Individual Differences in Body Composition and Cardiometabolic Response to Exercise

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I have no financial or non-financial relationships, interests, or affiliations to disclose

Trends in obesity defined by body mass index among adults before and during the COVID-19 pandemic: a repeated cross-sectional study of the 2009–2023 Canadian Community Heath Surveys

Laura N. Anderson PhD, Rabiul Islam PhD, Arthur Sweetman PhD

"Prevalence of BMI-defined obesity increased from 24.9% in 2009 to 32.7% in 2023 (absolute increase 7.7%)."
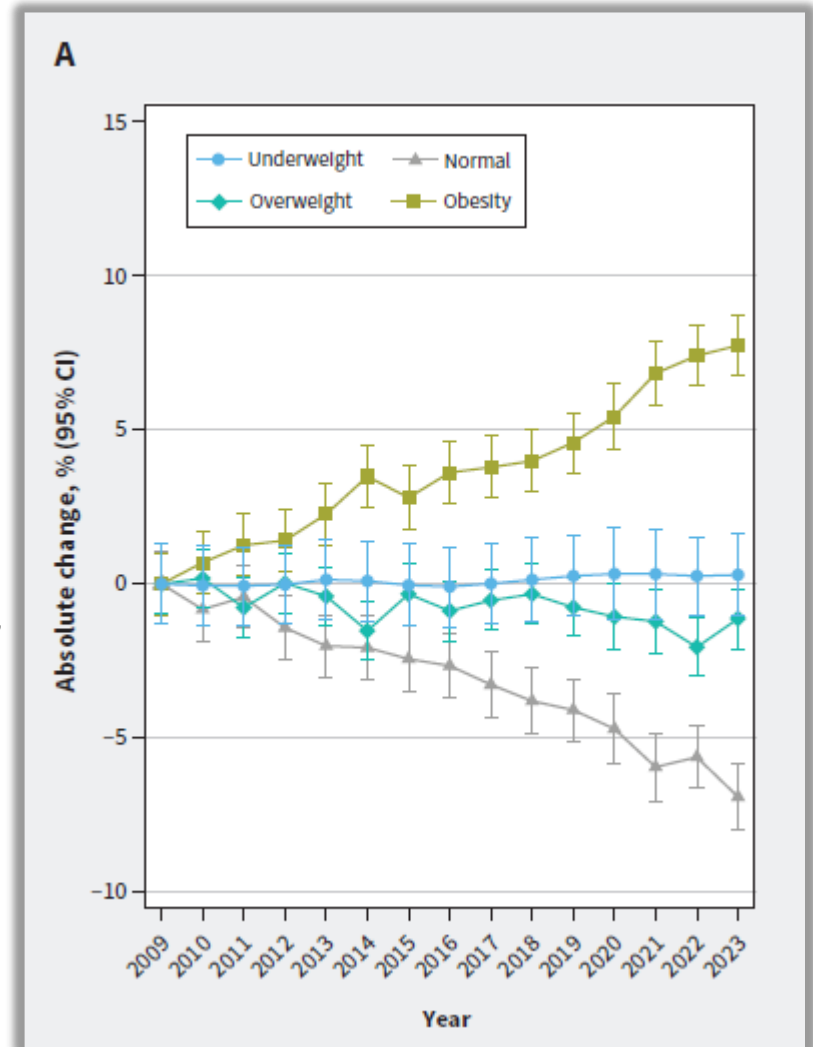
Physical Activity and Obesity Management: Individual Variability

Section 1:

In what context do we consider individual variability in response to exercise?
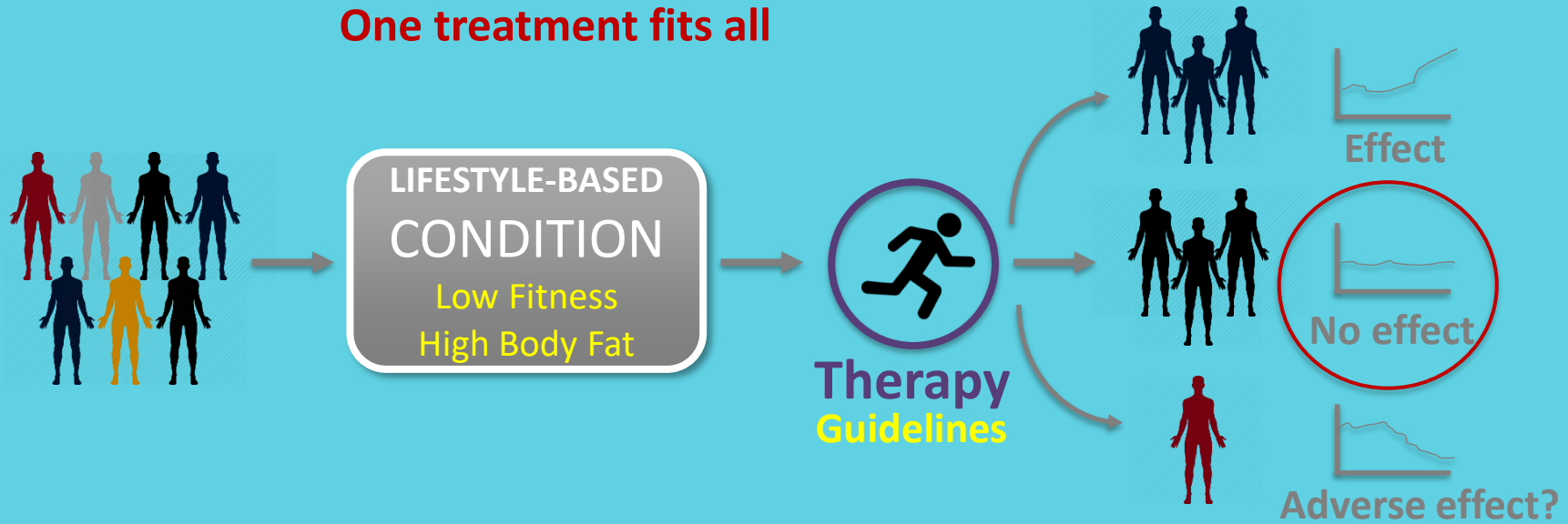
Section 2:

Determining the existence of exercise-induced variability for any trait *is a complex issue*.

Section 3:

Summary observations regarding exercise-induced variability in body composition and selected cardiometabolic risk factors.
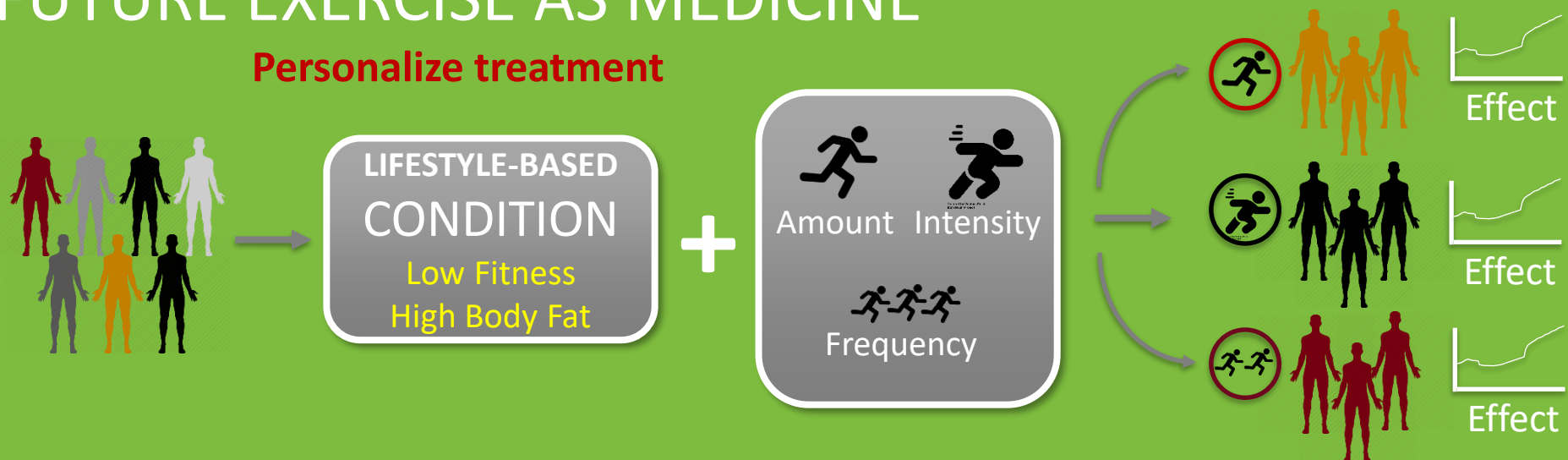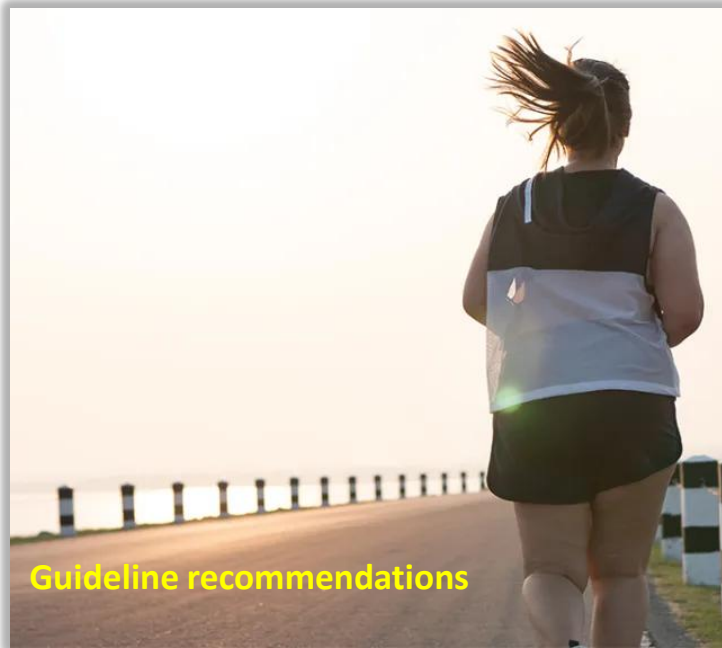
CURRENT EXERCISE AS MEDICINE

One treatment fits all

LIFESTYLE-BASED
CONDITION
Low Fitness
High Body Fat

Therapy
Guidelines

Effect

No effect

Adverse effect?

FUTURE EXERCISE AS MEDICINE

Personalize treatment

LIFESTYLE-BASED
CONDITION
Low Fitness
High Body Fat

+

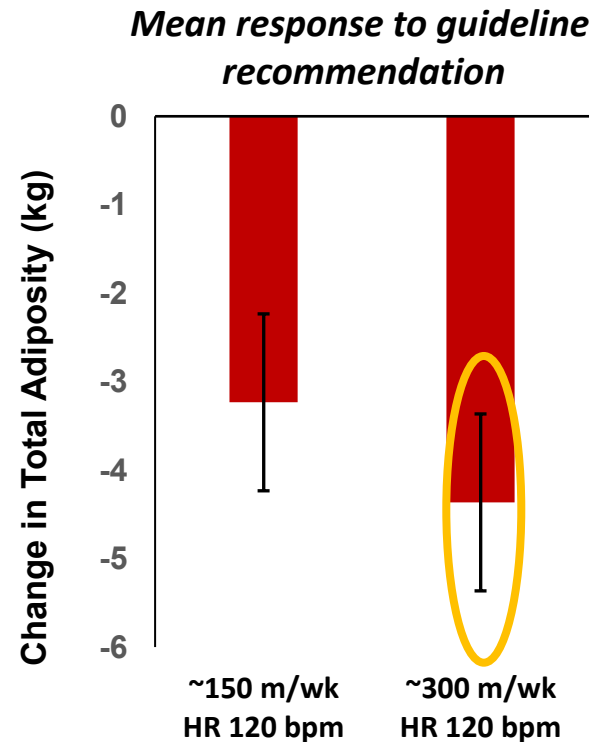Amount   Intensity

Frequency

Effect

Effect

Effect

Guideline recommendations

Obesity management guidelines worldwide prescribe increased aerobic-type physical activity (such as brisk walking) for more than 150 minutes per week.
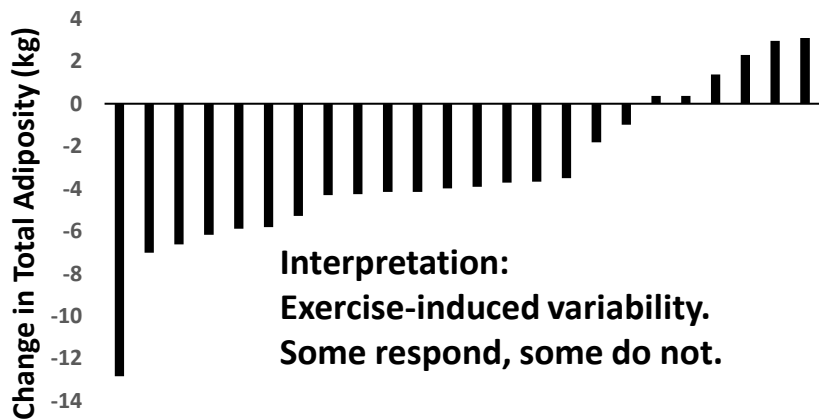
American College of Sports Medicine Position Stands, recommend 200 to 300 minutes a week for long-term weight loss.

Mean response to guideline recommendation

Change in Total Adiposity (kg)

~150 m/wk
HR 120 bpm

~300 m/wk
HR 120 bpm

Individual variation in adipose tissue (MRI) response at 24 weeks to standardized exercise in adults with obesity
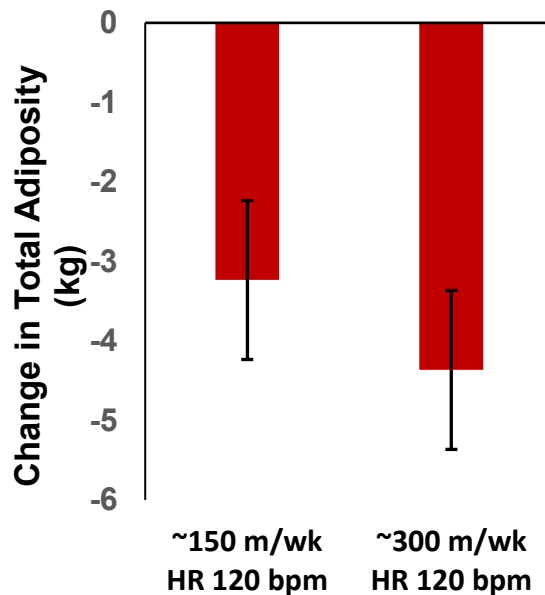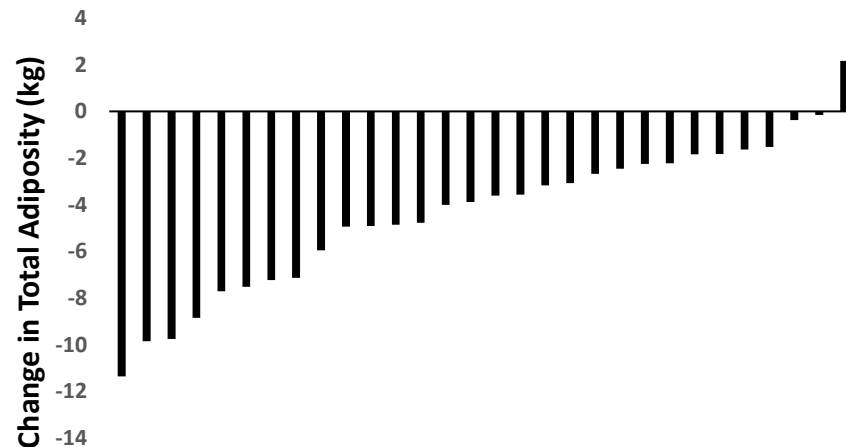

Implication for obesity management?

Interpretation:
Exercise-induced variability.
Some respond, some do not.

Individual Participants (n=24)
~150 m/wk

Individual Participants (n=30)
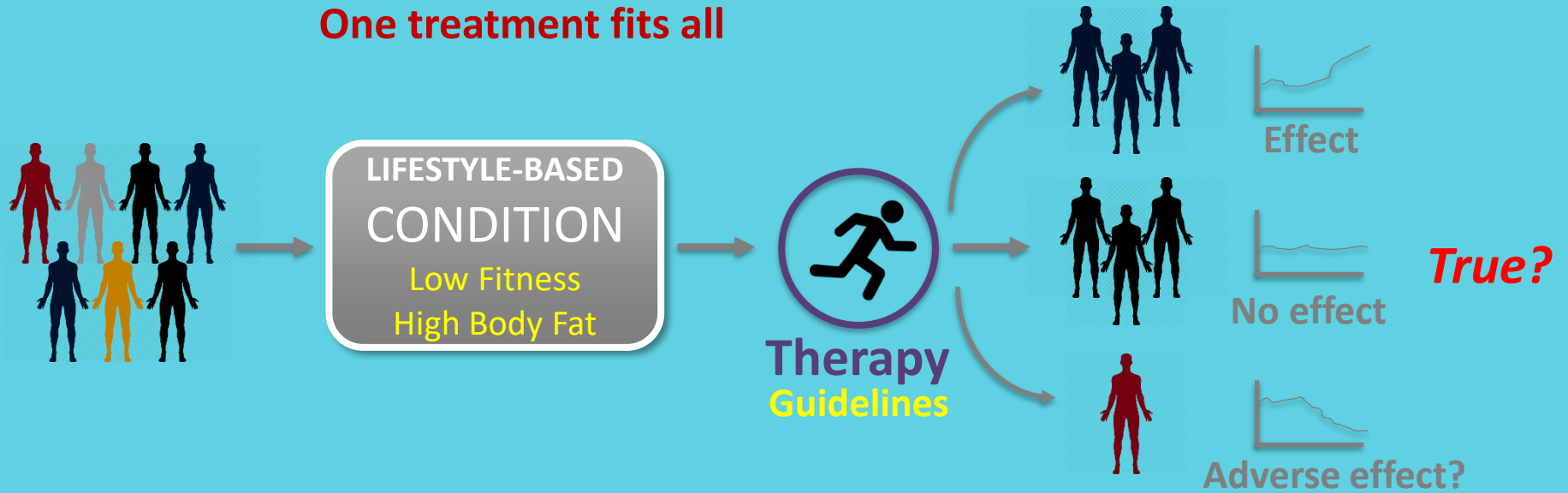~300 m/wk...

Adapted from *Cowan et al*. Obesity 2018.

We use consensus guidelines, based on *group* response, to prescribe the exercise dose, the *individual* response to the exercise dose is used to interpret treatment efficacy / benefit.

CURRENT EXERCISE AS MEDICINE

One treatment fits all

LIFESTYLE-BASED
CONDITION
Low Fitness
High Body Fat

Therapy
Guidelines

Effect

No effect

True?

Adverse effect?

FUTURE EXERCISE AS MEDICINE

Personalize treatment

LIFESTYLE-BASED
CONDITION
Low Fitness
High Body Fat

+

Amount   Intensity

Frequency

Effect

Effect

Effect
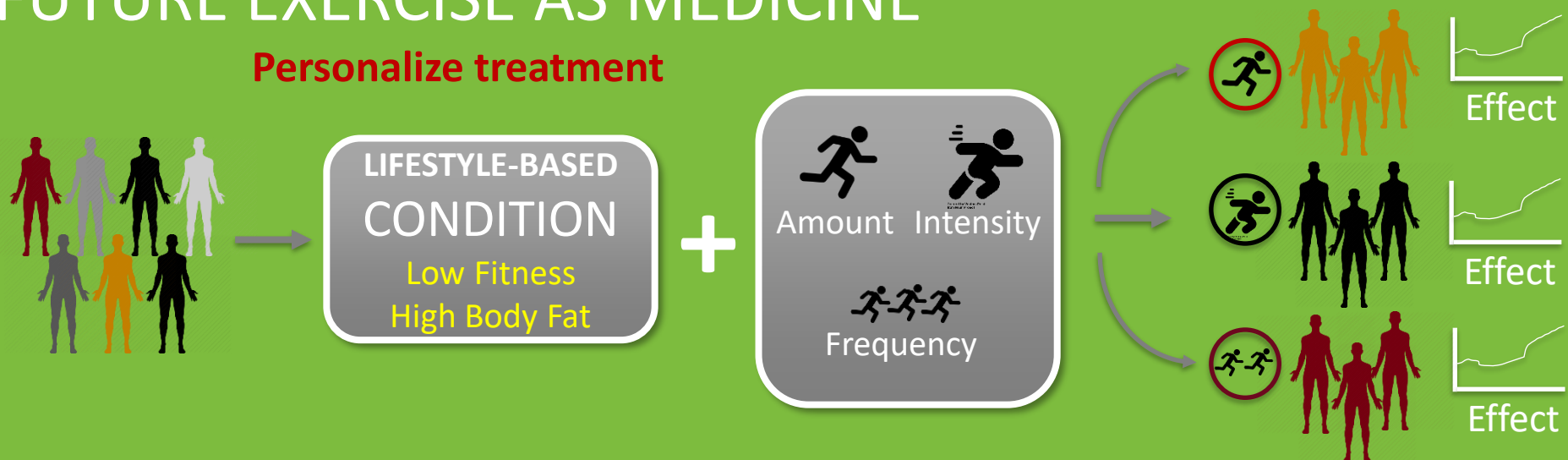
Individual variation in adipose tissue (MRI) response at 24 weeks to standardized exercise in adults with obesity
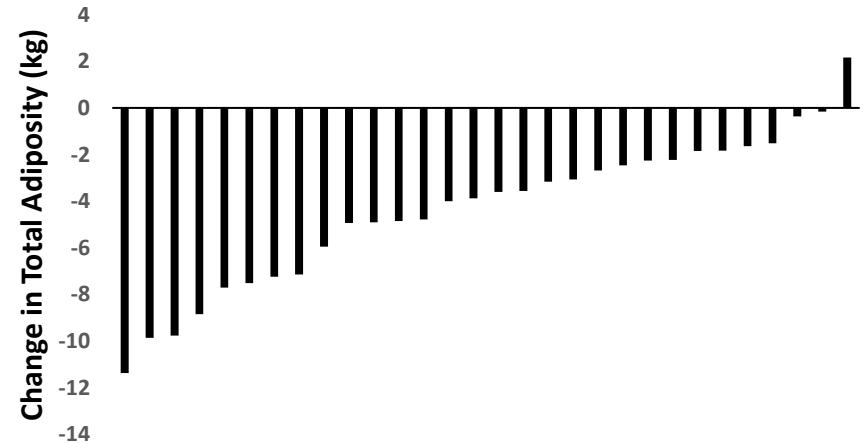
Individual variation in adipose tissue (MRI) response at 24 weeks to standardized exercise in adults with obesity

The question is not whether variability post exercise will be observed. But rather:

1) Is the variability due to treatment?
2) Is the variability clinically meaningful?
3) Is the *individual* treatment response beyond the technical error?

Change in Total Adiposity (kg)

4
2
0
-2
-4
-6
-8
-10
-12
-14

Individual Participants (n=24)
~150 m/wk

Change in To...

-8
-10
-12
-14

Individual Participants (n=30)
~300 m/wk...

Physical Activity and Obesity Management: Individual Variability

Section 1:

In what context do we consider individual variability in response to exercise, and is it important?

Section 2:

Determining the existence of exercise-induced variability for any trait is a complex issue.

Section 3:

Summary observations regarding exercise-induced variability in body composition and selected cardiometabolic risk factors.

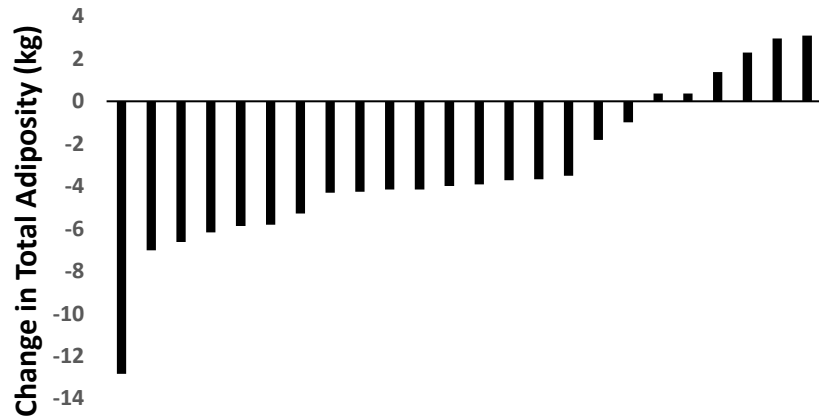# Does *Individual* variation in adipose tissue (MRI) response to exercise in adults with obesity

Change in Total Adiposity (kg)

Individual Participants (n=24)
~150 m/wk

Change in Total Adiposity (kg)

Individual Participants (n=30)
~300 m/wk...

To determine whether or not exercise-induced variability exists for a given trait, study designs, ideally, require:

Time-matched control group

Criterion/reference methods

Supervised, standardized exercise

24hr PA – Accelerometry (PA performed outside that prescribed)

Daily self-recording of Energy intake

# Inter-Individual Responses of Maximal Oxygen Uptake to Exercise Training: A Critical Review

Philip J. Williamson[1] · Greg Atkinson[1] · Alan M. Batterham[1]

True inter-individual differences in exercise training response can be precisely quantified and appraised for clinical importance only with parallel information from a suitable comparator group or data from a relevant reliability study. Importantly, none of the studies resulting from the HEalth, RIsk factors, exercise Training And GEnetics (HERITAGE) Family Study included a comparator sample.

Control Group

Measurement error
Day-to-day biological variability
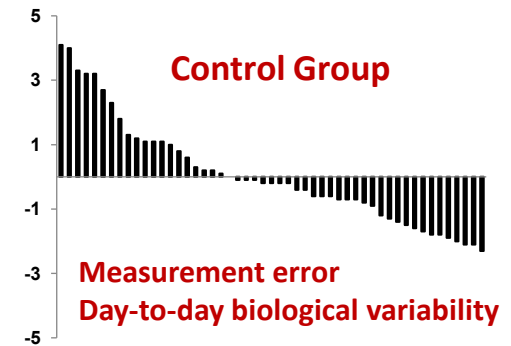
$$SD_R = \sqrt{SD_I{}^2 - SD_C{}^2}$$

**If the SD within the time-matched control group
is not *meaningfully* different from the SD in the exercise group (SDr),
there are no inter-individual differences (variability)
in response to exercise.**

To determine whether exercise-induced response variability exists:

Question 1: Is there clinically meaningful variability in response to standardized exercise?

Control   **LALI** (150 min/week)   **HALI** (300 min/week, 50%)   **HAHI** (200 min/week, 75%)

ΔCRF at 24 weeks (L/min)

$SD_R = 0.07$ $SD_R = 0.2$ $SD_R = 0.2$
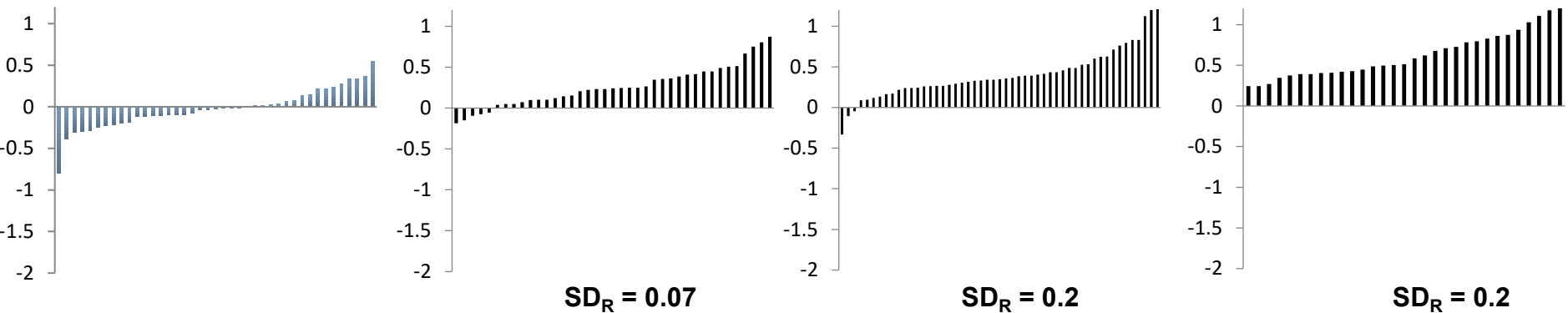
$$SD_R = \sqrt{SD_I{}^2 - SD_C{}^2}$$

If SD_R is clinically meaningful, then exercise-induced variability exists

However, whether a given individual result is beyond the 'technical error' observed within the control group requires further investigation.

To determine whether exercise-induced response variability exists:

Question 2: To what degree are we 'certain' that the individual response is exercise-induced?

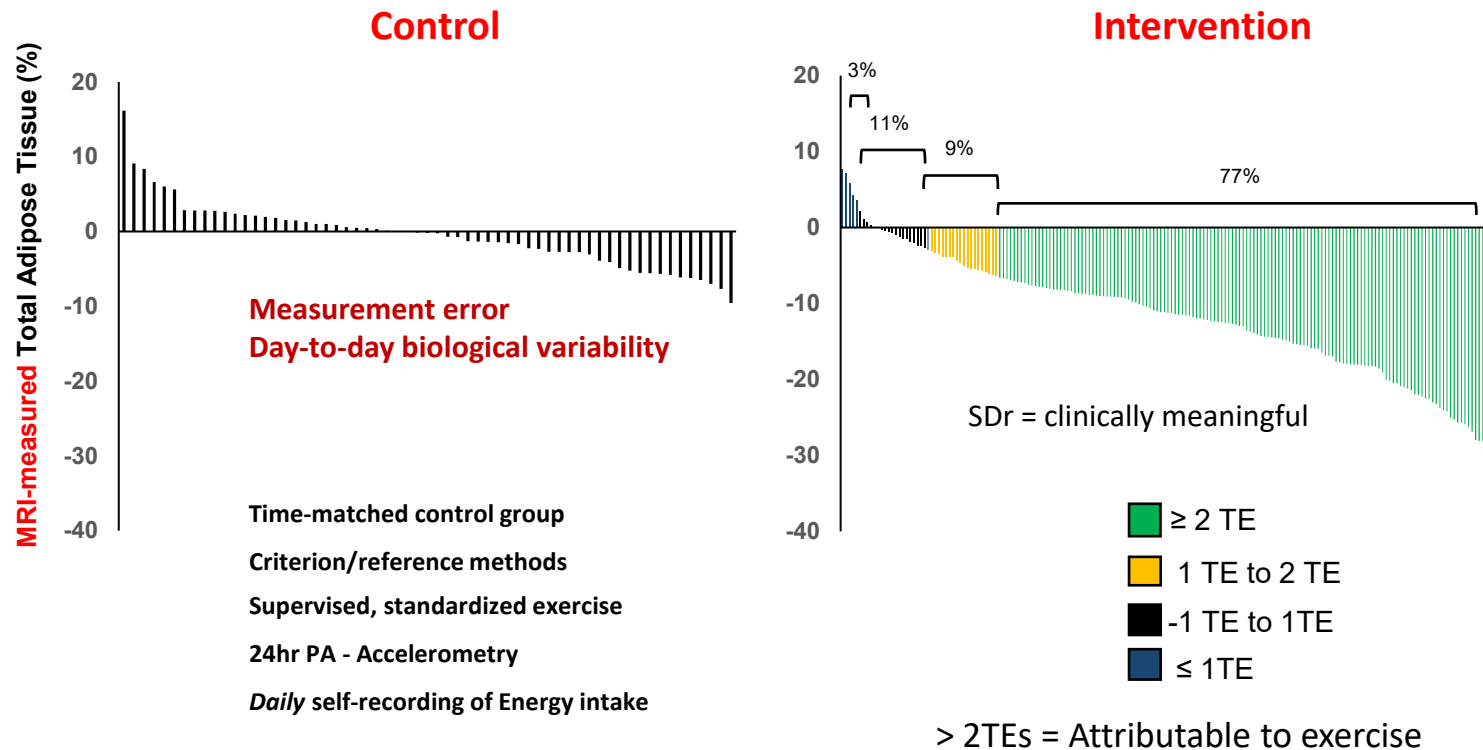$$TE = \frac{\sqrt{\sum(\text{measure}1 - \text{measure}2)^2}}{2n}$$

**TE reflects measurement error
and day-to-day biological variability**

The data used to derive the TE is obtained from a <u>time-matched</u> control group (use the pre- and post-treatment scores from the control group paticipants).

**Is the individual response to exercise (pre-post intervention) *beyond* the
TE (pre-post intervention) derived from the control group?**

To determine whether exercise-induced response variability exists:

Question 2: To what degree are we 'certain' that the individual response is exercise-induced?

Control

Intervention

MRI-measured Total Adipose Tissue (%)

3%
11%
9%
77%

Measurement error
Day-to-day biological variability

SDr = clinically meaningful

Time-matched control group

Criterion/reference methods

Supervised, standardized exercise

24hr PA - Accelerometry

Daily self-recording of Energy intake

≥ 2 TE

1 TE to 2 TE

-1 TE to 1TE

≤ 1TE

> 2TEs = Attributable to exercise

Brennan A. et al. MSSE 54, 2022.

Individual 2-hr glucose response at 24 weeks to standardized, supervised exercise: effects of exercise amount and intensity in adults with obesity
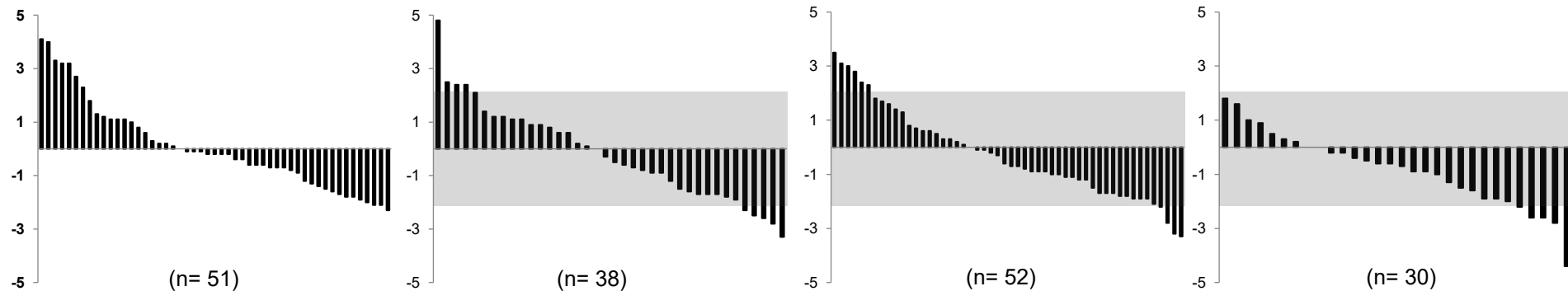
Control

LALI
(150 min/wk @ 50%)

HALI
(300 min/wk @ 50%)

HAHI
(200 min/wk @ 75%)

Δ 2hr Glucose at 24 weeks (mmol/L)

(n= 51) (n= 38) (n= 52) (n= 30)

No exercise-induced variability (SDr), and majority of Individual responses to exercise are 'uncertain' – do not exceed control group derived TE

= TE, day-to-day variability of measurement ('time matched control group')

$$TE = \frac{\sqrt{\sum(\text{measure1} - \text{measure2})^2}}{2n}$$

de Lannoy et al. PLoS ONE 12(5), 2017.

Determining the existence of exercise-induced variability for any trait is a complex issue.

For researchers:

Time-matched *control group* in the trial design?

Criterion method, measure the outcome twice at each time point (pre-post)

Measure the outcome at multiple time points throughout the intervention

Account for physical activity outside of that prescribed, dietary intake

$$SD_R = \sqrt{SD_I^2 - SD_C^2}$$

Is there exercise-induced variability?

$$TE = \frac{\sqrt{\sum(\text{measure1} - \text{measure2})^2}}{2n}$$

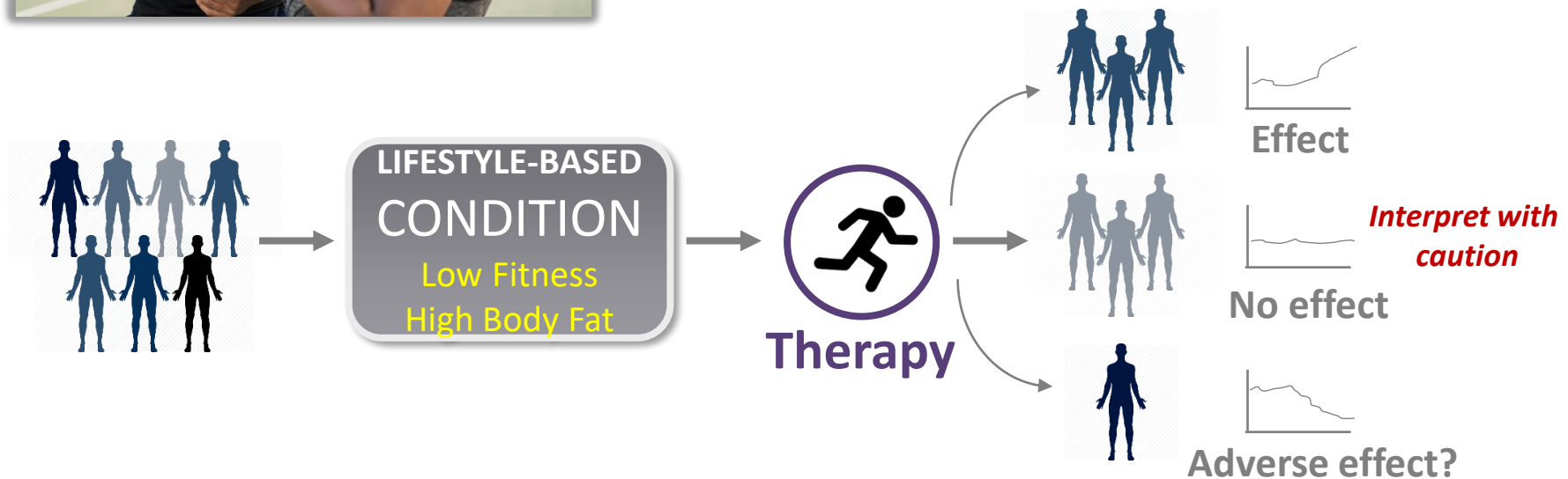Is the individual exercise response *beyond* the TE derived from the control group?

Determining the existence of exercise-induced variability for any trait is a complex issue.

For practitioners:

Obesity management guidelines worldwide prescribe increased aerobic-type physical activity (such as brisk walking) for more than 150 minutes per week.

American College of Sports Medicine Position Stands, recommend 200 to 300 minutes a week for sustained weight loss.

LIFESTYLE-BASED
CONDITION
Low Fitness
High Body Fat

Therapy

Effect

Interpret with caution

No effect

Adverse effect?

Measure the trait of interest, as often as possible
Measurement precision – TE (measurement error) is it known?

OPEN ACCESS

Precision exercise medicine: understanding exercise response variability

Robert Ross,[1] Bret H Goodpaster,[2] Lauren G Koch,[3] Mark A Sarzynski,[4] Wendy M Kohrt,[5] Neil M Johannsen,[6,7] James S Skinner,[8] Alex Castro,[9] Brian A Irving,[7,10] Robert C Noland,[11] Lauren M Sparks,[2] Guillaume Spielmann,[7,10] Andrew G Day,[12] Werner Pitsch,[13] William G Hopkins,[14] Claude Bouchard[15]

Br J Sport Med 2018

rossr@queensu.ca

Physiological Reports

Open Access

Physiological Reports ISSN 2051-817X

REVIEW ARTICLE

An appraisal of the SD_{IR} as an estimate of true individual differences in training responsiveness in parallel-arm exercise randomized controlled trials

Jacob T. Bonafiglia, Andrea M. Brennan, Robert Ross & Brendon J. Gurd

School of Kinesiology and Health Studies, Queen's University, Kingston, Ontario

Jacob T. Bonafiglia is a PhD Candidate studying under the supervision of Dr. Brendon Gurd in the School of Kinesiology and Health Studies at Queen's University in Kingston, Ontario, Canada. Their research is focused on exercise and skeletal muscle physiology in humans, with a current emphasis on exploring the statistical approaches and underlying mechanisms of individual response variability to exercise training. Drs. Andrea Brennan and Robert Ross also share an interest in individual responses to exercise training, with a particular focus on using large randomized controlled trials to investigate response variability in clinically-relevant health outcomes.

Physiol Rep 2019

Directions for Exercise Treatment Response Heterogeneity and Individual Response Research

Authors

Travis J. Hrubeniuk[1,2], Jacob T. Bonafiglia[3], Danielle R. Bouchard[2,4], Brendon J. Gurd[3], Martin Sénéchal[2,4]

Int J Sport Med 2022

Repeated testing for the assessment of individual response to exercise training

Anne Hecksteden,[1] Werner Pitsch,[2] Friederike Rosenberger,[3,4] and Tim Meyer[1]

[1]Institute of Sports and Preventive Medicine, Saarland University, Saarbruecken, Germany; [2]Institute for Sport Sciences, Department of Sociology and Economics of Sports, Saarland University, Saarbruecken, Germany; [3]Heidelberg University

J Appl Physiol 2018

The application of repeated testing and monoexponential regressions to classify individual cardiorespiratory fitness responses to exercise training

Jacob T. Bonafiglia[1] · Robert Ross[1] · Brendon J. Gurd[1]

Eur J Appl Physiol 2019

Physical Activity and Obesity Management: Individual Variability

Section 1:

In what context do we consider individual variability in response to exercise, and is it important?

Section 2:

Determining the existence of exercise-induced variability for any trait is a complex issue.

Section 3:

Summary observations regarding exercise-induced variability in body composition and selected cardiometabolic risk factors.

When trying to determine the existence of individual variability in response to exercise for any trait..

Toward Personalized Exercise Medicine: A Cautionary Tale

ANDREA M. BRENNAN[1], ANDREW G. DAY[2], JOHN CLARKE[2], and ROBERT ROSS[3,4]

[1]AdventHealth Orlando, Translational Research Institute, Orlando, FL; [2]Kingston Health Sciences Centre, Kingston, Ontario, CANADA; [3]Department of Medicine, Division of Endocrinology and Metabolism, Queen's University, Kingston, Ontario, CANADA; and [4]School of Kinesiology and Health Studies, Queen's University, Kingston, Ontario, CANADA

Andrea Brennan, PhD
Research Scientist
AdventHealth Research Institute
Orlando, USA

After adjustment for the variability observed within the control group,
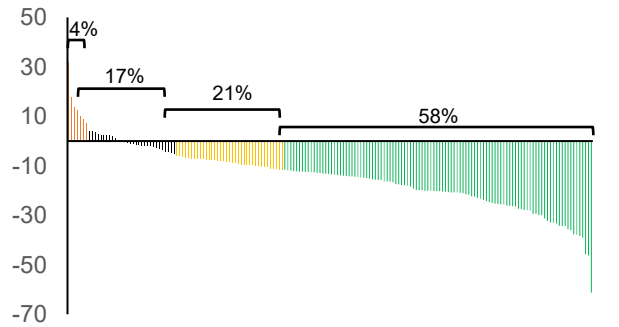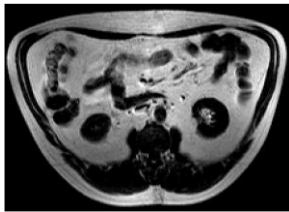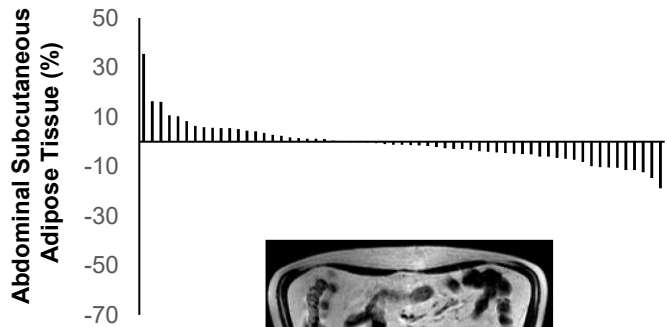## To what extent do changes in exercise-induced body composition or cardiometabolic risk factors exist?

Control

Intervention

Total Adipose Tissue (%)

Response variability exists, and it is exercise-induced
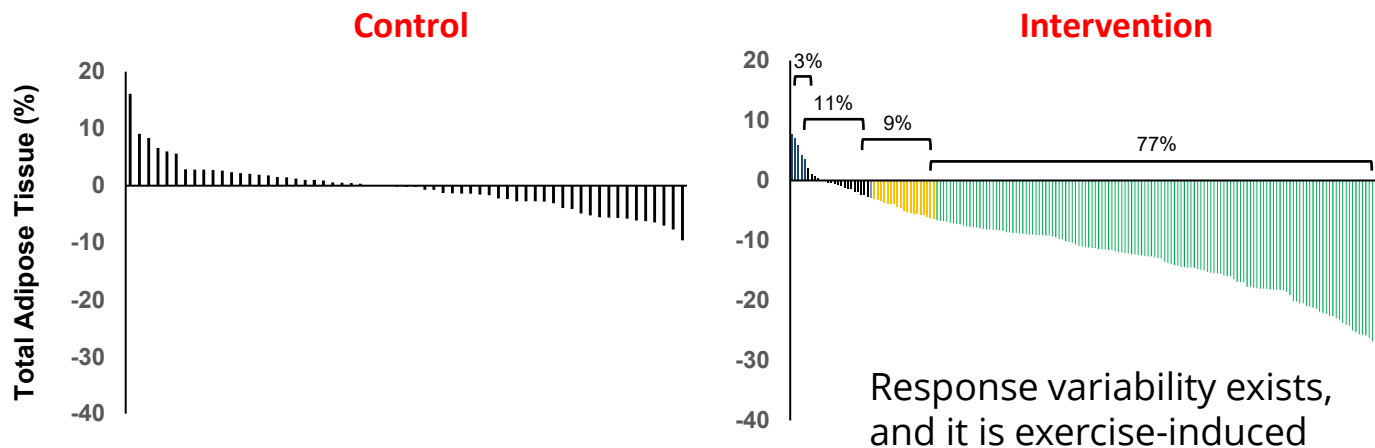
We are '*certain*' that 77% of the participants benefitted from the exercise intervention whereas for 23%, we are '*uncertain*'
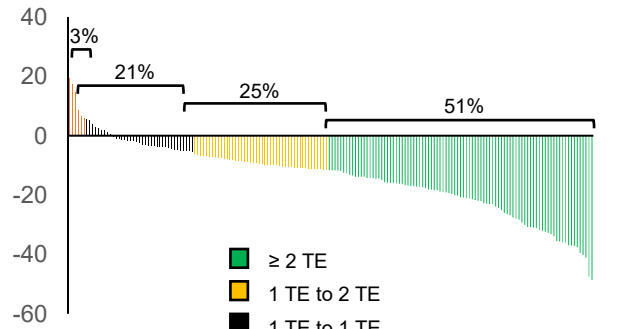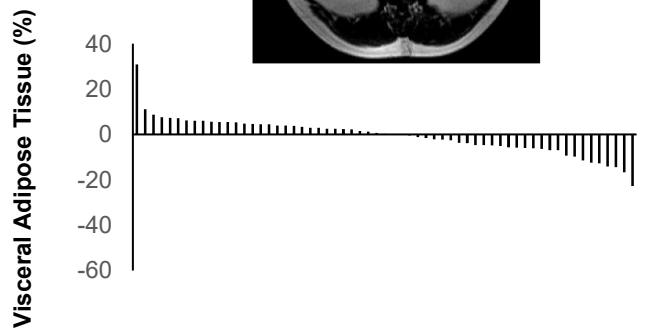
- ≥ 2 TE
- 1 TE to 2 TE
- -1 TE to 1TE
- ≤ 1TE

Brennan A. et al. MSSE 54: 1861-68, 2022.

Individual MRI-measured adipose tissue (%) response to standardized exercise in adults with obesity
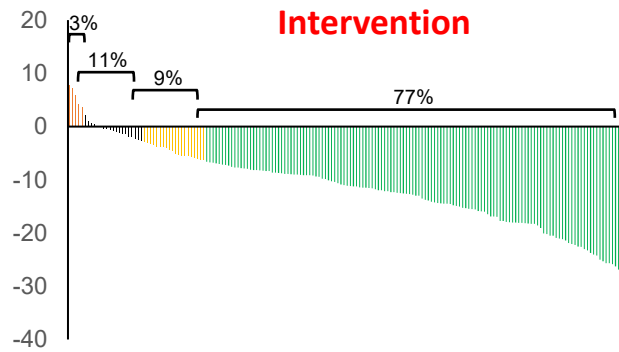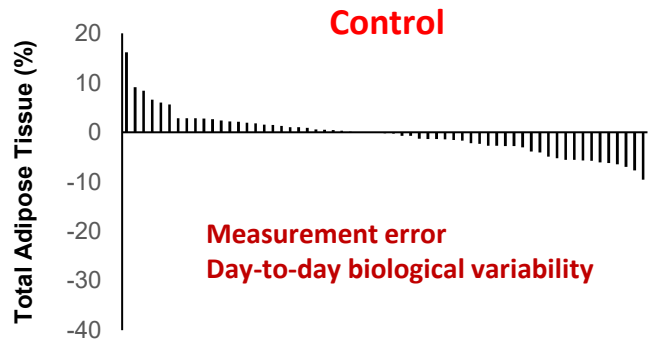
Control

Intervention

Control = 87
Exercise = 251

Total Adipose Tissue (%)

Measurement error
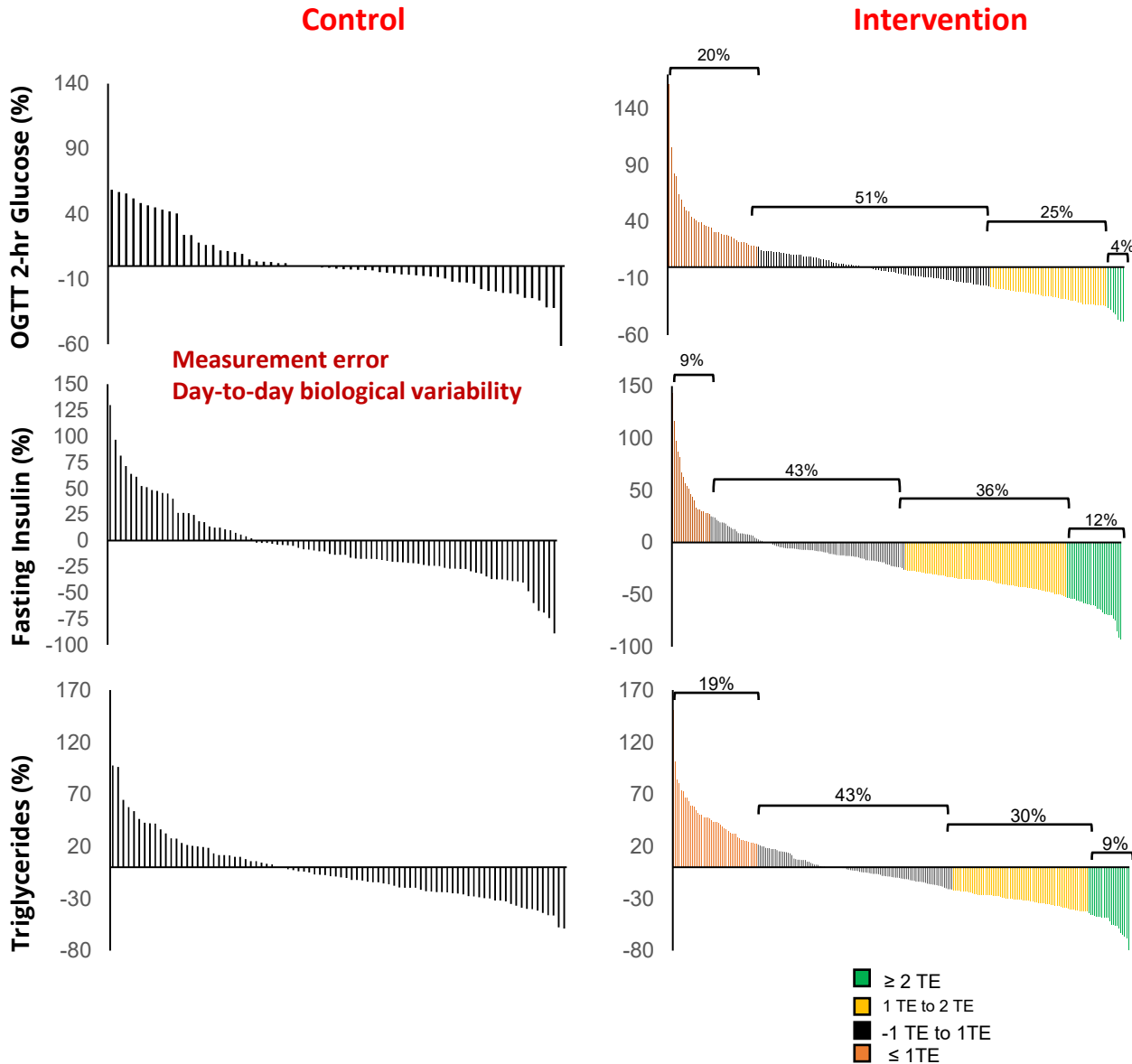**Day-to-day biological variability**

3%
11%
9%
77%

Time-matched control group

Criterion/reference methods

Supervised, standardized exercise

24hr PA - Accelerometry

Daily self-recording of Energy intake

Abdominal Subcutaneous Adipose Tissue (%)

4%
17%
21%
58%

Visceral Adipose Tissue (%)

3%
21%
25%
51%

Legend:
- ≥ 2 TE
- 1 TE to 2 TE
- -1 TE to 1 TE
- ≤ 1TE

Brennan A. et al. MSSE 54: 1861-68, 2022.

Individual cardiometabolic response (%) to standardized exercise in adults with obesity

Control

Intervention

Control = 87
Exercise = 251

Measurement error
Day-to-day biological variability

OGTT 2-hr Glucose (%): 20%, 51%, 25%, 4%

Fasting Insulin (%): 9%, 43%, 36%, 12%

Triglycerides (%): 19%, 43%, 30%, 9%

Time-matched control group
Criterion/reference methods
Supervised, standardized exercise
24hr PA - Accelerometry
Daily self-recording of Energy intake

Legend:
- ≥ 2 TE
- 1 TE to 2 TE
- -1 TE to 1TE
- ≤ 1TE

Brennan A. et al. MSSE 54: 1861-68, 2022.

> 2TEs = Attributable to exercise

Individual CPET-measured CRF response to standardized exercise in adults with obesity

Control

Intervention

Legend:
- ≥ 2 TE (green)
- 1 TE to 2 TE (yellow)
- -1 TE to 1 TE (black)
- ≤ 1TE (orange)

Brennan A. et al. MSSE 54: 1861-68, 2022.
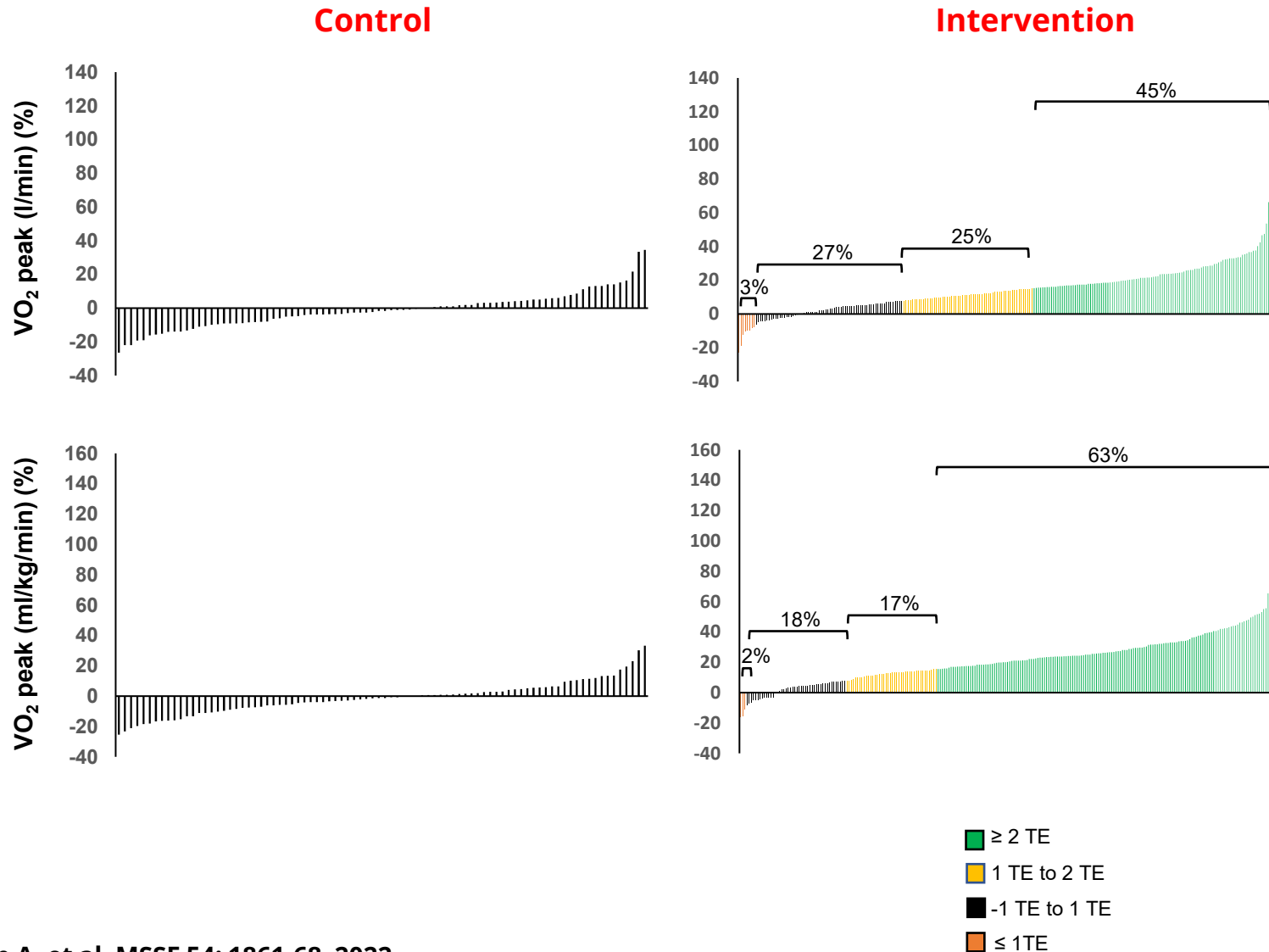
Does *Individual* variation in CRF response to standardized exercise in adults with obesity exit?
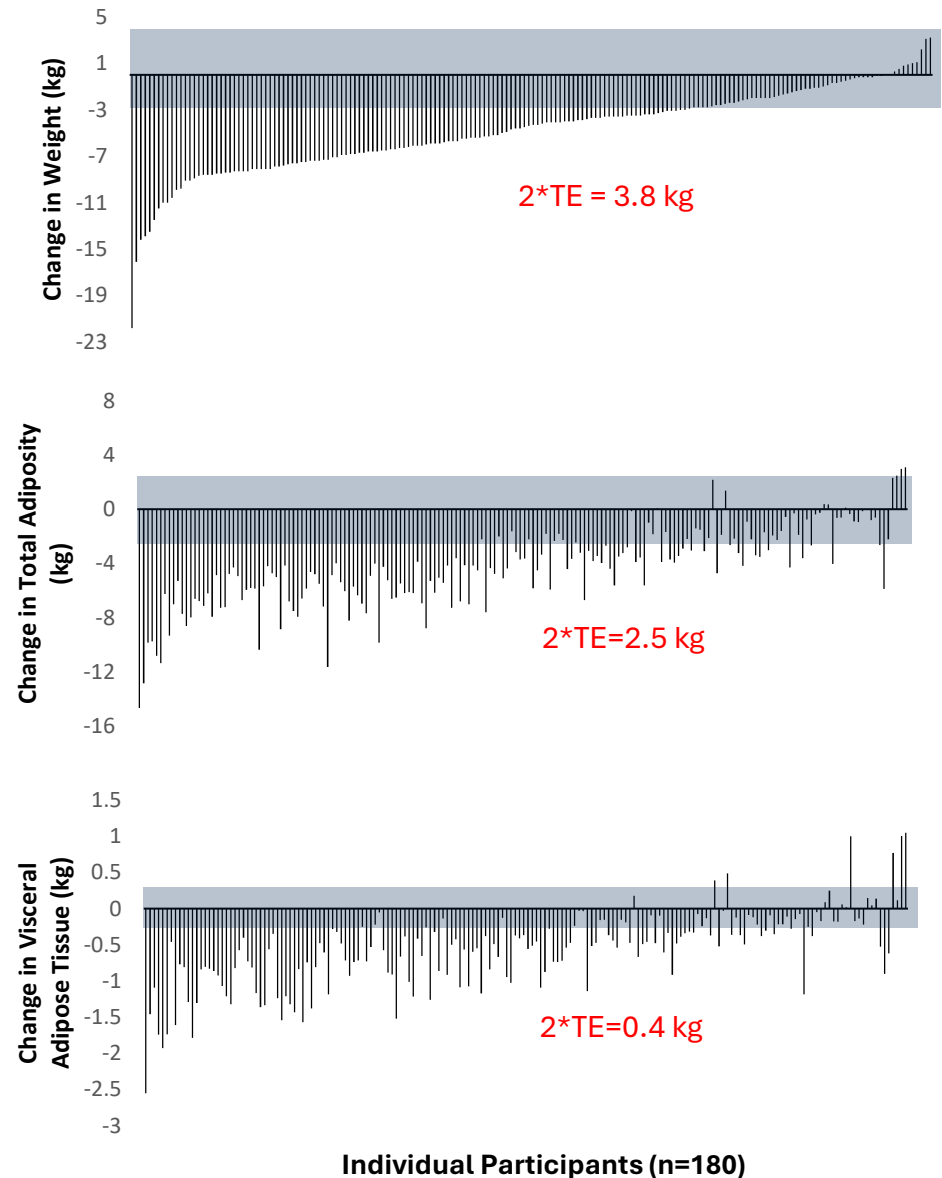

Ross et al. *Ann Intern Med*, 2015
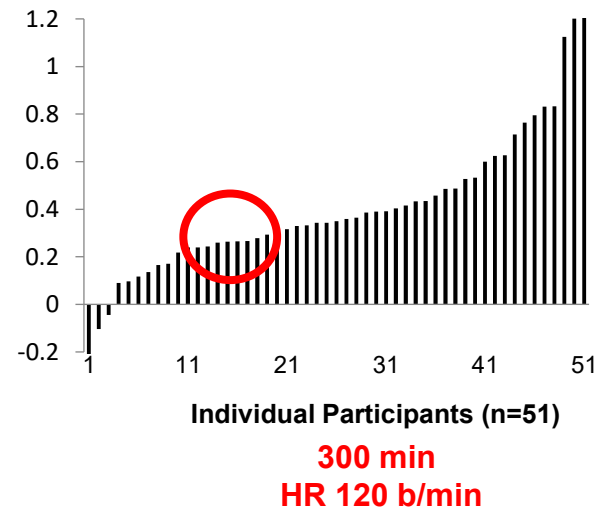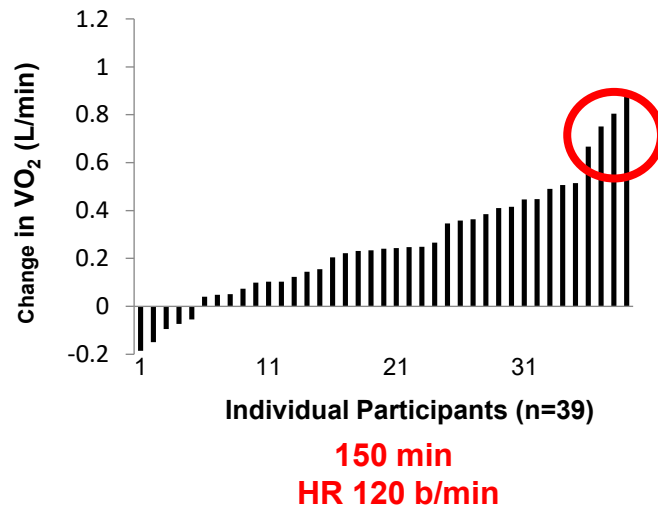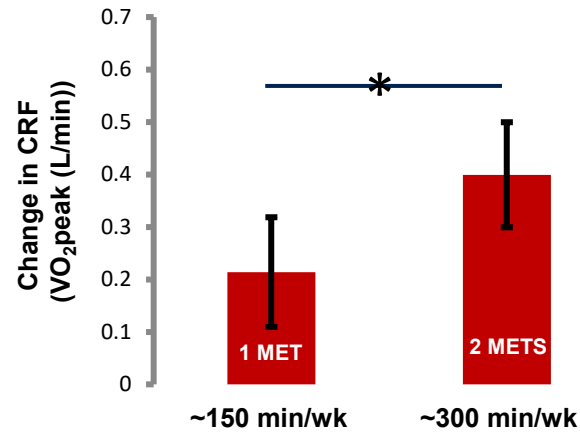
Does individual change in body weight predict corresponding change in adipose tissue depots?
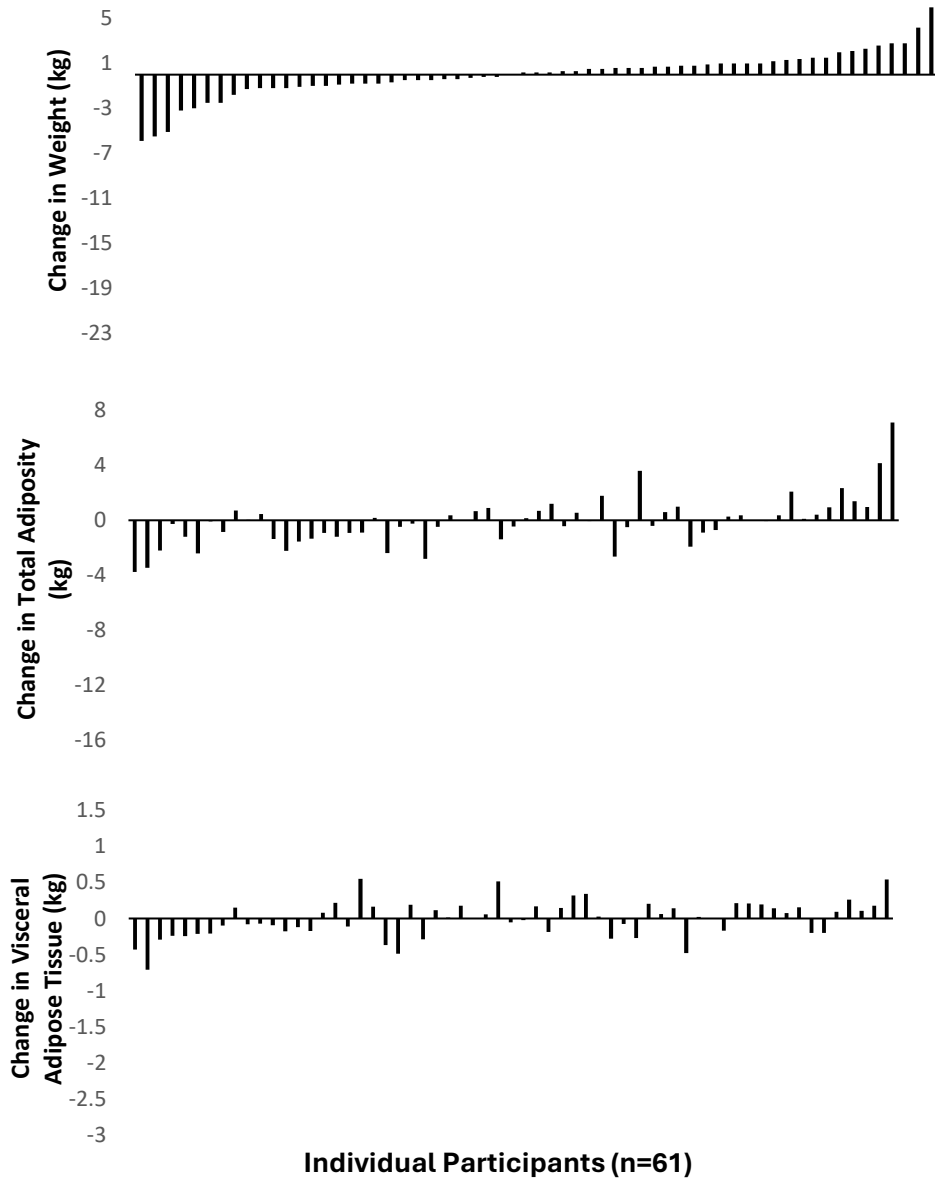
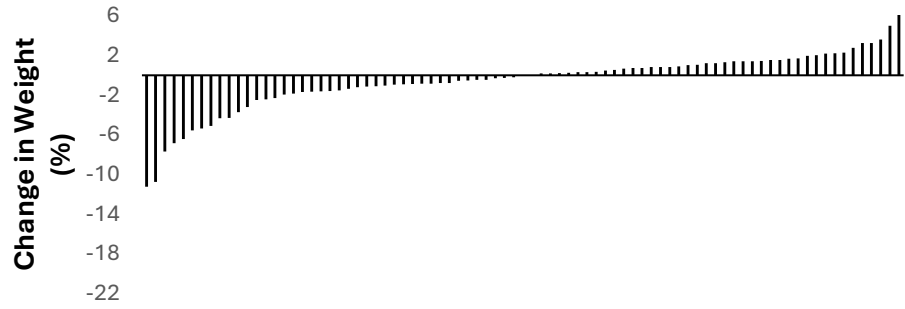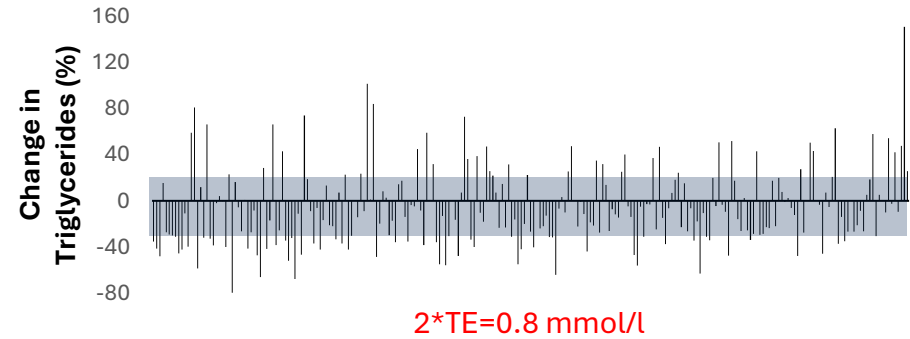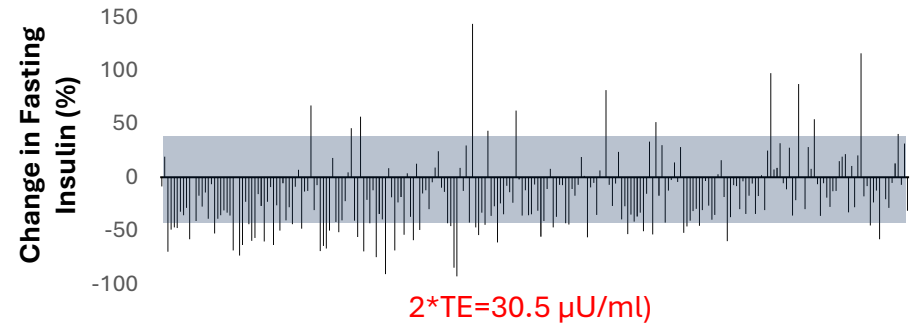# Does individual change in body weight predict corresponding change in metabolic risk factors?

Control

Exericse

2*TE=3.8 kg

2*TE=30.5 µU/ml)

2*TE=0.8 mmol/l
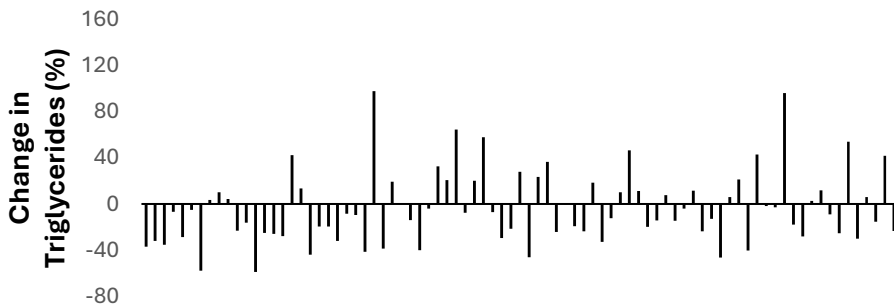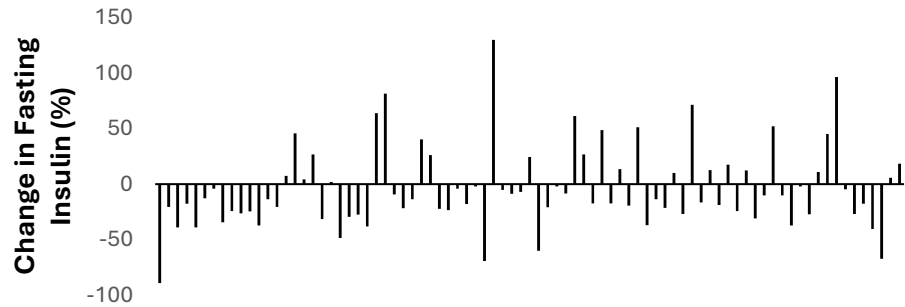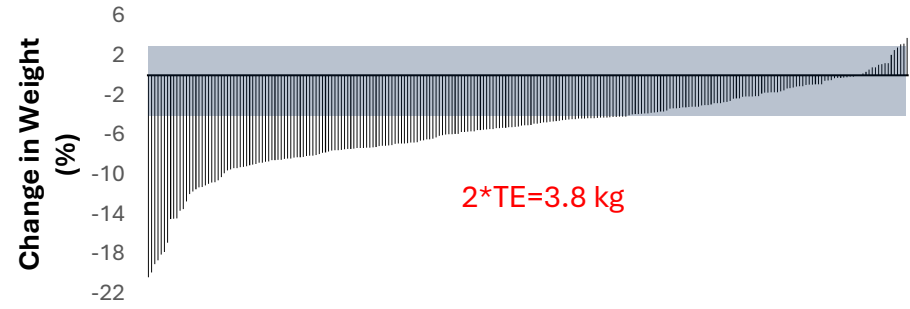
Do individual changes in adiposity correspond to change in metabolic risk factors?

Control

Exercise

Change in Total Adiposity (kg)

2*TE=2.5 kg

Change in Fasting Insulin (µU/ml)

2*TE=30.5 µU/ml)

Change in Triglycerides (mmol/l)

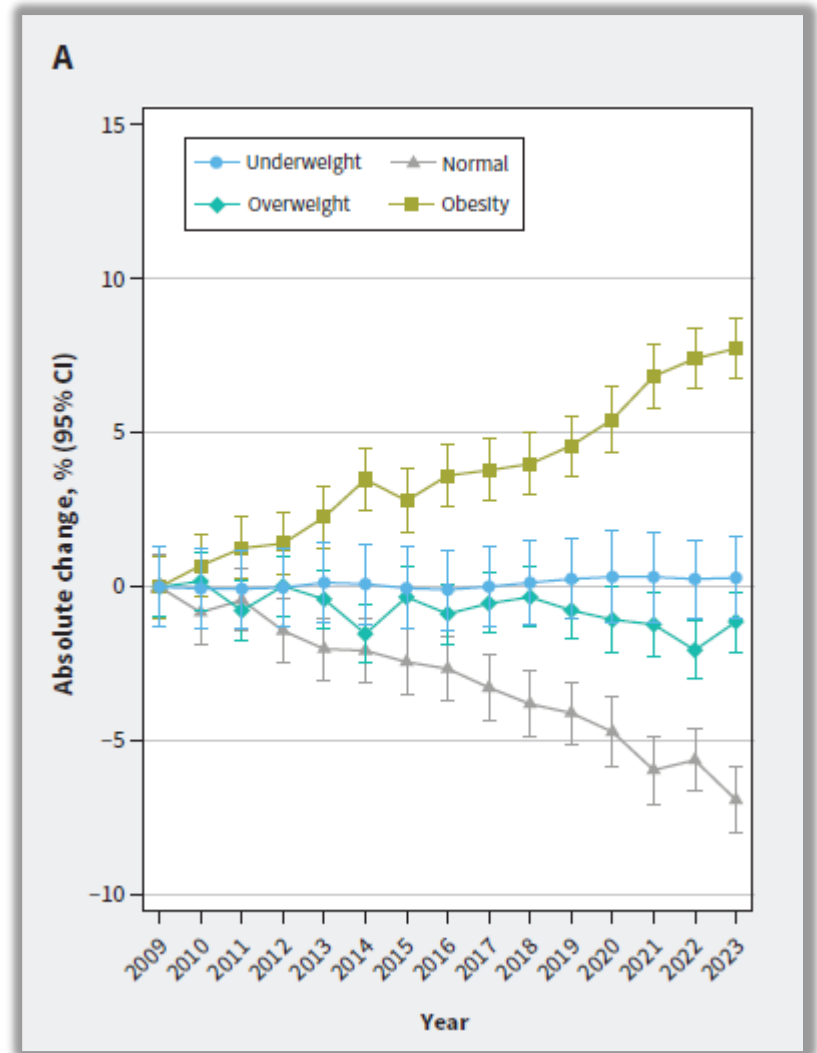2*TE=0.8 mmol/l
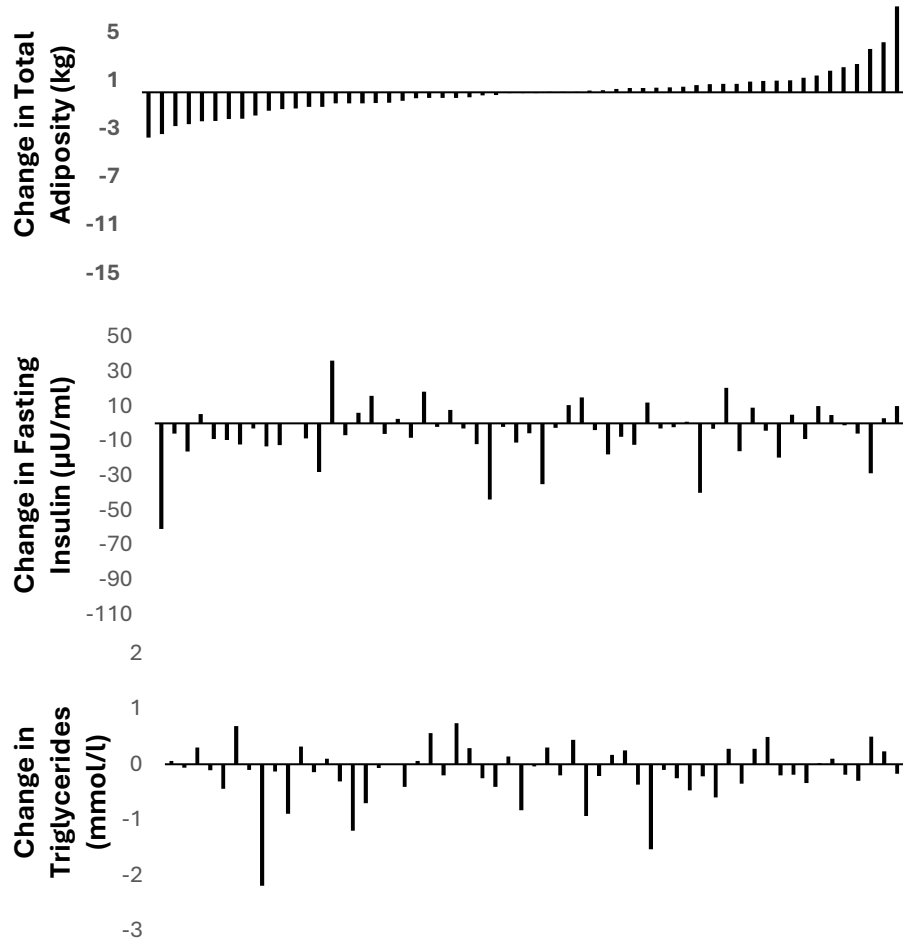
Individual Participants (n=57)
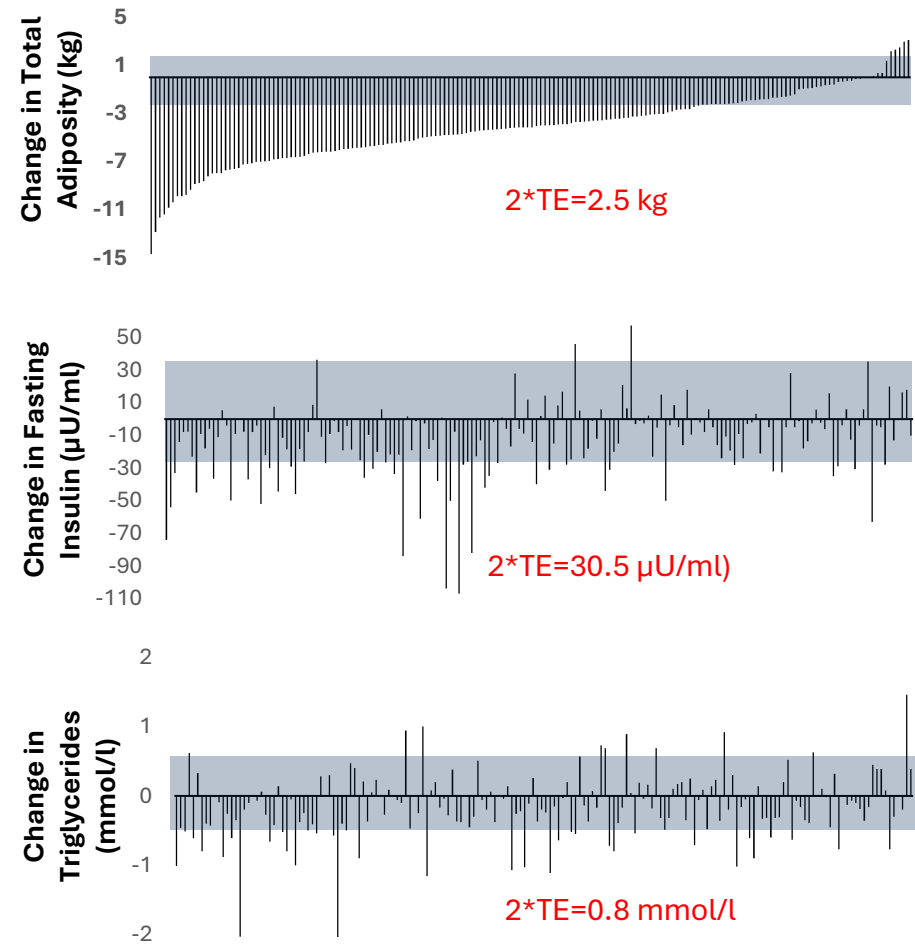
Individual Participants (n=174)

SUMMARY

Trends in obesity defined by body mass index among adults before and during the COVID-19 pandemic: a repeated cross-sectional study of the 2009–2023 Canadian Community Heath Surveys

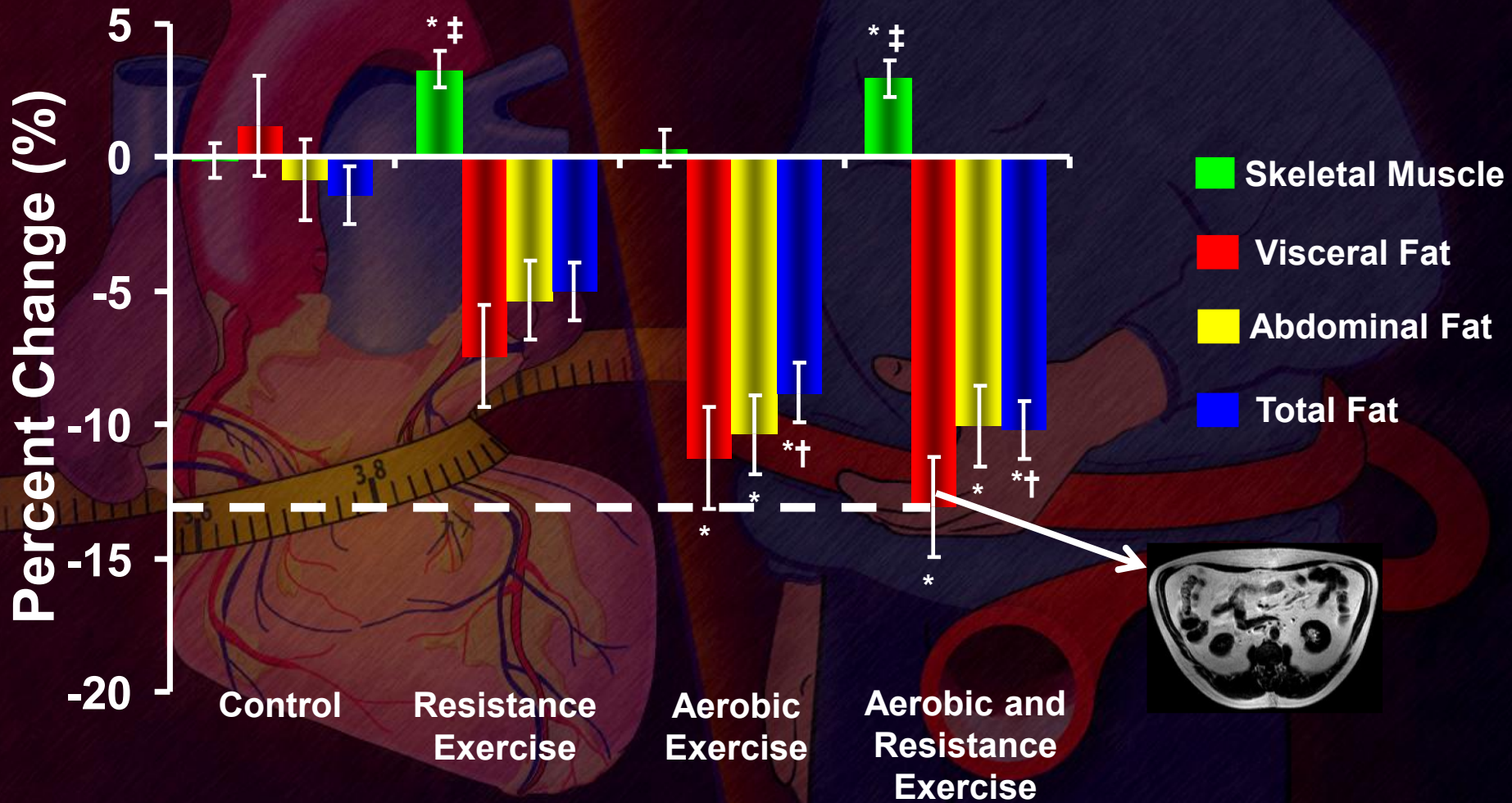Laura N. Anderson PhD, Rabiul Islam PhD, Arthur Sweetman PhD

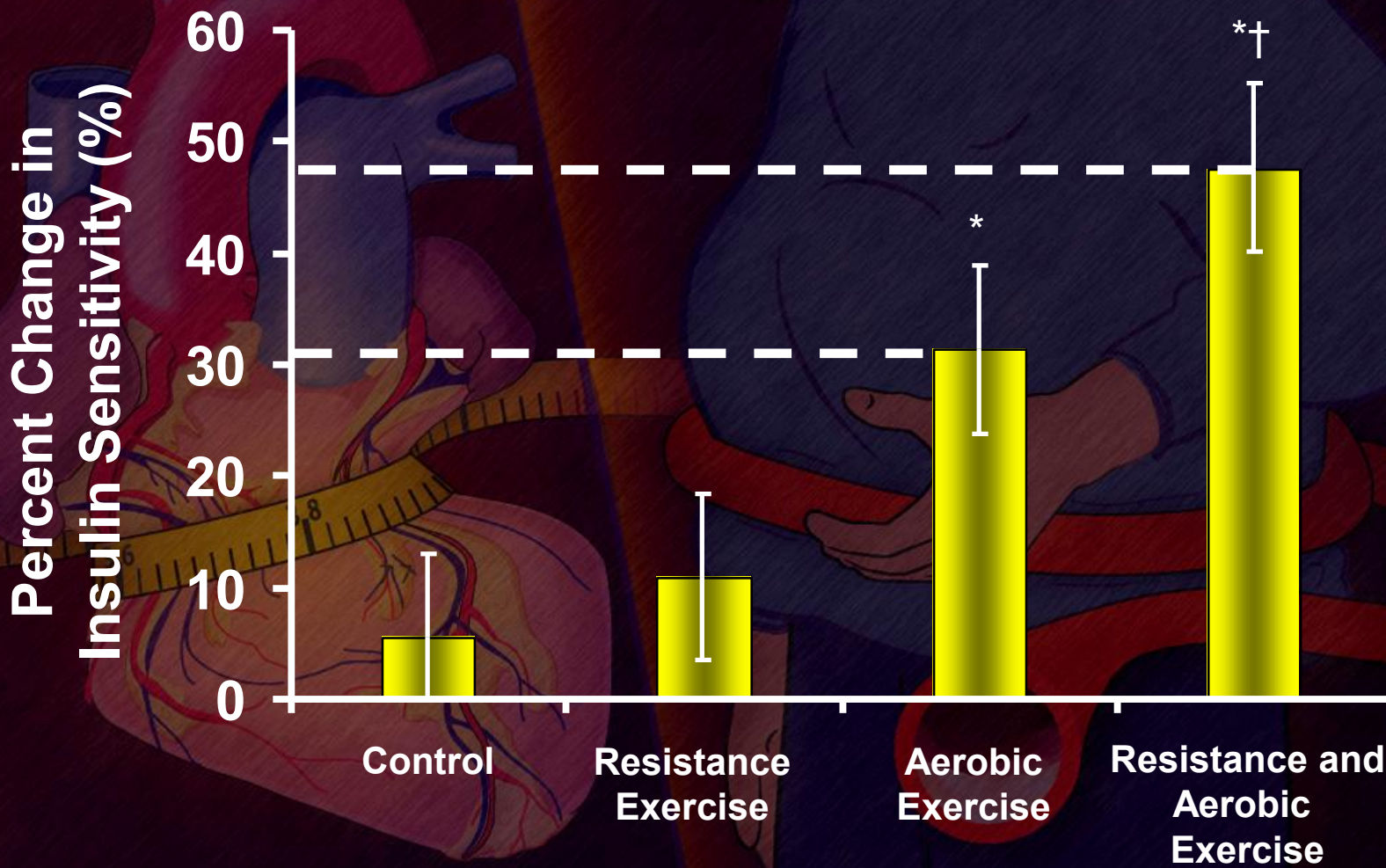*This is a terrifying observation*

Exercise must/should be a fundamental component in strategies designed to prevent and/or manage overweight or obesity

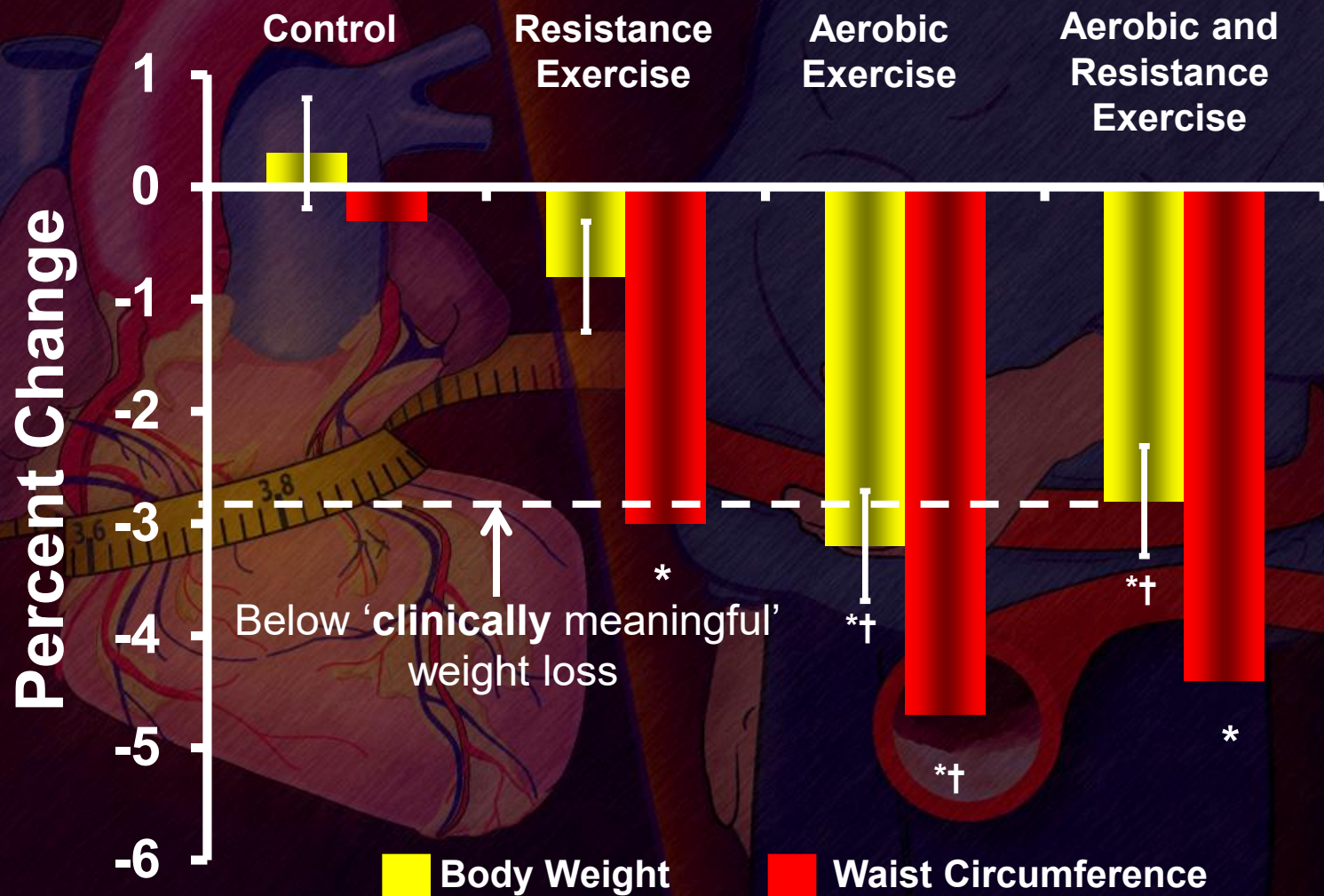**Certainty of exercise benefit based on treatment group verses control group is established**

Effects of Exercise Modality on Visceral Fat, Total Fat and Skeletal Muscle in Older Men and Women: A Randomized Controlled Trial

Davidson et al. *Arch Intern Med* 169(2): 122-131, 2009.

Effects of Exercise Modality on Insulin Resistance in Older Men and Women: A Randomized Controlled Trial

Percent Change in Insulin Sensitivity (%)

60
50
40
30
20
10
0

Control   Resistance Exercise   Aerobic Exercise   Resistance and Aerobic Exercise

*

*†

Davidson et al. *Arch Intern Med* 169(2): 122-131, 2009.

Effects of Exercise Modality on Body Weight and Waist Circumference in Older Men and Women

Control | Resistance Exercise | Aerobic Exercise | Aerobic and Resistance Exercise

Percent Change

1
0
-1
-2
-3
-4
-5
-6

Below '**clinically** meaningful' weight loss

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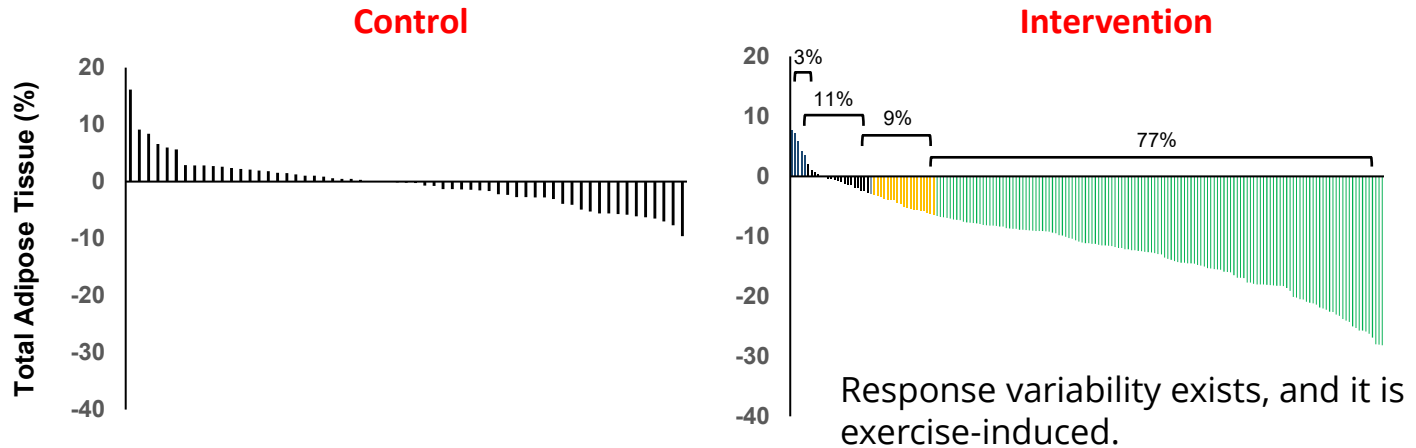■ Body Weight   ■ Waist Circumference

Exercise must/should be a fundamental component in strategies designed to prevent and/or manage overweight or obesity

Certainty of exercise benefit based on treatment group verses control group is established

Certainty of exercise benefit for a given individual is not established

Does individual variability in total and regional adipose tissue response to guideline exercise exist?

Control

Intervention

Total Adipose Tissue (%)

3%
11%
9%
77%

Response variability exists, and it is exercise-induced.

There is benefit for most adults

Legend:
- ≥ 2 TE
- 1 TE to 2 TE
- -1 TE to 1TE
- ≤ 1TE

Efficacy trials – internal control

Time-matched control group

Criterion/reference methods
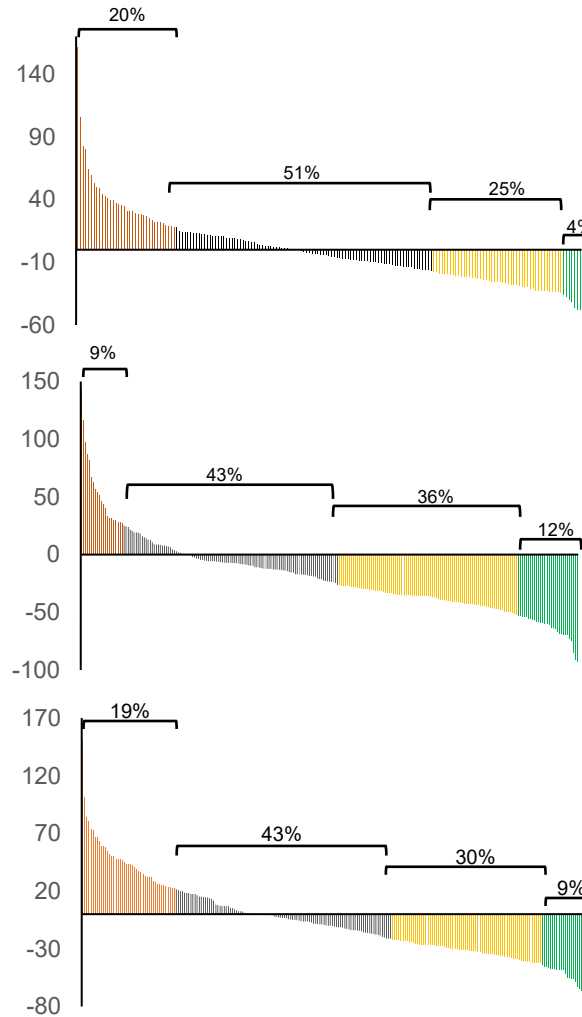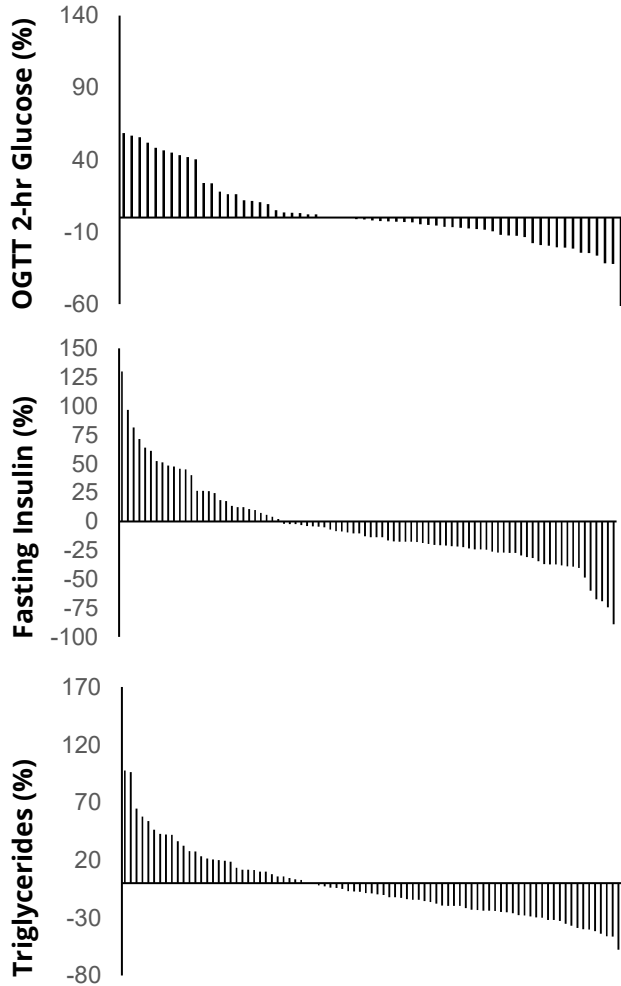
Supervised, standardized exercise

24hr PA - Accelerometry

Daily self-recording of Energy intake

Individual cardiometabolic response (%) to standardized exercise in adults with obesity
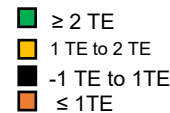
Control

Intervention

Control = 87
Exercise = 251

Time-matched control group

Criterion/reference methods

Supervised, standardized exercise

24hr PA - Accelerometry

***Daily* self-recording of Energy intake**

Legend:
- ≥ 2 TE
- 1 TE to 2 TE
- -1 TE to 1TE
- ≤ 1TE

> 2TEs = Attributable to exercise

Brennan A. et al. MSSE 54: 1861-68, 2022.

Determining the existence of exercise-induced variability for any trait is a complex issue.

For researchers:

Time-matched *control group* in the trial design?

Measure the outcome twice at each time point (pre-post) – improve precision

Measure the outcome at multiple time points throughout the intervention

Account for physical activity outside of that prescribed, dietary intake

$$SD_R = \sqrt{SD_I{}^2 - SD_C{}^2}$$

$$TE = \frac{\sqrt{\sum(\text{measure1} - \text{measure2})^2}}{2n}$$

Is there exercise-induced variability?

Is the individual exercise response *beyond* the TE derived from the control group?
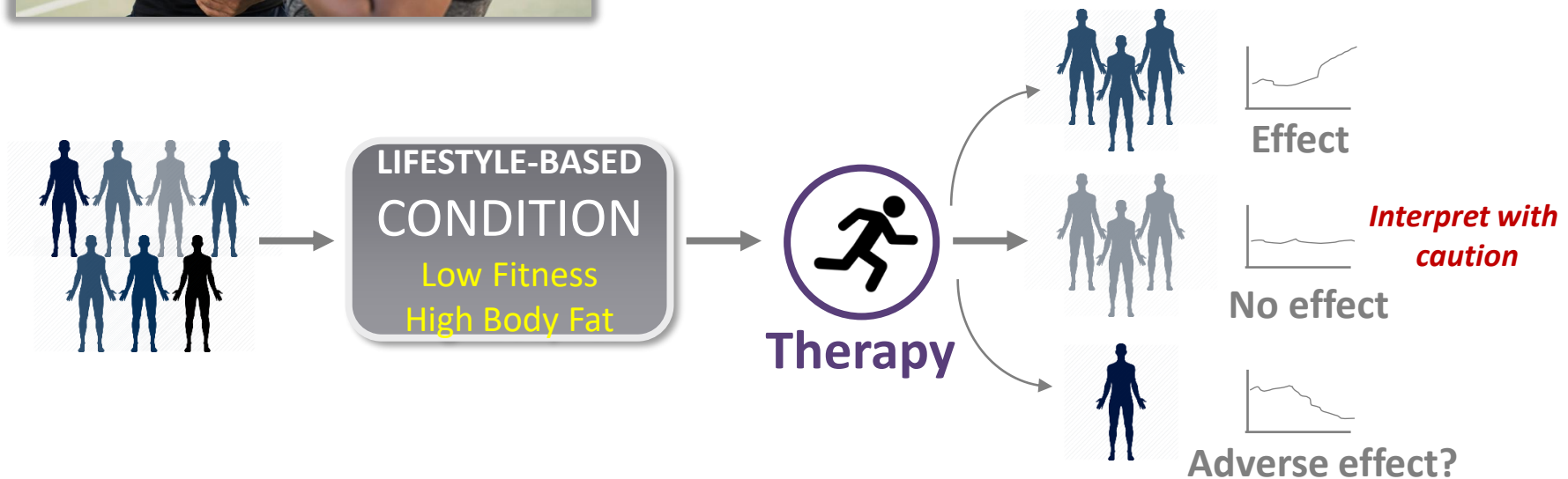
Determining the existence of exercise-induced variability for any trait is a complex issue.

For practitioners:

Obesity management guidelines worldwide prescribe increased aerobic-type physical activity (such as brisk walking) for more than 150 minutes per week.

American College of Sports Medicine Position Stands, recommend 200 to 300 minutes a week for sustained weight loss.
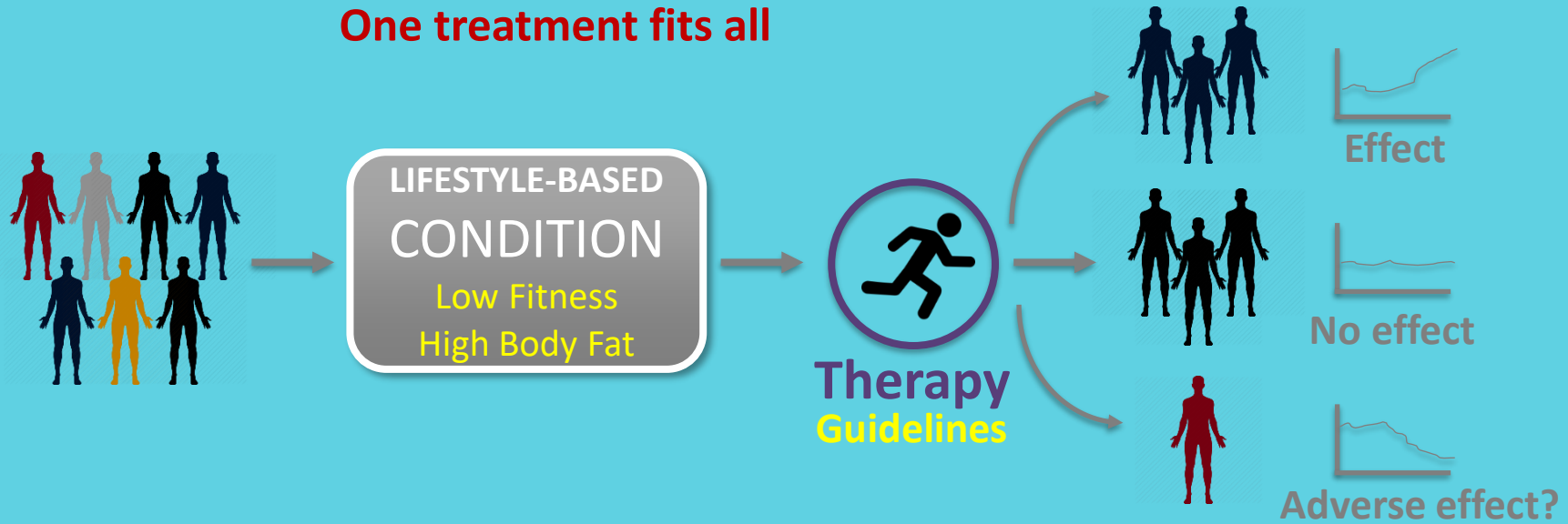

LIFESTYLE-BASED CONDITION
Low Fitness
High Body Fat

Therapy

Effect

Interpret with caution

No effect

Adverse effect?

Measure the trait of interest, as often as possible
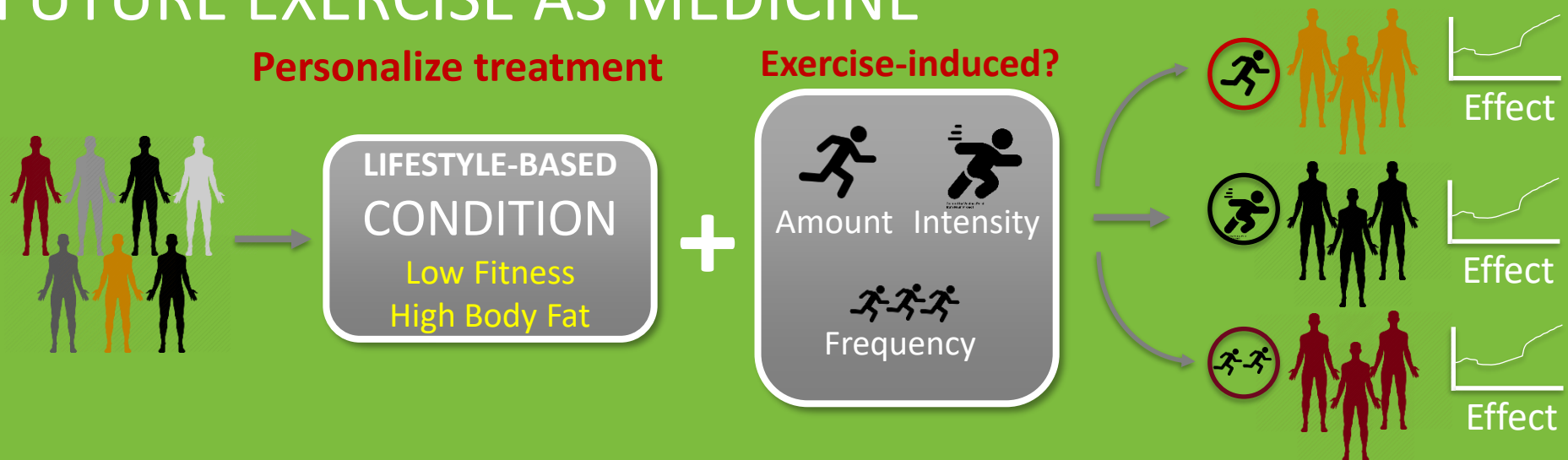Measurement precision – TE (measurement error) is it known?

Acknowledgement

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Thank You