VO_2 max limitations in ageing

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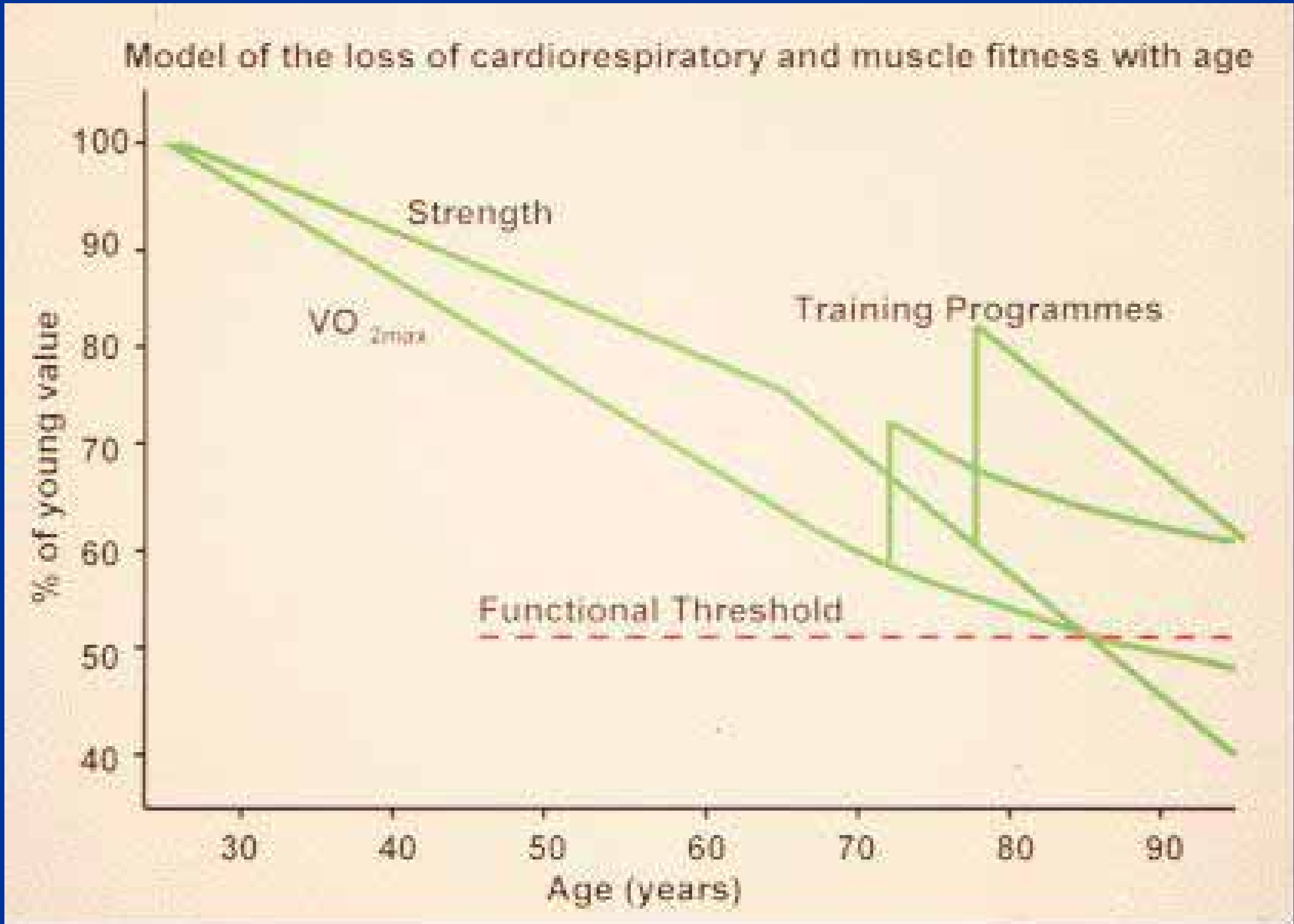
Physiological performance decline in ageing: training effect



How much cardiorespiratory fitness in a successful ageing ?

Population:

441 randomly selected men and women 55-85 y

10-y follow-up, n = 115 (62 VO_2max, fatigue treadmill; 45 T_{VE})
lost to follow-up (death, dependent, refusals, no contact)

(Paterson et al . Longitudinal changes in aerobic power in older men and women. JAP, 97: 2004)

Therefore "successful" ageing; from mean ages
64 to 74 y

Purpose/Rationale:

1. 10-y change in CR fitness in older adults
2. men and women
3. relationship with daily physical activity

10-y change in VO_2max in older men and women

Figure 1a

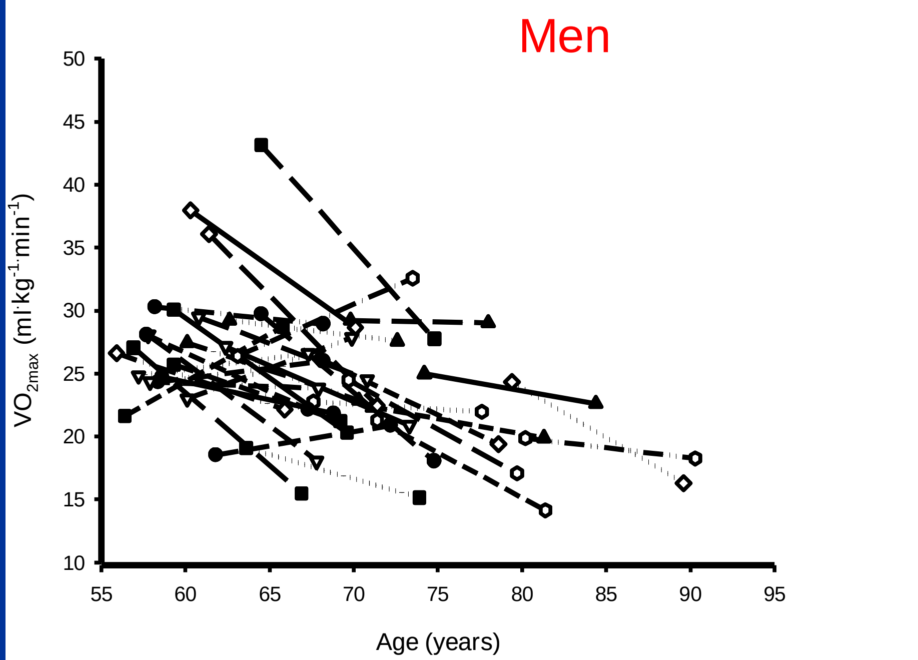
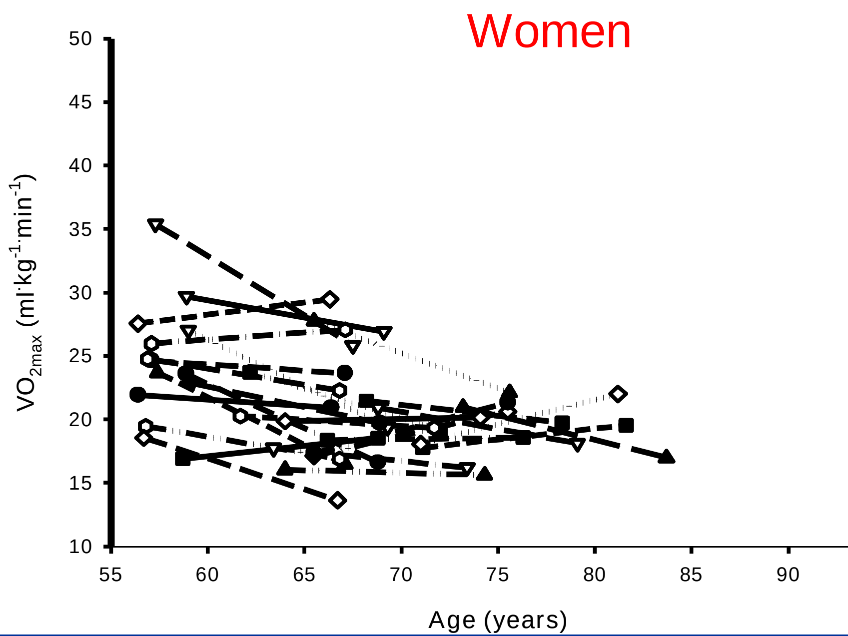


Figure 1b



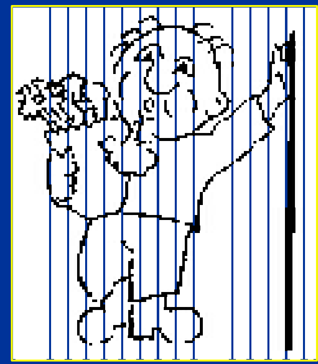
Decline: men > women
A few exceptions (increase)
Age 75 y ~ 20 ml/kg.min
➢15 ml/kg.min – independent living
[Weiss et al. (2005) – oldest old as low as 13 ml/kg.min (standing=50%VO_2max)]

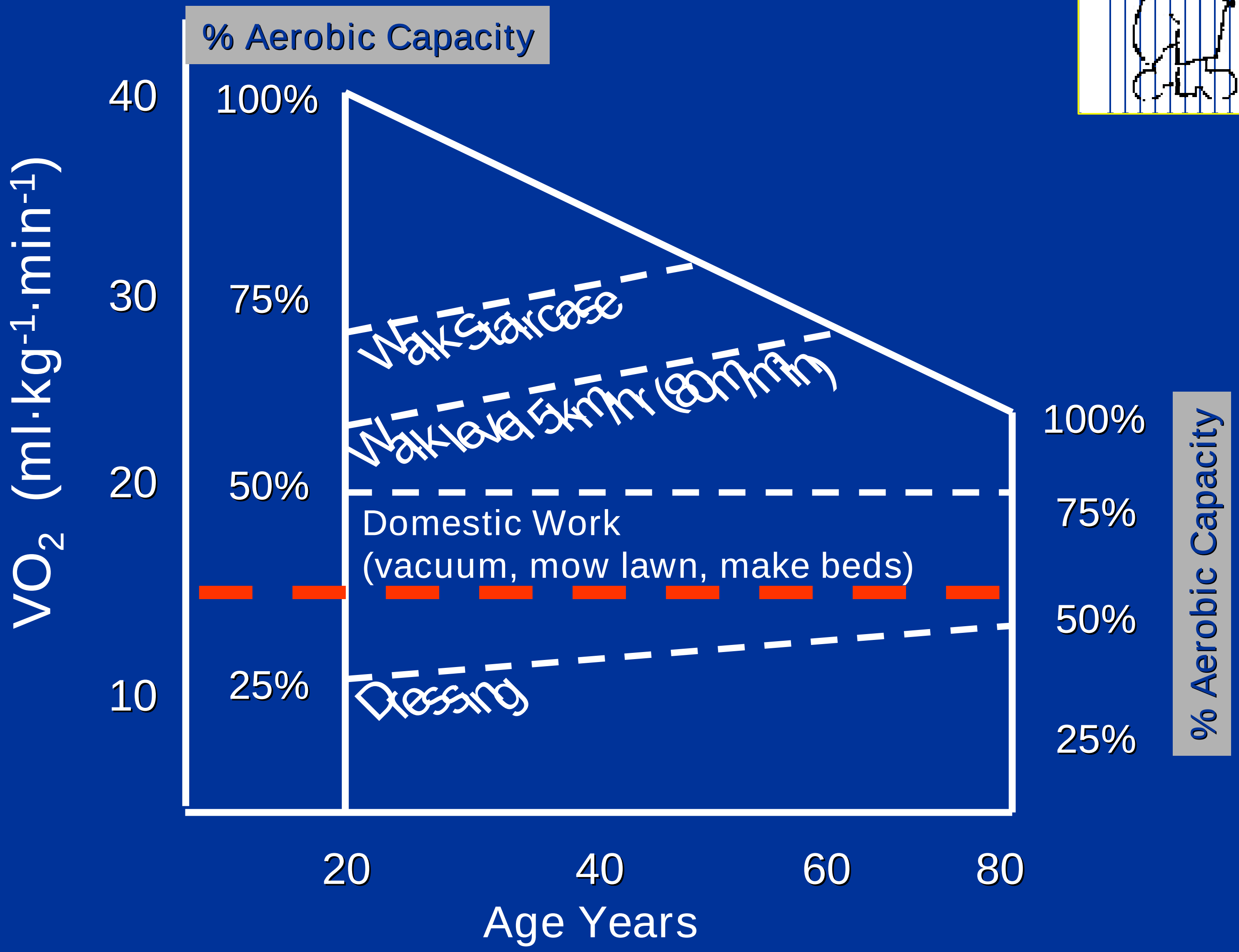
- Longitudinal Decline in VO_2max
  - Stathokostas, Paterson et al., 2004
  - Men: 15% per decade (4.3 ml/kg.min per decade, to 22 ml/kg.min at age 73 y)
  - Women: 7% per decade (1.9 ml/kg.min per decade, to 20 ml/kg.min at age 72 y)

  - Hollenberg et al., 2006
  - median age 70 years longitudinally for 6-years;
  - Men: 24% per decade (6.9 ml/kg.min per decade)
  - Women: 18% per decade (3.9 ml/kg.min per decade)

  - Fleg et al., 2005
  - accelerated decline with each decade from ~5% in the 20s and 30s to >20% in the 70s and 80s, and greater rate of decline in men (Stathokostas: not so 55 - 70 vs 70 - 85 y)

Aerobic capacity required for selected activities





CR Fitness and Function: Conclusions

1. Loss in VO_2 max:

   O_2 delivery:

   Cardio – Cardiac Output (Maximum HR = 220 – age)

   Vascular - blood flow to exercising muscle (Doppler blood flow; NIRS - vascular control, microvascular O_2)

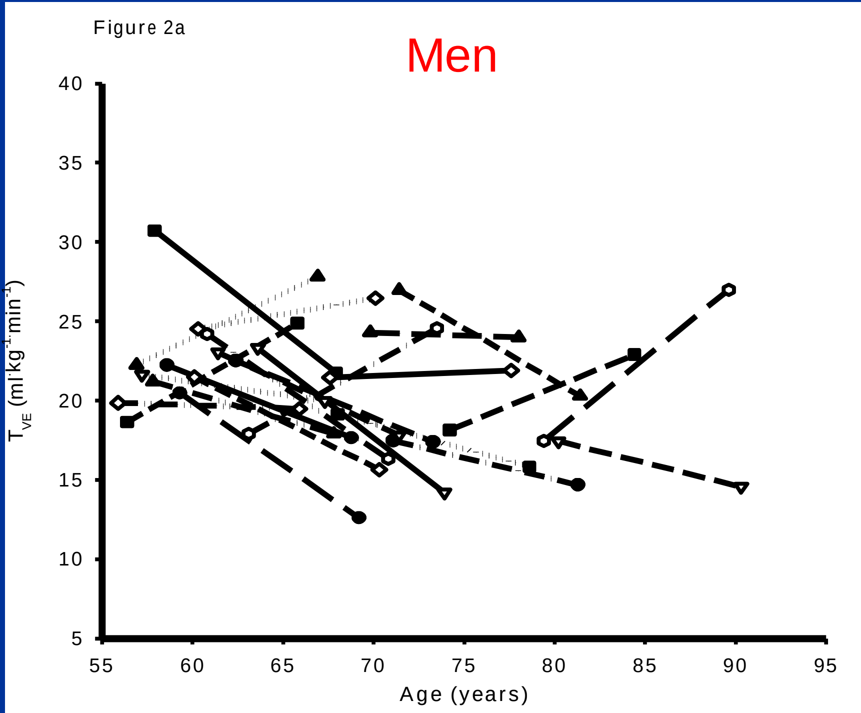
   O_2 utilization:

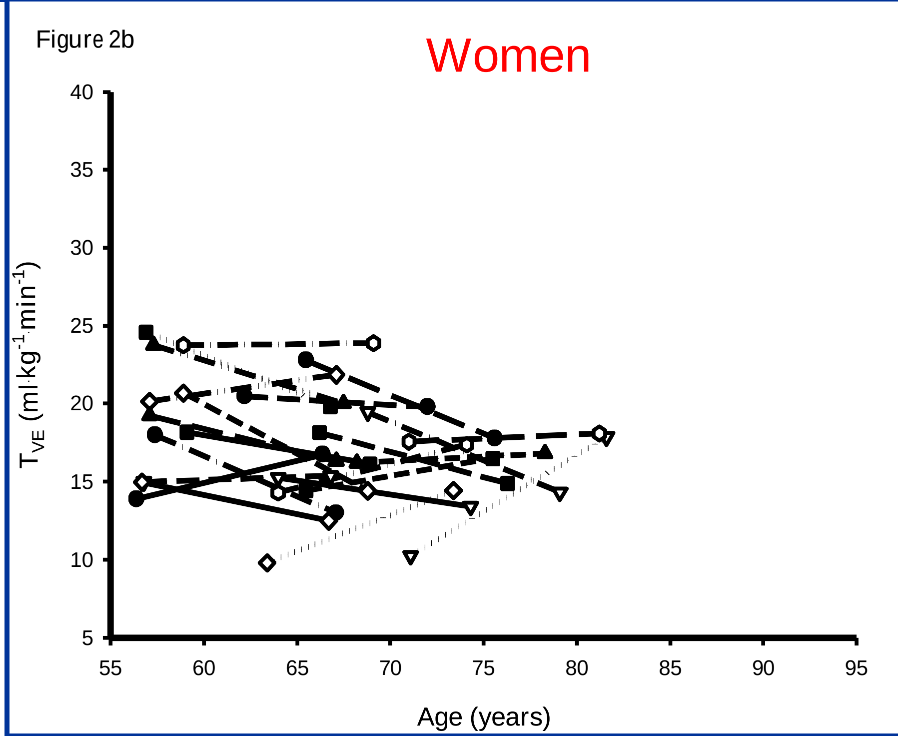
   Respiratory - muscle mitochondria (oxidative enzymes)

1b. T_{VE} as %VO_2max increases (T_{VE} preserved with age)

   T_{VE} determined by muscle metabolism - mitochondria (preserved); VO_2max limited by blood flow

Stathokostas et al. (2004) - 10-y change of T_{VE} in older men and women





- Lesser decline with age than VO_2max;
- Threshold greater $\%VO_2$max

CR Fitness and Function: Conclusions (cont'd)

2. Successful ageing: ~75 y - VO_2max ~20 $ml.kg^{-1}.min^{-1}$

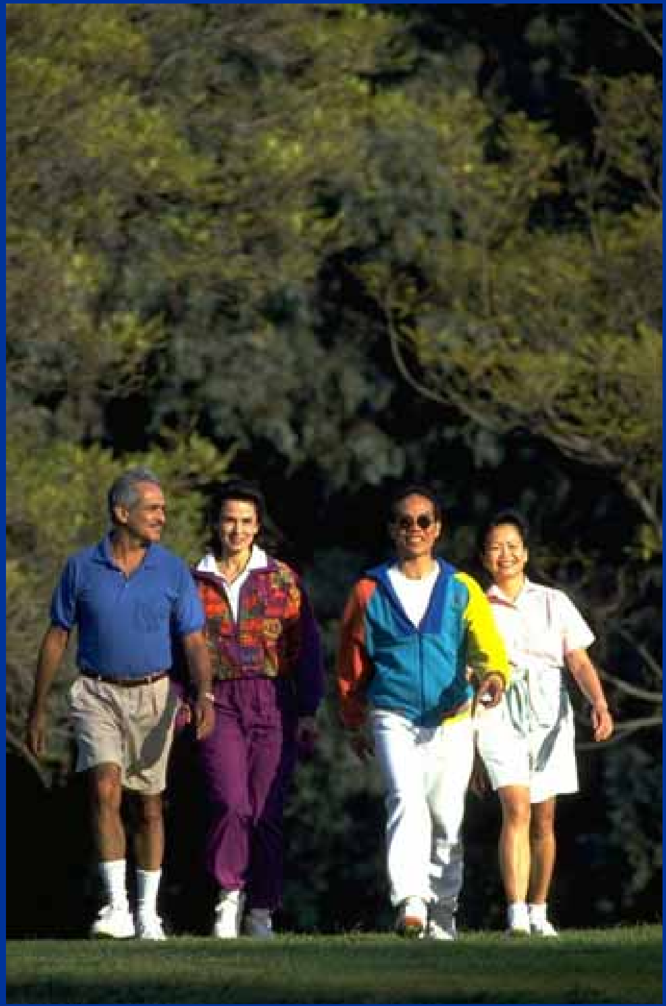
   Thus, activities > 4 METS (14 $ml.kg^{-1}.min^{-1}$) i.e., ADL

   = "heavy" intensity – fatiguing

3. Relative to VO_2max - e.g., brisk walking - 3.5 mph, VO_2 12-14 $ml.kg^{-1}.min^{-1}$, 60-70% VO_2max = exercise training prescription

Functions vs independent life

Purpose: To describe those factors, from the host of initial measures in ambulatory, independent older men and women that were determinants of becoming dependent in an 8-y follow-up



8-y follow-up sample

188 independent
(89 m, 99 f; age 67 y)

43 dependent (15 m, 28 f; age 76 y)
- 25 nursing home or LTC
- 9 non-ambulatory,
- 9 professional assessment (home care)

not in follow-up: deceased (n = 48),
not contacted (n = 53),
did not participate (n = 41)
follow-up sample was representative of initial sample

Results:

Univariate analysis (variables associated with increased odds of dependence)

significant: age, VO_2max, plantar flexion strength

other physical factors: shoulder abduction, grip strength, self-paced walking speed

Disease: stroke, angina, disease5

NOT: BMI, physical activity, smoking, hypertension

Determinants of Future Dependence in the Final Logistic Model (Normal walk, Depression, Education – Effect Modifiers)

Variable	Probability	Odds Ratio	Confidence Interval
Age	<.001	1.22	1.11-1.34
Gender	.885	1.10	0.31-4.0
Disease	.012	3.97	1.35-11.7
VO_2max	.047	0.86	0.74-0.99
Plantar Flexion	.084	1.00	0.97-1.00

Determinants of Independence/Dependence – Conclusions (Petrella et al., 2004)

longitudinal follow-up study first to provide evidence that CR is a critical determinant of dependence/independence in older adults

1. Lower CR fitness (VO_2max) significantly associated with increased odds of dependent living in the elderly (after controlling for age, disease, gender, and other covariates)
2. Given VO_2max for independent lifestyle ~15 $ml.kg^{-1}.min^{-1}$, and age-related decline in VO_2max: at >age 78 y - 1/4 at minimum threshold

3. Magnitude of relationship of VO_2max with dependency similar to relationship with morbidity and all-cause mortality (OR = 0.86)

   i.e., higher VO_2max decreased the odds of subsequent dependence by 14% for each ml/kg.min, or ~50% lower in those of above average CR fitness

4. Given OR = 0.86 (14% reduction per unit)

   - with exercise training 10% - 20% (~3 - 4 $ml.kg^{-1}.min^{-1}$) increase in VO_2max predicts 50% decrease in odds for becoming dependent

Cardiorespiratory Exercise Training Studies in Older Adults

– An extensive Table - training programs and CR fitness outcomes in older adults (mean age >65 y), conducted since 1990 (>40 studies)

– overall - older men and women improve VO_2max by a similar relative magnitude to that observed with training in young individuals (10 to 30%); [may be attenuated in 80s….???]

Summary and 3. Cardiorespiratory Training Recommendations

- CR fitness decline with age: by mid-70s approach thresholds for functional daily activities
- Higher CR fitness is associated with decreased morbidity and all-cause mortality, AND improved odds of remaining independent
- Moderately vigorous exercise, NOT more activities of daily living (“accumulation” not likely to affect functional outcomes) is required to improve CR fitness for function, and

Summary

- Reduced risk associated with moderately vigorous activity (~4 ½ METS or 60% VO_2max); 1000 kcal/wk (3 hrs brisk walking)

- Above recipe improves fitness and is associated with a 20-30% reduction in risk of morbidity, mortality and loss of independence; progression to higher intensity and greater volume will further increase fitness and achieve a 60% reduction in risk

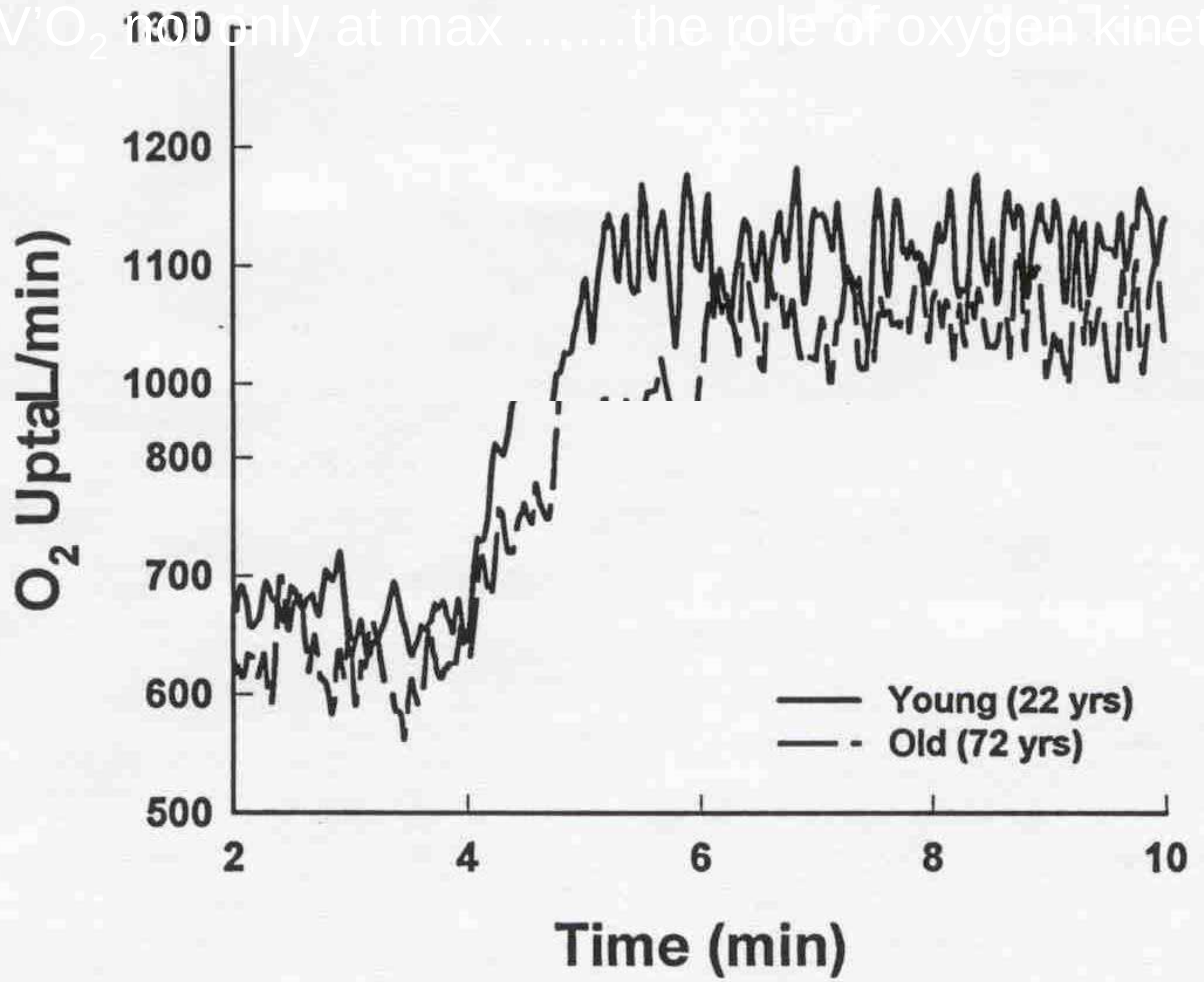
Practical Conclusion:

Public health initiatives aimed at preserving and or improving CR fitness in the later years provide an important strategy for maintaining independence

Initiatives to encourage physical activity in older adults should emphasize exercise, such as brisk walking, to maintain or improve CR fitness

"Get Fit for Active Living"

V'O_2 not only at max ……the role of oxygen kinetics



Paterson, 2003

$V'O_2$ Kinetics – overall view

1. Slow VO_2 kinetics in older adults may elicit fatigue early in moderate or heavy exercise. Activities of daily life with their intermittent nature and change in energy requirements are more fatiguing in older adults

2. In heavy-intensity exercise, above the T_{VE}, the VO_2 slow component approaches VO_2max with imminent fatigue.

   Exercise prescription, monitoring requires more precision in older adults (to be moderately vigorous, but not fatiguing)

3. Avoiding "step" changes in work demand will prevent "early" fatigue

4. Studies of DeLorey, Kowalchuk, Paterson - JAP, 2004

In older adults, slow VO_2 kinetics during moderate- and heavy-intensity exercise may be limited by local muscle blood flow and O_2 delivery

intracellular mechanisms of fundamental control of muscle O_2 consumption appear not to be the cause of slow kinetics

Thus, are there specific exercise training stimuli that engender adaptations in local vascular control of blood flow distribution? - indeed in older adults with cardiorespiratory training VO_2 kinetics can revert to values of youth

(Babcock, Paterson et al., 1994; Bell, Paterson et al., 2001)

How does train the elderly for VO2 max?

If cardiorespiratory fitness is so important we can determine the limitations in the training effects?

Central and peripheral adaptations to exercise training in elderly.
(with special empahsys on the arm)

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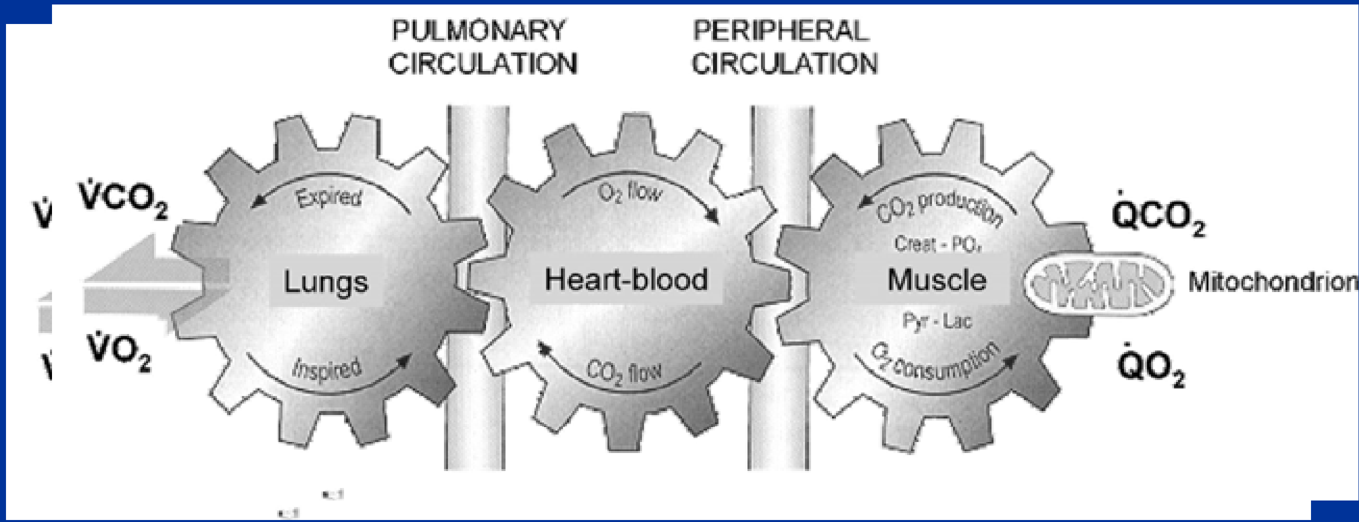
FACTORS INFLUENCING V'O2max DECREASE IN AGEING



CENTRAL FACTORS:

Cardiac Output

Blood mass

Hb Saturation

PERIPHERAL FACTORS

Muscle mass

Caps/fibers ratio

Mitho&enzym activities

Main question

How central and peripheral factors contribute to aerobic training adaptation in eldelry subject

Goal

describe a quantitative model that can allow to detremine the changes in aerobic capacity as a result of physiological changes in the ageing framework

Methodology

separate central and peripheral factors by using:

- Measurements of specific parameters
- Training and testing protocol
- Special populations

Subjects

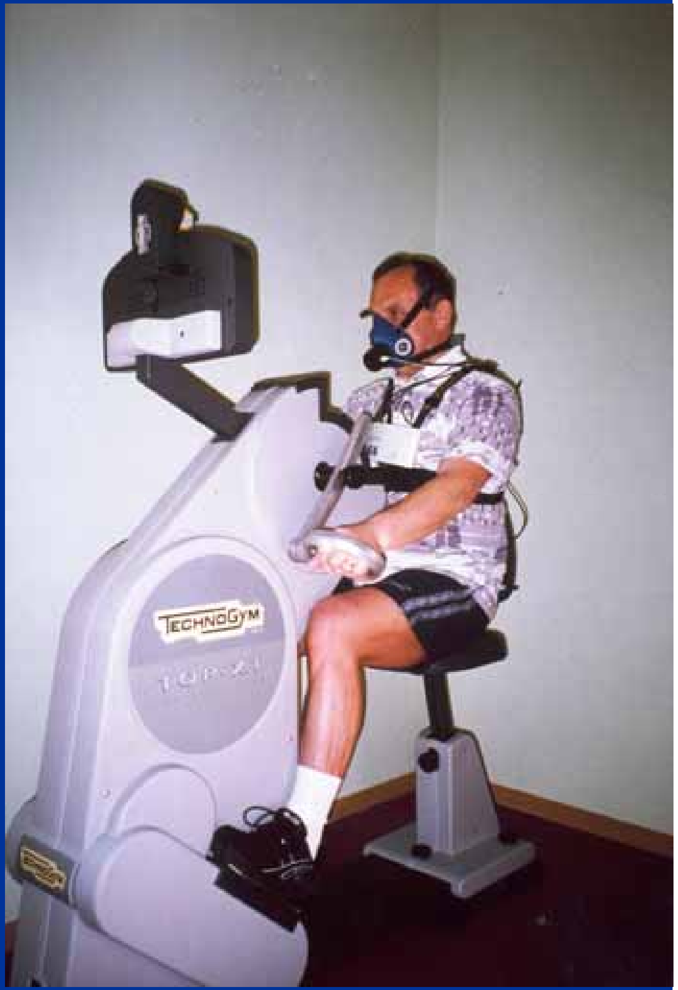
a total number of 30 older male sedentaries subjects (ageing between 63 and 74y)
were divided into the following groups in respect to training and condition:

Healthy (HE) or Hypertensive (HYP)
Up-Body (ARM) Low-Body (CYC) No-tr (C)

HE- ARM: arm cranking 12-week training (30 min, 3 times/week)
HE - CYC: cycloergometry 12-week supervised training (30 min, 3 times/week)
HE - C: control group, continued their habitual lifestyle for 12 weeks

HYP- ARM: arm cranking 12-week training (30 min, 3 times/week)
HYP-CYC: cycloergometry 12-week supervised training (30 min, 3 times/week)
HYP-C: control group, continued their habitual lifestyle for 12 weeks

Protocol



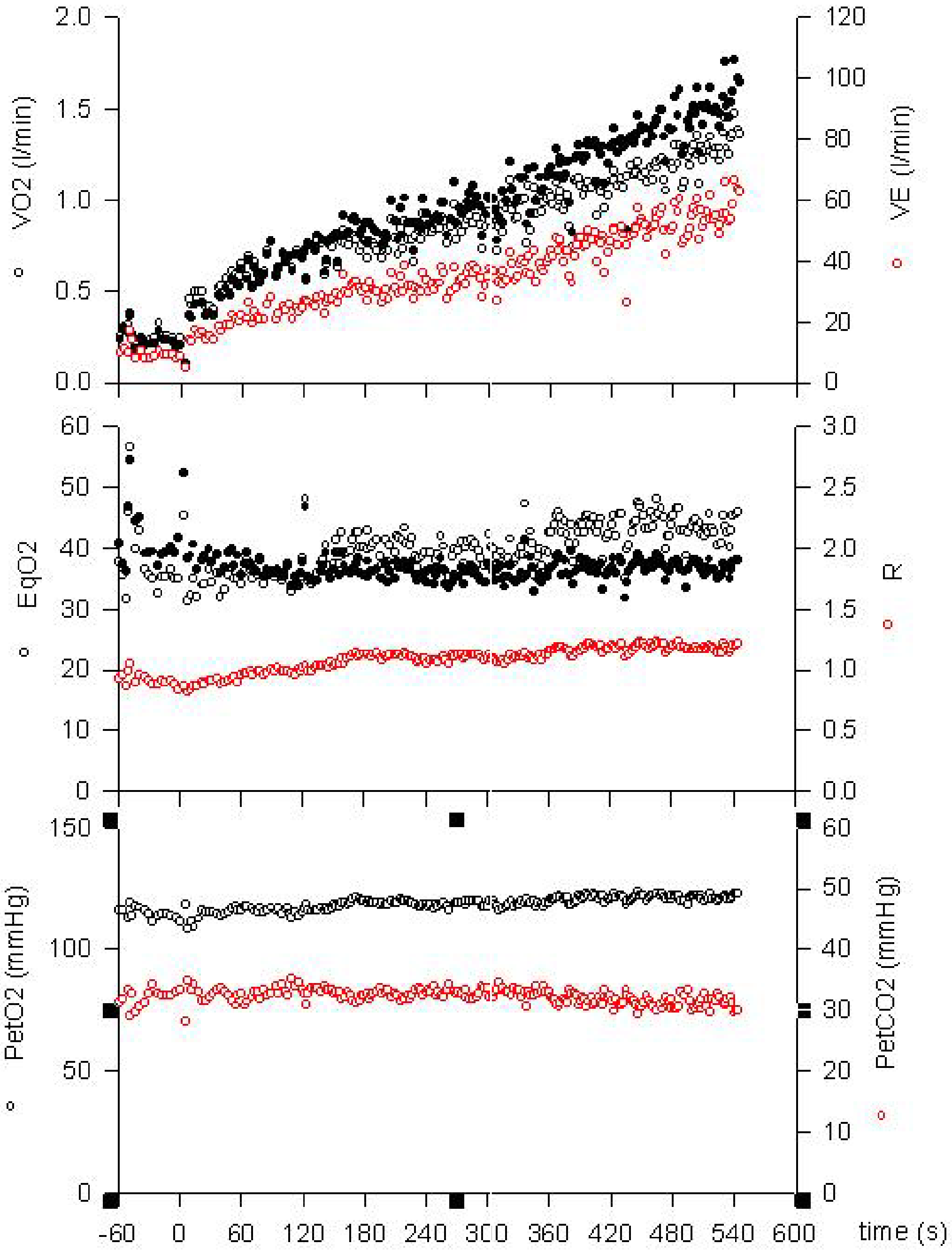
Measures

- respiratory variables were measured breath by breath and heart rate (HR) was continuously recorded.

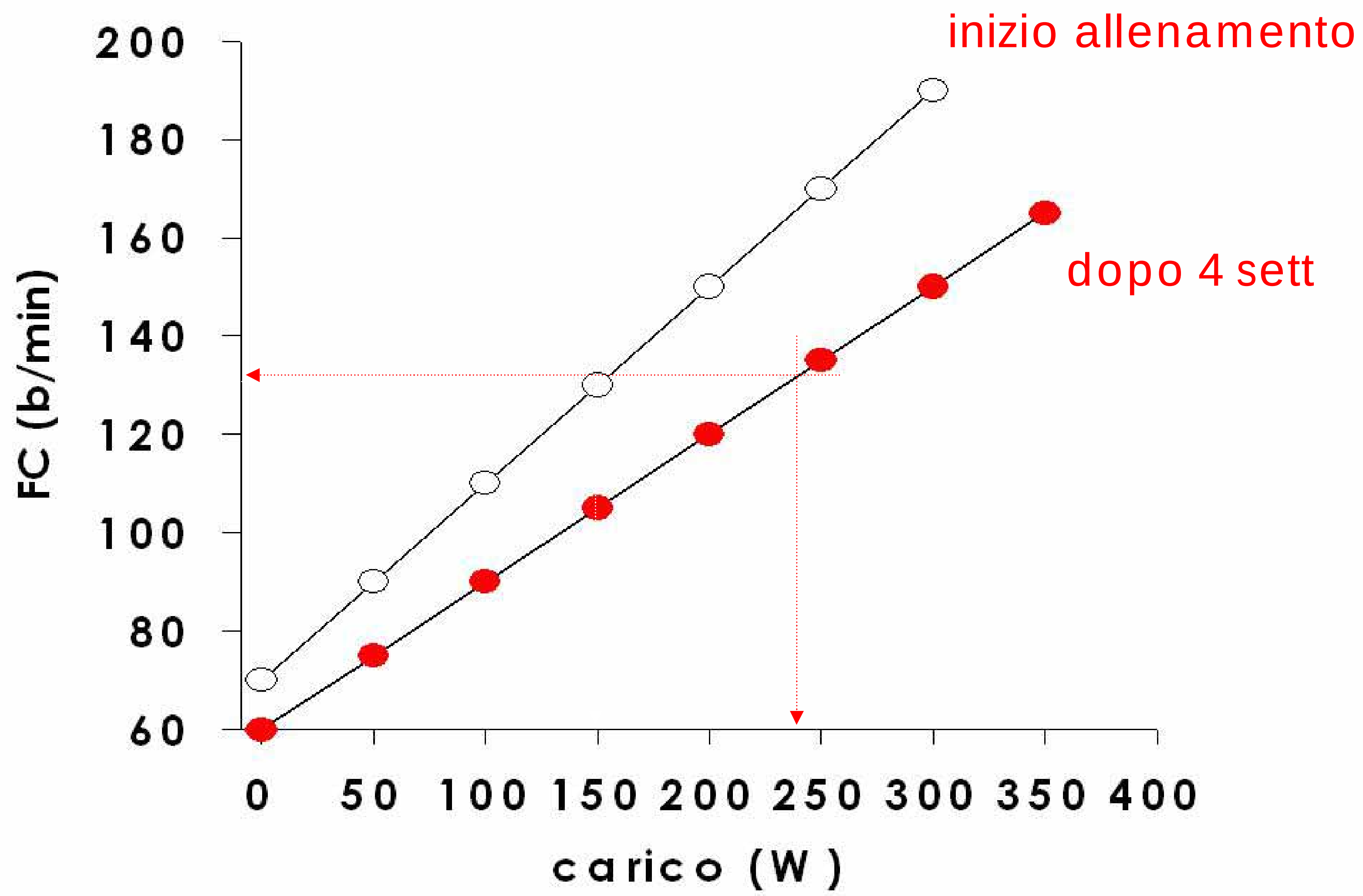
- Power (Wpeak)
- Oxygen uptake (VO2peak)
- ventilation (VEpeak)
- oxygen pulse (O2Ppeak)
- Heart rate (HRpeak)

were calculated as the average of the last 10s of exercise.

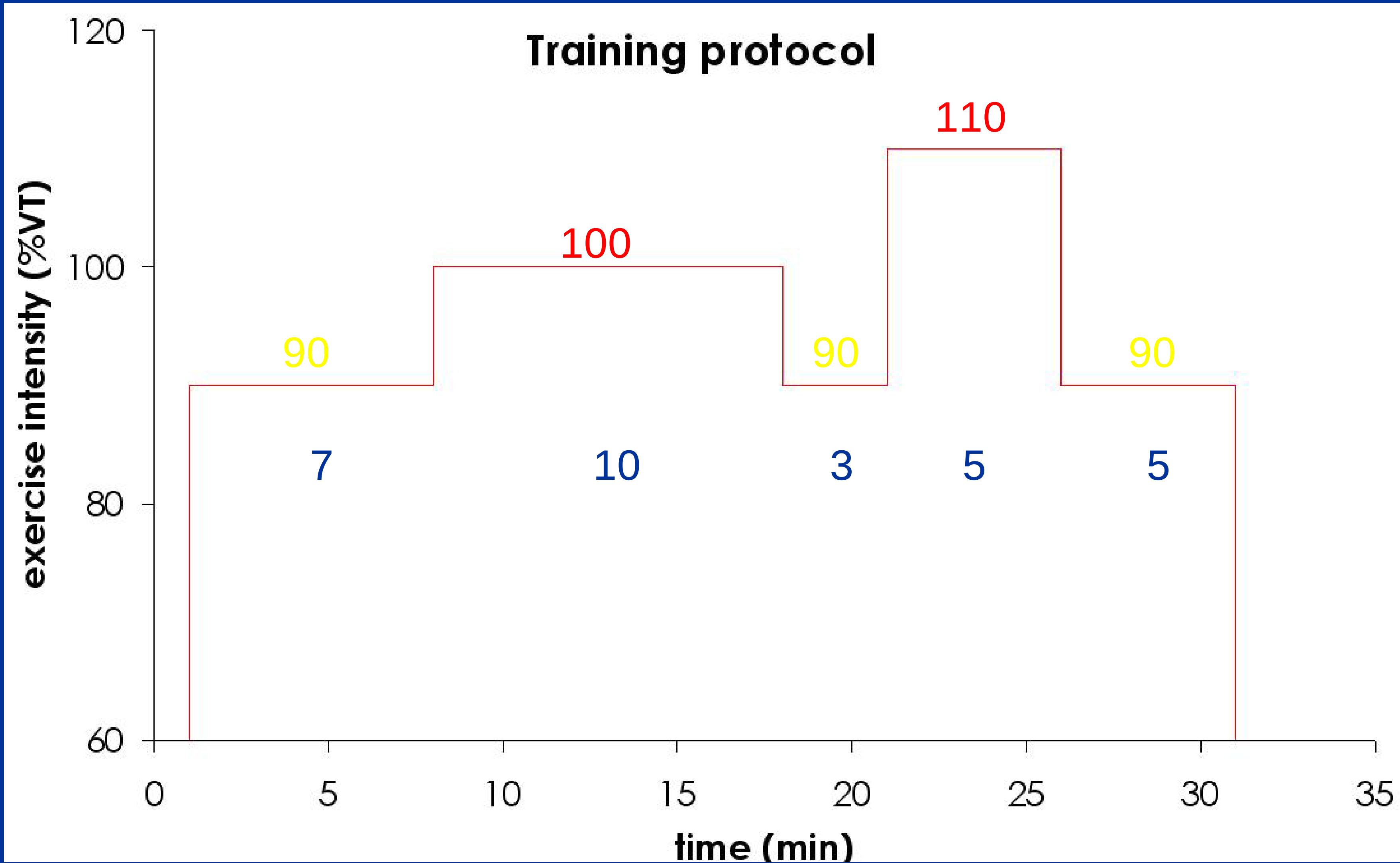
Ventilatory threshold (VT) was determined by Wasserman method



- ✓ VT identification during incremental test
- ✓ HR corresponding to VT
- ✓ using steady-state tests, translate HR_{VT} in W_{VT}
- ✓ calculate $W_{90\%VT}$ and $W_{110\%VT}$
- ✓HR monitored and recorded every training session
- ✓ every 2 weeks check the HR/W relationship
- ✓Re-calculation of W related to the

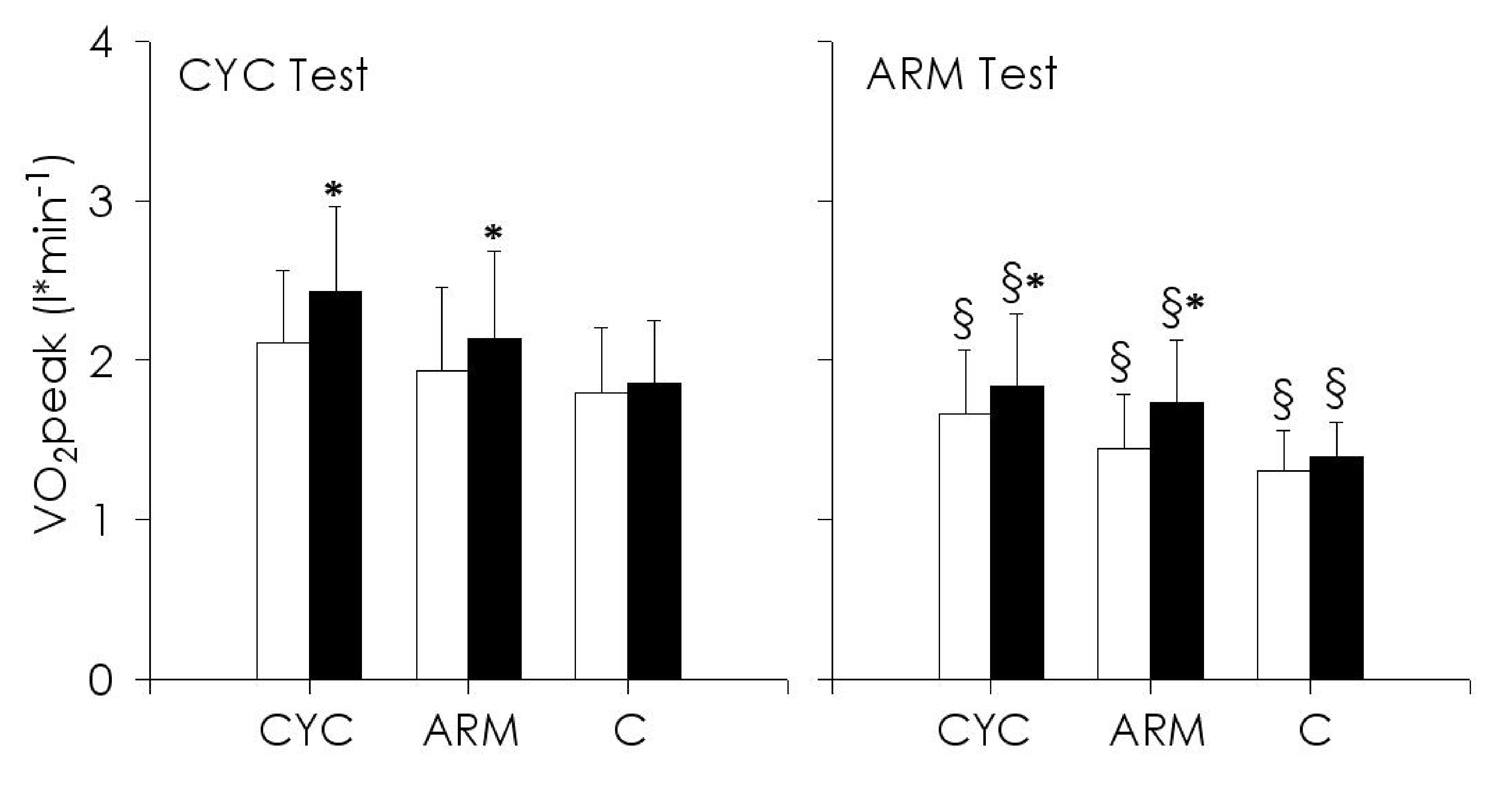


inizio allenamento
dopo 4 sett
FC (b/min)
200
180
160
140
120
100
80
60
0
50
100
150
200
250
300
350
400
carico (W)



Average WL 97% individual VT
12-weeks 3 times /week

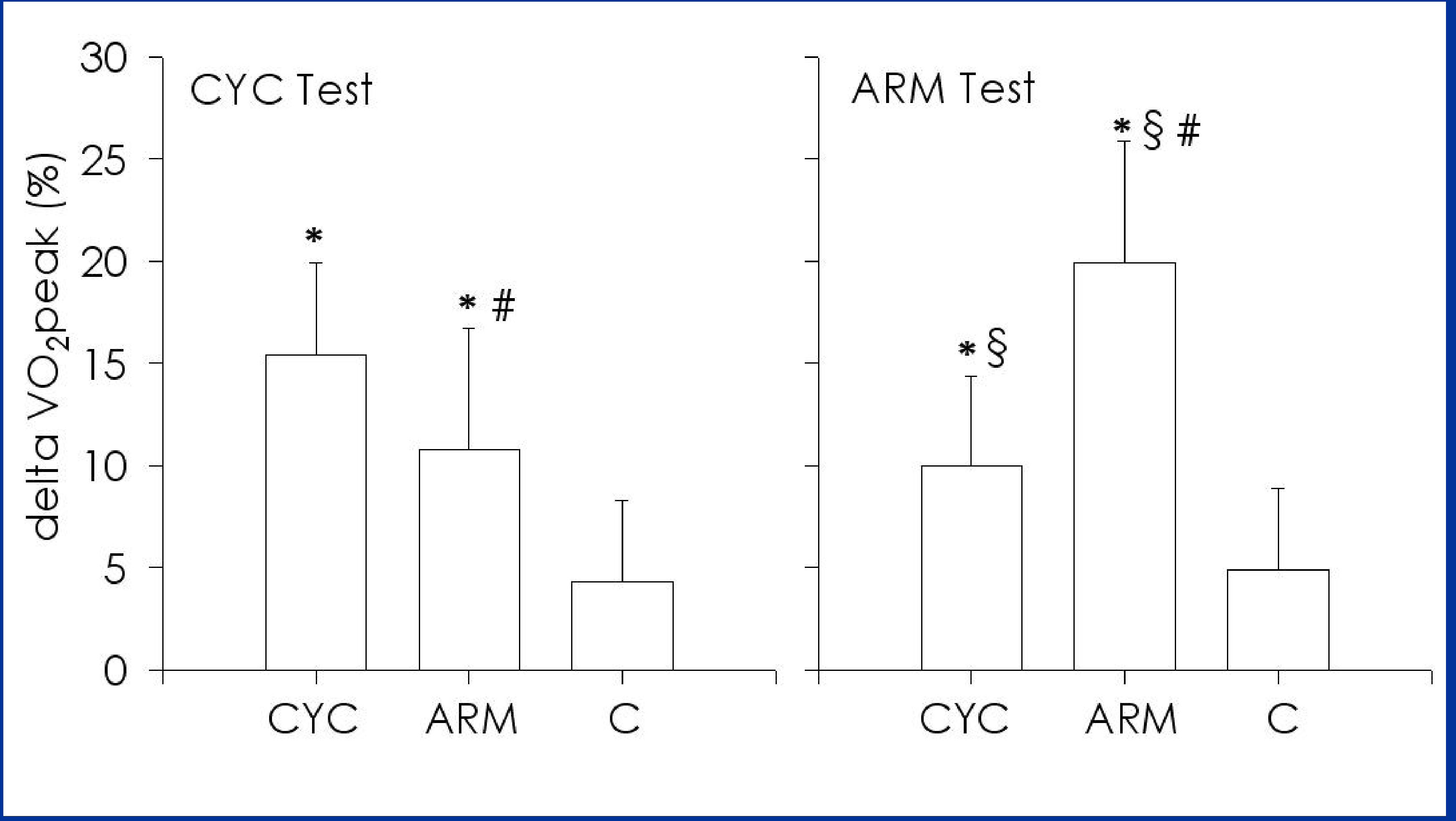
Absolute values before and after 12 w training



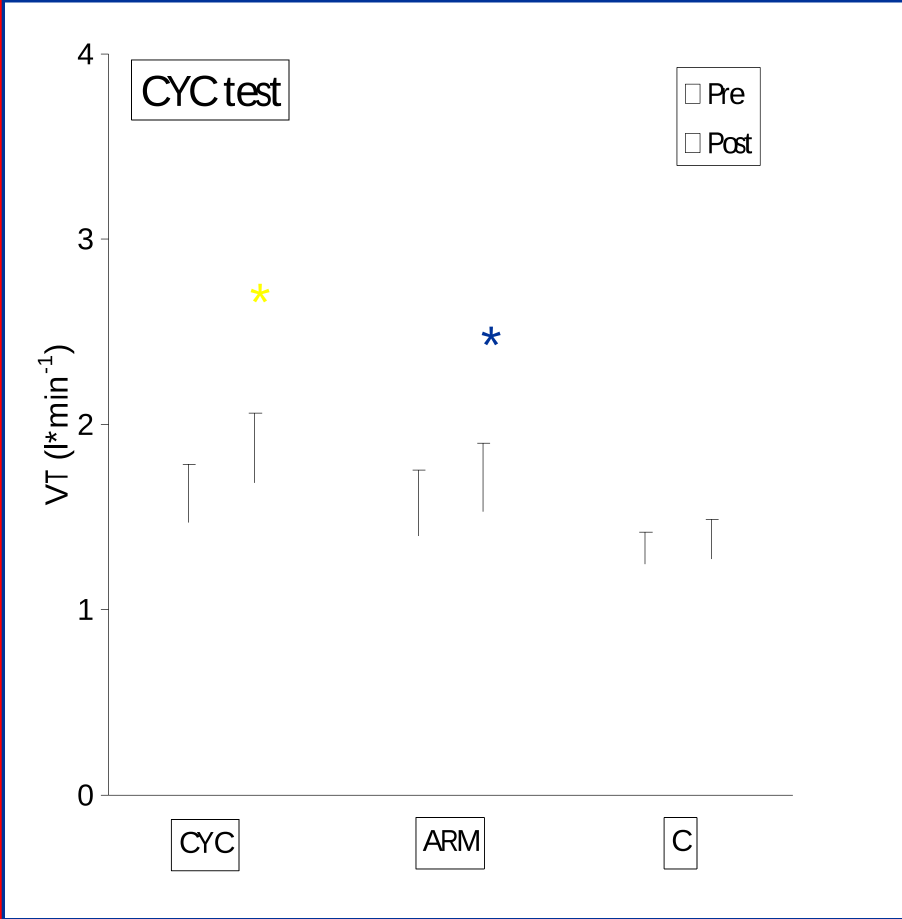
* Post vs. pre

§ ARM vs CYC

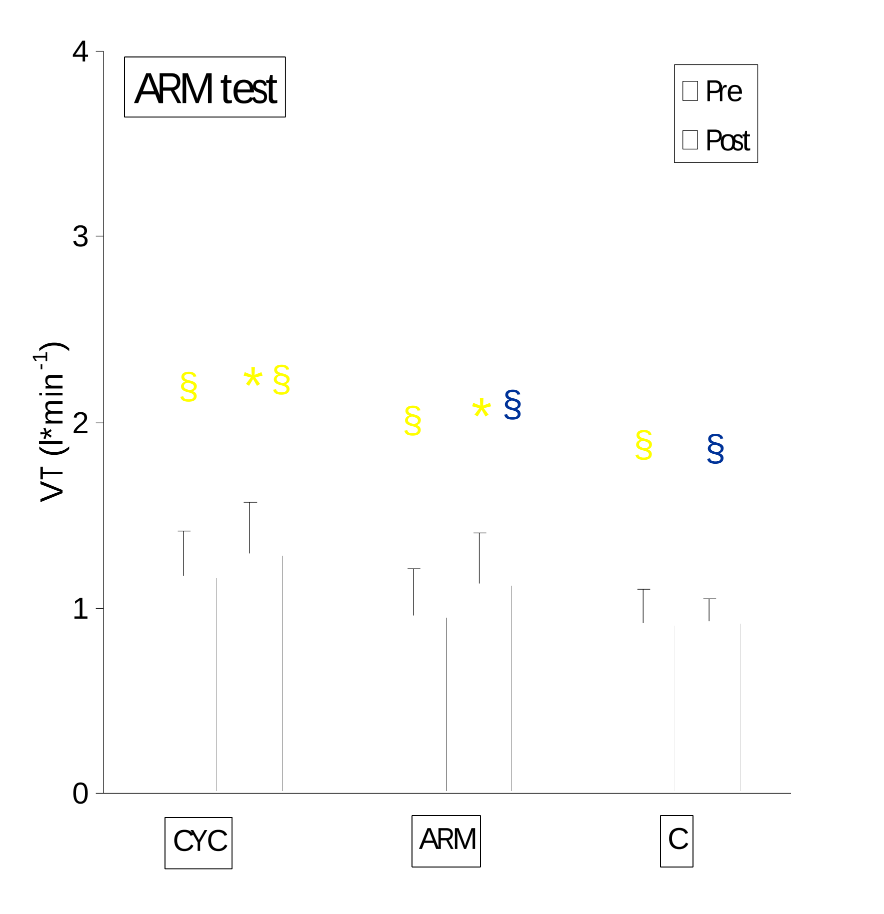
% Changes



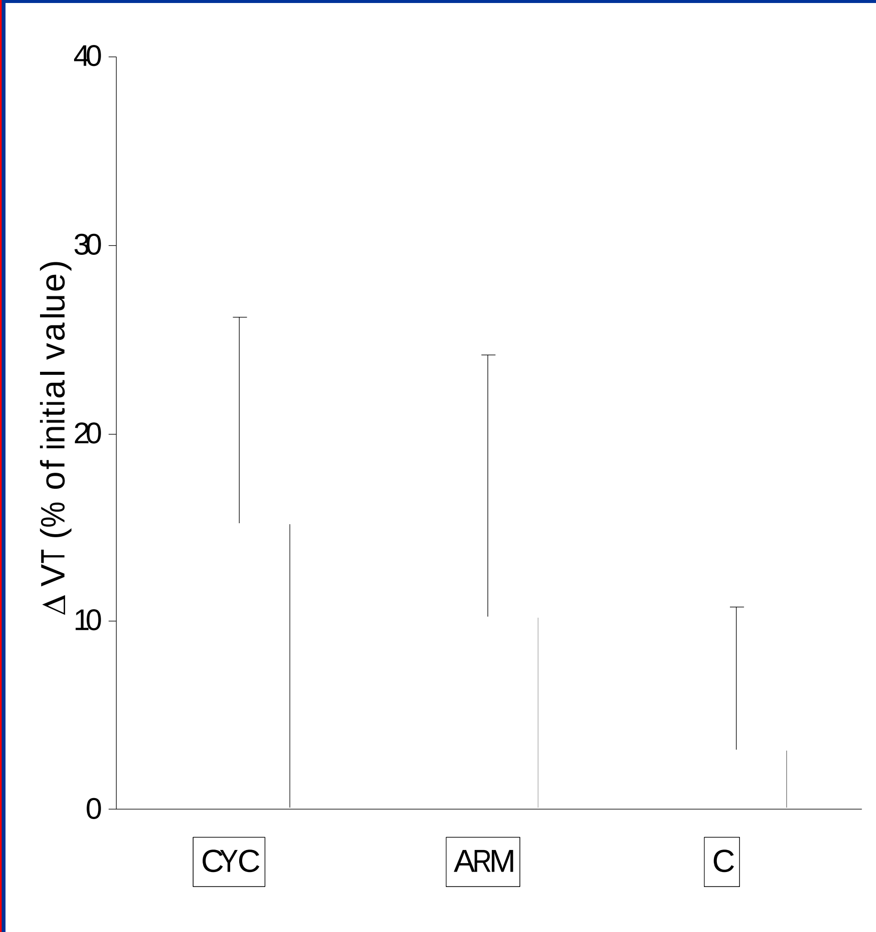
ARMgr vs CYC gr

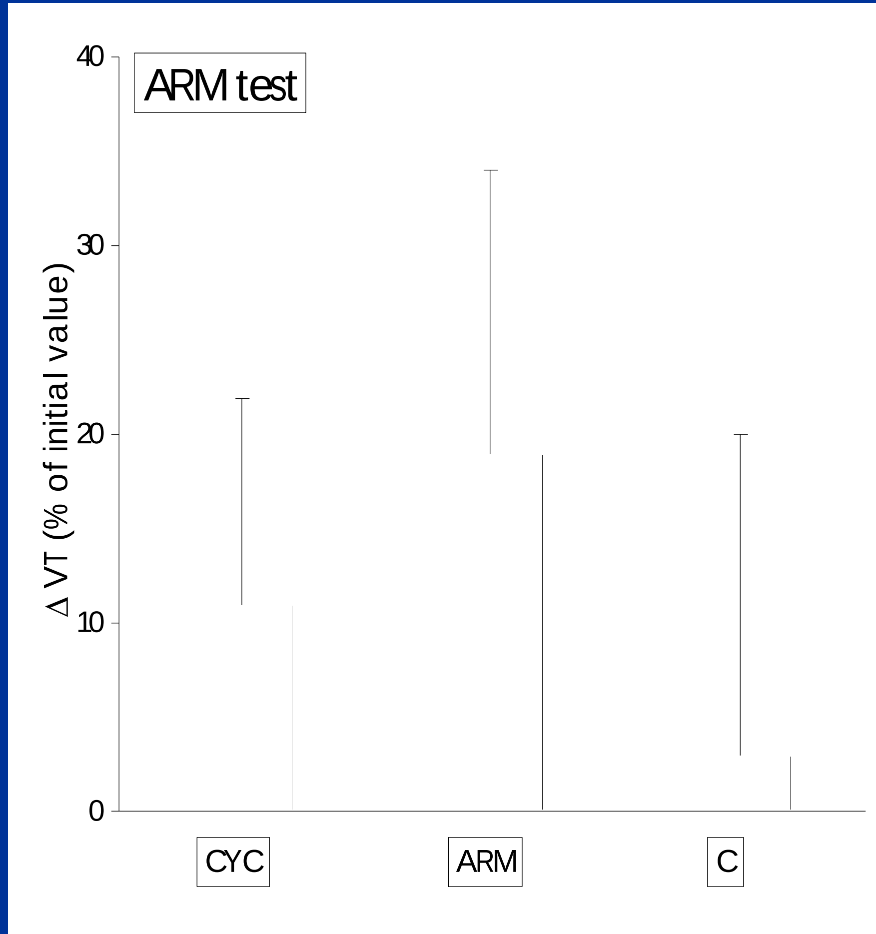


CYC test
Pre
Post
VT (l*min-1)
4
3
2
1
0
*
*
CYC
ARM
C



ARM test
Pre
Post
VT (l*min-1)
4
3
2
1
0
§
* §
§
* §
§
§
CYC
ARM
C


40
30
20
10
0
Δ VT (% of initial value)
CYC
ARM
C


ARM test
40
30
20
10
0
Δ VT (% of initial value)
CYC
ARM
C

Conclusions:

Our data demonstrate that a 12-week CYC (large muscle masses) and ARM (smaller muscle masses) training have a similar potential to increase hetero-ergometer exercise tolerance by ~10 % (aspecific effect).

Similarly, both ARM and CYC training increase homeo-ergometer exercise capacity by ~15-20 % (specific effect).

It could also be suggested that central and peripheral factors contribute for about 50% each at the adaptations to training

perspectives for future studies