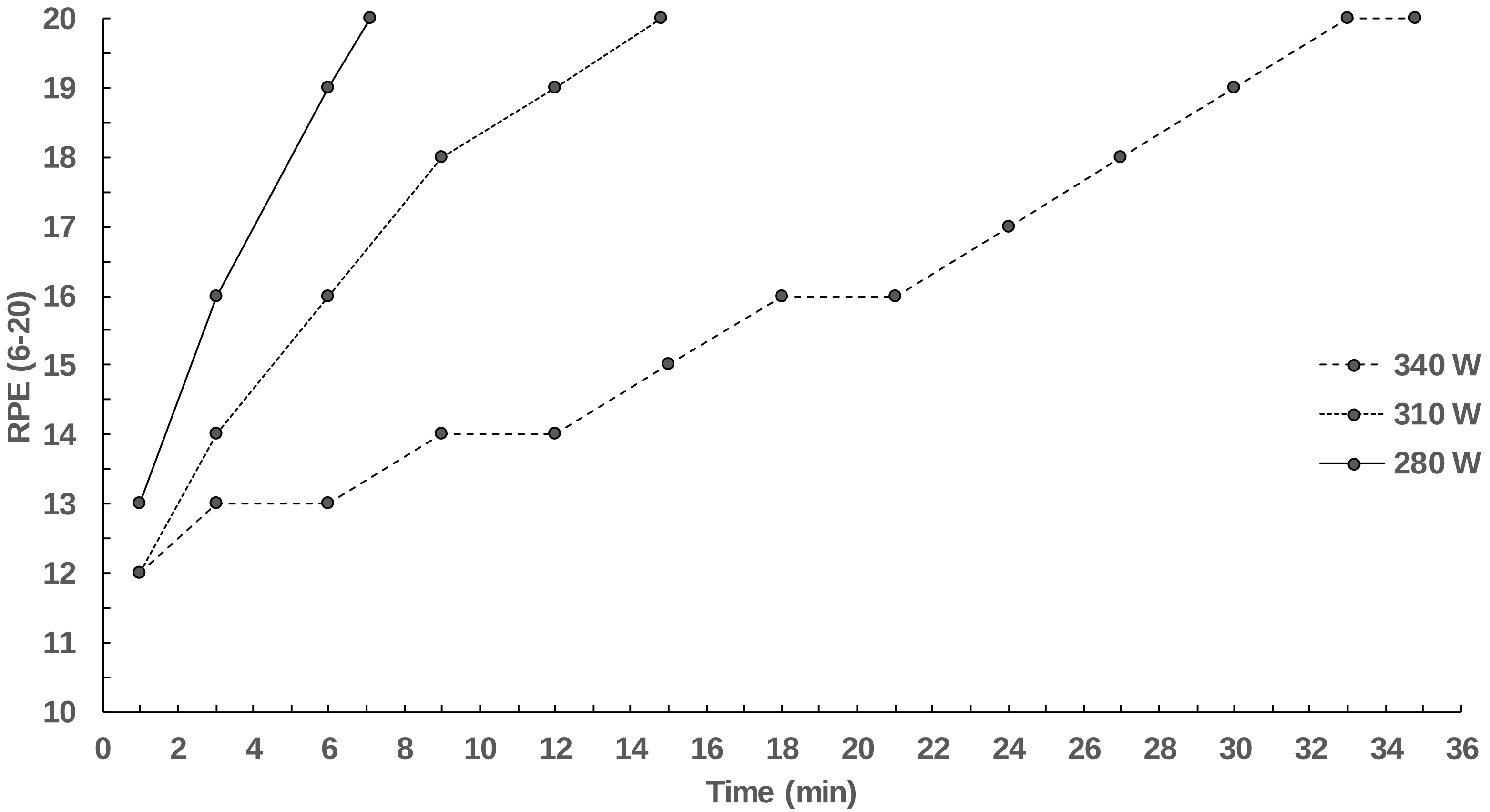
(Sechrist et al., 1987)

Perceived Exercise Benefits and Barriers of Non-Exercising Female University Students in the United Kingdom

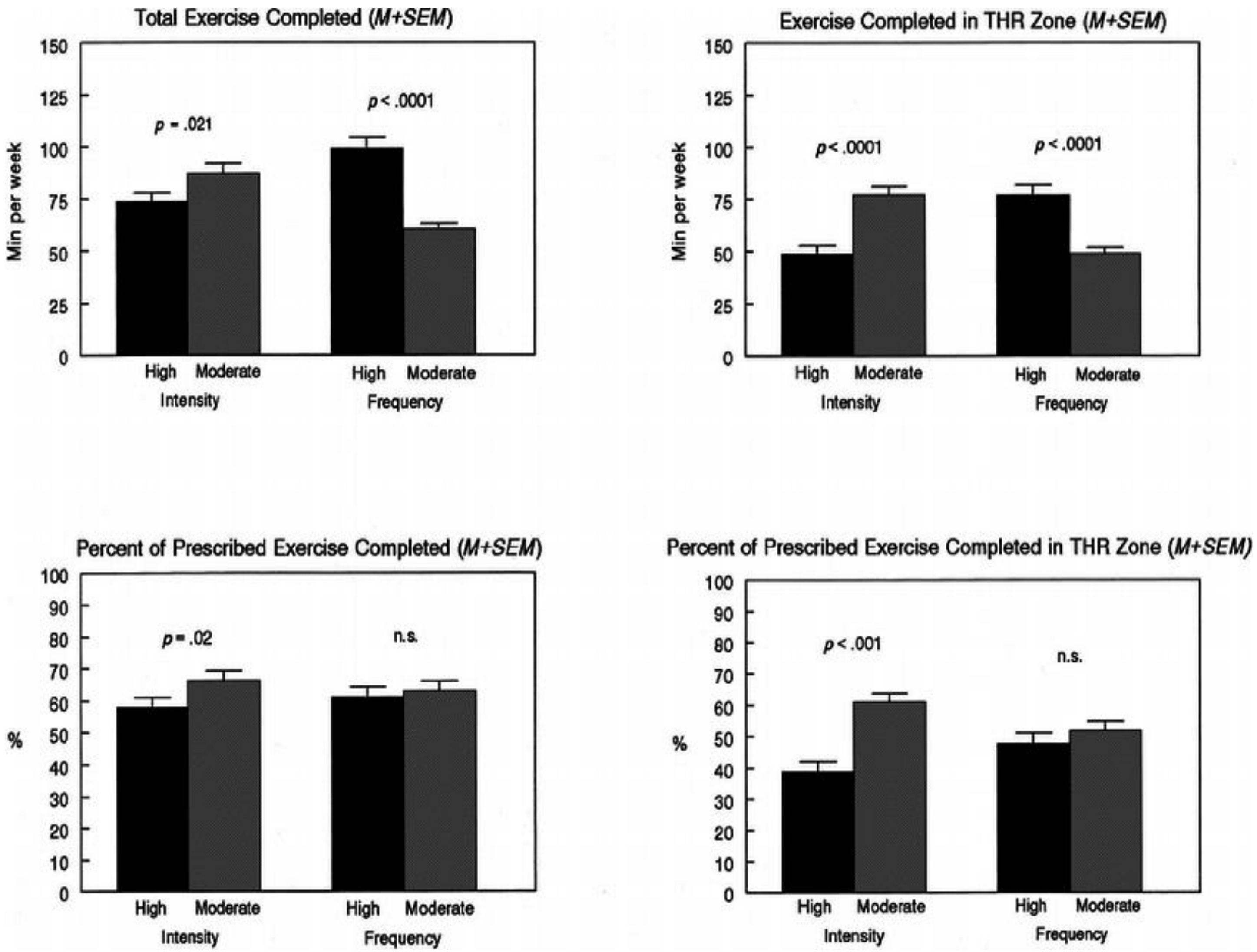
Perceived Barriers Items	M (SD)
Exercise Milieu Sub-scale	
9: Places for me to exercise are too far away	2.69 (0.70)
12: I am too embarrassed to exercise	1.85 (0.83)
14: It costs too much money to exercise	2.26 (0.86)
16: Exercise facilities do not have convenient schedules for me	2.09 (0.74)
28: I think people in exercise clothes look funny	2.04 (0.88)
42: There are too few places for me to exercise	2.10 (0.77)
Time Expenditure Sub-scale	
4: Exercising takes too much of my time	2.31 (0.81)
24: Exercise takes too much time from family relationships	1.95 (0.67)
37: Exercise takes too much time from my family responsibilities	2.04 (0.71)
Physical Exertion Sub-scale	
6: Exercise tires me	2.69 (0.70)
19: I am fatigued by exercise	2.57 (0.75)
40: Exercise is hard work for me	2.63 (0.70)
Family Discouragement Sub-scale	
21: My spouse (or significant other) does not encourage exercising	2.15 (0.87)
33: My family members do not encourage me to exercise	1.96 (0.65)
All Barriers items of all subscales	**2.22 (0.46)**

(Lovell et al., 2010)

Exercise Intensity and Duration

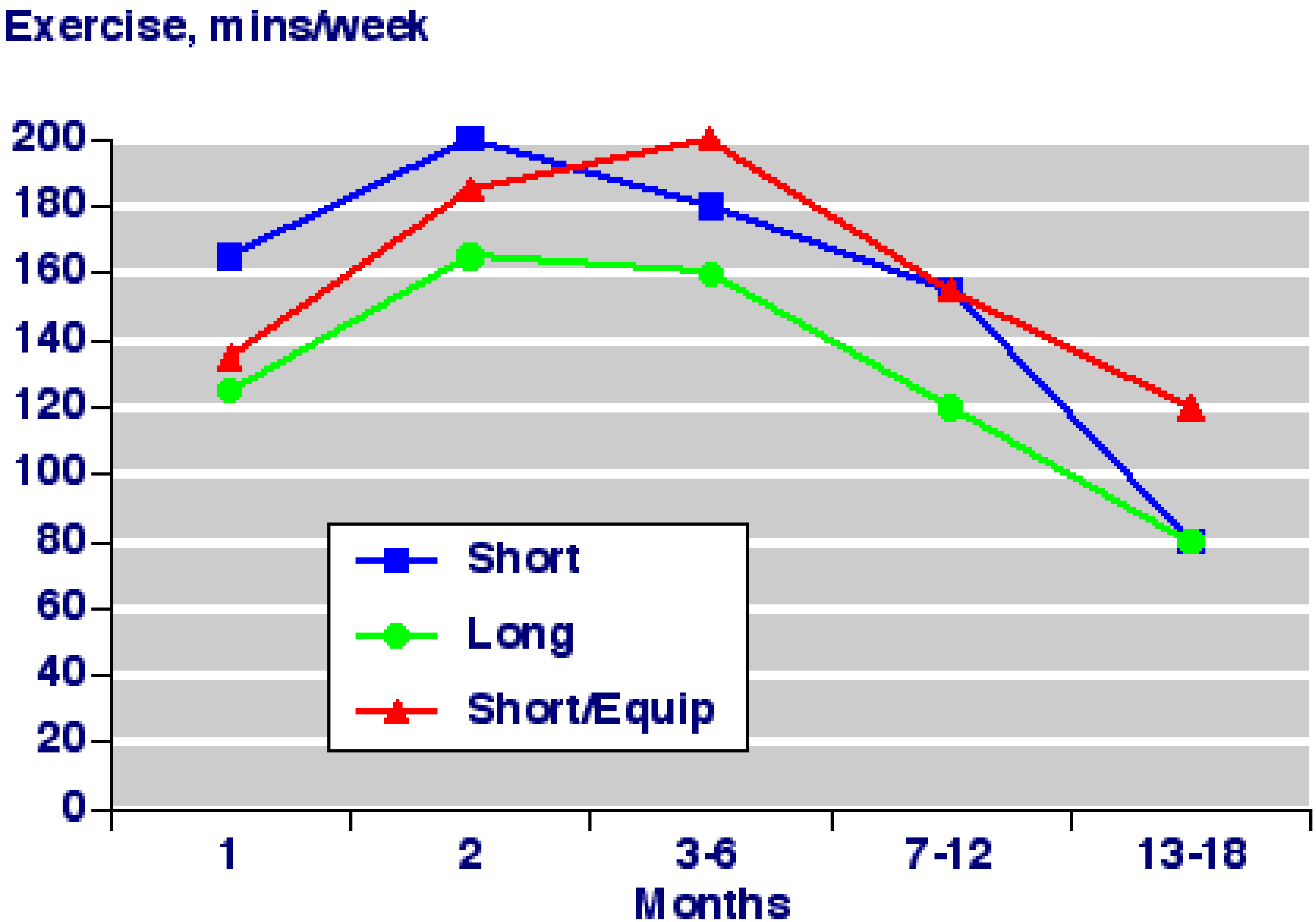


Exercise Intensity and Adherence



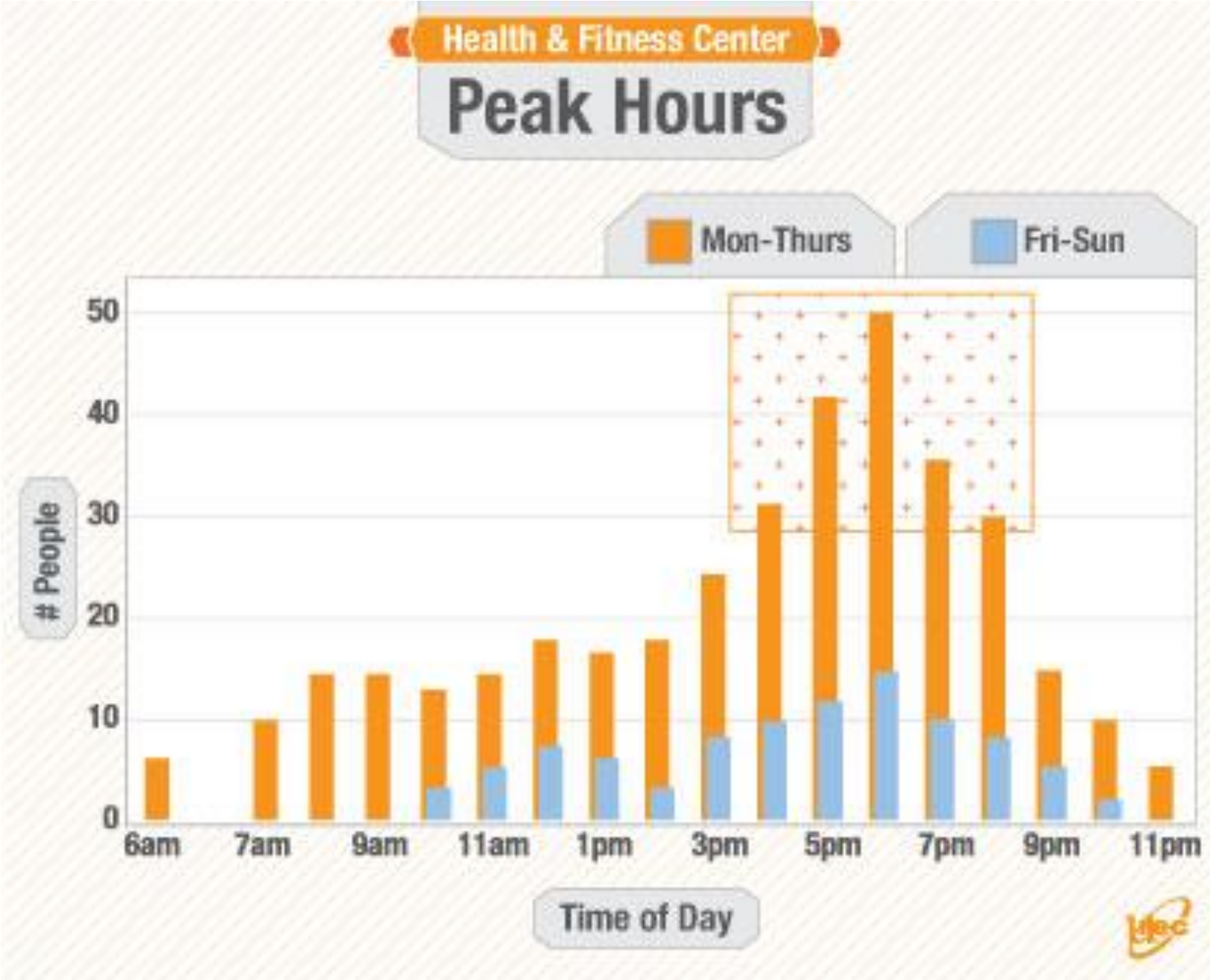
(Perri et al., 2002)

Exercise Duration and Adherence



JM Jakicic et al. Effects of intermittent exercise and use of home exercise equipment on adherence, weight loss, and fitness in overweight women. Journal of the American Medical Association 1999 282: 1554-1560.

Mental Fatigue



Health & Fitness Center
Peak Hours
Mon-Thurs
Fri-Sun
People
50
40
30
20
10
0
6am
7am
9am
11am
1pm
3pm
5pm
7pm
9pm
11pm
Time of Day

Personal and Environmental Factors Associated With Physical Inactivity Among Different Racial–Ethnic Groups of U.S. Middle-Aged and Older-Aged Women

Table 3

Most Frequently Reported Perceived Barriers, Along With Relative Rankings, for the Sample as a Whole (N = 2,912) and for Each Racial–Ethnic Subgroup

Perceived barrier	% total sample	Overall rank	% White (rank)	% Black (rank)	% American Indian–Alaskan Native (rank)	% Hispanic (rank)
Lack of time	22.3	1 (tie)	24.6 (1)	17.0 (5)	24.8 (2)	22.5 (3)
Caregiving duties	22.3	1 (tie)	20.7 (2)	20.2 (3)	23.6 (4)	25.6 (1)
Lack energy	21.7	3	19.9 (4)	21.1 (2)	25.1 (1)	20.3 (4)
Too tired	20.7	4	20.4 (3)	19.0 (4)	24.5 (3)	18.9 (5)
Lack safe place to exercise	20.1	5	16.5 (6)	22.9 (1)	23.0 (5)	17.6 (6)
Self-conscious about physical appearance	19.6	6	18.9 (5)	15.1 (7)	20.6 (6)	23.8 (2)
Not in good health	16.2	7	13.6 (7)	16.8 (6)	19.2 (8)	15.2 (8)
Afraid of injury	15.3	8	11.0 (9)	14.9 (8)	19.4 (7)	16.3 (7)
Bad weather	10.4	9	12.4 (8)	8.8 (9)	11.2 (9)	8.8 (9)
Others discourage me	5.6	10	3.4 (10)	6.2 (10)	7.1 (10)	5.3 (10)

(King et al., 2000)

Personal and Environmental Factors Associated With Physical Inactivity Among Different Racial–Ethnic Groups of U.S. Middle-Aged and Older-Aged Women

Table 5

Simultaneous Logistic Regression: Correlates of Being Sedentary Versus Underactive–Active (n = 2,633)

Correlate	Odds ratio	95% CI
Personal barriers		
Others discourage me from exercising	1.07	0.98–1.17
Self-conscious about physical appearance	1.08*	1.01–1.14
Afraid of injury	1.05	0.98–1.13
Lack of time	0.95	0.89–1.02
Too tired	0.92*	0.85–0.99
Lack safe place to exercise	0.98	0.93–1.05
Caregiving duties	0.95	0.90–1.01
Bad weather	1.00	0.93–1.08
Not in good health	0.93*	0.86–0.99
Lack energy	0.90**	0.84–0.97

Note. CI = confidence interval.
* $p < .05$. ** $p < .01$. *** $p < .001$.

(King et al., 2000)

Mental Fatigue and Perception of Effort

Mentally Fatiguing Task

AX-Continuous Performance Task (AX-CPT) for 90 min

Endurance Performance Test

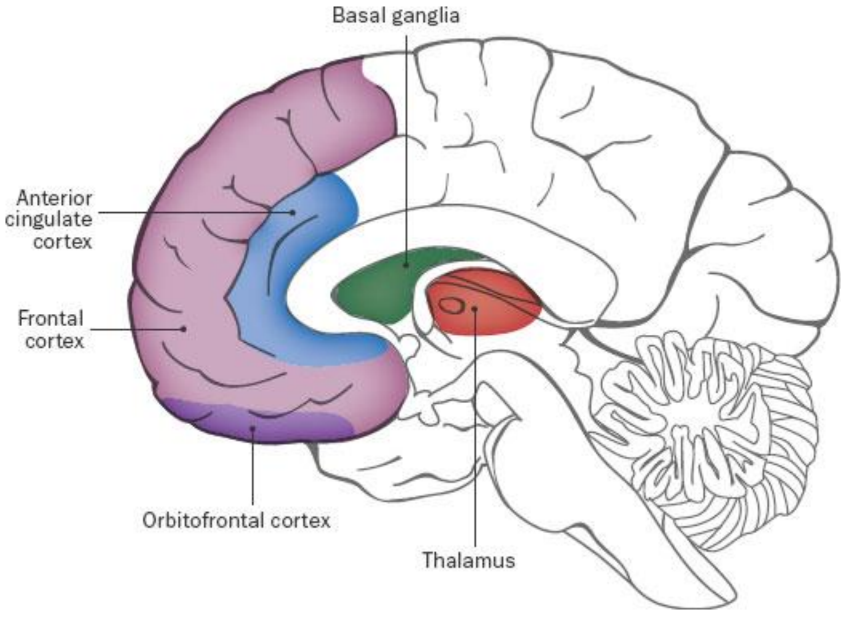
Time to Exhaustion at 230W (80% of Peak Power Output)

(Marcora et al., JAP 2009)

Randomized crossover experiment N = 16

Mental Fatigue and Perception of Effort

Mentally Fatiguing Task



AX-Continuous Performance Task (AX-CPT) for 90 min

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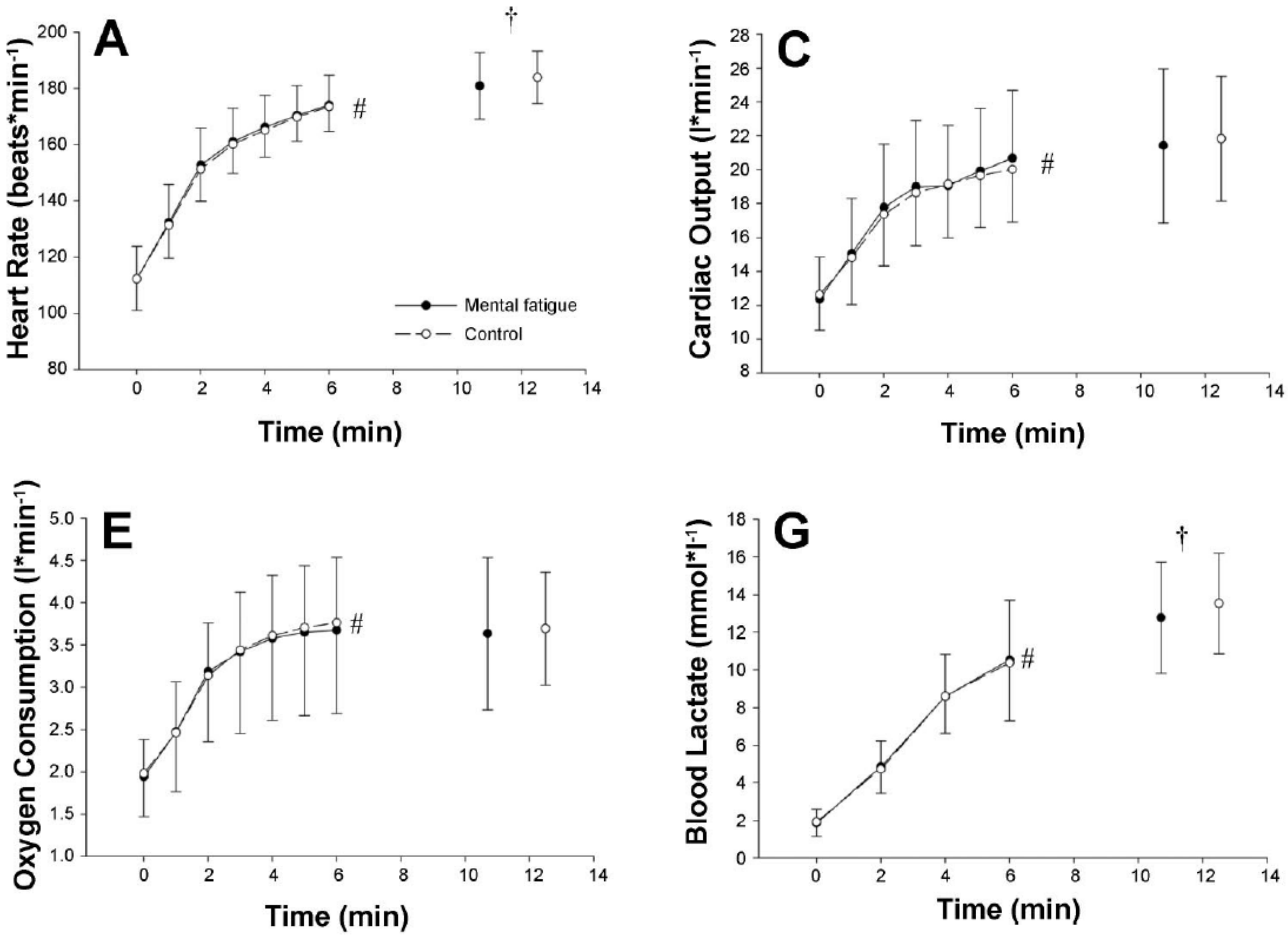
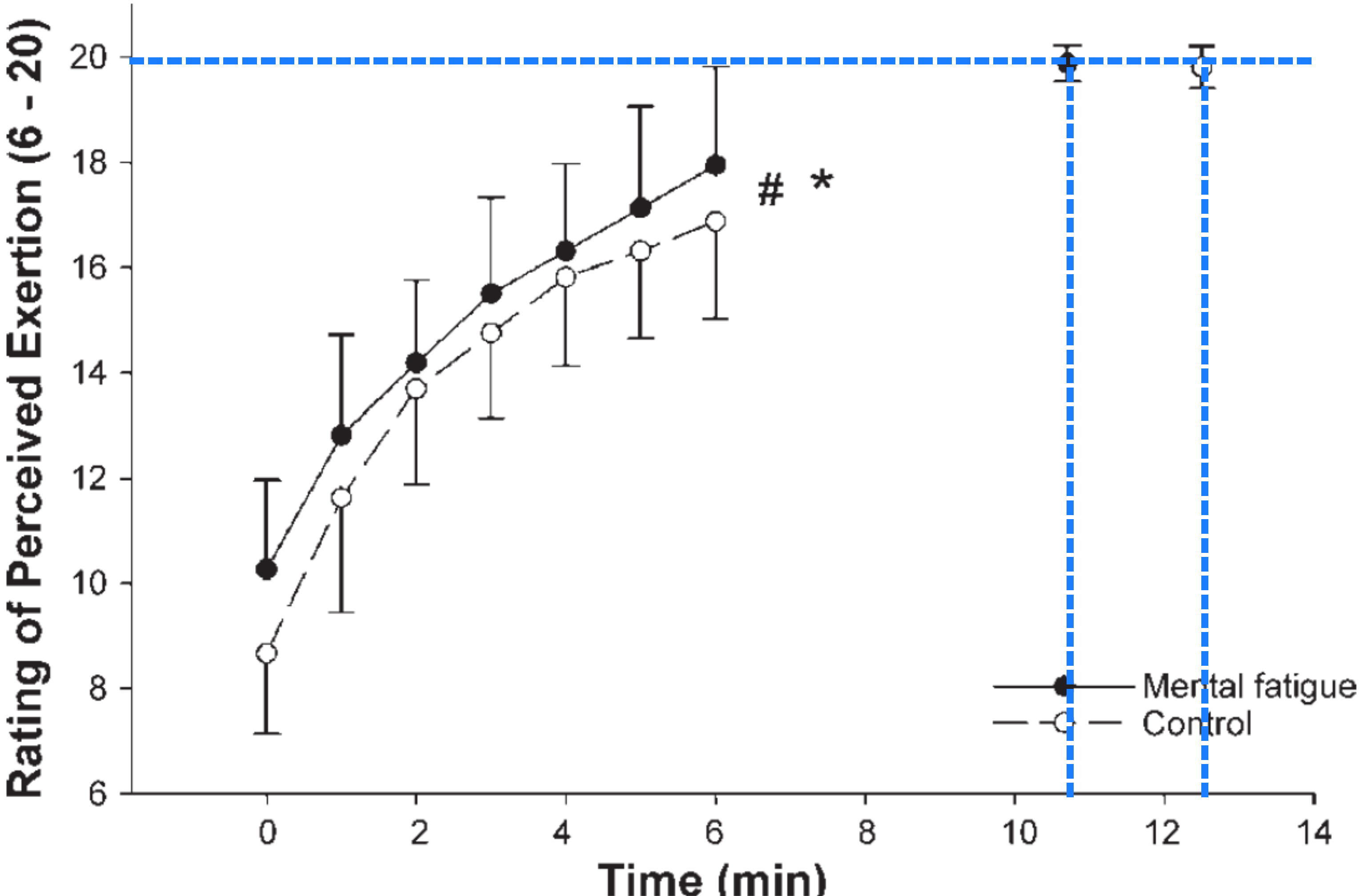
Mental Fatigue and Perception of Effort



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

(Marcora et al., JAP 2009)

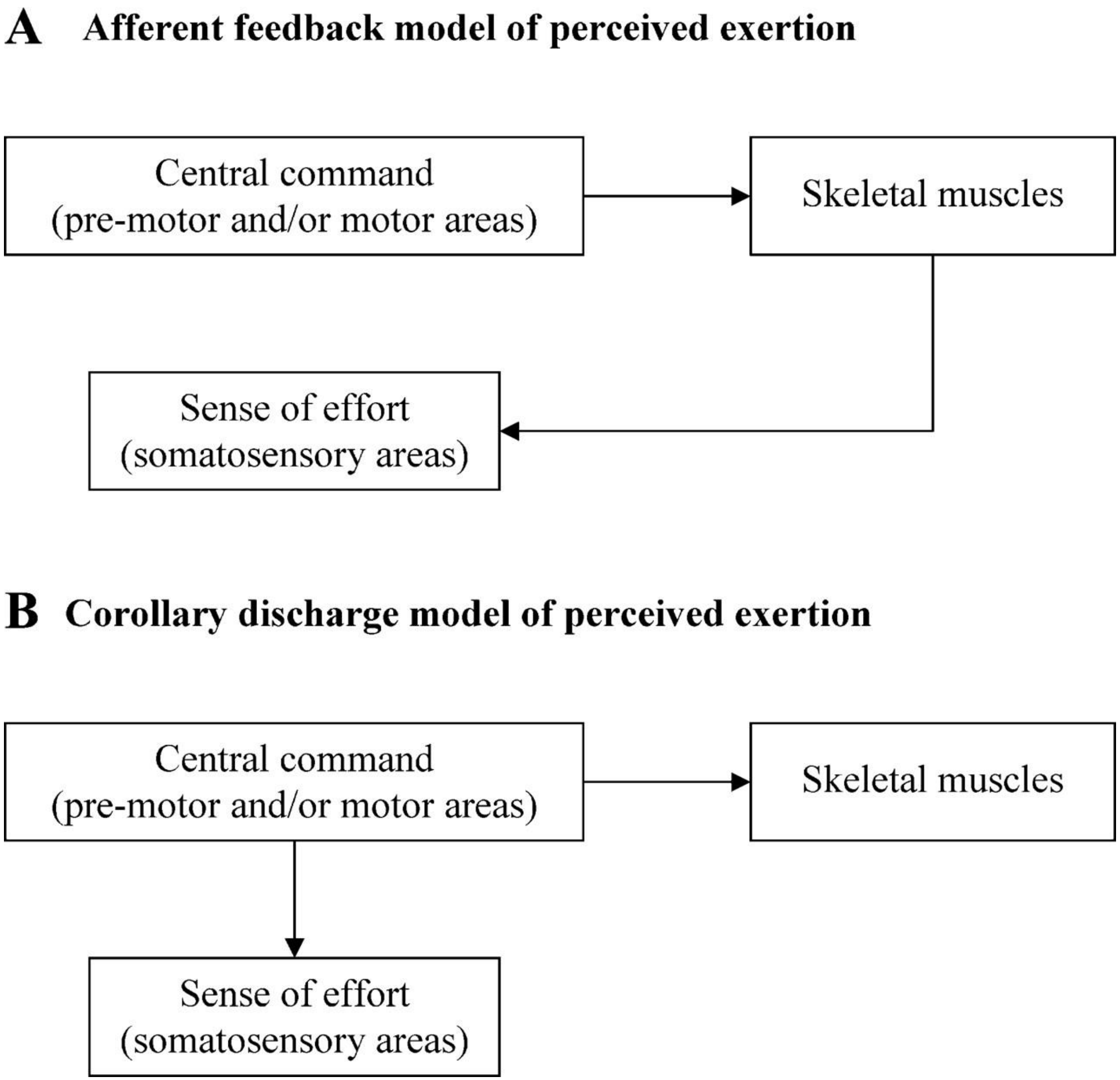
Mental Fatigue and Perception of Effort



(Marcora et al. JAP 2009)

Biological Level

Neurophysiology of Perception of Effort



(Marcora. JAP 2009)

Afferent Feedback Model of Perceived Effort

Table I. Sources of afferent information that may alter ratings of perceived exertion

Cardiopulmonary	Peripheral/metabolic
Heart rate	Blood lactate level
Oxygen uptake	Blood and/or muscle pH
Respiratory rate	Mechanical strain
Ventilatory rate	Muscle damage
	Core temperature
	Carbohydrate availability
	Skin temperature

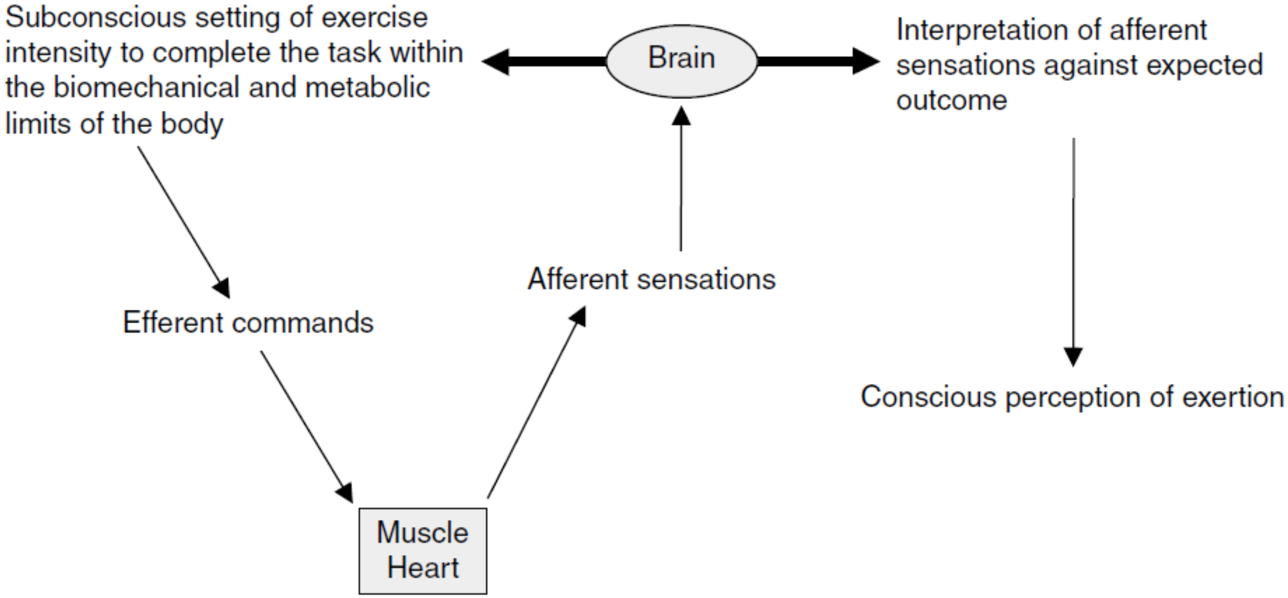
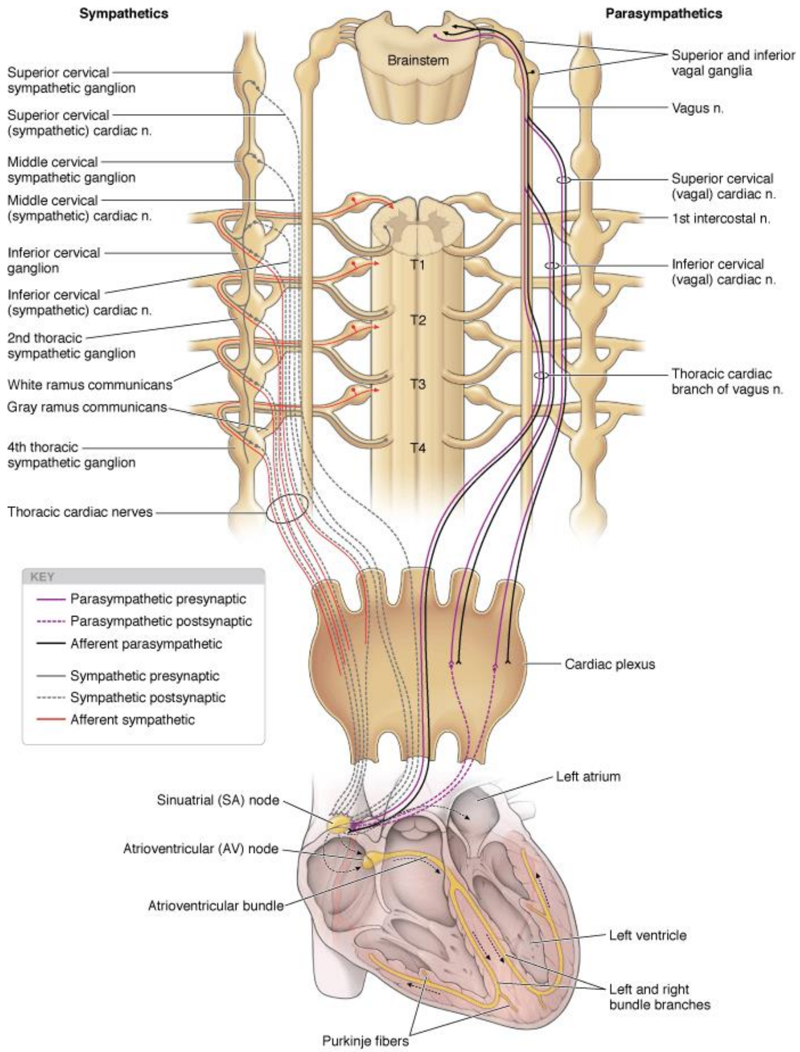


Fig. 1. Teleoanticipation and perceived exertion. A precise regulation of exercise performance may be achieved through a process of teleoanticipation. The perception of exertion results from the interpretation of afferent sensations against an expected outcome.

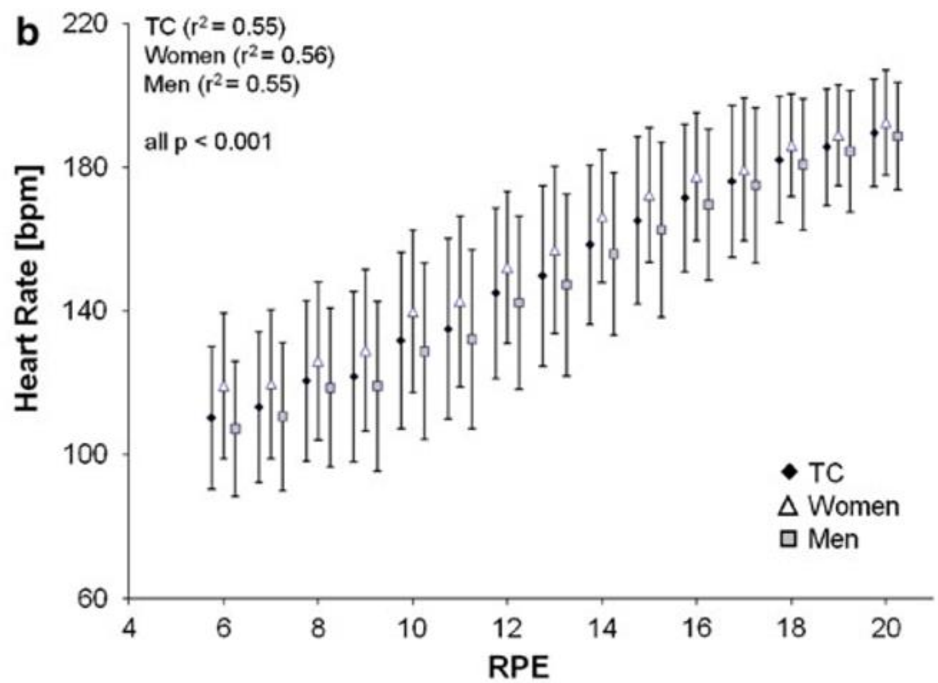
(Hampson et al., 2001)

Cardiopulmonary Sources of Afferent Feedback



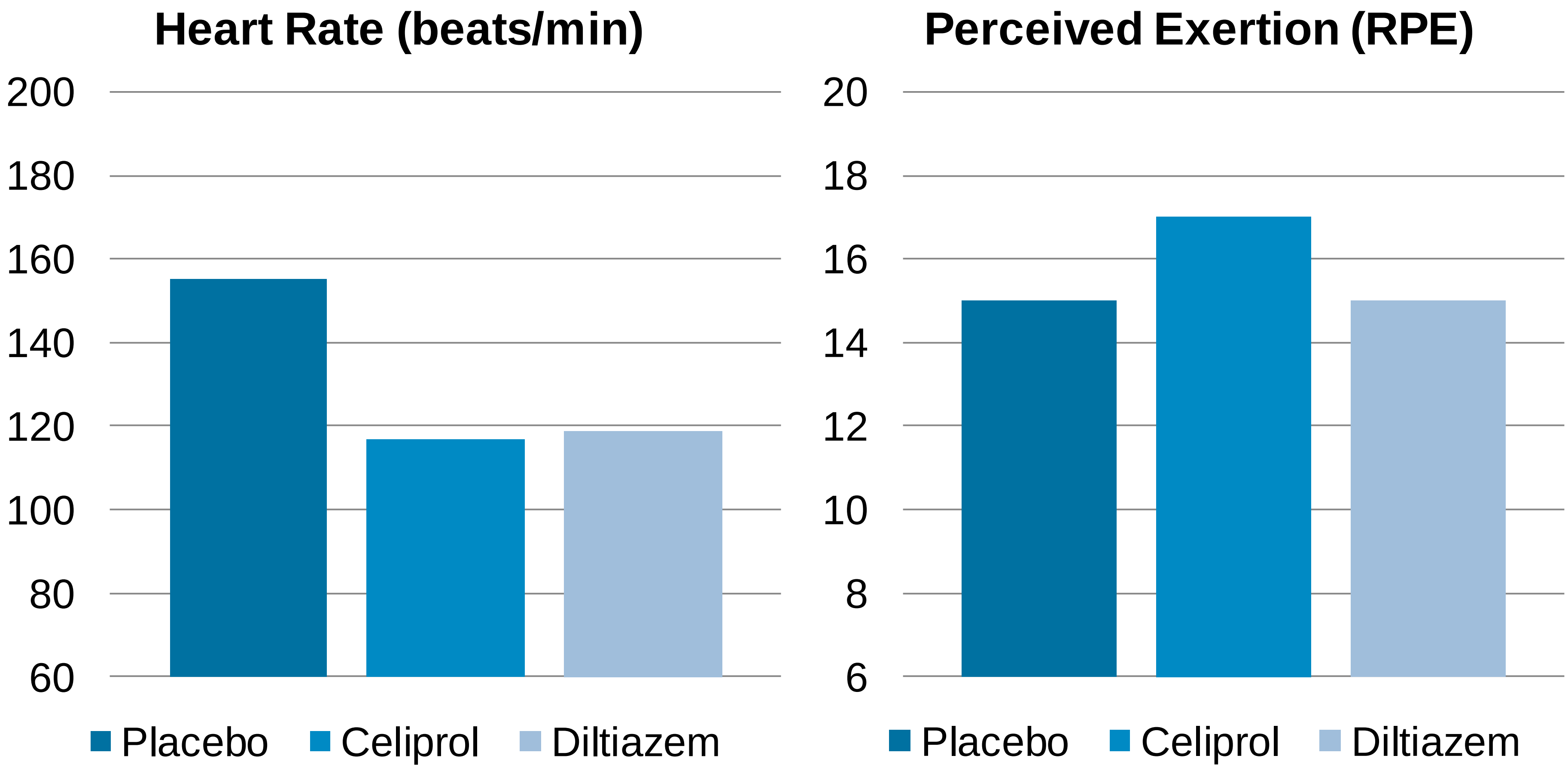
Source: Morton DA, Foreman KB, Albertine KH: *The Big Picture: Gross Anatomy:* www.accessmedicine.com

RPE and heart rate during incremental exercise tests in 2,560 Men and Women



(Scherr et al., 2013)

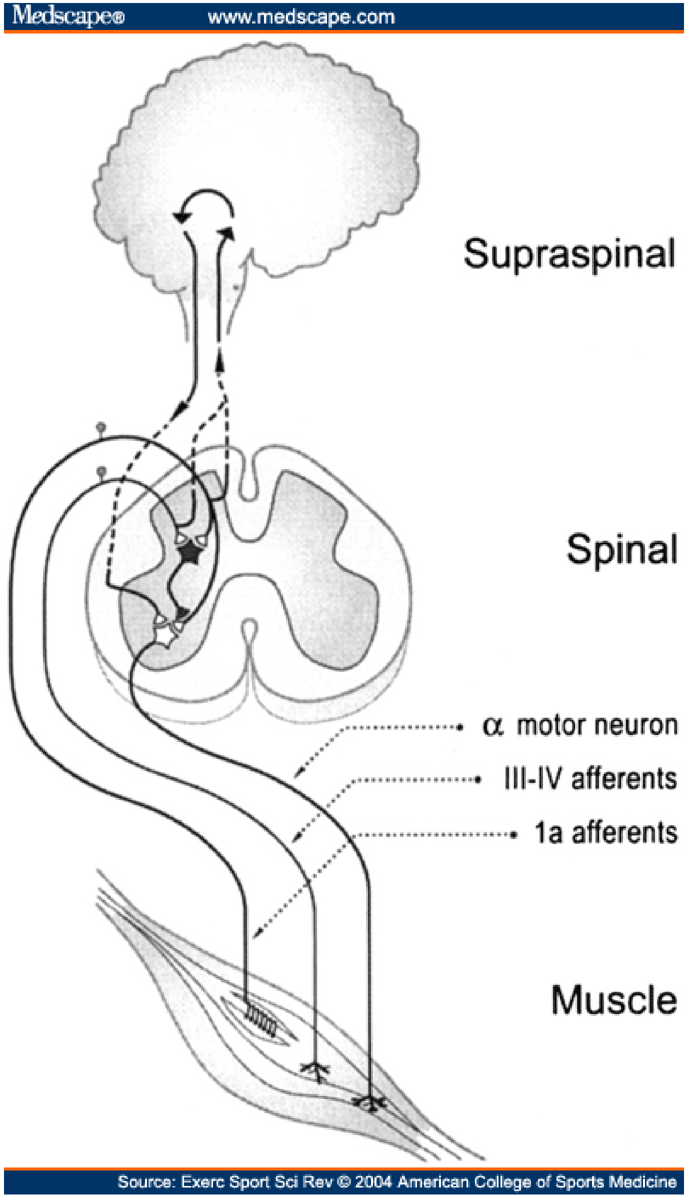
Cardiopulmonary Sources of Afferent Feedback



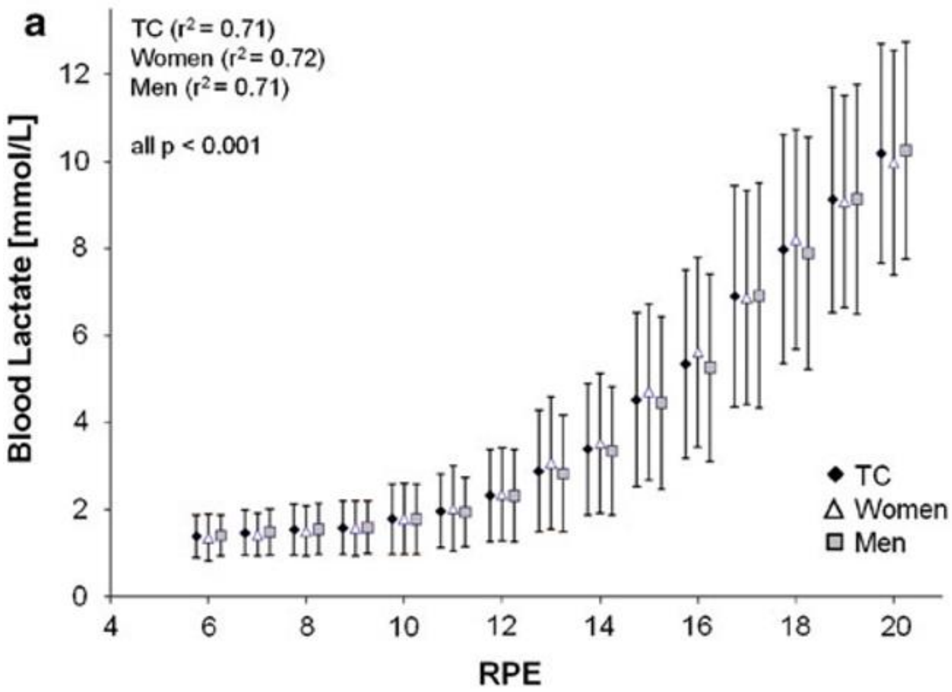
Nine men with chronic atrial fibrillation during treadmill exercise testing

(Myers et al., 1987)

Peripheral/Metabolic Sources of Afferent Feedback



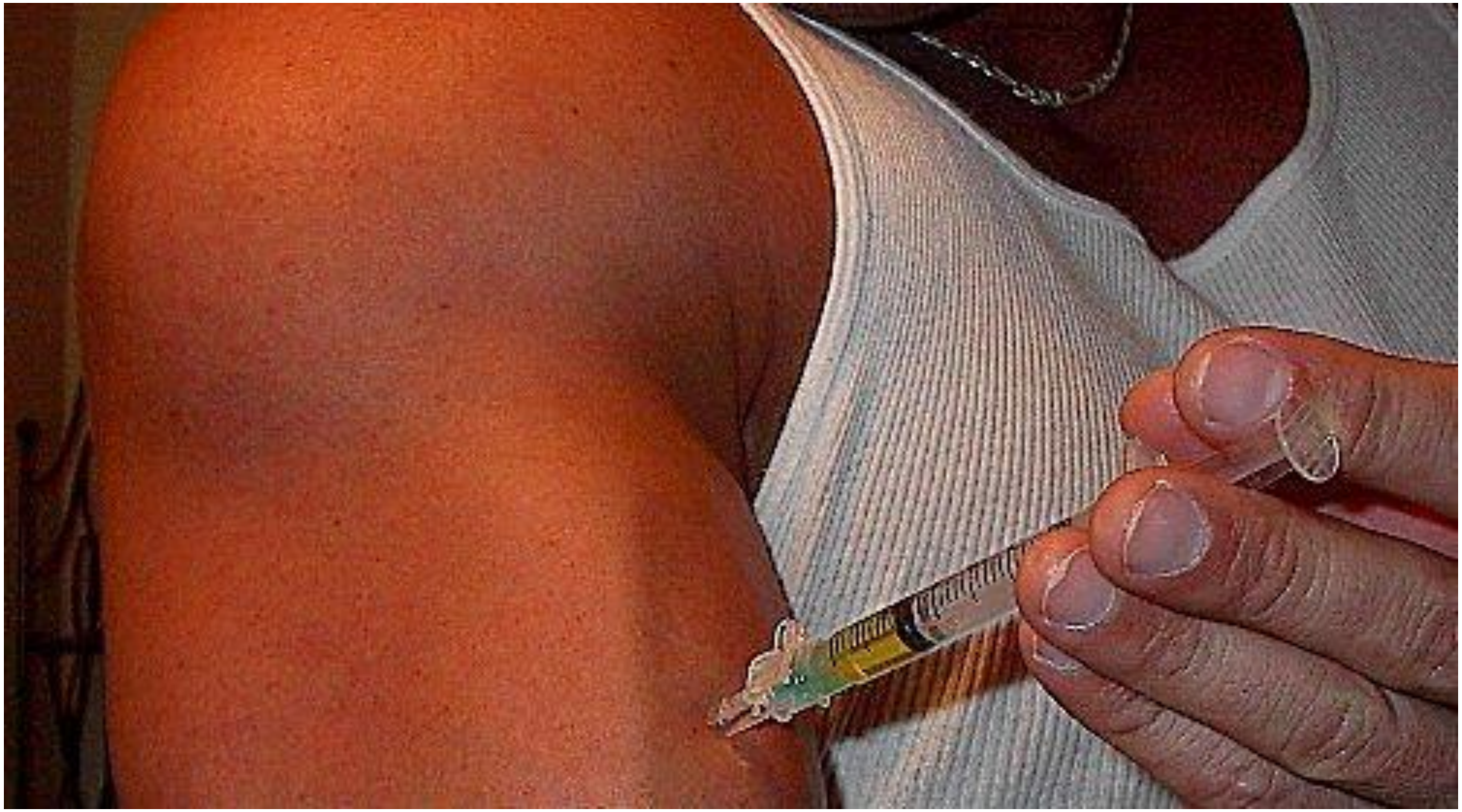
RPE and blood lactate during incremental exercise tests in 2,560 Men and Women



(Scherr et al., 2013)

Peripheral/Metabolic Sources of Afferent Feedback

Experimental Muscle Pain



(Khan et al., 2011)

Peripheral/Metabolic Sources of Afferent Feedback

Isometric Contractions of Elbow Flexors

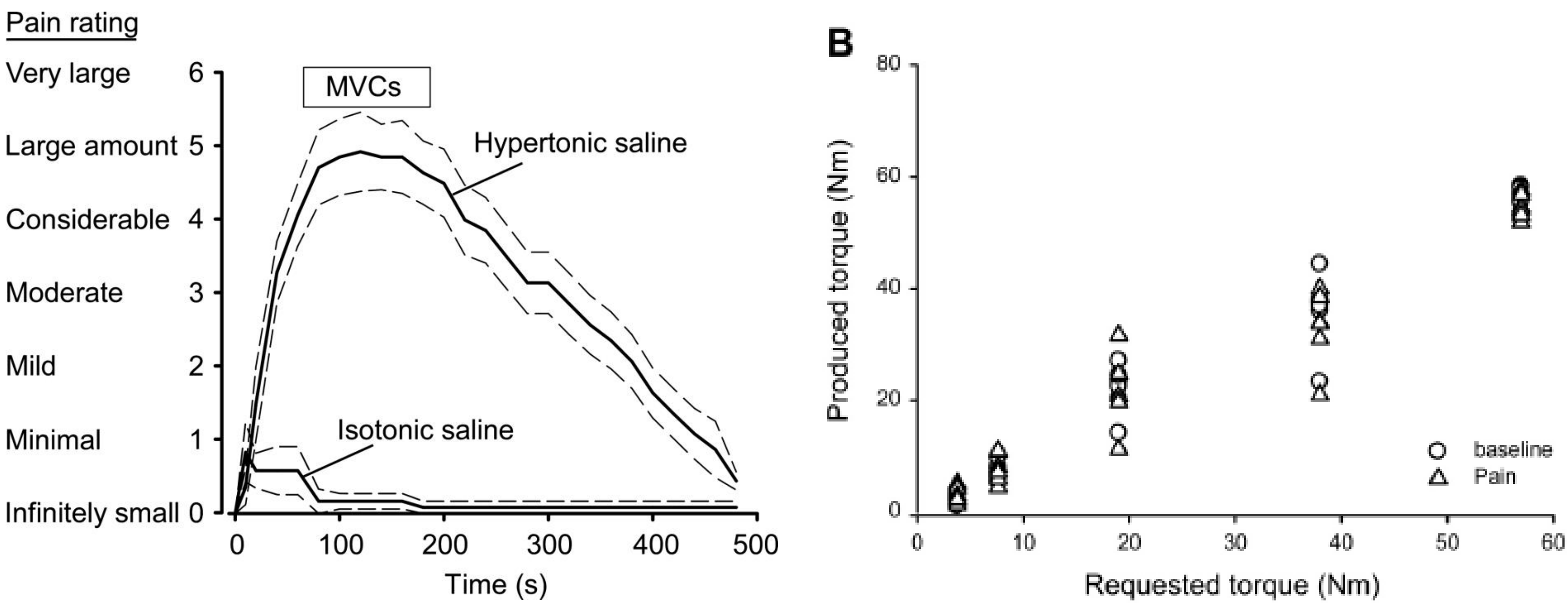
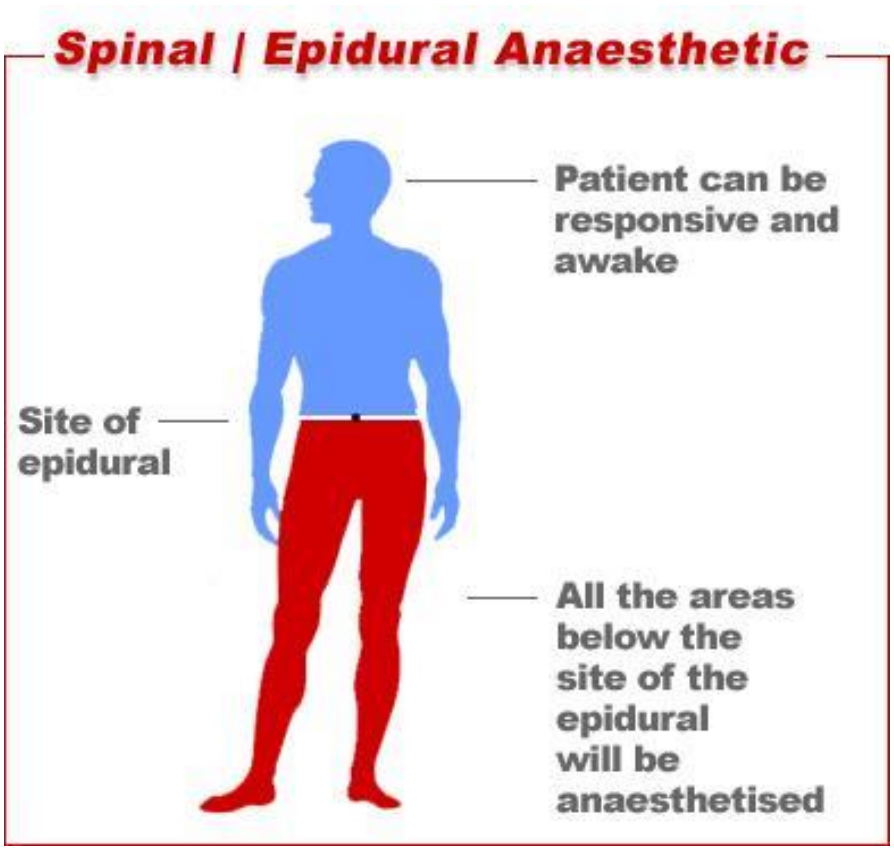


Figure B. Subjects instructed to “pull up with 5%, 10%, 25%, 50%, or 75% of your maximal effort” (RPE Production Method)

(Khan et al., 2011)

Afferent Feedback and Perception of Effort

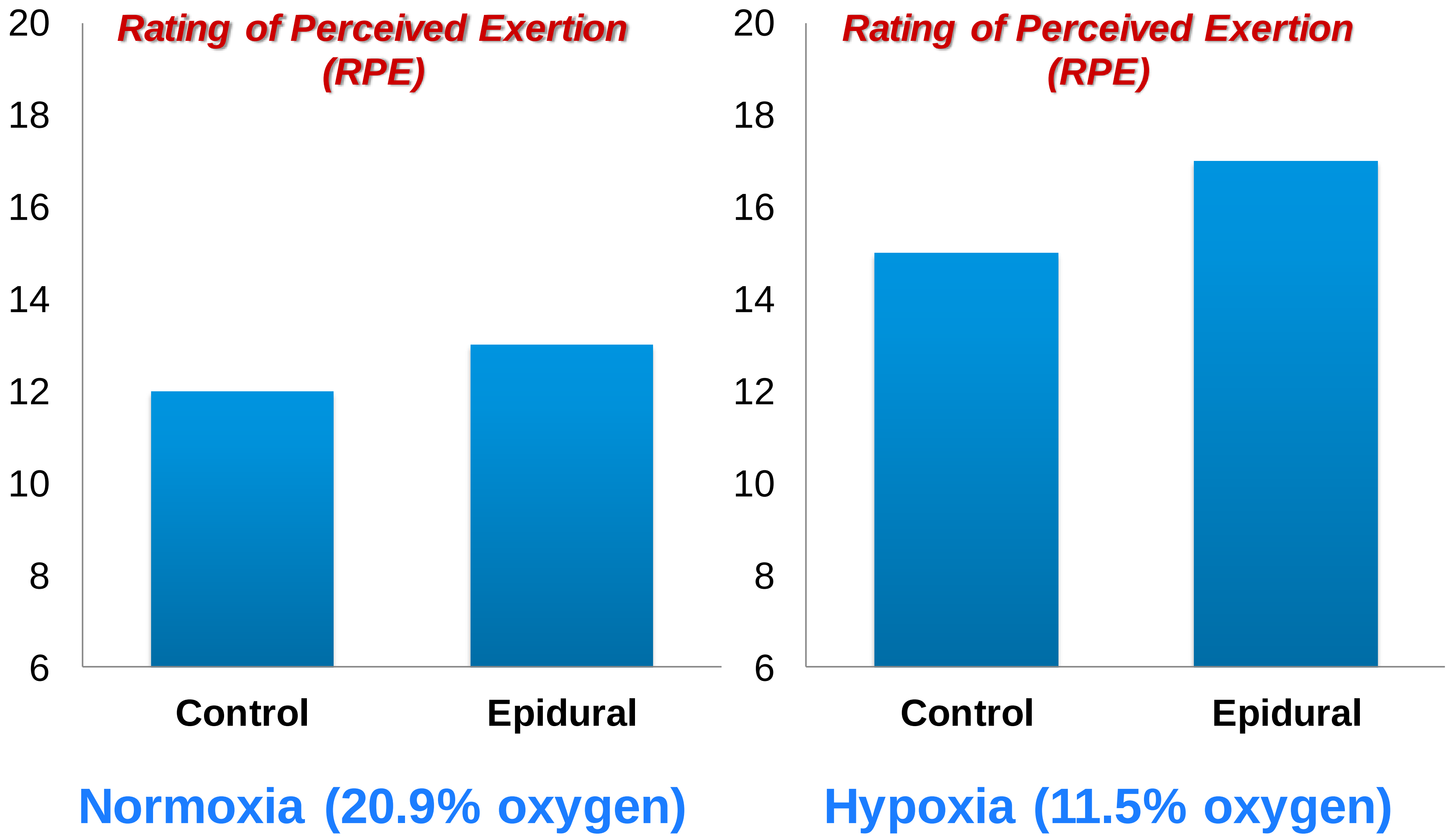


Epidural anaesthesia at lumbar level

Cycling exercise for 20 min at 46% VO2max

(Kjaer et al. 1999)

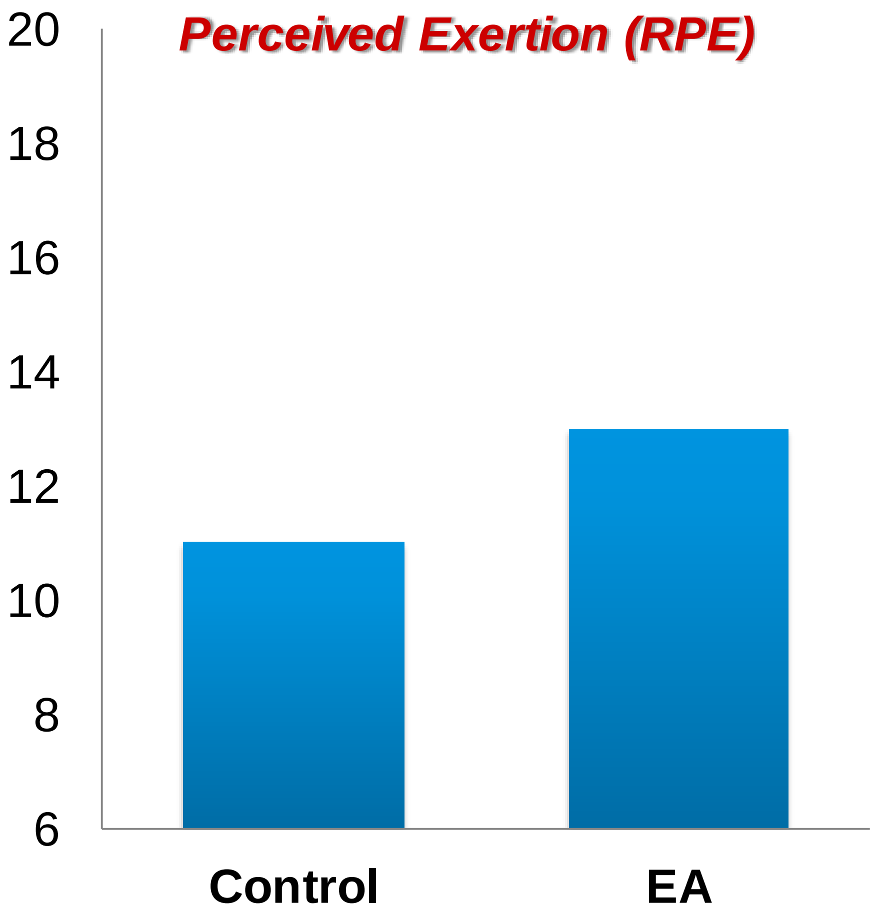
Afferent Feedback and Perception of Effort



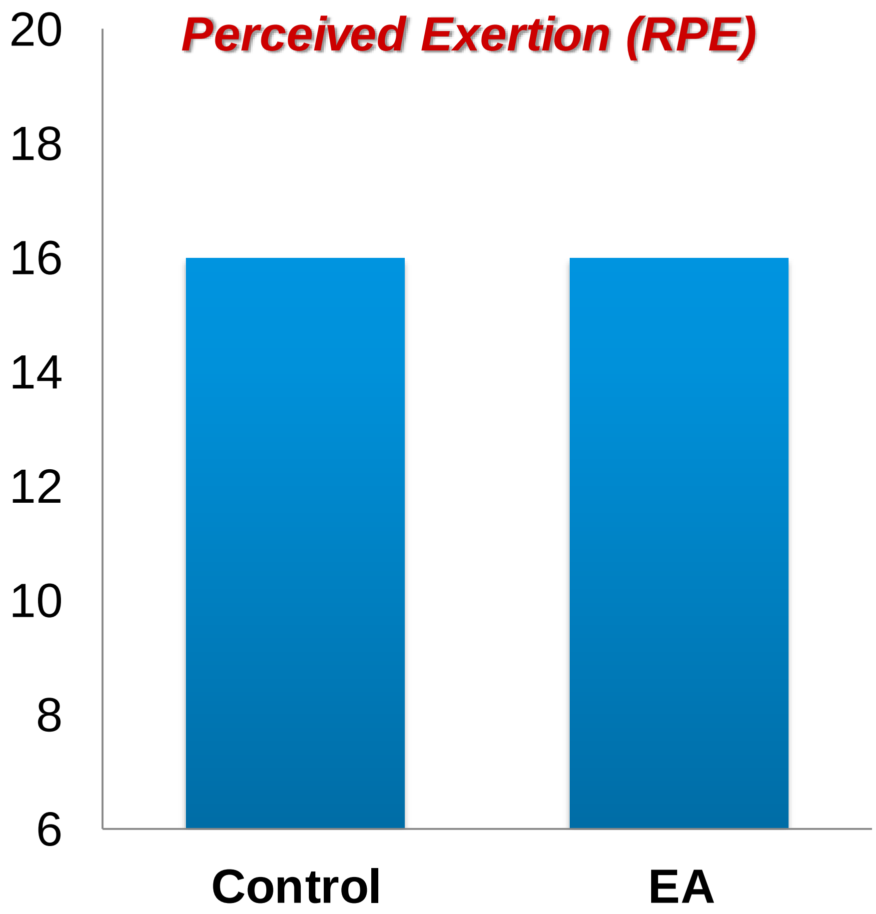
(Kjaer et al. 1999)

Peripheral/Metabolic Sources of Afferent Feedback

5 min of isometric one leg extension at same absolute force (10% of initial MVC = 21 ± 2 Nm)

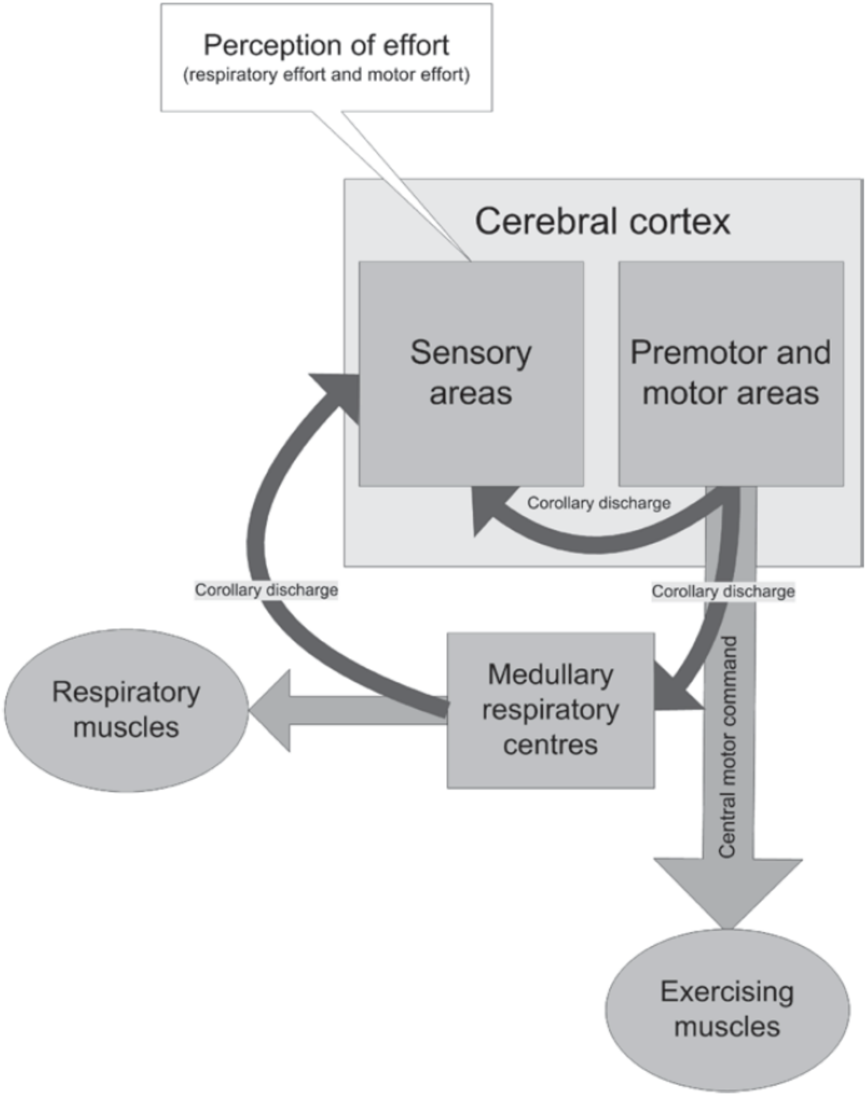


2 min of isometric one leg extension at same relative force (30% of current MVC)



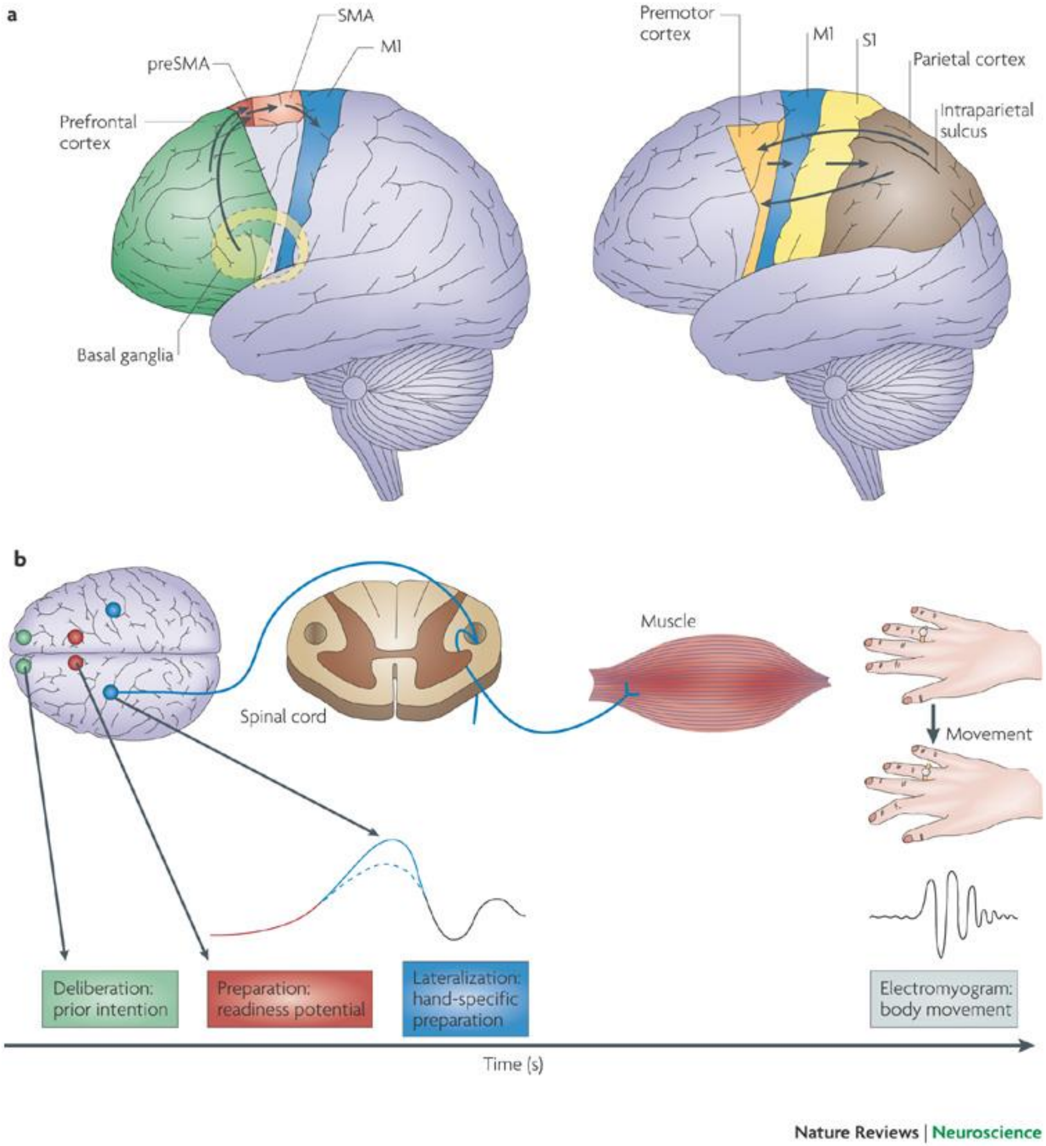
Mitchell et al. (1989)

Corollary Discharge Model of Perceived Effort

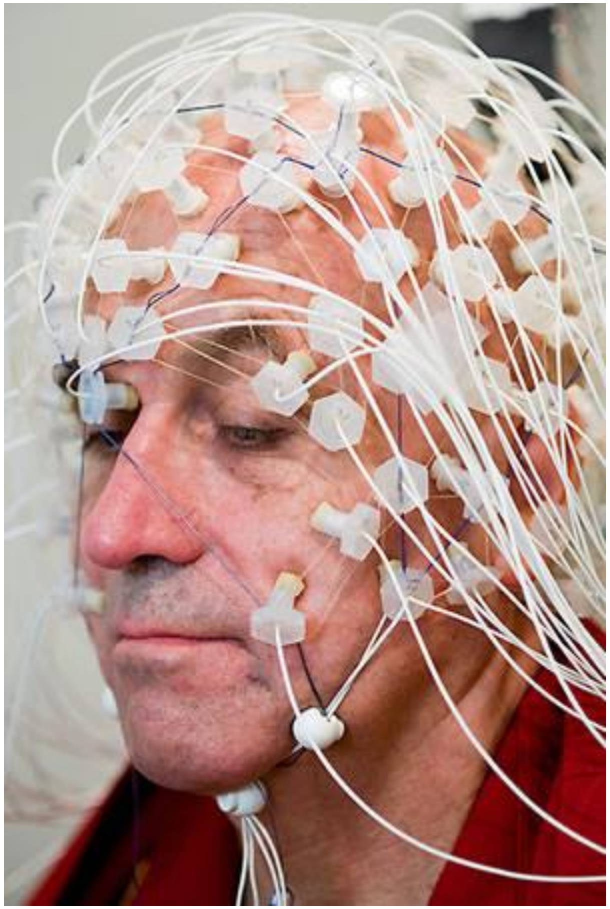


(de Morree and Marcora, 2015)

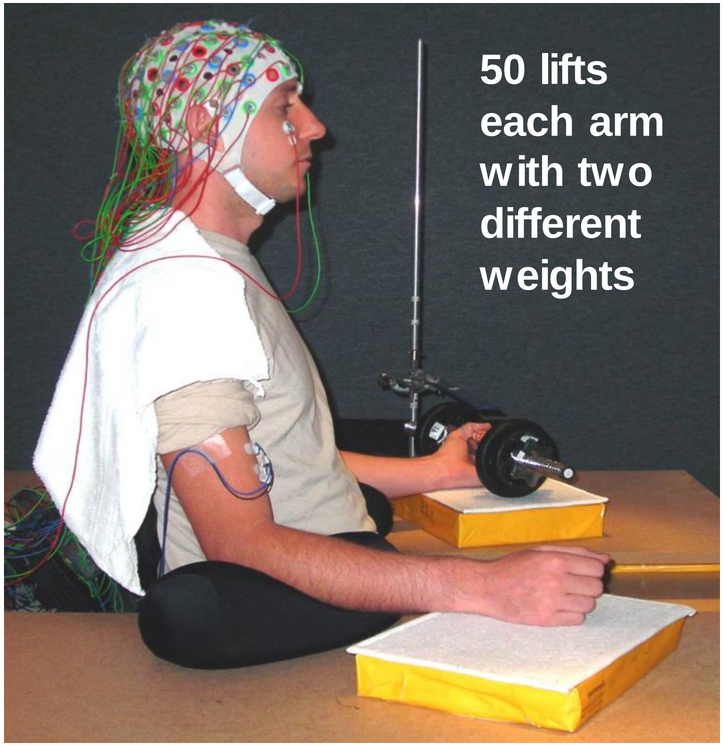
Motor-Related Cortical Potentials

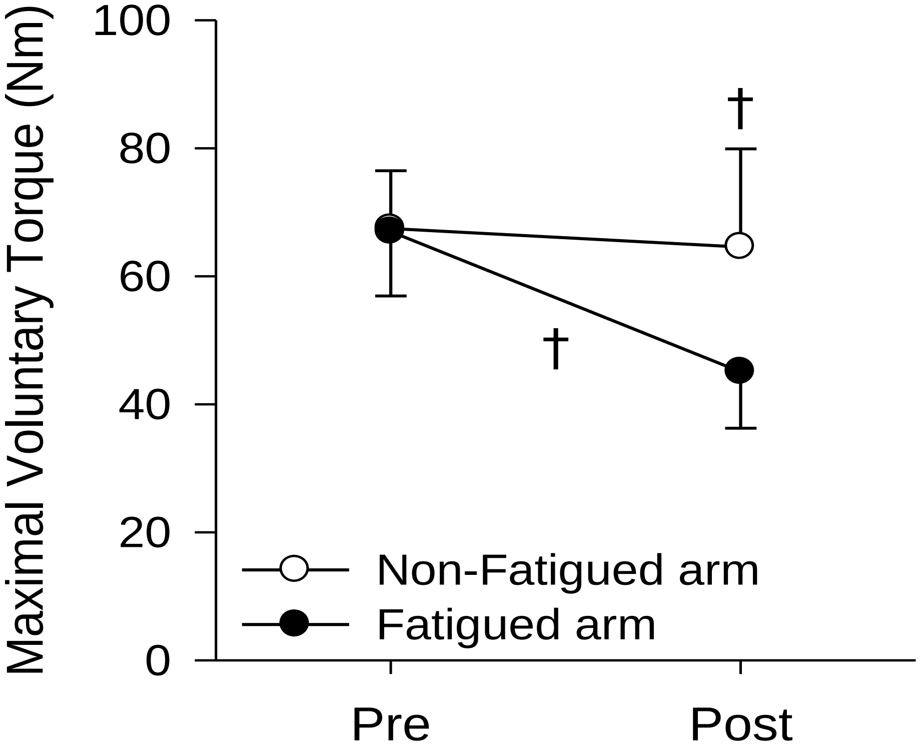


Electroencephalography (EEG)



Central Command and Perception of Effort

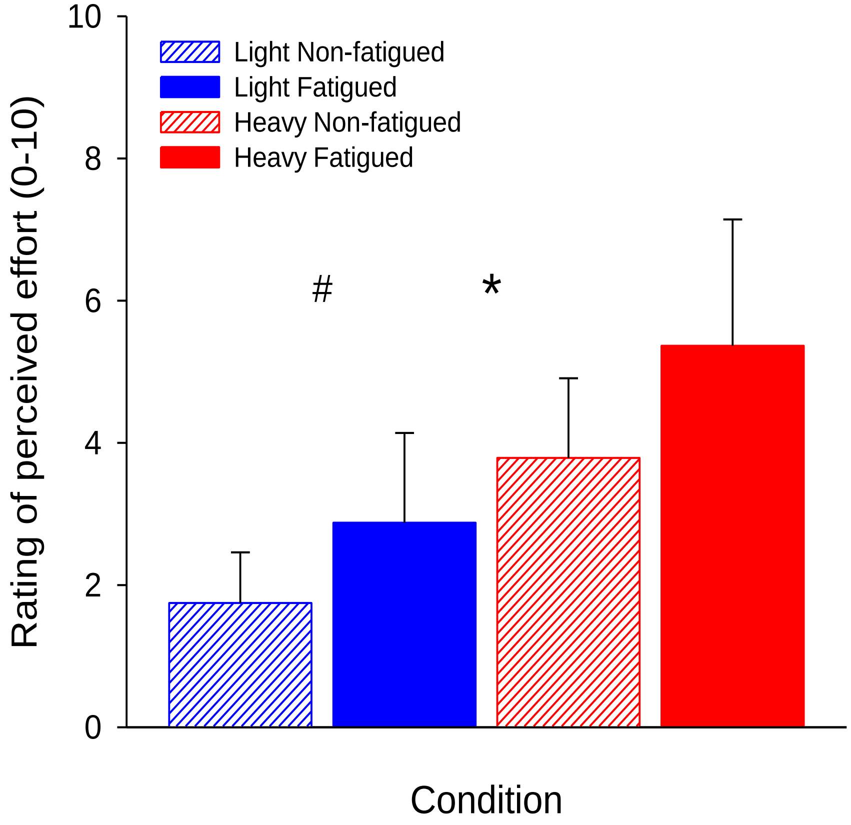




Left. Experimental set-up. *Right.* Strength loss after fatiguing protocol. † significant paired difference.

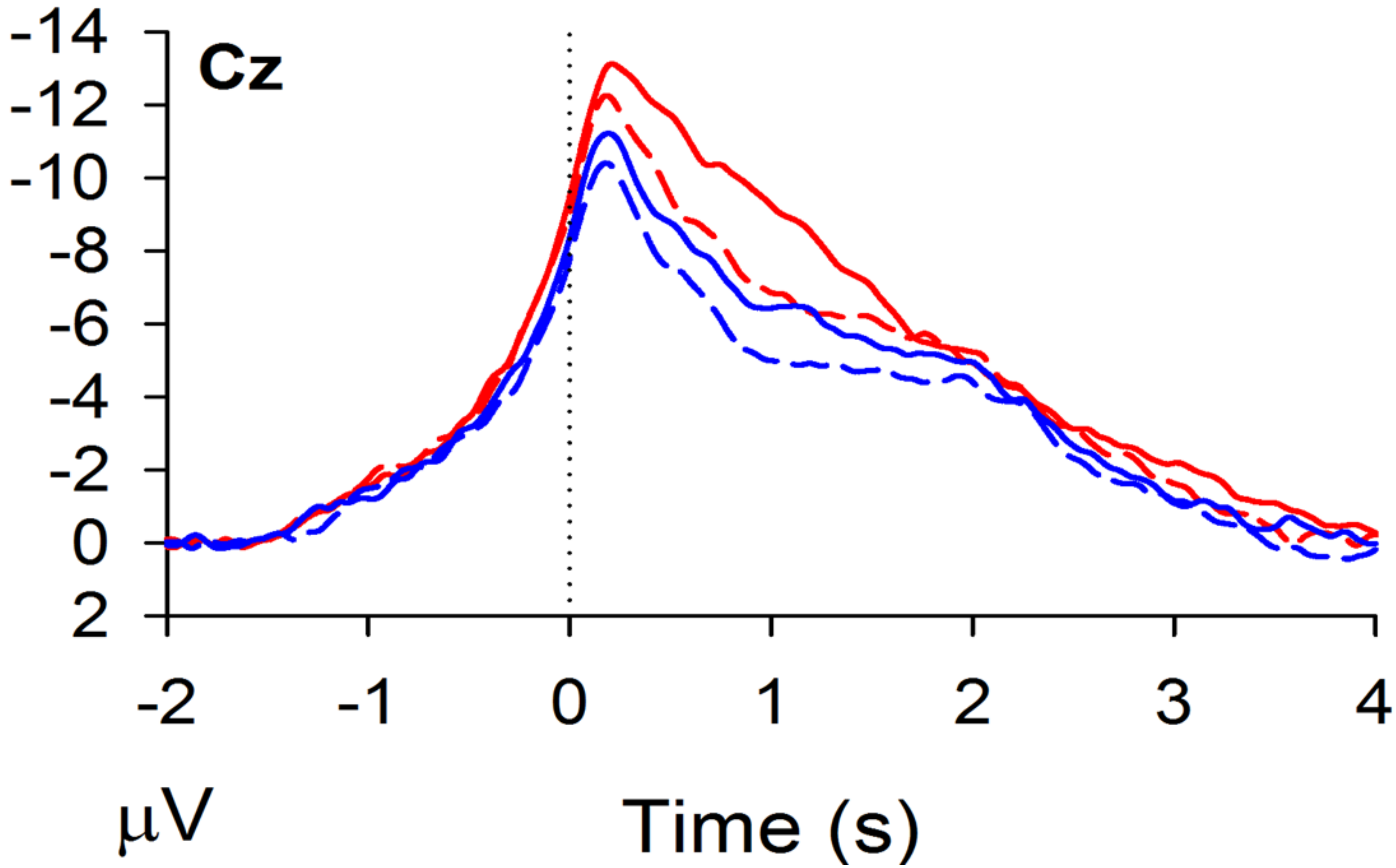
De Morree et al. Psychophysiology 2012; 49(9): 1242-1253

Central Command and Perception of Effort



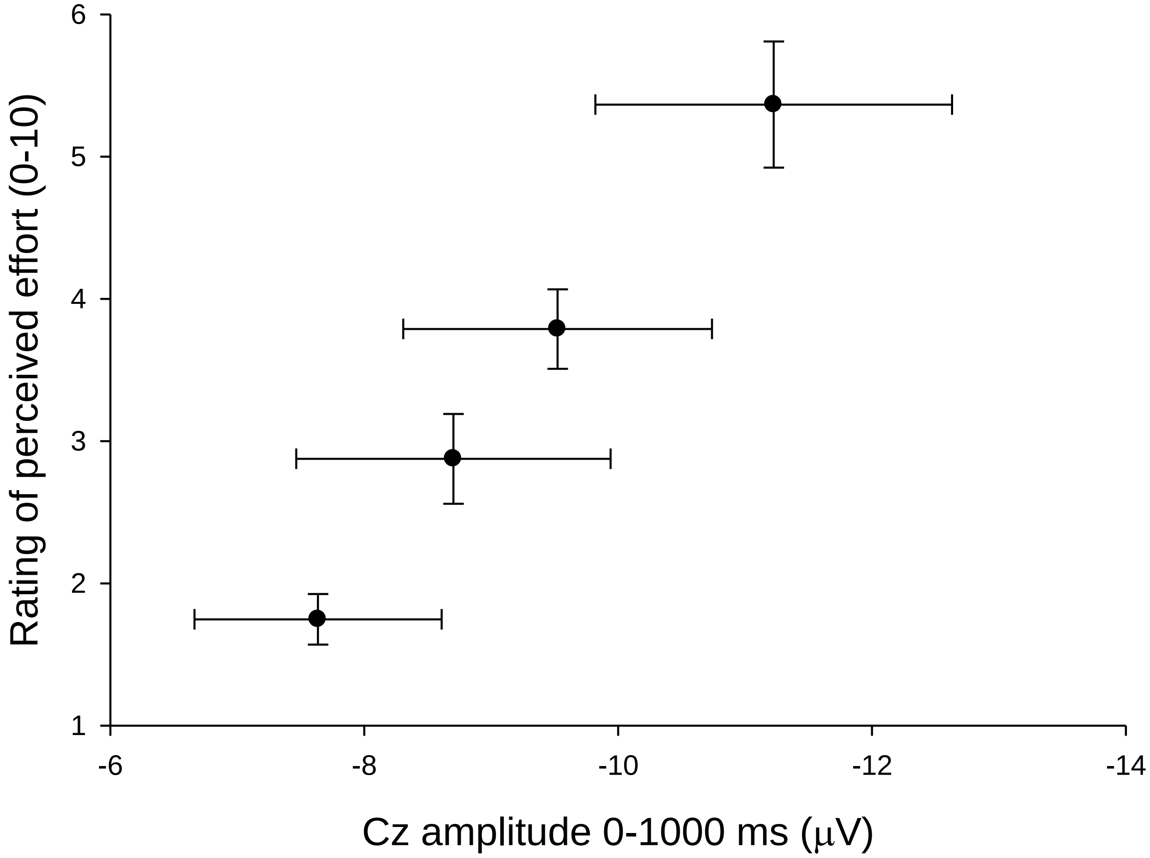
Rating of perceived effort for all four weightlifting conditions. Data are presented as means ± standard deviations. # Significant main effect of fatigue ($p < 0.001$), * significant main effect of weight ($p < 0.001$).

Central Command and Perception of Effort



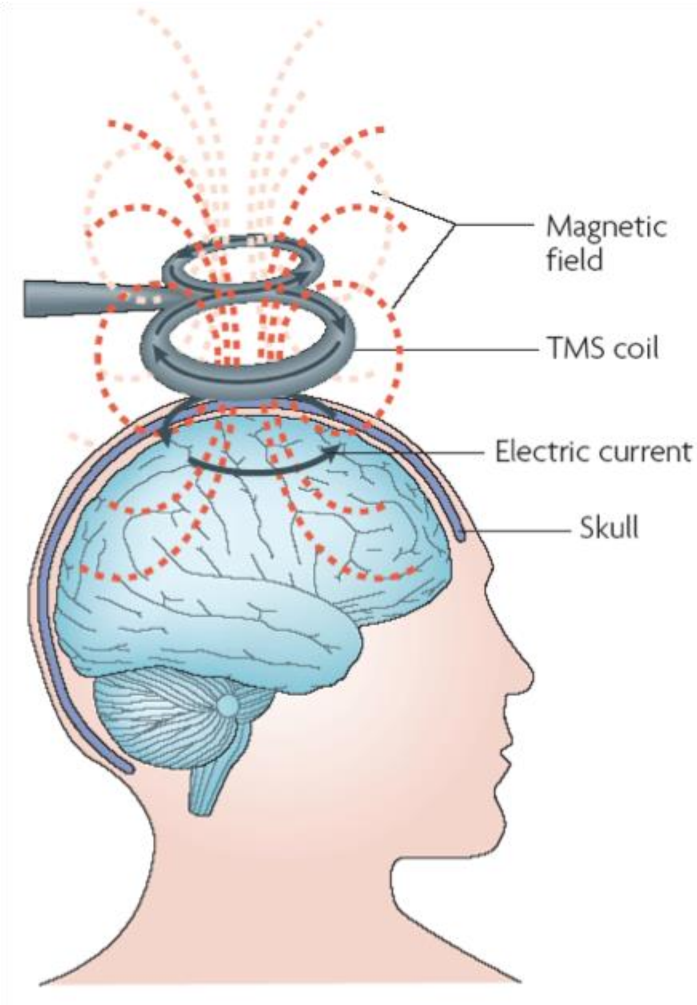
Movement-related cortical potentials at five electrodes for the four weightlifting conditions over time. $_{contra}$ is contralateral to the movement and $_{ipsi}$ is ipsilateral to the movement. Time 0 s is EMG onset.

Central Command and Perception of Effort



Within-subject correlation between rating of perceived effort and average Cz amplitude during the first 1000 ms of movement. Each data point represents the means ± standard errors for one of the four conditions. The correlation coefficient was $r_{(14)}$ = -0.64 (p < 0.001).

Disrupting the Supplementary Motor Area Makes Physical Effort Appear Less Effortful



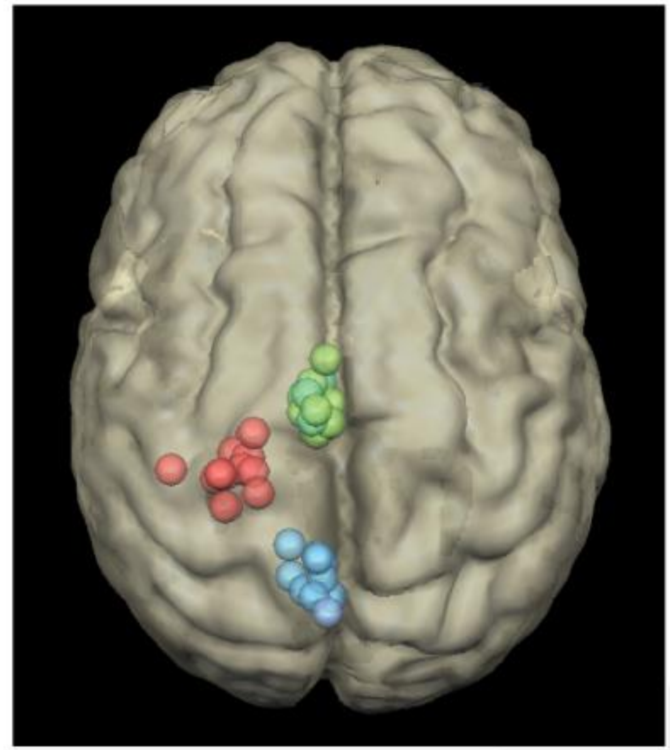


Figure 2. Localization of the cTBS sites in the 12 participants for the SMA (green), M1 (red), and control (blue) conditions. These coordinates were obtained by projecting the stimulation sites onto the individual brain MRI of each participant, which was then normalized into the Talairach space.

Zenon et al. The Journal of Neuroscience. 2015, 35(23): 8737-8744.

Disrupting the Supplementary Motor Area Makes Physical Effort Appear Less Effortful

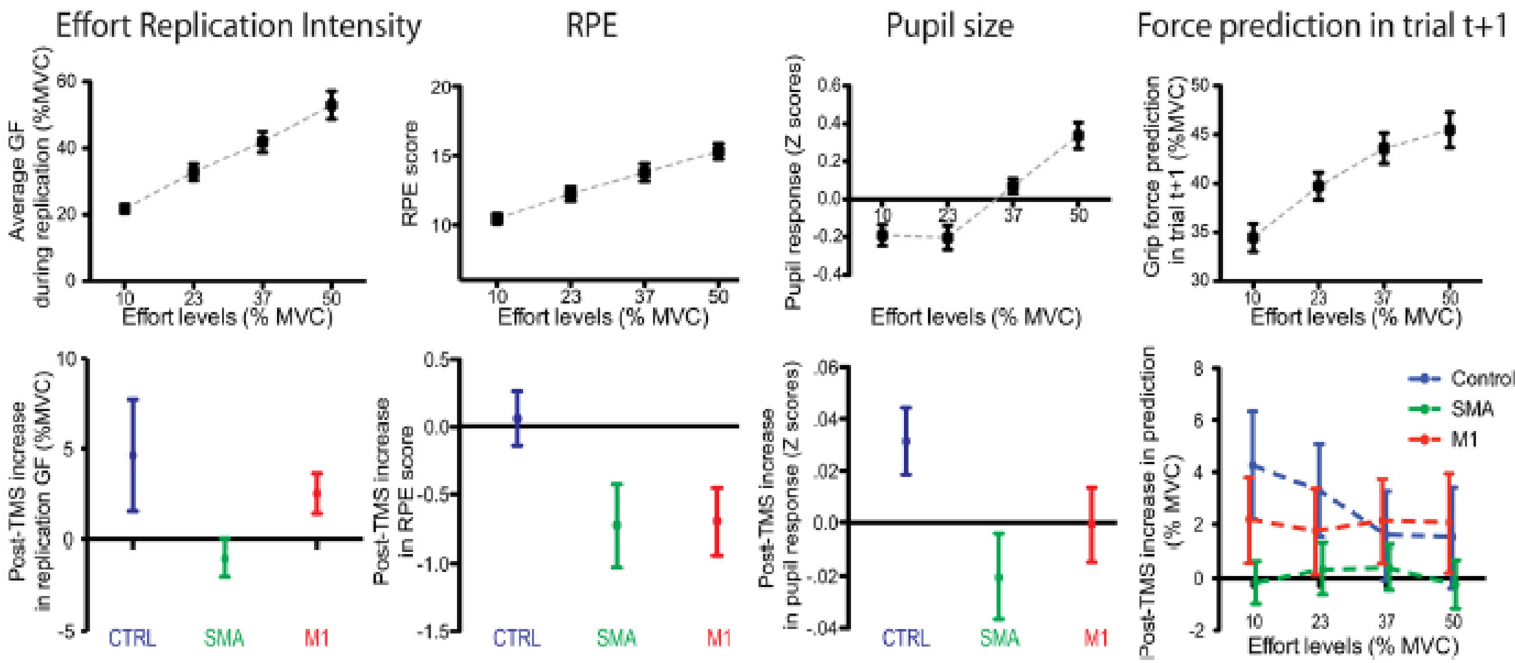
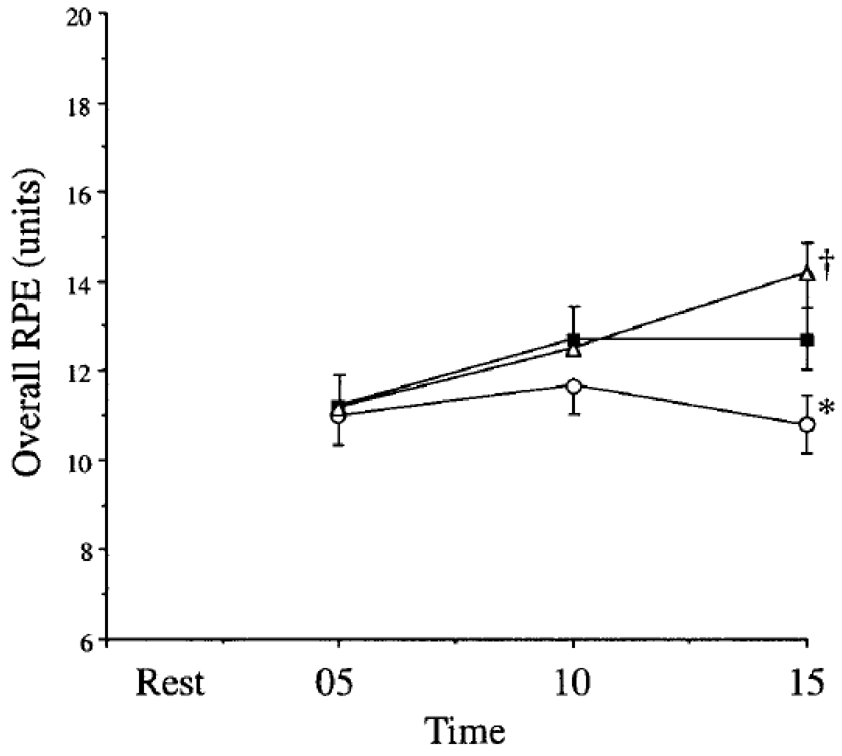


Figure 3. Continuous measurements of effort perception. Each column corresponds to a different effort perception variable. Error bars indicate the SEM. Top row, Relationship between each variable and the effort intensity condition. Bottom row, Changes observed in the four continuous variables after cTBS application to each of the three cTBS sites. Main effects of cTBS sites are illustrated for all variables except the force prediction in trial t + 1, in which the EFFORT INTENSITY × cTBS SITE interaction is shown instead, because this was the only significant result obtained from the statistical analysis.

Handgrip Exercise

Zenon et al. The Journal of Neuroscience. 2015, 35(23): 8737-8744.

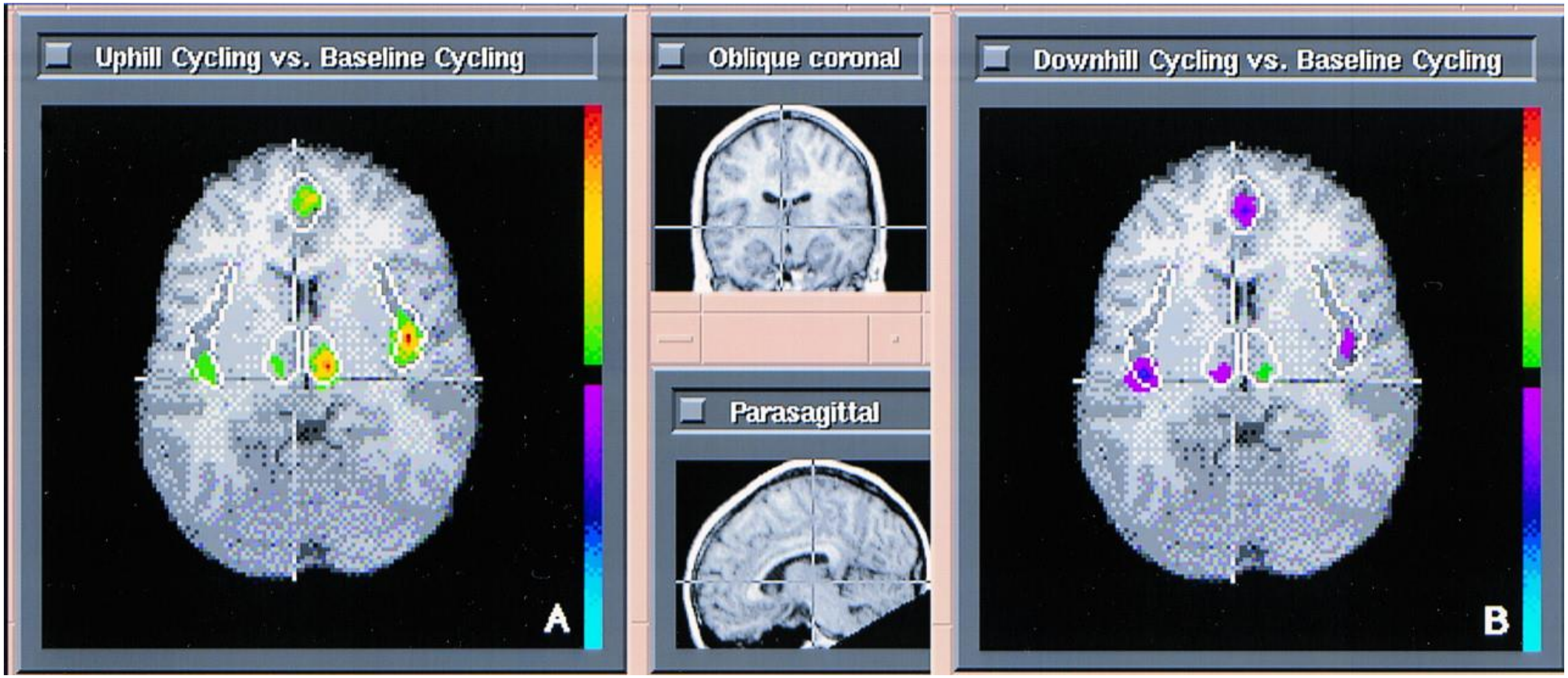
Anterior Cingulate Cortex (ACC)



Rating of Perceived Exertion (RPE) during perceived uphill and downhill cycling at a constant workload

J. W. Williamson et al. J Appl Physiol 2001;90:1392-1399

Anterior Cingulate Cortex (ACC)



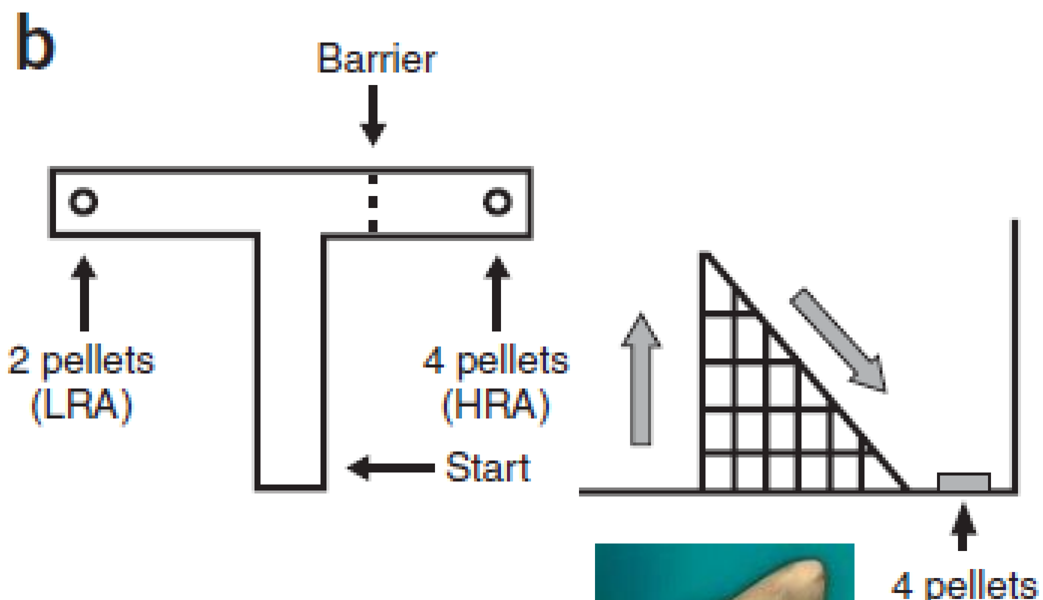
Coregistered single-positron-emission computed tomography and magnetic resonance imaging data during perceived uphill and downhill cycling at a constant workload

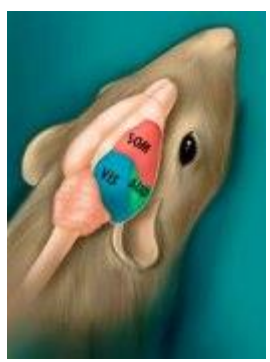
J. W. Williamson et al. J Appl Physiol 2001;90:1392-1399

Separate neural pathways process different decision costs

Peter H Rudebeck, Mark E Walton, Angharad N Smyth, David M Bannerman & Matthew F S Rushworth

NATURE NEUROSCIENCE VOLUME 9 | NUMBER 9 | SEPTEMBER 2006





Anterior cingulate cortex (ACC) lesions affect how much effort rats decided to invest for rewards **("lazy rats").**

Novel Interventions to Facilitate Physical Activity Behaviour

Investments that Work for Physical Activity

- ‘Whole-of-**school’ programs**
- **Transport policies and systems** that prioritise walking, cycling and public transport
- **Urban design regulations and infrastructure** that provides for equitable and safe access for recreational physical activity, and recreational and transport-related walking and cycling across the life course
- Physical activity and NCD prevention integrated into **primary health care systems**
- **Public education**, including mass media to raise awareness and change social norms on physical activity
- **Community-wide programs** involving multiple settings and sectors and that mobilize and integrate community engagement and resources
- **Sports systems and programs** that promote ‘sport for all’ and encourage participation across the life span

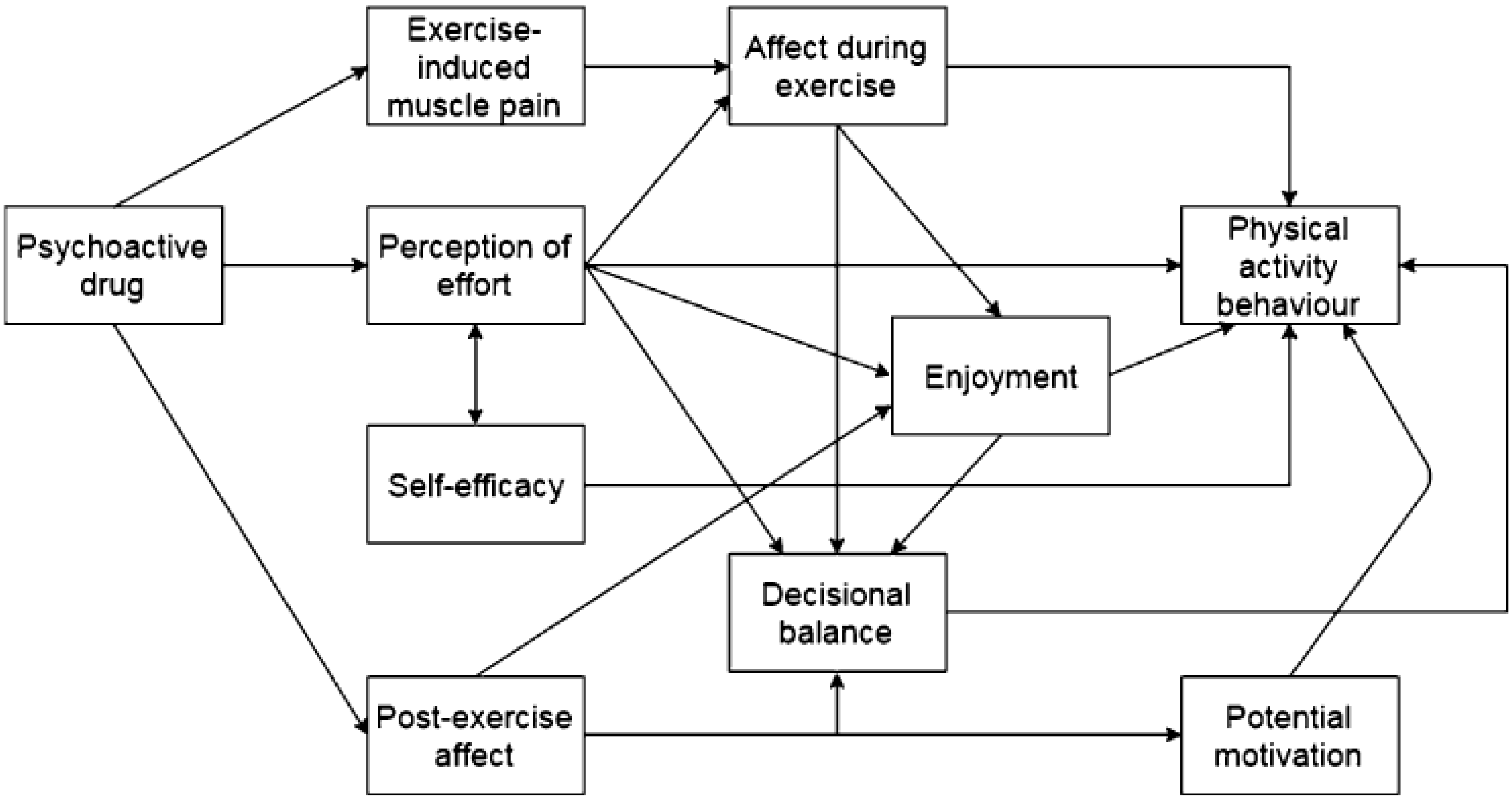
(Toronto Charter for Physical Activity, 2010)

BCTs in intervention studies to increase self-efficacy and PA in people with obesity

- **Goal setting (behaviour)**
- **Prompt self-monitoring of behaviour**
- **Prompt practice**
- Barrier Identification/Problem solving
- Relapse prevention/coping planning
- Provide instruction on how to perform the behaviour
- **Plan social support/social change**
- Provide information on consequences of behaviour in general
- Provide information on consequences of behaviour for the individual
- **Set graded tasks**
- **Prompt review of behavioural goals**
- […]

(Olander et al., 2013)

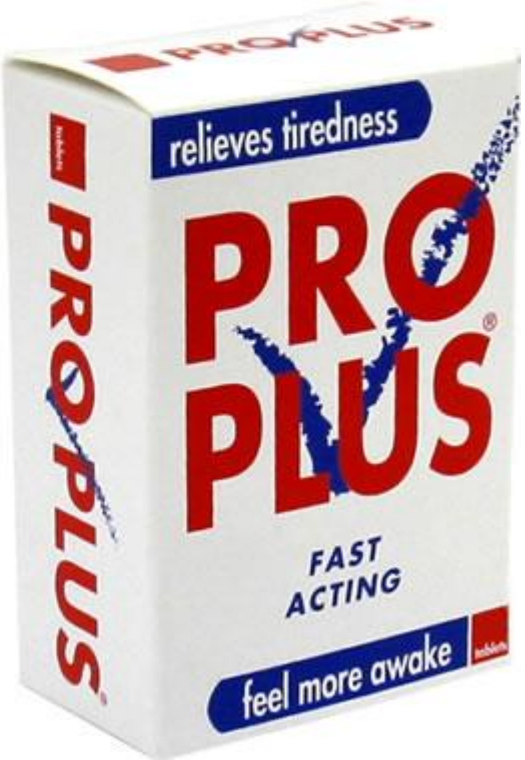
Can Doping be a Good Thing? Using Psychoactive Drugs to Facilitate Physical Activity Behaviour



(Marcora, 2016)

Pharmacotherapy as a BCT for other health behaviours

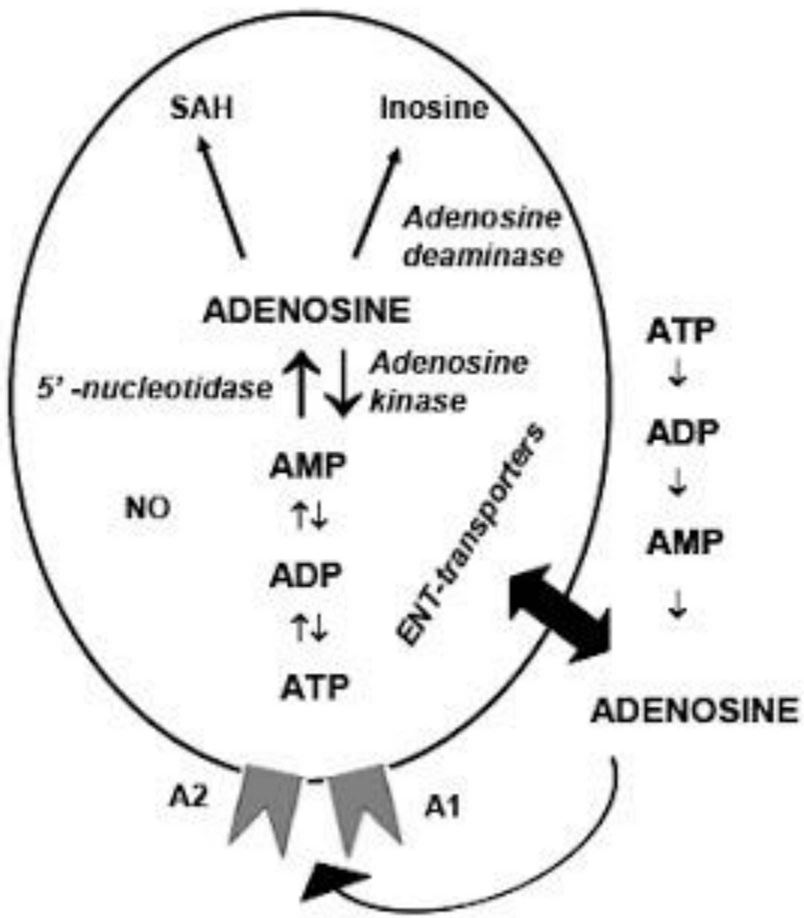
Cheap, widely available, safe and effective psychoactive drug

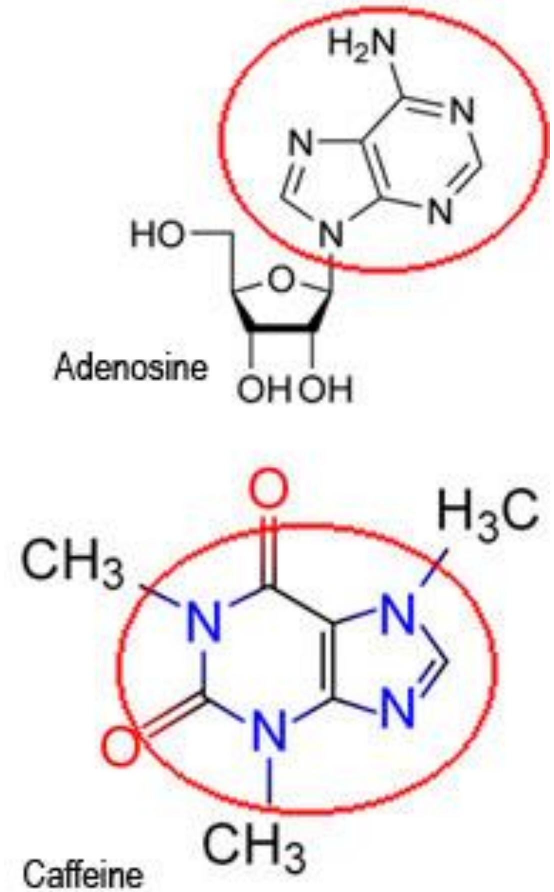


Neuronal adenosine release, and not astrocytic ATP release, mediates feedback inhibition of excitatory activity

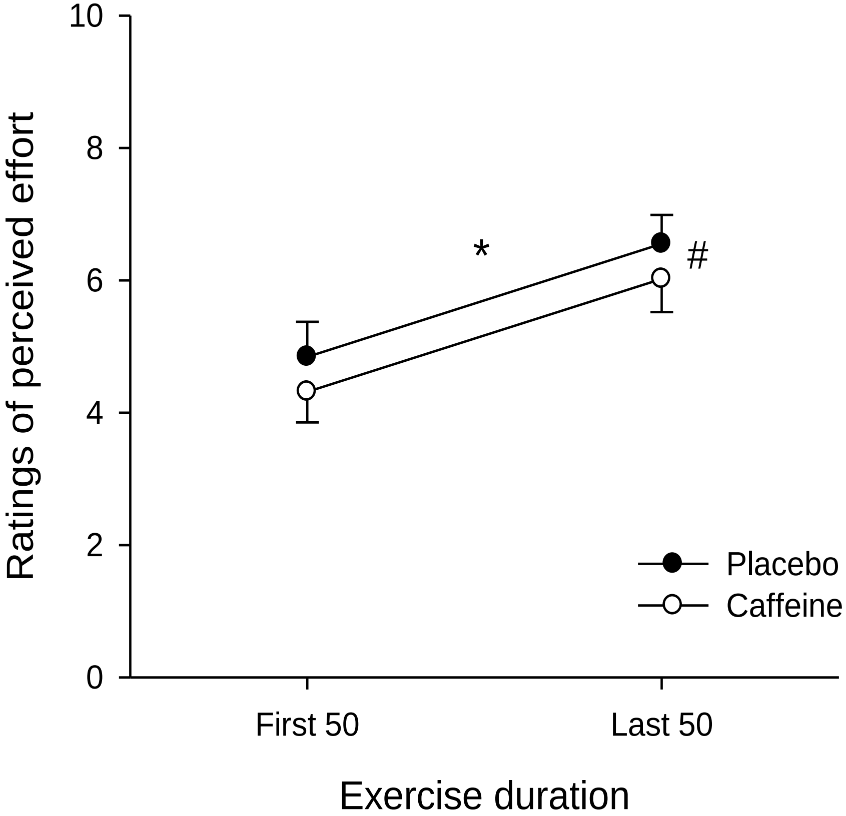
PNAS | April 17, 2012 | vol. 109 | no. 16 | 6265–6270

Ditte Lovatt[a,1,2], Qiwu Xu[a,1], Wei Liu[a,3], Takahiro Takano[a], Nathan A. Smith[a], Jurgen Schnermann[b], Kim Tieu[a], and Maiken Nedergaard[a,2]





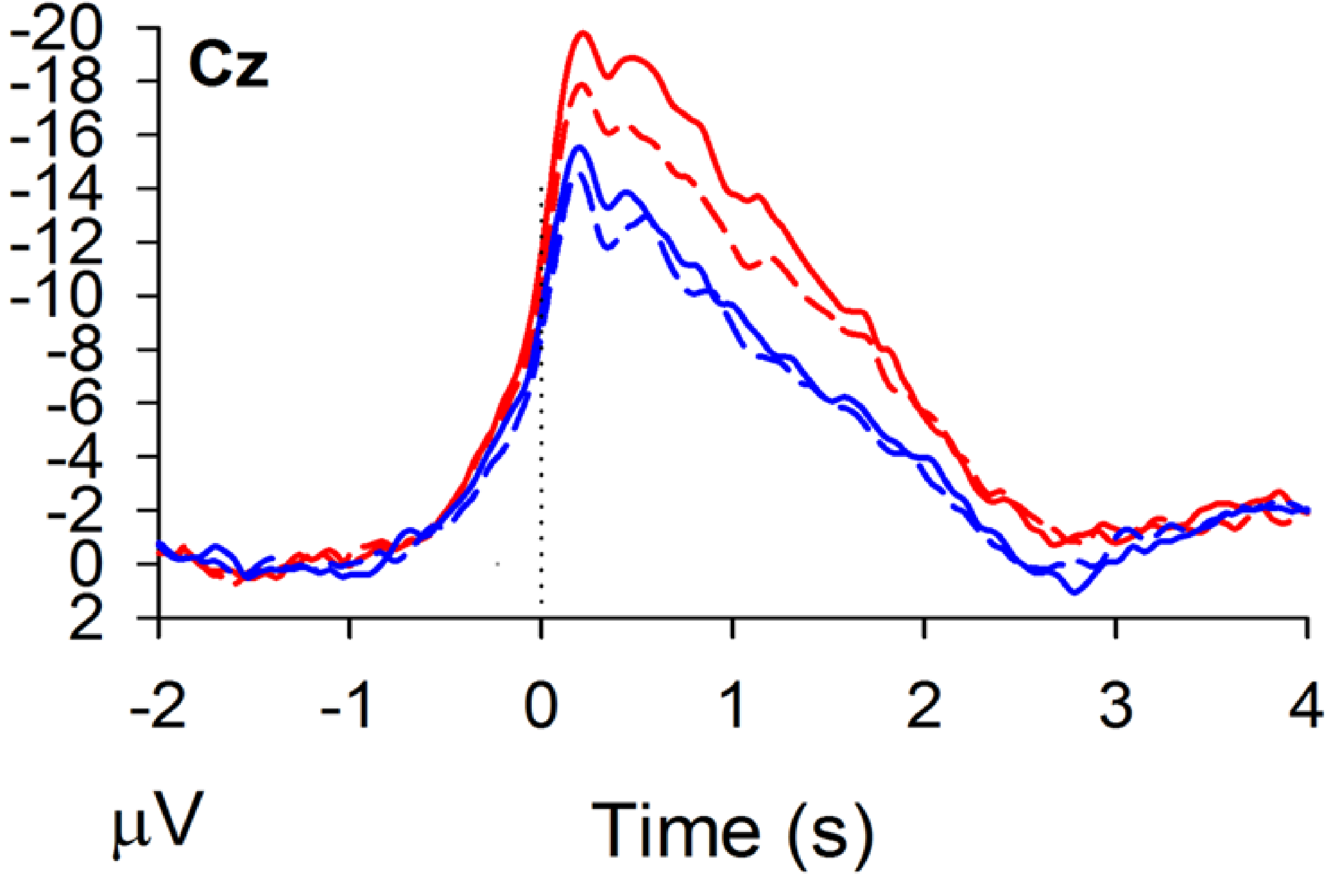
Central Command and RPE



Left. Experimental set-up. *Right.* Effects of caffeine and exercise duration on perception of effort. * Significant main effect of caffeine. # Significant main effect of exercise duration

De Morree et al. Journal of Applied Physiology 2014 : 1514-1523

Central Command and RPE



Movement-related cortical potentials at five electrodes for the first 50 and last 50 contractions in the caffeine and placebo conditions. Time 0 ms is EMG onset.

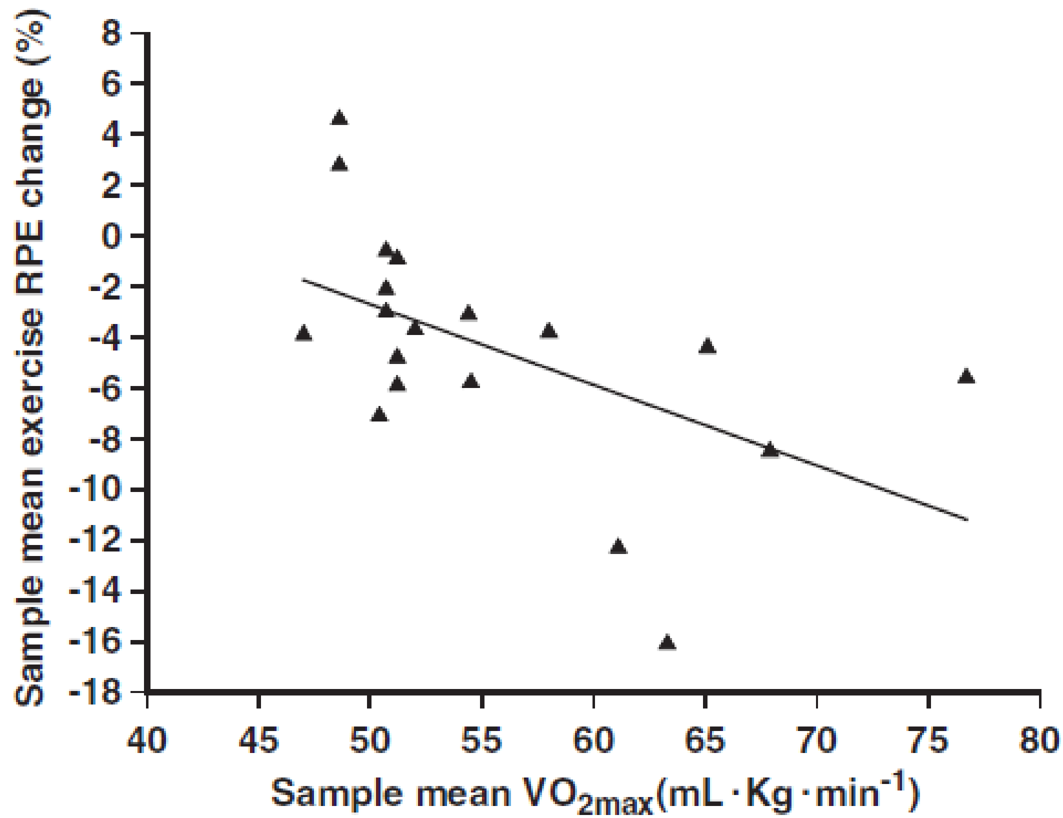
Scand J Med Sci Sports 2005: 15: 69–78
Printed in Denmark ·
DOI: 10.1111/j.1600-0838.2005.00445.x

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE
IN SPORTS

Review

Effects of caffeine ingestion on rating of perceived exertion during and after exercise: a meta-analysis

M. Doherty, P. M. Smith



Effects of Caffeine in Inactive People

Aims

Investigate whether the effect of caffeine ingestion on psychological responses to HIIT are associated with changes in exercise behaviour, as determined by choice.

Study Design

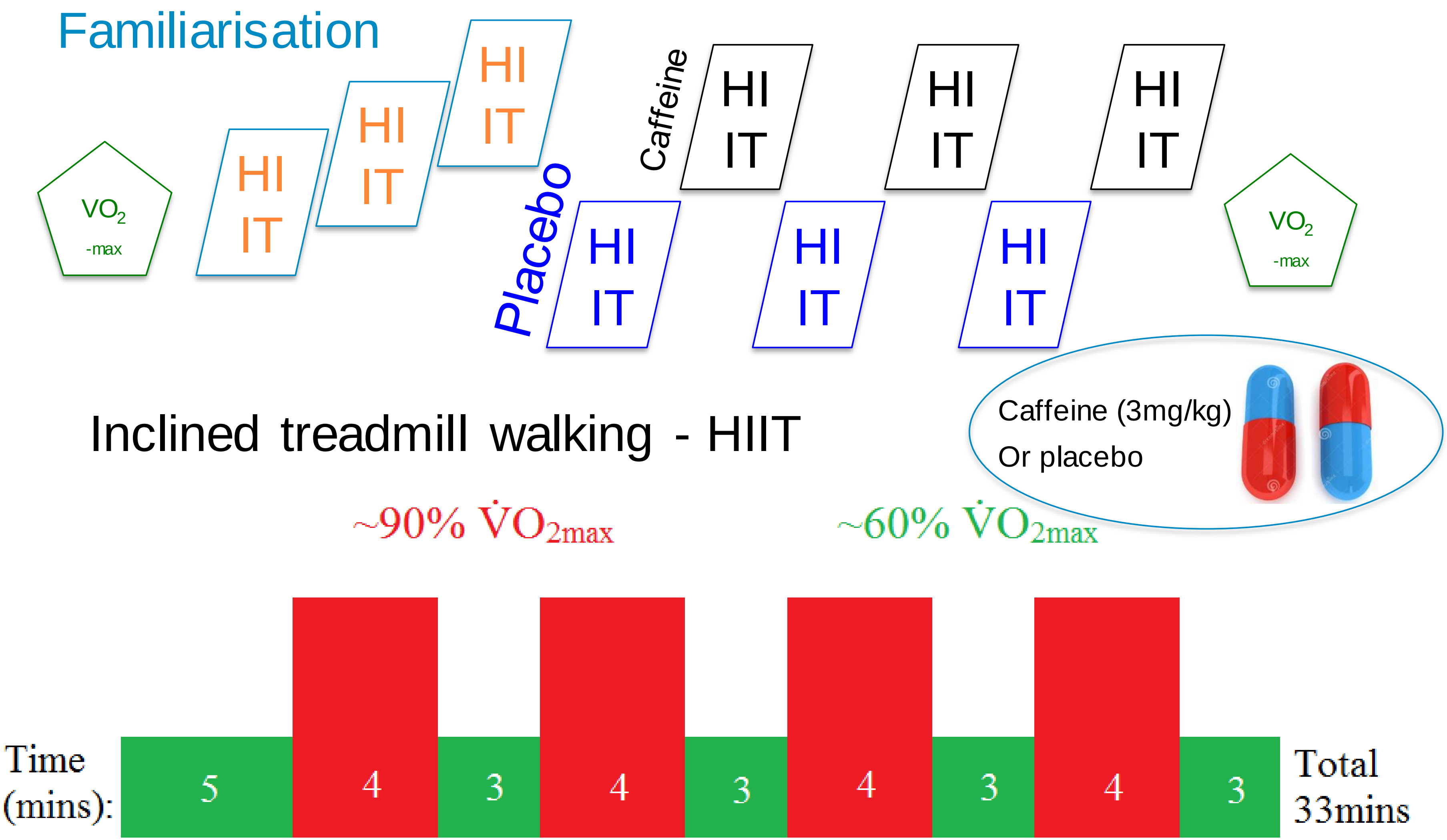
Double-blind, repeated measures crossover design

Participants

Eight physically inactive adults (M±SD) age, 34±12 years; height 168±7 cm; weight 85±23 kg; BMI 31±7; and VO2max 32±6.

Thanks to Joel Chidley and Dr Gurprit Lall

Study Protocol and Treatment



Rognmo *et al.*, (2004) EJCPR, 11(3), 216-222.

Outcome Measures

Measurements during exercise:

Heart rate (HR)

Rating of perceived exertion (RPE, Borg 6-20)

Feeling Scale (FS)

Exercise-induced muscle pain (pain, Cook 0-10)

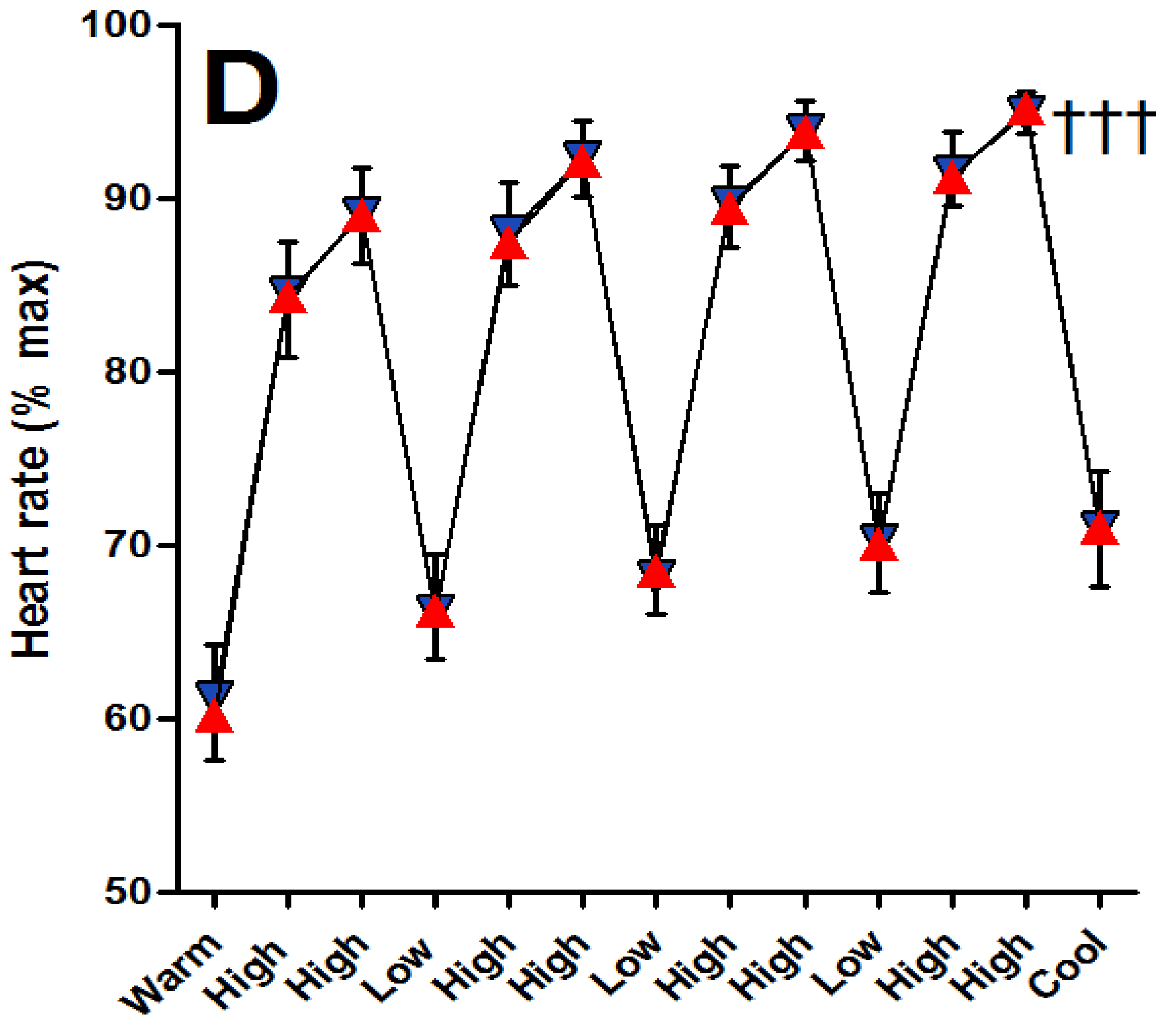
Measurements pre and/or post exercise:

- Physical Activity Enjoyment Scale (PACES)
- Brunel Mood Scale (BRUMS)
- Exercise 'liking'
- 10-minutes post exercise, session RPE

Choice measure:

On three occasions, subjects were asked to choose whether they preferred 'this' or the previous session – providing 3 opportunities to choose between treatment pairs.

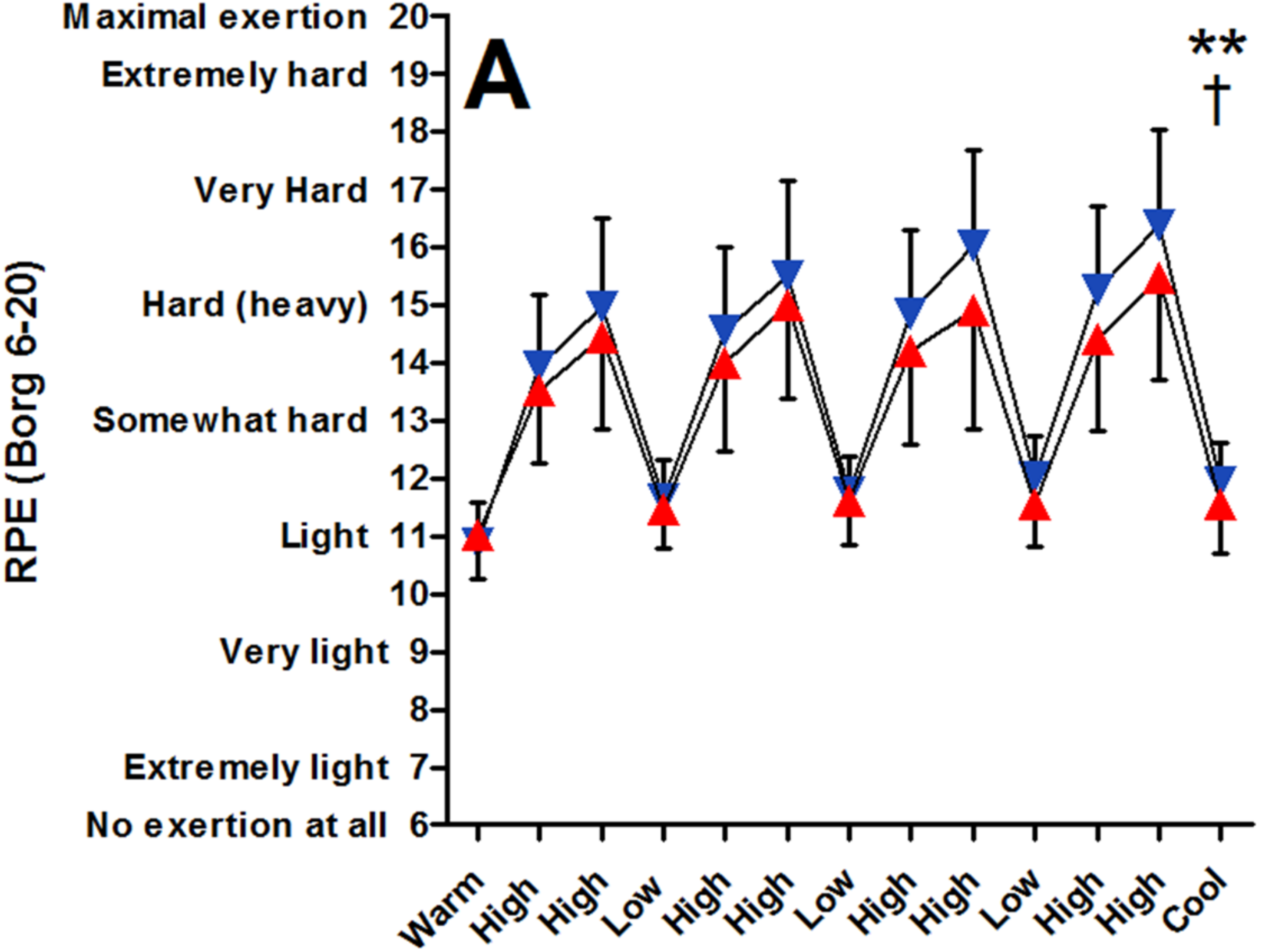
Results



*Indicates a significant main effect of condition p≤0.1; **p ≤0.05; ***p ≤0.01.

† Indicates a significant main effect of time p≤0.1; ††p ≤0.05; †††p ≤0.01

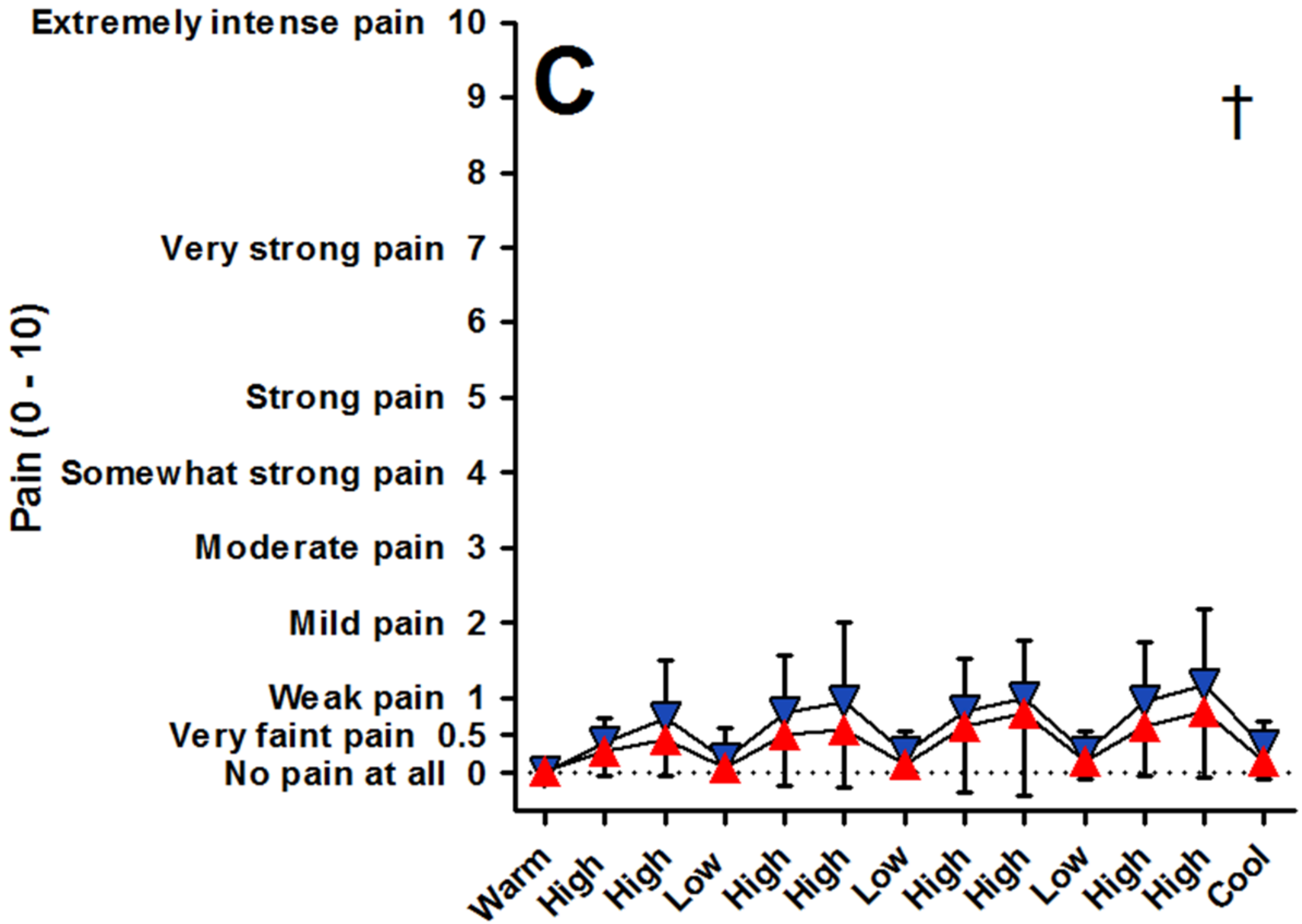
Results



*Indicates a significant main effect of condition p≤0.1; **p ≤0.05; ***p ≤0.01.

† Indicates a significant main effect of time p≤0.1; ††p ≤0.05; †††p ≤0.01

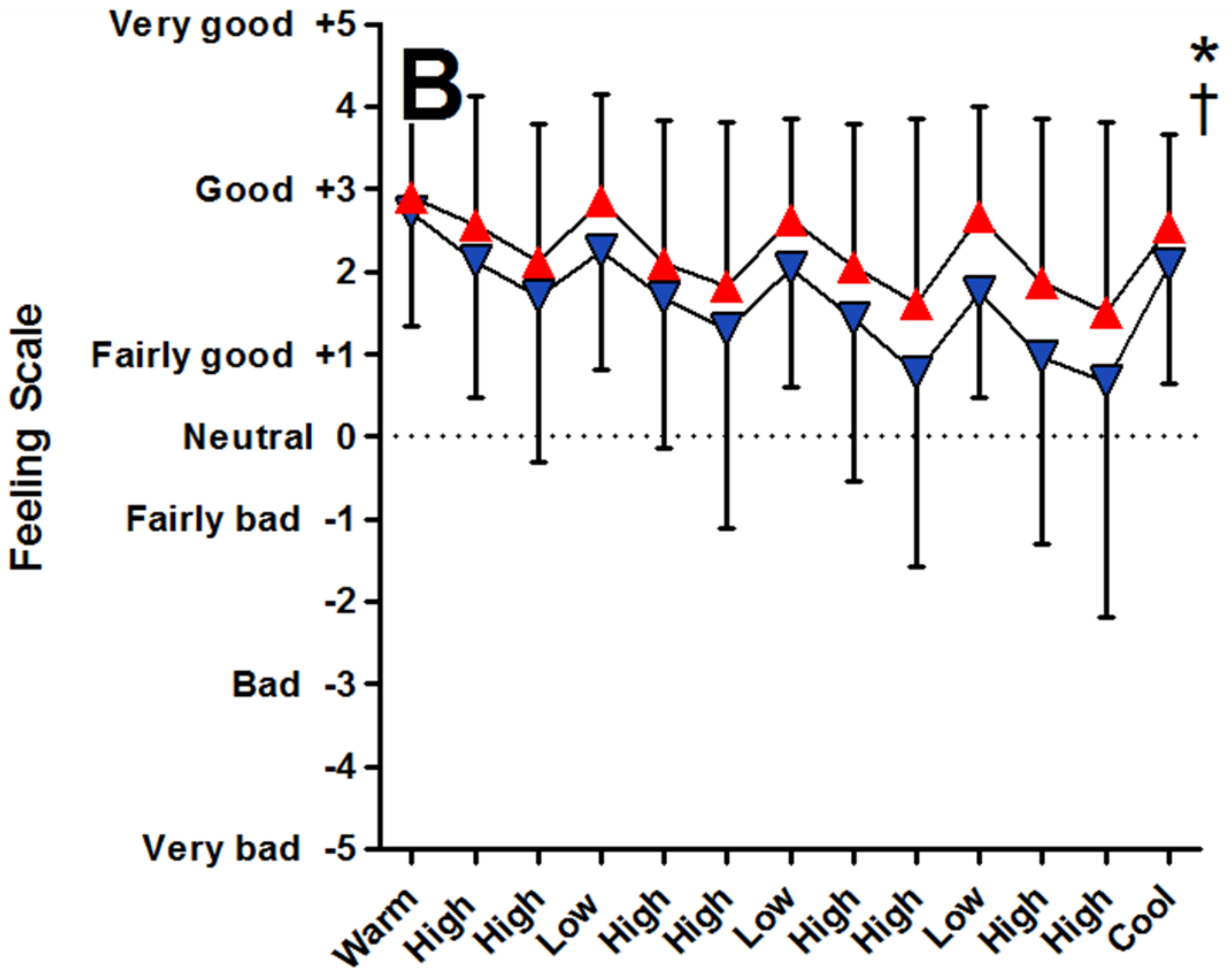
Results



*Indicates a significant main effect of condition p≤0.1; **p ≤0.05; ***p ≤0.01.

† Indicates a significant main effect of time p≤0.1; ††p ≤0.05; †††p ≤0.01

Results



*Indicates a significant main effect of condition p≤0.1; **p ≤0.05; ***p ≤0.01.

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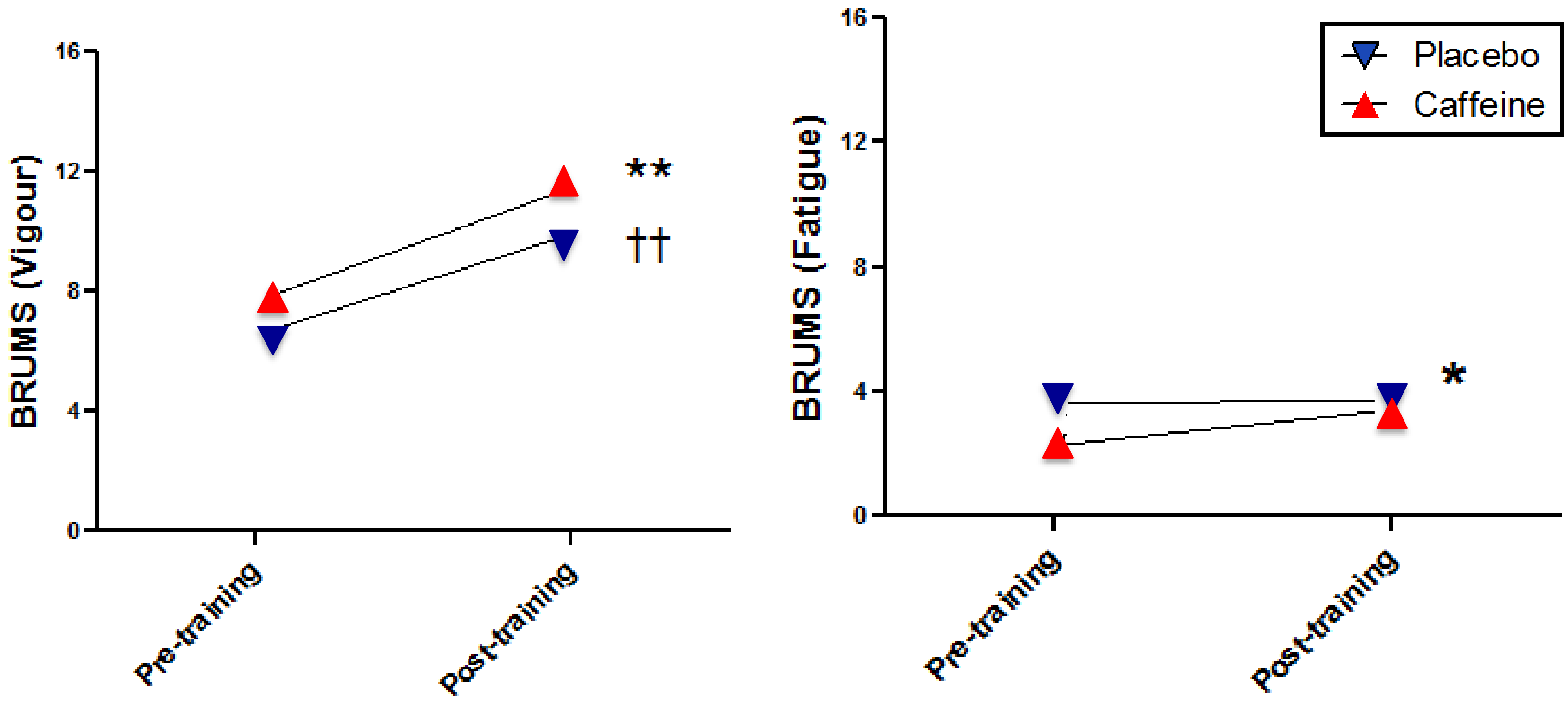
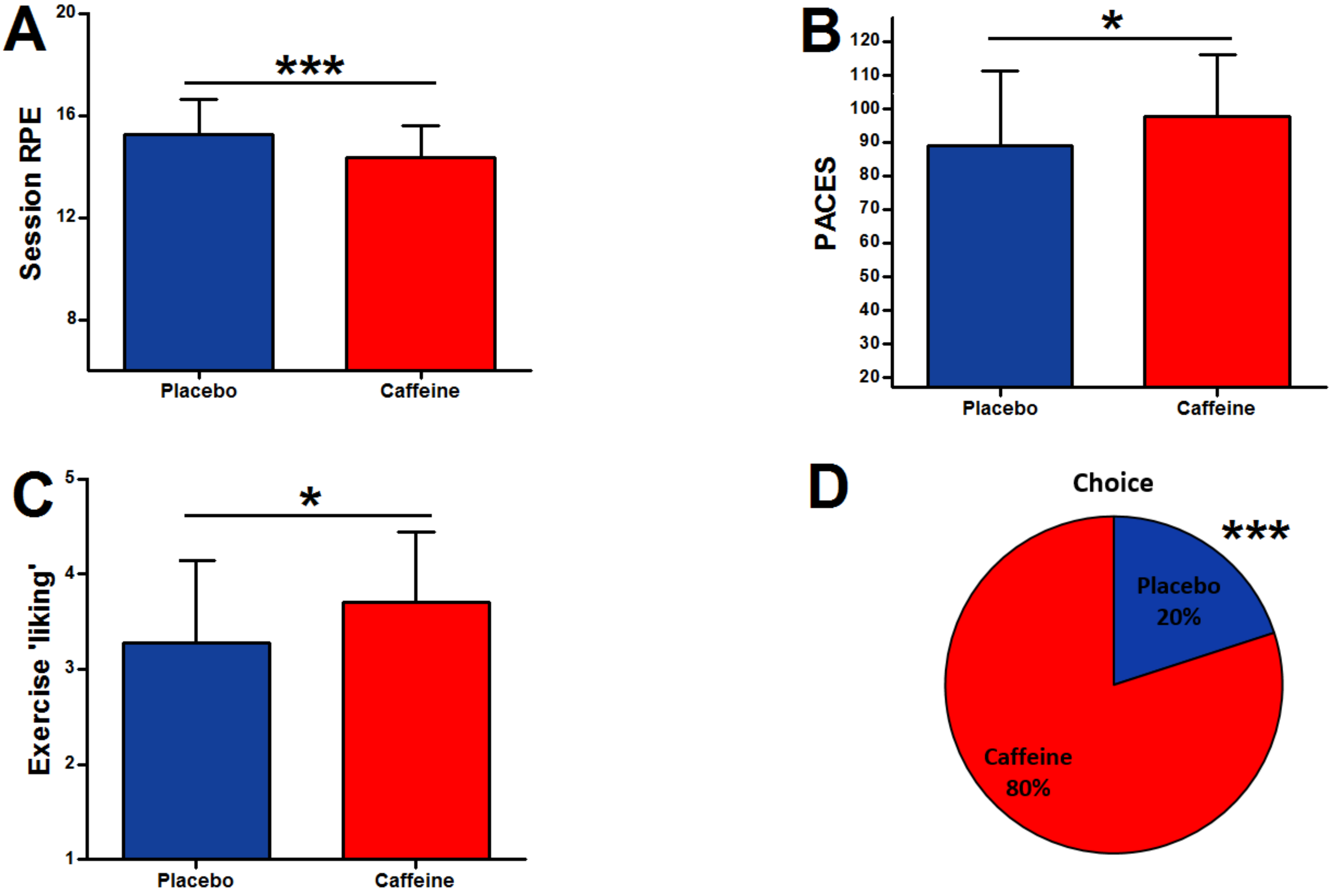
Results



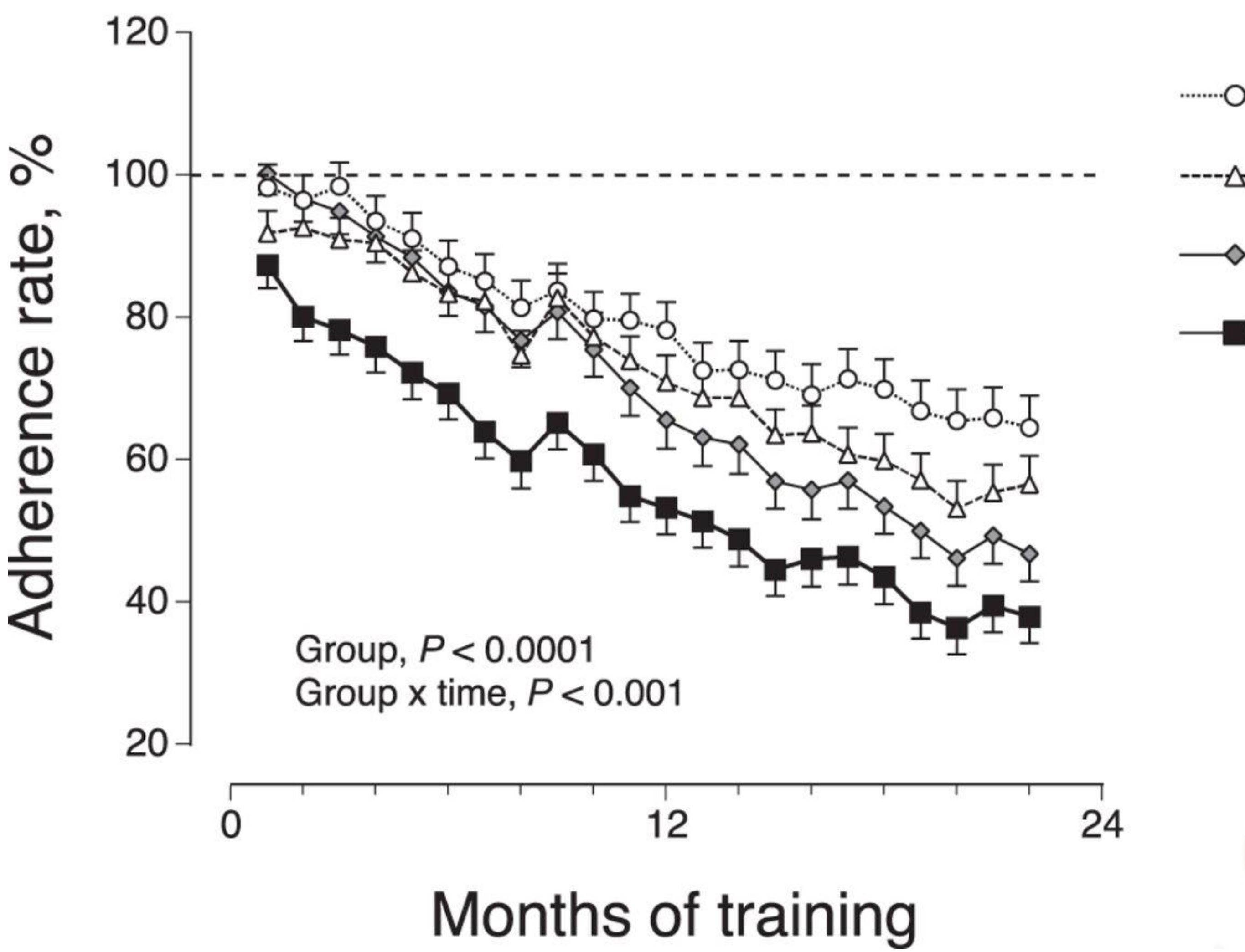
*Indicates a significant main effect of condition p≤0.05; **p ≤0.01; ***p ≤0.001.

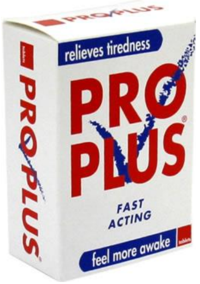
† Indicates a significant main effect of time p≤0.05; ††p ≤0.01; †††p ≤0.001

Results


A
20
16
12
8
Session RPE
***
Placebo
Caffeine
B
120
110
100
90
80
70
60
50
40
30
20
PACES
*
Placebo
Caffeine
C
5
4
3
2
1
Exercise 'liking'
*
Placebo
Caffeine
D
Choice
***
Placebo
20%
Caffeine
80%

Future Research





Shizue Masuki et al. J Appl Physiol 2015;118:595-603

Questions?