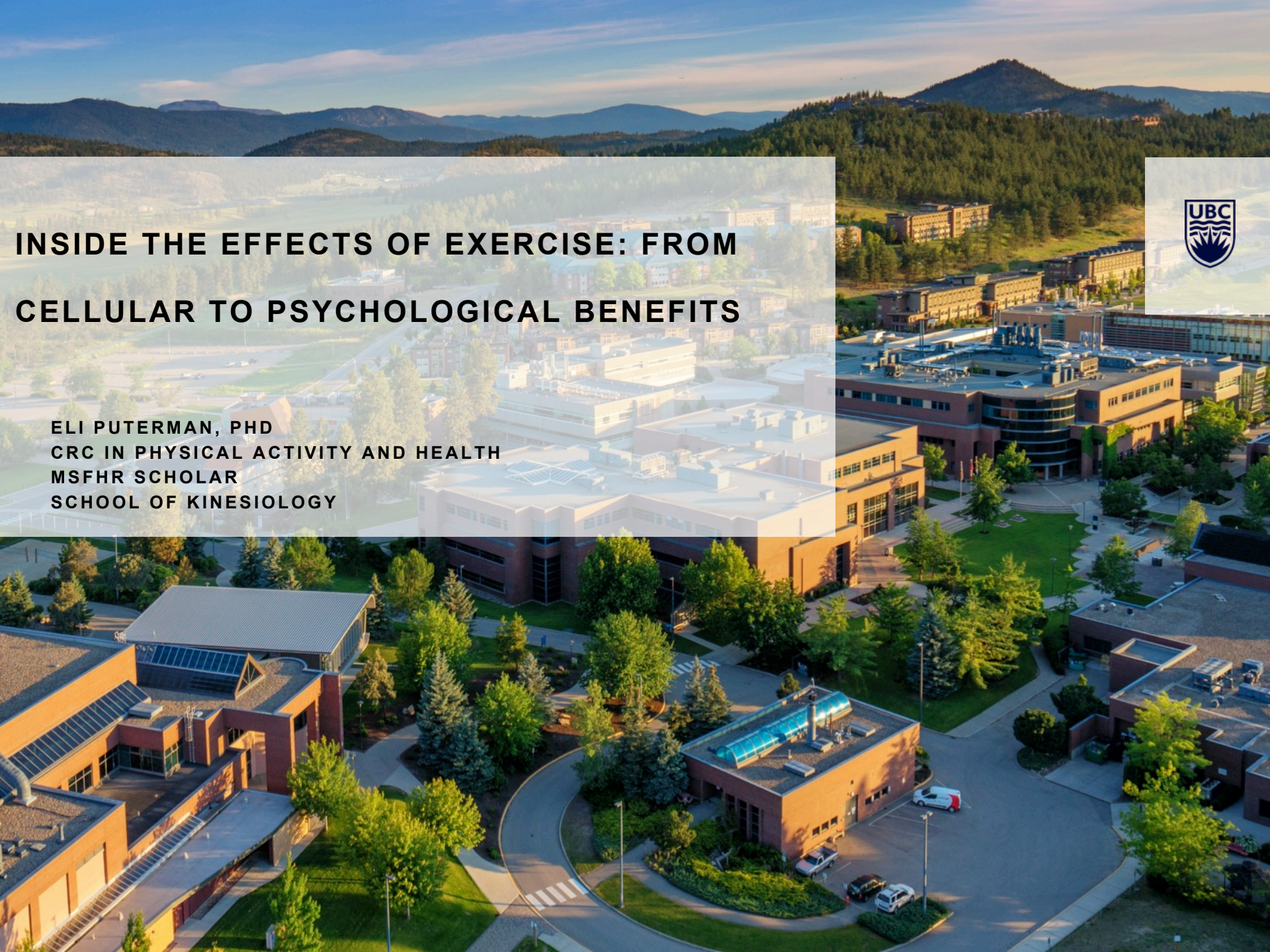


INSIDE THE EFFECTS OF EXERCISE: FROM CELLULAR TO PSYCHOLOGICAL BENEFITS

ELI PUTERMAN, PHD
CRC IN PHYSICAL ACTIVITY AND HEALTH
MSFHR SCHOLAR
SCHOOL OF KINESIOLOGY

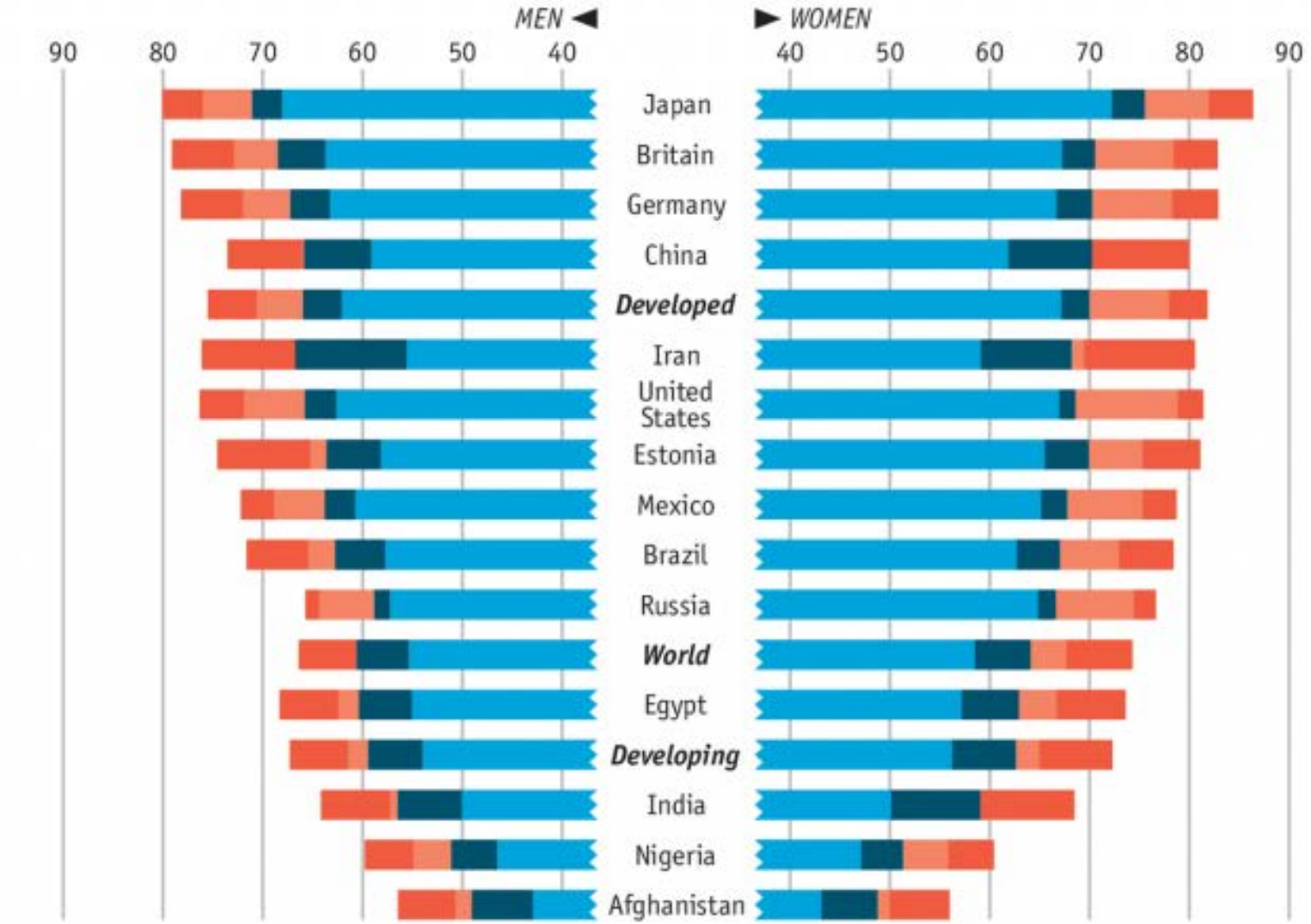
How long do we live and what impacts the quantity and quality of our lives?

How does exercise extend our quantity and quality of life?

How can we increase exercising in previously inactive adults, and does it extend health?

Lifespan

Life expectancy at birth



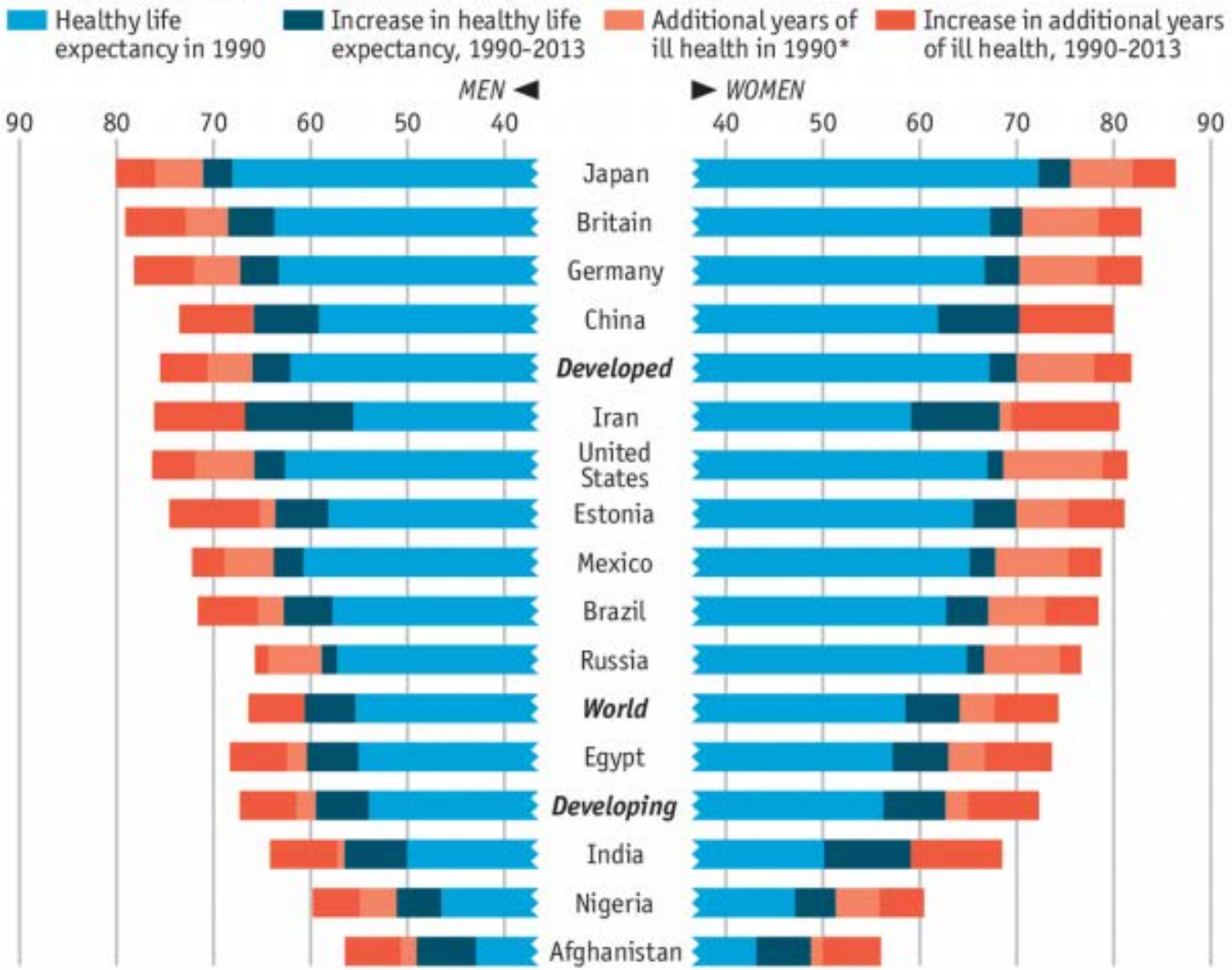
Source: "Global, regional, and national disability-adjusted life years...", by Christopher Murray et al, *The Lancet*, 2015

*Where figure is not shown, life expectancy in 1990 is less than healthy life expectancy in 2013

Lifespan vs. Healthspan

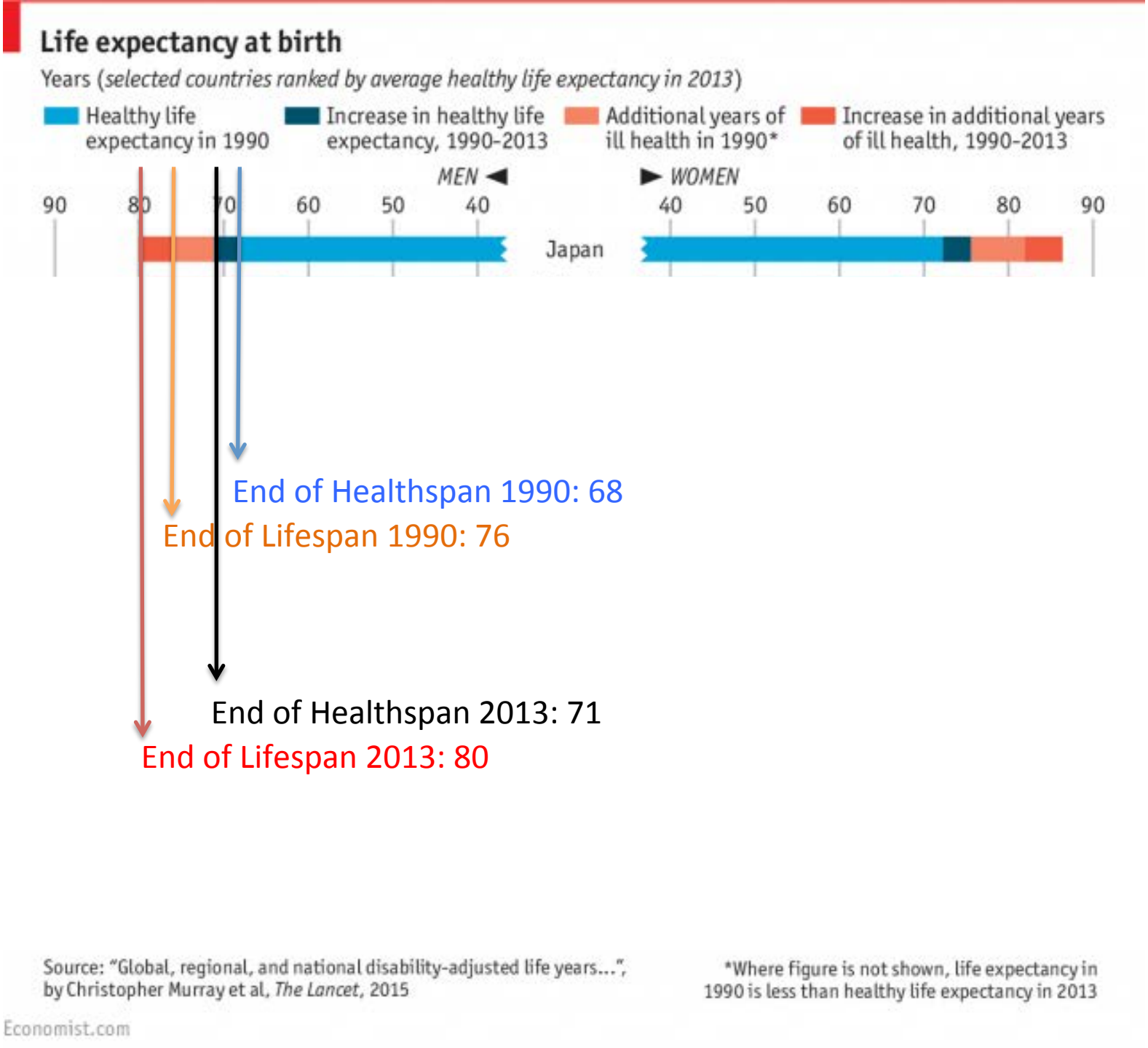
Life expectancy at birth

Years (*selected countries ranked by average healthy life expectancy in 2013*)



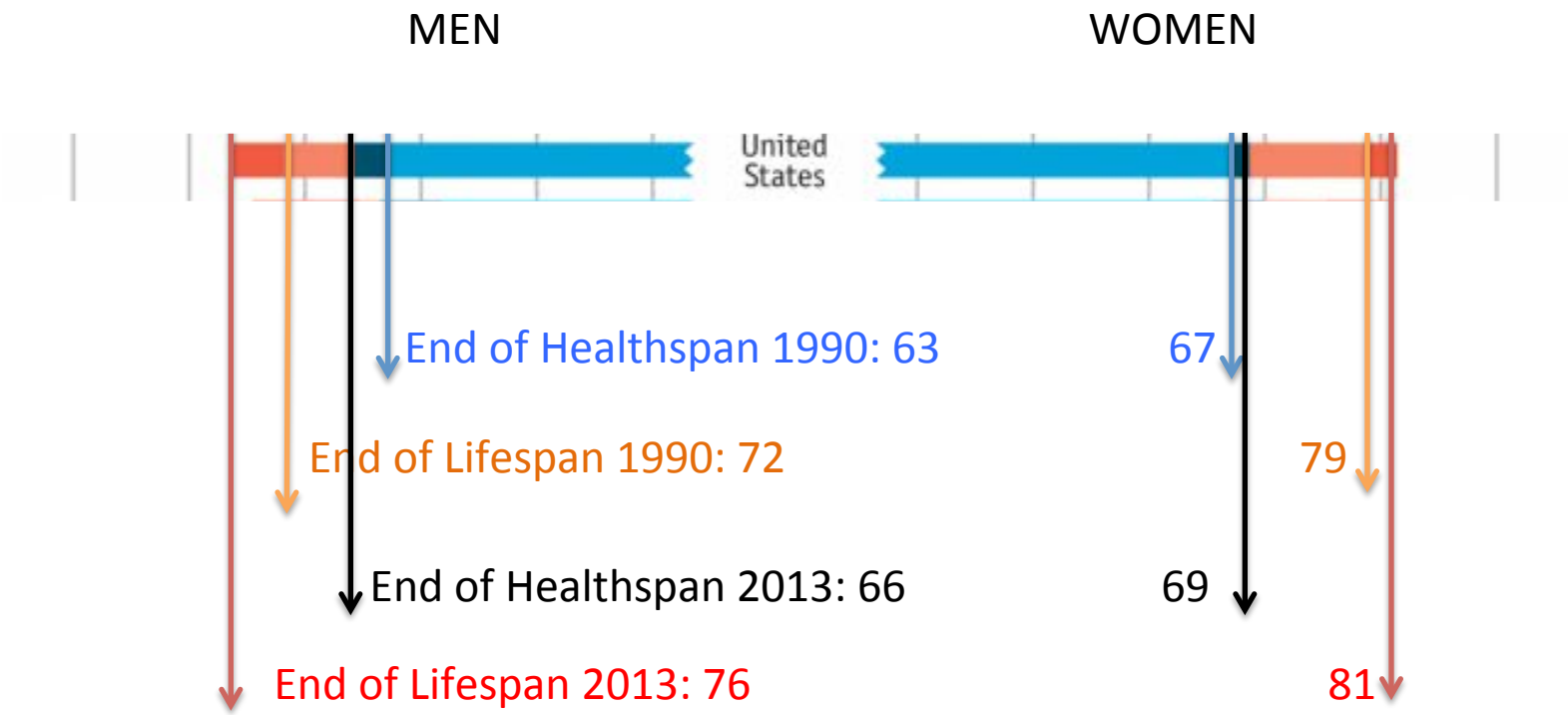
Source: "Global, regional, and national disability-adjusted life years...", by Christopher Murray et al, *The Lancet*, 2015

*Where figure is not shown, life expectancy in 1990 is less than healthy life expectancy in 2013


Life expectancy at birth
Years (selected countries ranked by average healthy life expectancy in 2013)
Healthy life expectancy in 1990
Increase in healthy life expectancy, 1990-2013
Additional years of ill health in 1990*
Increase in additional years of ill health, 1990-2013
MEN
WOMEN
90 80 70 60 50 40
40 50 60 70 80 90
Japan
End of Healthspan 1990: 68
End of Lifespan 1990: 76
End of Healthspan 2013: 71
End of Lifespan 2013: 80
Source: "Global, regional, and national disability-adjusted life years...", by Christopher Murray et al, The Lancet, 2015
*Where figure is not shown, life expectancy in 1990 is less than healthy life expectancy in 2013
Economist.com

Life expectancy at birth

Years (*selected countries ranked by average healthy life expectancy in 2013*)



Source: "Global, regional, and national disability-adjusted life years...", by Christopher Murray et al, *The Lancet*, 2015

*Where figure is not shown, life expectancy in 1990 is less than healthy life expectancy in 2013

HOW WILL YOU SPEND YOUR LAST 10 YEARS?

The average Canadian will spend their last ten years in sickness. Change your future now.

MAKE HEALTH LAST.CA

HEART&™ STROKE FOUNDATION

HOW WILL YOU SPEND YOUR LAST 10 YEARS?

The average Canadian will spend their last ten years in sickness. Change your future now.

MAKE HEALTH LAST.CA

HEART&™ STROKE FOUNDATION

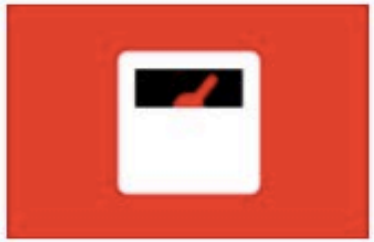
Last 10 Years Commercial

Lifestyle risk factors

Many risk factors are within your power to control. Find out what they are. Learn the steps to lower your risk.

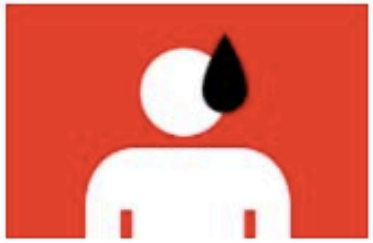
Unhealthy diet

Physical inactivity



Unhealthy weight

Smoking

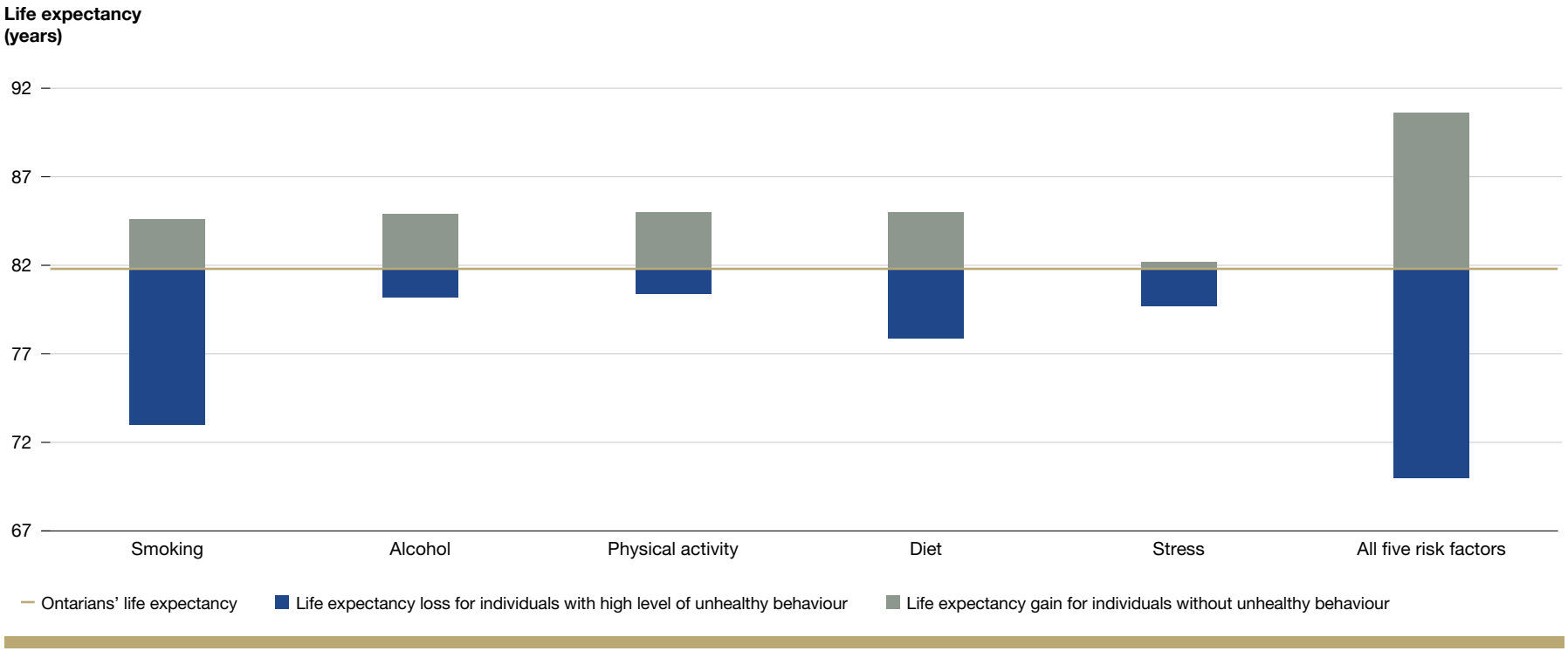


Stress

Excessive alcohol & drug abuse

Exhibit 5

Gain or loss in life expectancy for Ontarians aged 20 and older with healthy versus high level of unhealthy exposure for selected behaviours, relative to average Ontario life expectancy, 2007

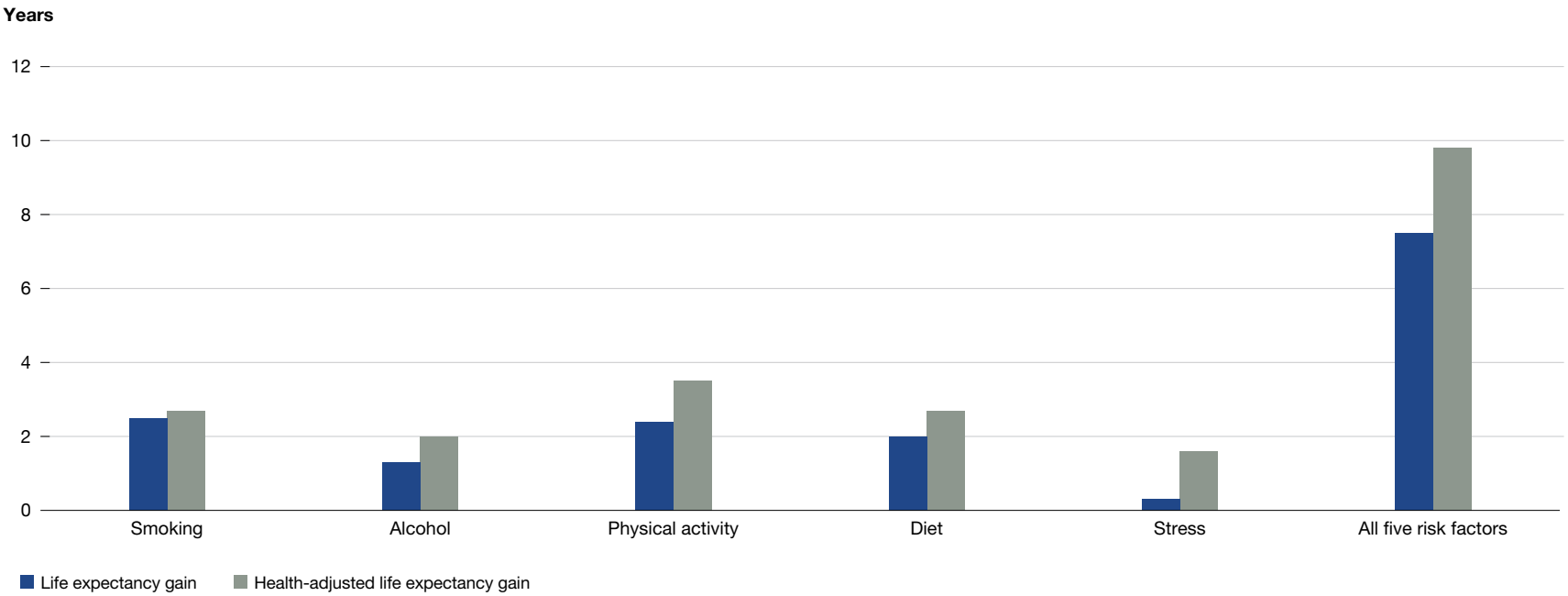


Key message:

- A 20-year difference in life expectancy existed between people who have all five behavioural risks and those with none of the five risks.

Exhibit 7

Impact of eliminating five behavioural risks on life expectancy and health-adjusted life expectancy for Ontarians aged 20 and older, 2007



*Considers all risk exposure categories compared to healthiest (reference) category (Exhibit 3)

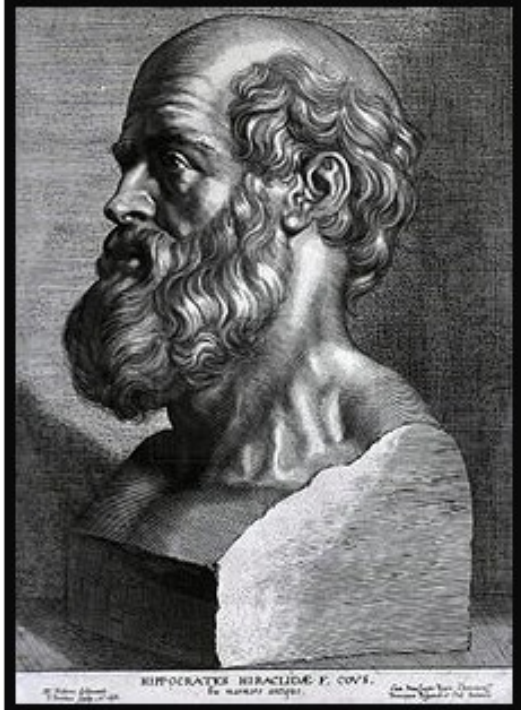
Key messages

- Smoking, physical inactivity and inadequate diet each accounted for about two years of life expectancy lost.
- Combined, the five risk factors reduced life expectancy by 7.5 years.
- Reducing or eliminating behavioural risks resulted in even greater gains in health-adjusted life expectancy (up to 9.8 years)—adding life to years as well as years to life.

Take Home

Quality equally as important to quantity of life

Health behaviours and stress matter



Walking is man's best medicine.

(Hippocrates)


QUIZ

The American Heart Association Recommendations for Physical Activity in Adults

How many minutes of moderate physical activity are recommended per week?

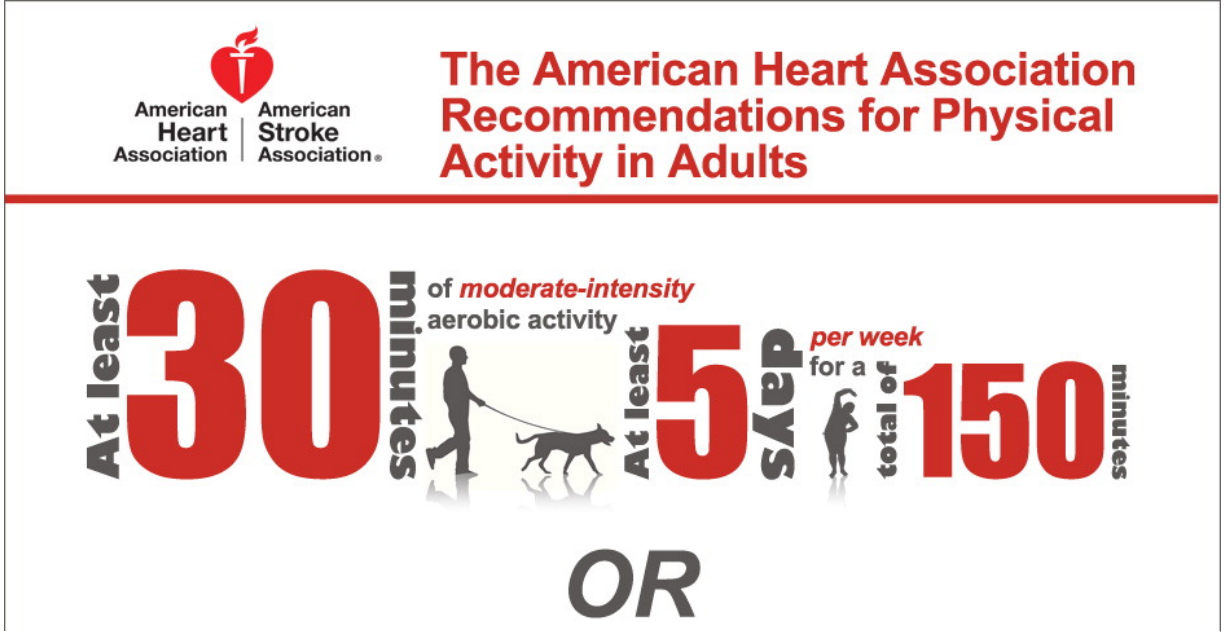
Moderate activity is defined as 3-6 METs

Examples include brisk walking, ballroom dancing, gardening, water aerobics

American Heart Association | American Stroke Association

The American Heart Association Recommendations for Physical Activity in Adults

Minimum of 10 minute dose



How many minutes of vigorous physical activity are recommended per week?

VPA = > 6 METs

Examples include jogging, running, swimming laps, jumping rope, biking >10 miles/hr

American Heart Association | American Stroke Association

The American Heart Association Recommendations for Physical Activity in Adults

At least **30** minutes of *moderate-intensity* aerobic activity

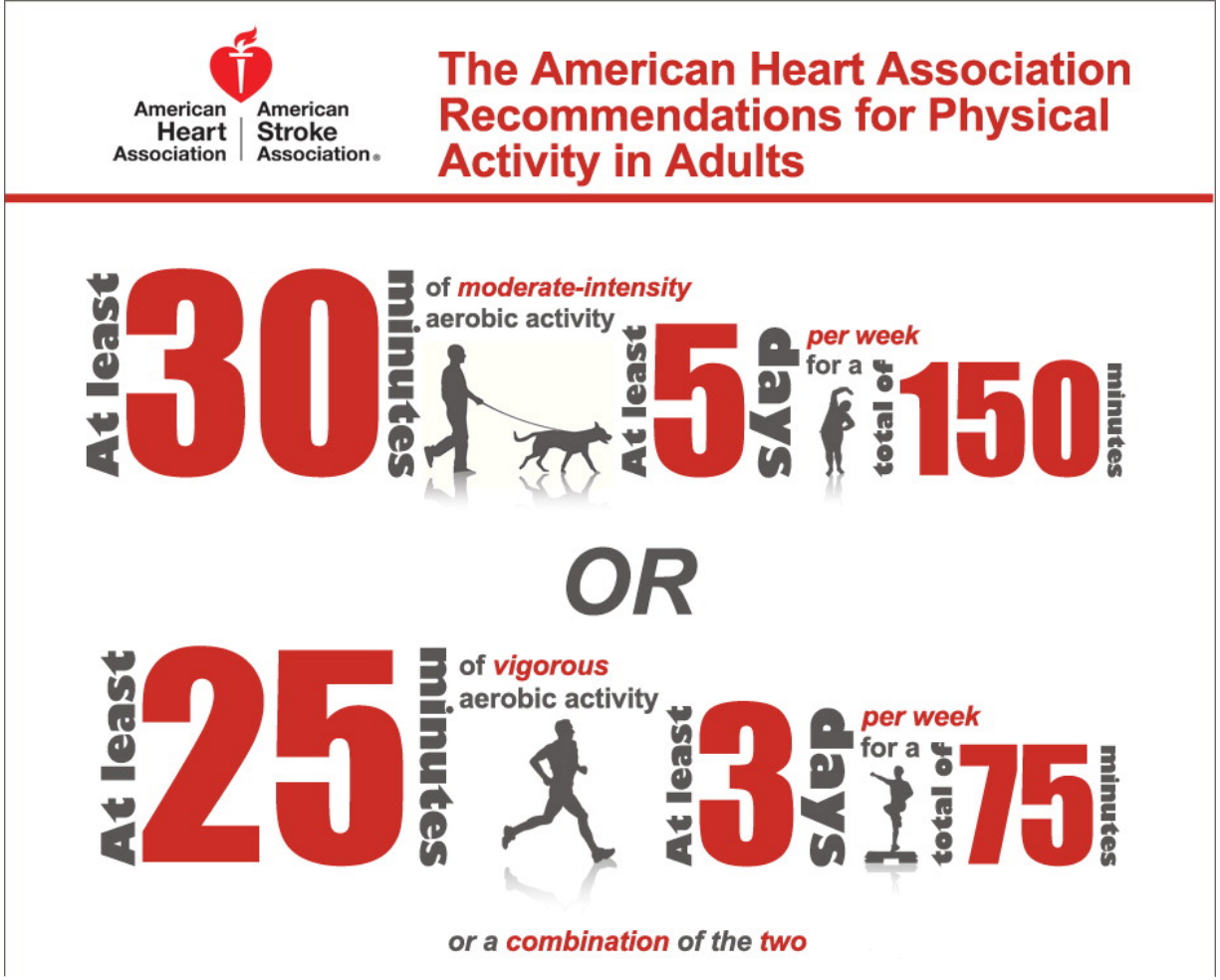
At least **5** days *per week* for a total of **150** minutes

OR

At least **25** minutes of *vigorous* aerobic activity

At least **3** days *per week* for a total of **75** minutes

*or a **combination** of the **two***



How many days of strength training are recommended?

American Heart Association | American Stroke Association

The American Heart Association Recommendations for Physical Activity in Adults

At least 30 minutes of *moderate-intensity* aerobic activity

At least 5 days *per week* for a **total of 150 minutes**

OR

At least 25 minutes of *vigorous* aerobic activity

At least 3 days *per week* for a **total of 75 minutes**

or a combination of the two

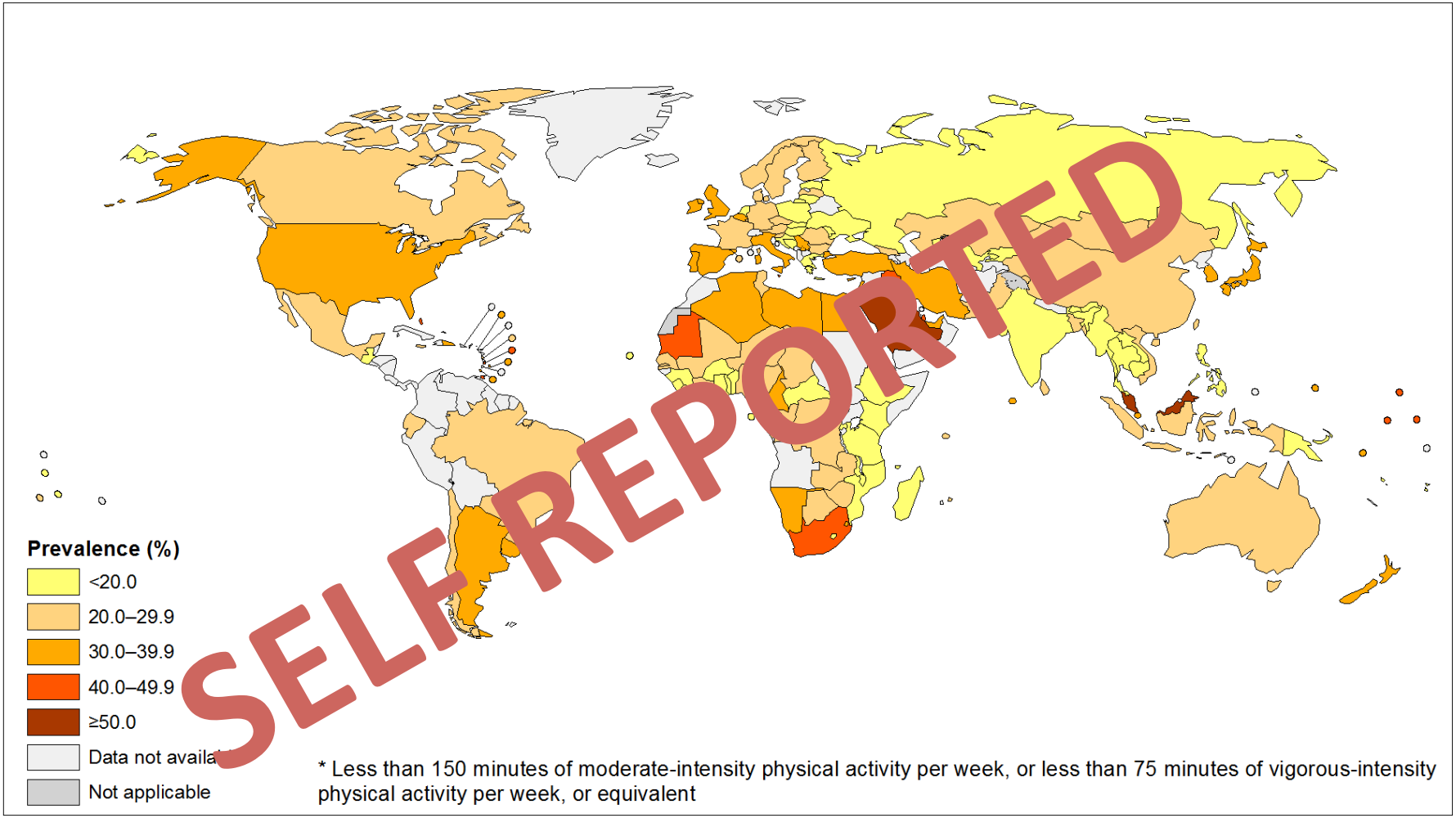
AND

Moderate to HIGH INTENSITY muscle-strengthening activity

At least 2 days *per week* for additional health benefits

Learn more at **heart.org/ActivityRecommendations**.

Prevalence of physical inactivity* among adults, ages 18+ (age standardised estimates)
Both sexes

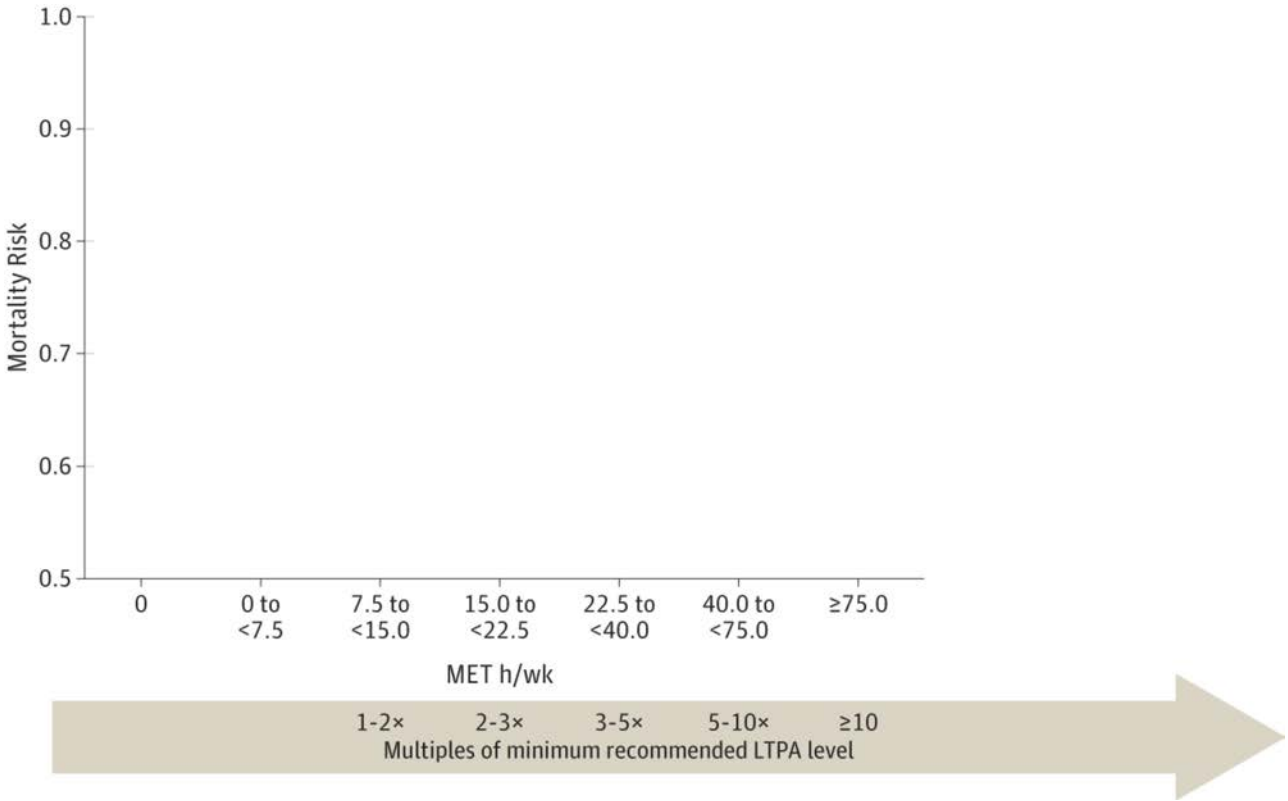


Data Source: World Health Organization
Map Production: Health Statistics and Information Systems (HSI)
World Health Organization

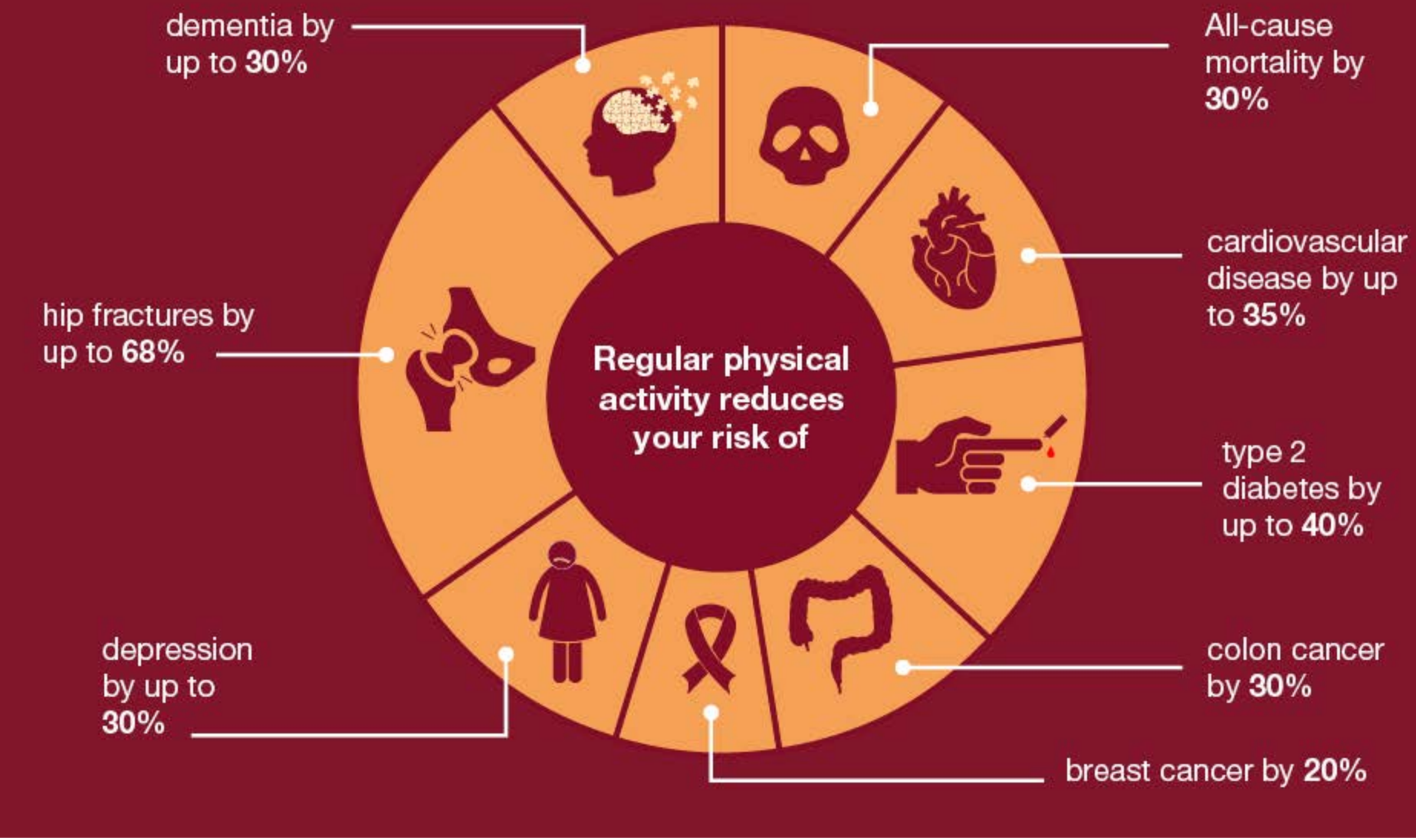
World Health Organization

From: **Leisure Time Physical Activity and Mortality: A Detailed Pooled Analysis of the Dose-Response Relationship**

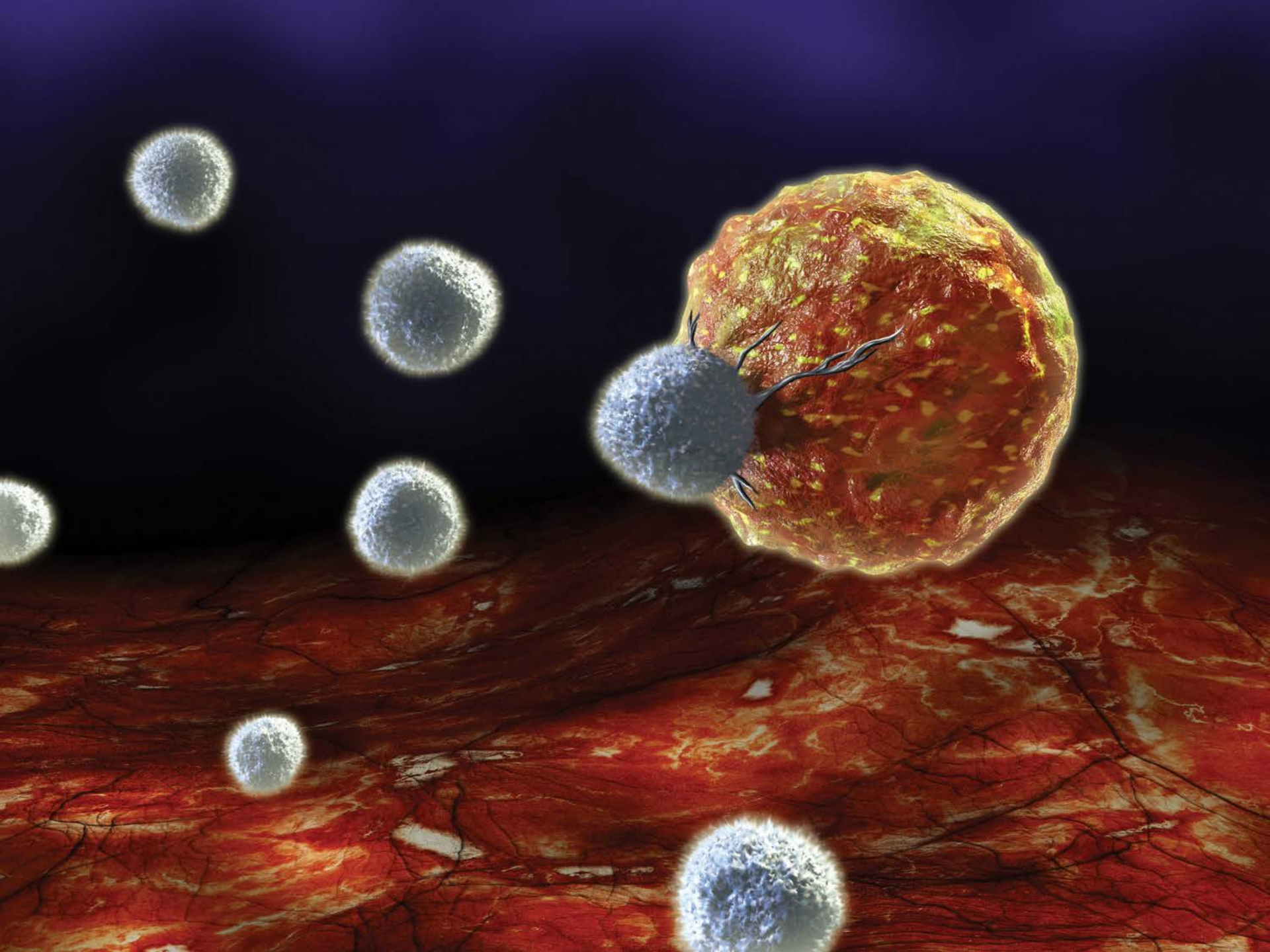
Arem et al, JAMA Intern Med. 2015;175(6):959-967. doi:10.1001/jamainternmed.2015.0533

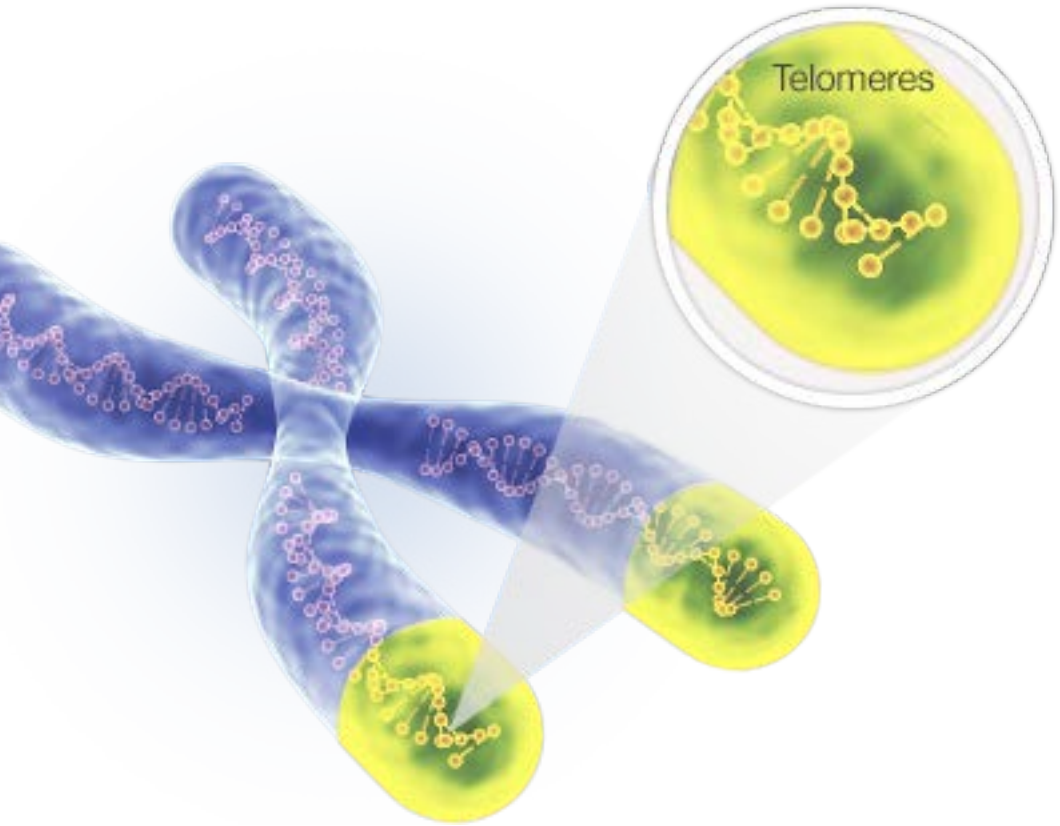


What are the health benefits of physical activity?



Source: https://www.gov.uk/government/publications/physical-activity-applying-all-our-health/physical-activity-applying-all-our-health

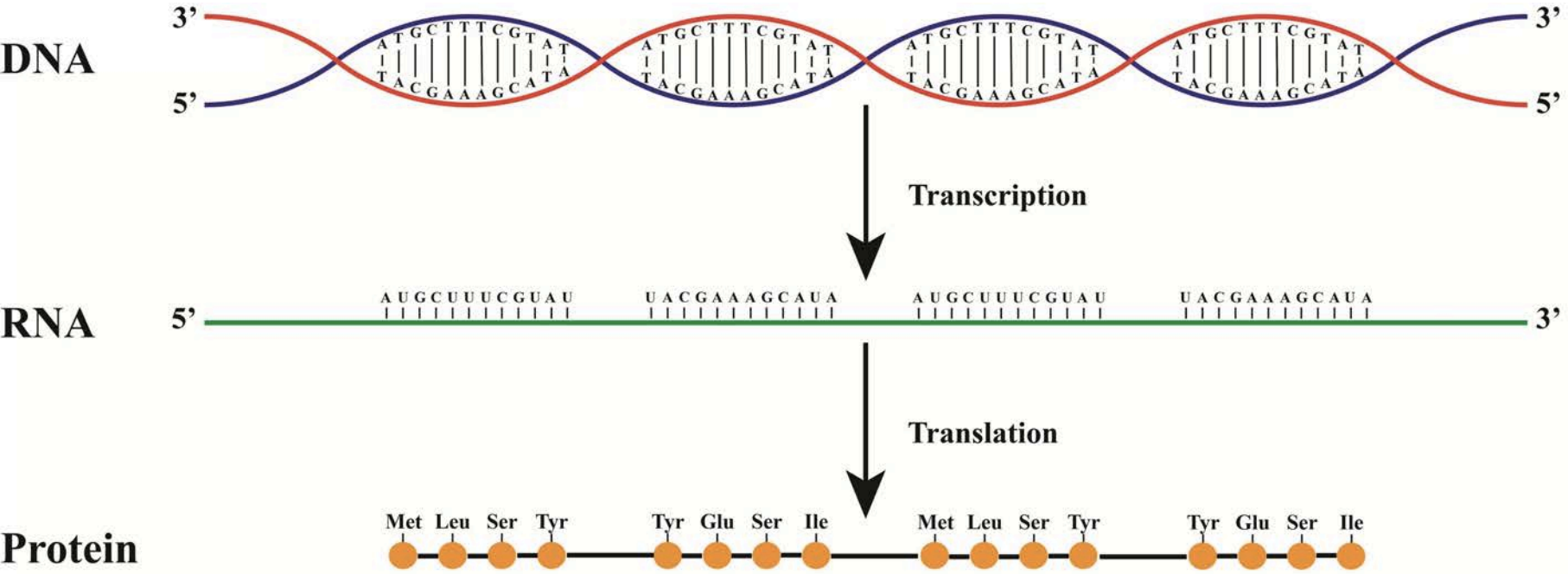


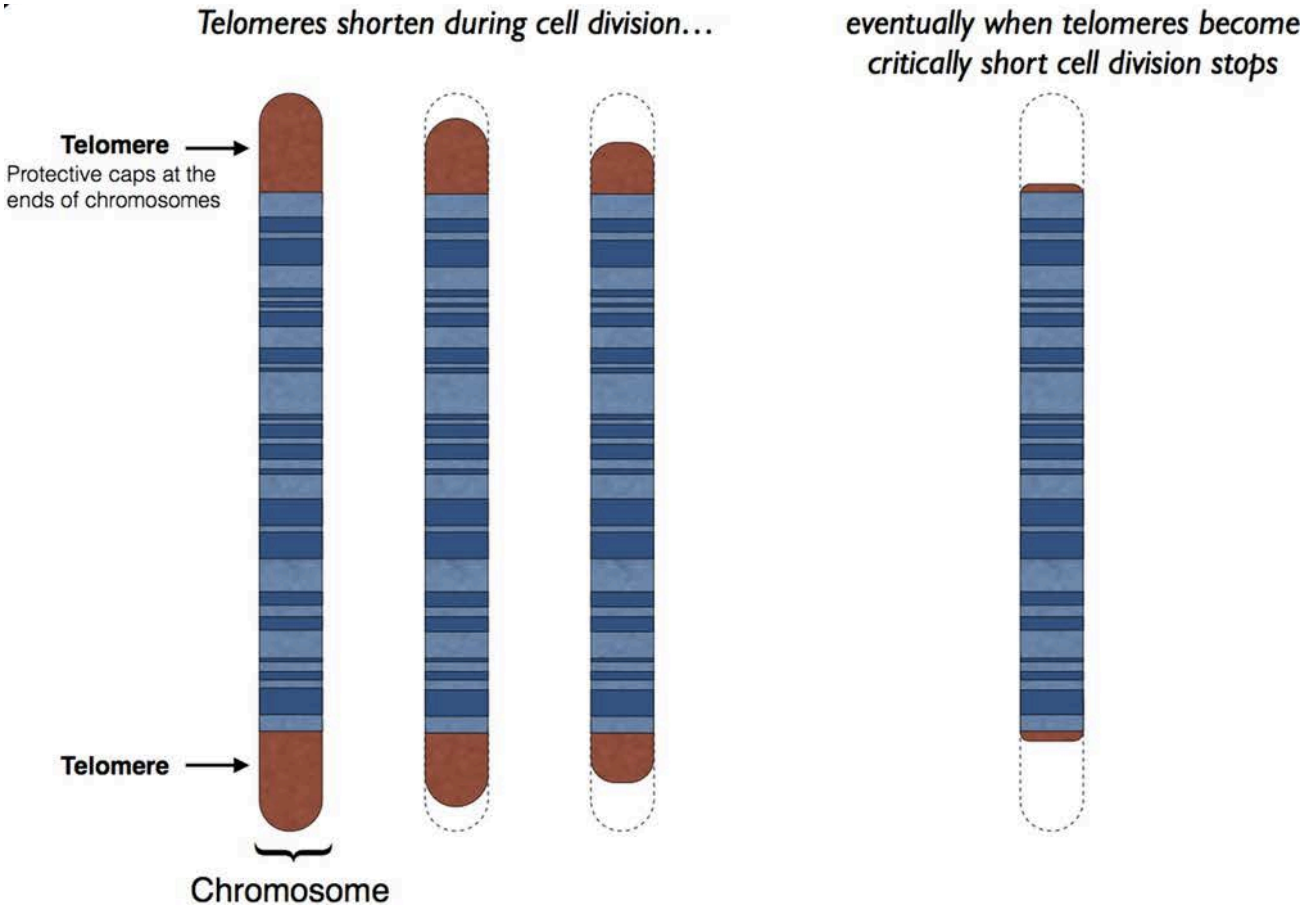


TELOMERES

'TTAGGG(n)

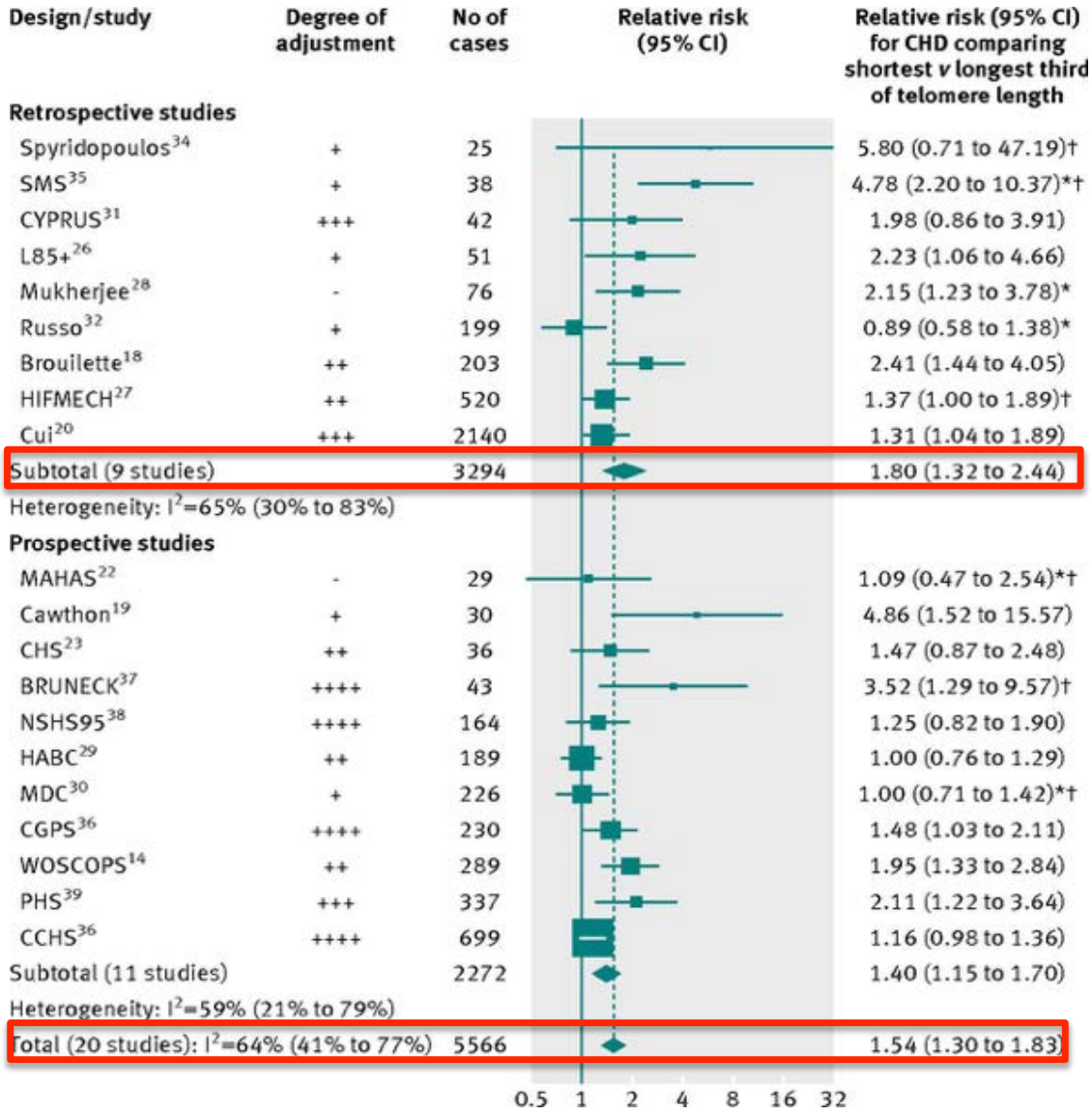
Blackburn, 2000
Armanios & Blackburn, 2012


DNA
3'
5'
3'
5'
ATGCTTTCGTATT
TACGAAAGCATA
Transcription
RNA
5'
3'
AUGCUUUCGUAU
UACGAAAGCAUA
Translation
Protein
Met Leu Ser Tyr
Tyr Glu Ser Ile


Telomeres shorten during cell division…
eventually when telomeres become critically short cell division stops
Telomere
Protective caps at the ends of chromosomes
Telomere
Chromosome

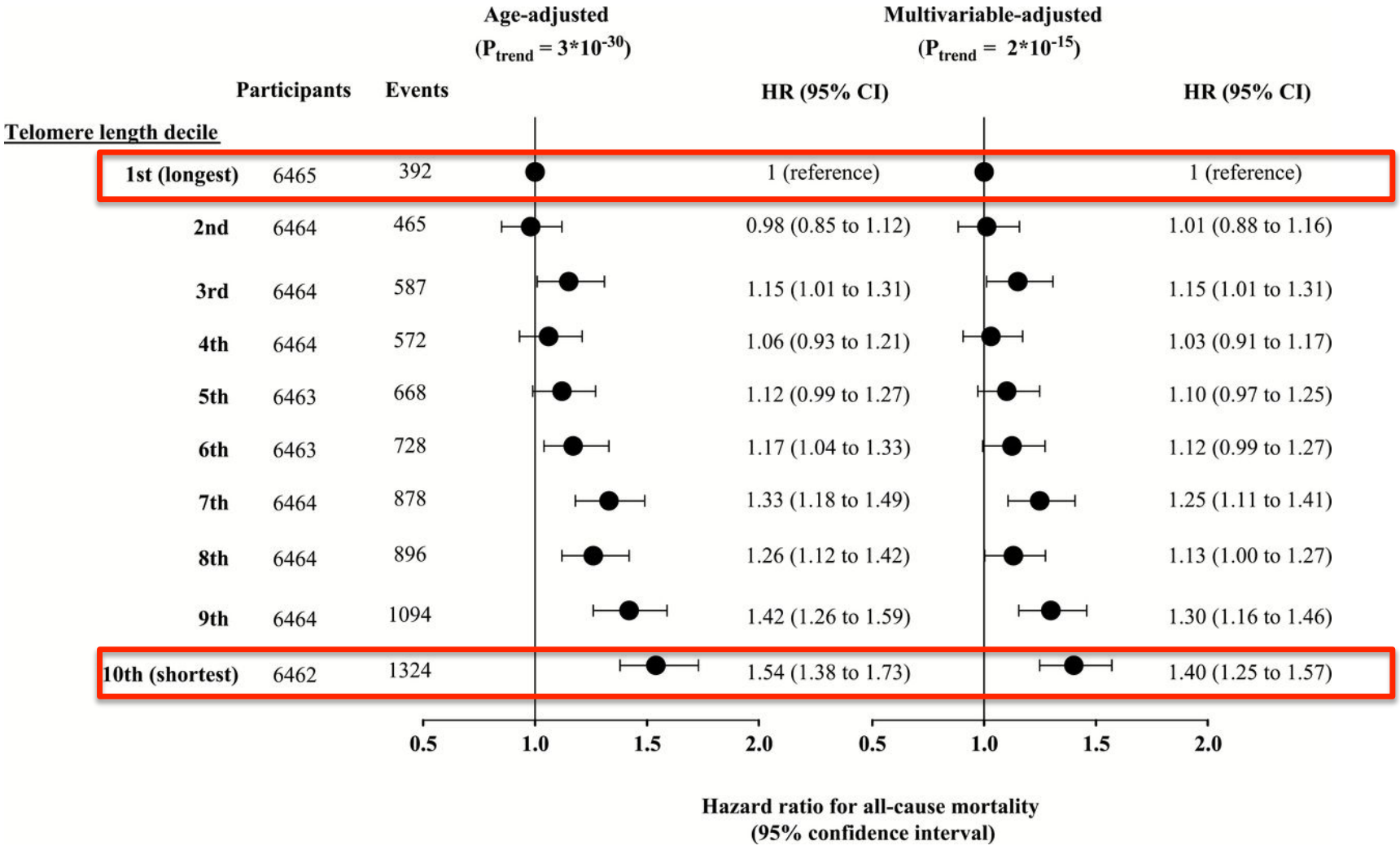
Are telomeres important to health and longevity?

Meta-analysis of the association between telomere length and cardiovascular disease.



Haycock et al, BMJ, 2014

Risk of all-cause mortality in the 64637 participants from the general population according to telomere length deciles in age-adjusted and multivariable-adjusted Cox regression analysis.



Rode et al. JNCI J Natl Cancer Inst, 2015

Preventive Medicine 100 (2017) 145–151

Contents lists available at ScienceDirect

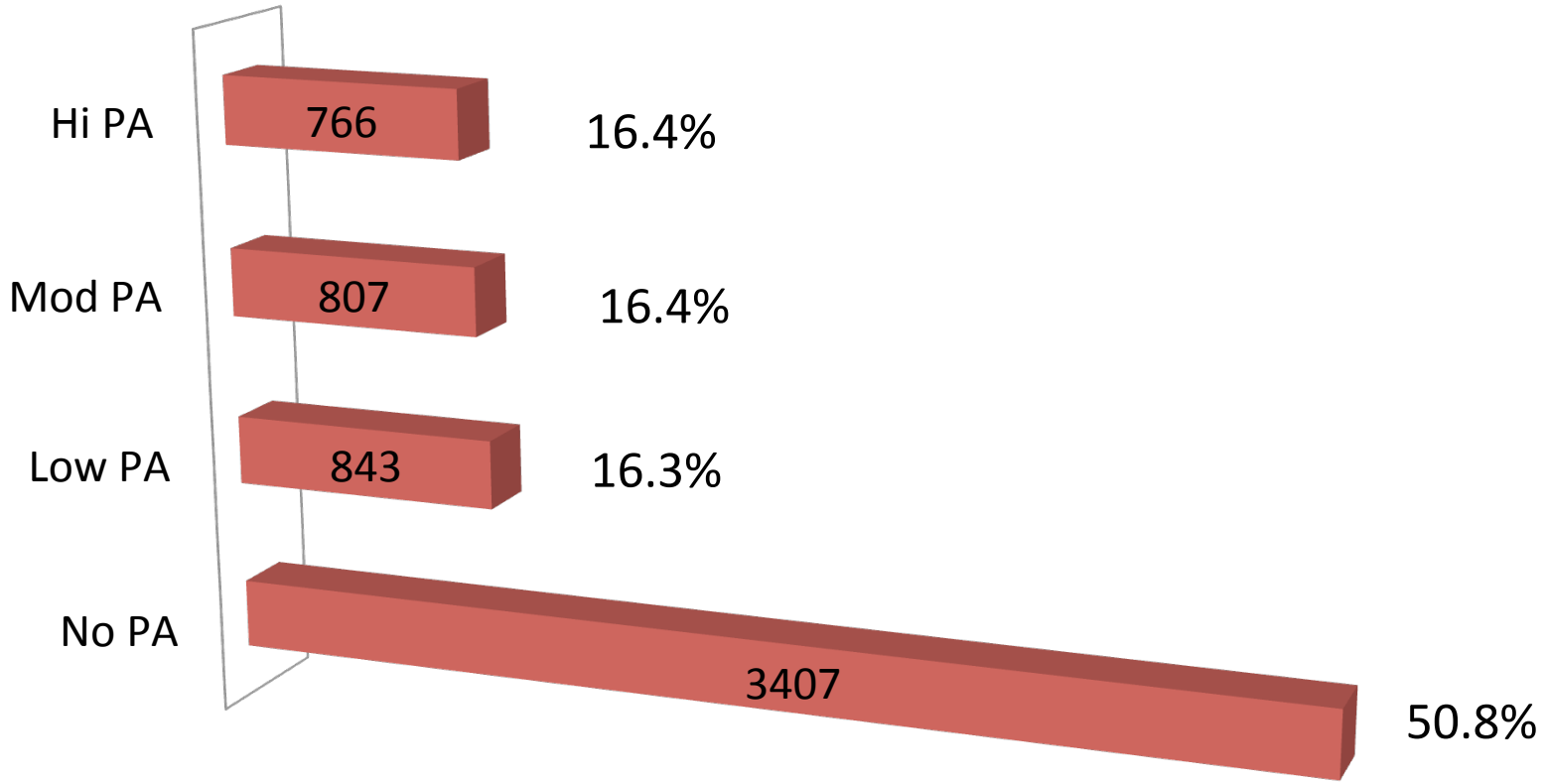
Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

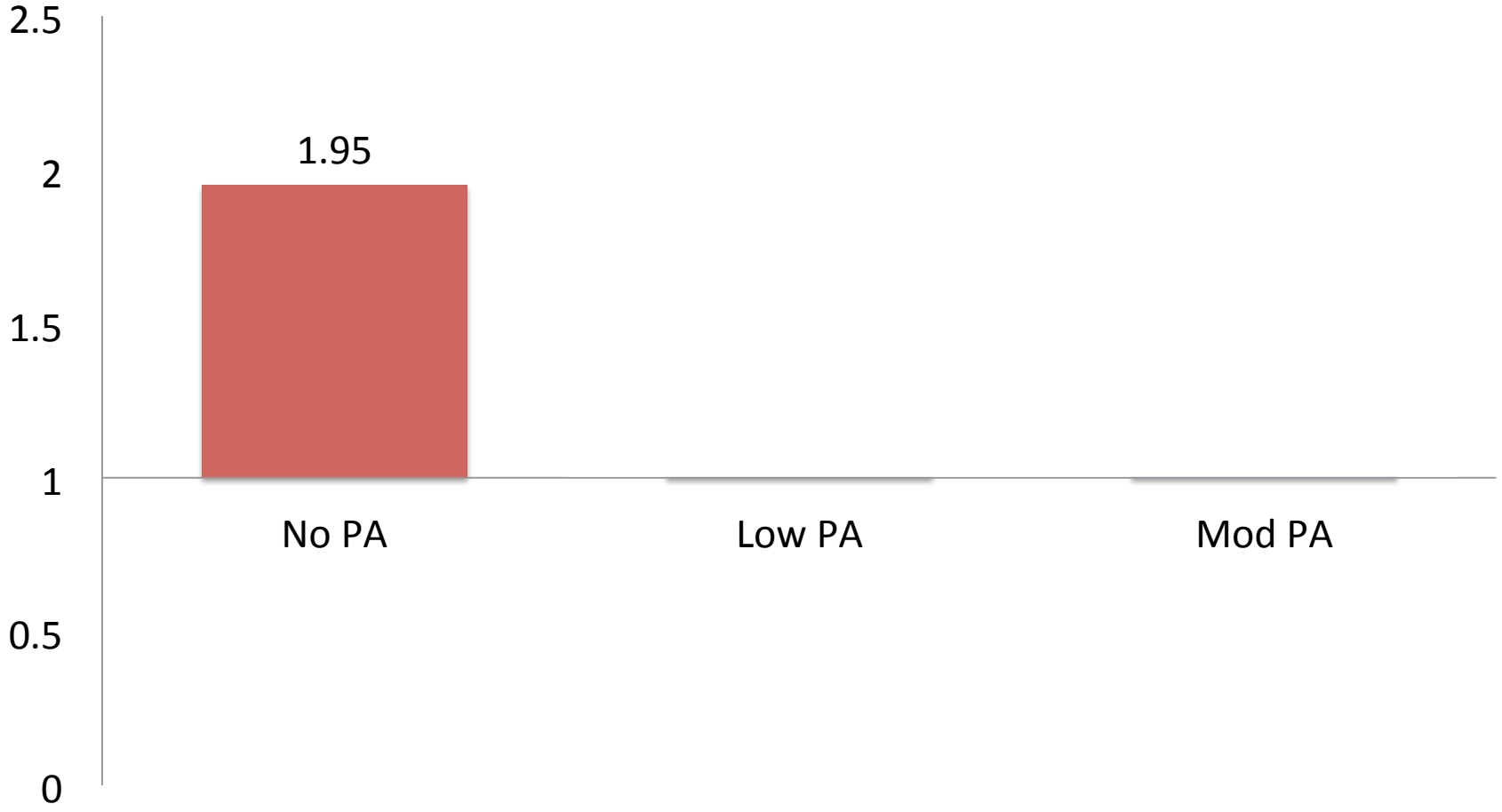
Physical activity and telomere length in U.S. men and women: An NHANES investigation

Larry A. Tucker

Department of Exercise Sciences, 237 SFH, Brigham Young University, Provo, UT 84602, USA

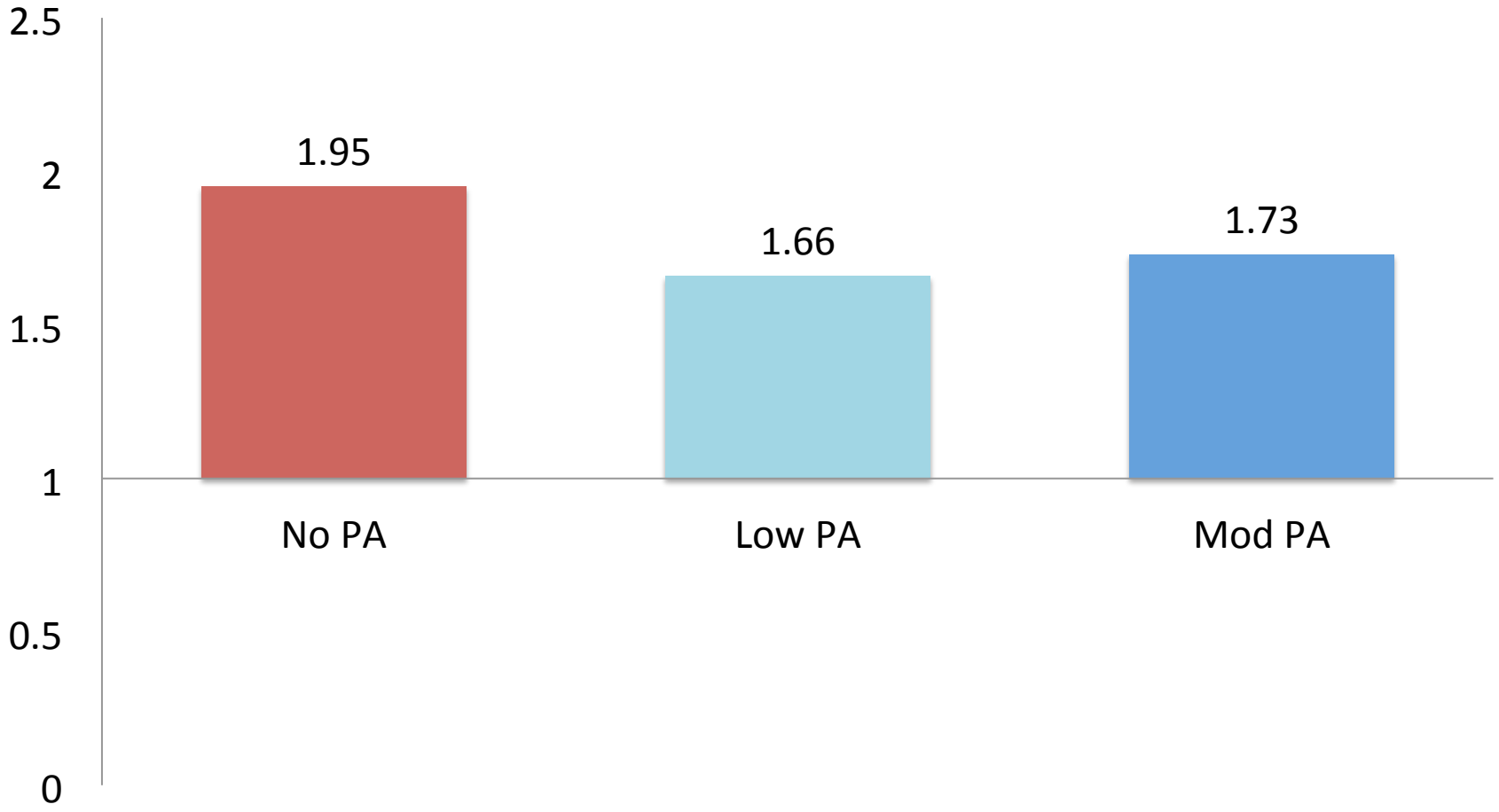

Hi PA
766
16.4%
Mod PA
807
16.4%
Low PA
843
16.3%
No PA
3407
50.8%

Odds of having short telomeres compared to high PA group



Odds of having short telomeres compared to high PA group

Odds of having short telomeres compared to high PA group



Experimental Gerontology 95 (2017) 141–147

Contents lists available at ScienceDirect

Experimental Gerontology

journal homepage: www.elsevier.com/locate/expgero

Leisure-time physical activity and leukocyte telomere length among older women

Aladdin H. Shadyab [a,*], Michael J. LaMonte [b], Charles Kooperberg [c], Alexander P. Reiner [d], Cara L. Carty [e], Todd M. Manini [f], Lifang Hou [g], Chongzhi Di [c], Caroline A. Macera [h], Linda C. Gallo [i], Richard A. Shaffer [h], Sonia Jain [j], Andrea Z. LaCroix [a]

THE GERONTOLOGICAL SOCIETY OF AMERICA®

Journals of Gerontology: Medical Sciences
cite as: *J Gerontol A Biol Sci Med Sci*, 2017, Vol. 72, No. 11, 1532–1537
doi:10.1093/gerona/glx037
Advance Access publication March 9, 2017

OXFORD

Research Article

Association of Accelerometer-Measured Physical Activity With Leukocyte Telomere Length Among Older Women

Aladdin H. Shadyab,[1] Michael J. LaMonte,[2] Charles Kooperberg,[3] Alexander P. Reiner,[4] Cara L. Carty,[5] Todd M. Manini,[6] Lifang Hou,[7] Chongzhi Di,[3] and Andrea Z. LaCroix[1]

American Journal of Epidemiology

Vol. 185, No. 3
DOI: 10.1093/aje/kww196
Advance Access publication:
January 18, 2017

Original Contribution

Associations of Accelerometer-Measured and Self-Reported Sedentary Time With Leukocyte Telomere Length in Older Women

Aladdin H. Shadyab*, Caroline A. Macera, Richard A. Shaffer, Sonia Jain, Linda C. Gallo, Michael J. LaMonte, Alexander P. Reiner, Charles Kooperberg, Cara L. Carty, Chongzhi Di, Todd M. Manini, Lifang Hou, and Andrea Z. LaCroix

TIME

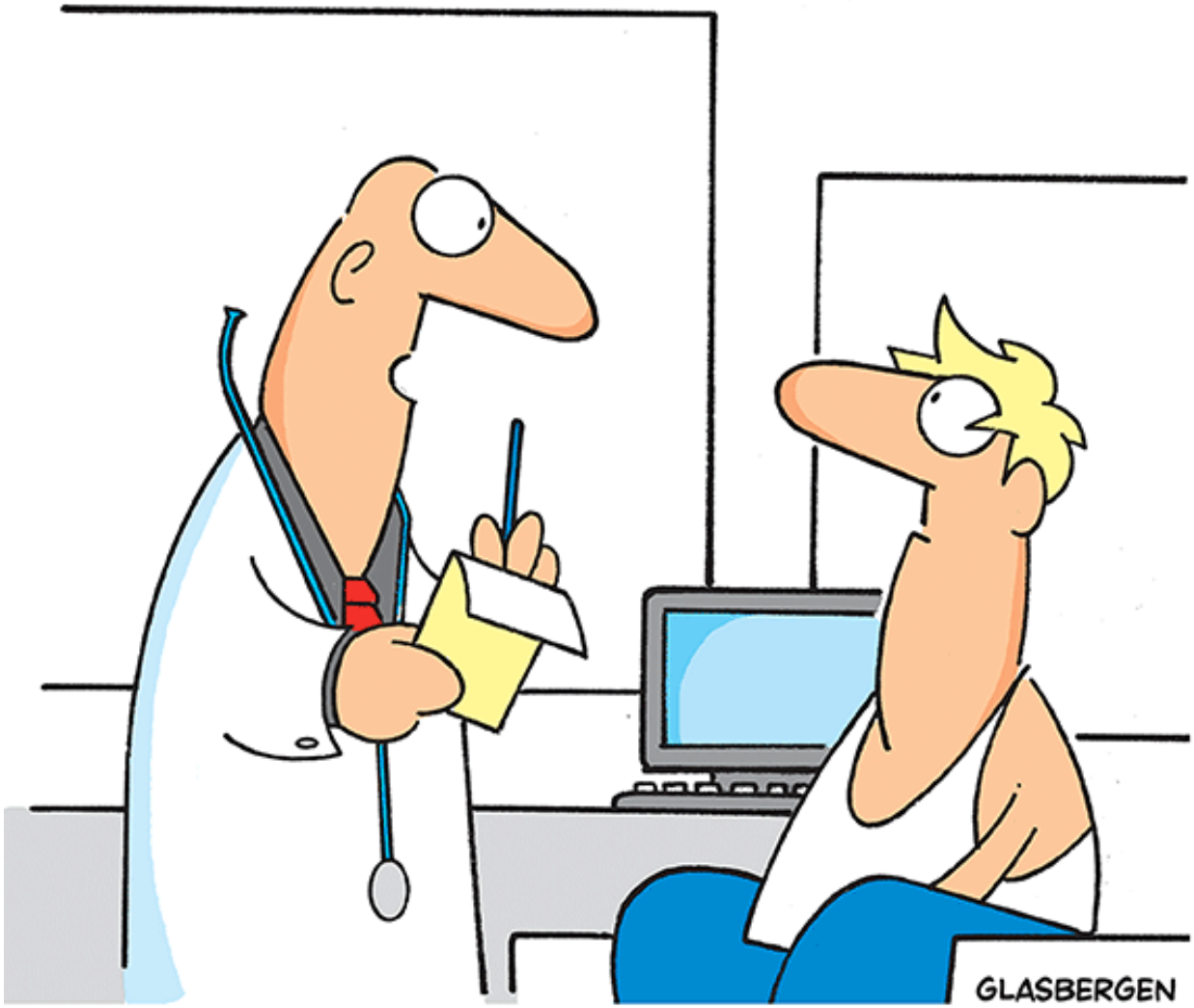
HEALTH • AGING

Sitting Too Much Ages You By 8 Years

Take Home

Any exercise matters for healthspan and lifespan, effects are seen deep into our cells

But more is better.



"I'm prescribing exercise. Think of it as a stress pill that takes 30 minutes to swallow."


↑STRESS=?TELOMERE LENGTH

July 2015

Valuing the Invaluable:
Putting a Dollar Value to Family Caregiving

In 2013, about **40 million** family caregivers in the United States provided an estimated **37 billion hours** of care. The estimated value of their unpaid service was approximately **$470 billion**.

HOW DOES FAMILY CAREGIVING COMPARE?

2013–2014 in billions

Walmart Annual Sales $477

Family Caregiving estimated value $470

Combined Annual Sales $469

Apple, IBM, Hewlett Packard and Microsoft

Total Medicaid Expenditures $449

TIME COMMITMENT

Caregivers spend an average of
18 hours per week
providing care to a family member.

60% Family caregivers caring for an adult while employed full or part time.

Provide **21+ hours** of family care per week while working a job. **22%**

FINANCIAL COMMITMENT

68%
Family caregivers who say they have to use their own money to help provide care to their relative.

39%
felt financially strained.

EMOTIONAL COMMITMENT

55%
Caregivers who felt overwhelmed by the amount of care needed for a family member.

WORK COMMITMENT

1 in 4 workers age 25+ are family caregivers.

72% workers 40+ that say allowing work flexibility for caregiving would help improve work/life balance.

AARP Real Possibilities

AARP Public Policy Institute

Source: Reinhard, Susan C., Feinberg, Lynn Friss, Choula, Rita, and Houser, Ari. Valuing the Invaluable: 2015 Update - Undeniable Progress, but Big Gaps Remain (2015): 1-25. AARP Public Policy Institute. 16 July 2015.

aarp.org/**valuing**

2X risk for depression

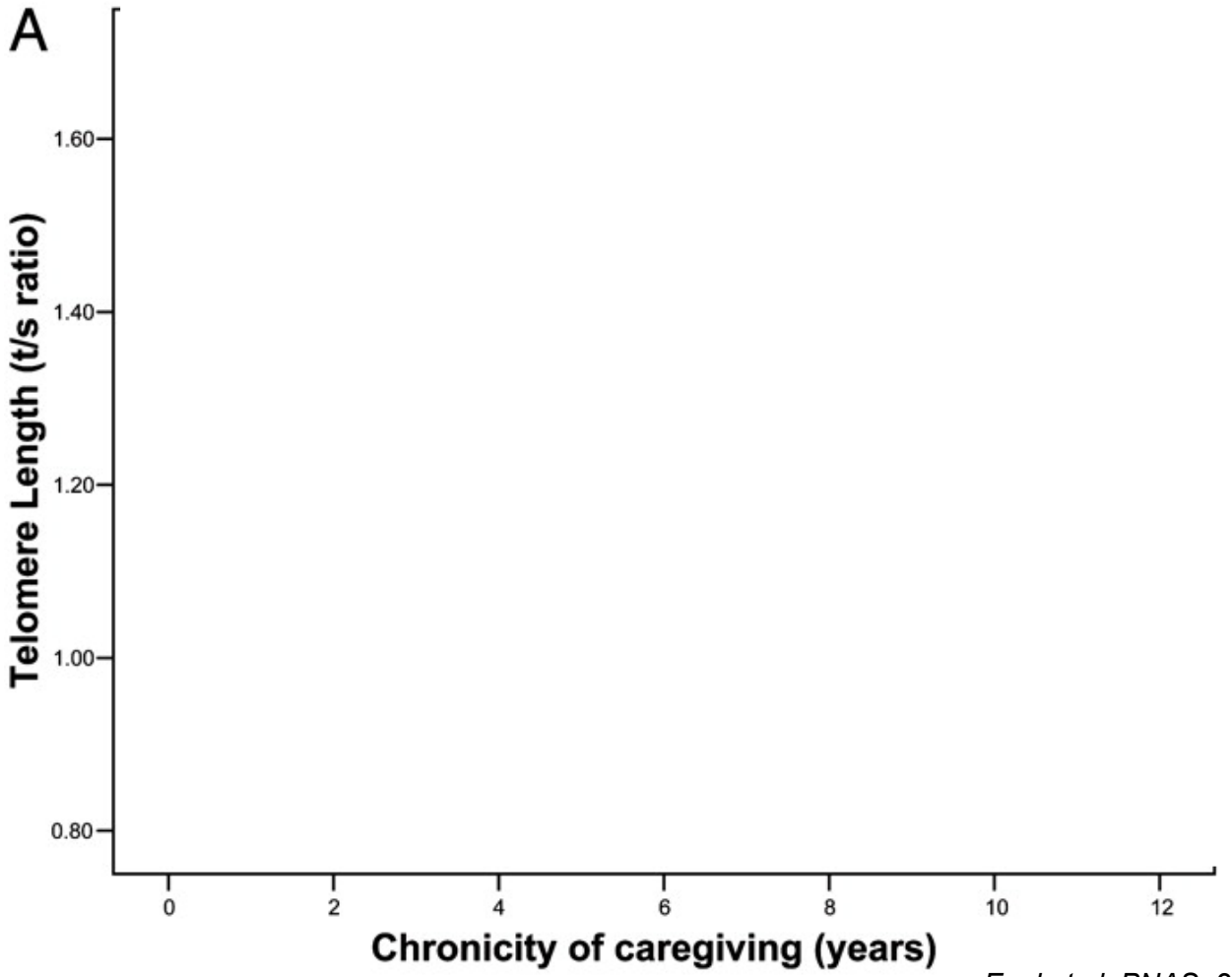
2X risk for cardiovascular diseases

63% risk for early mortality

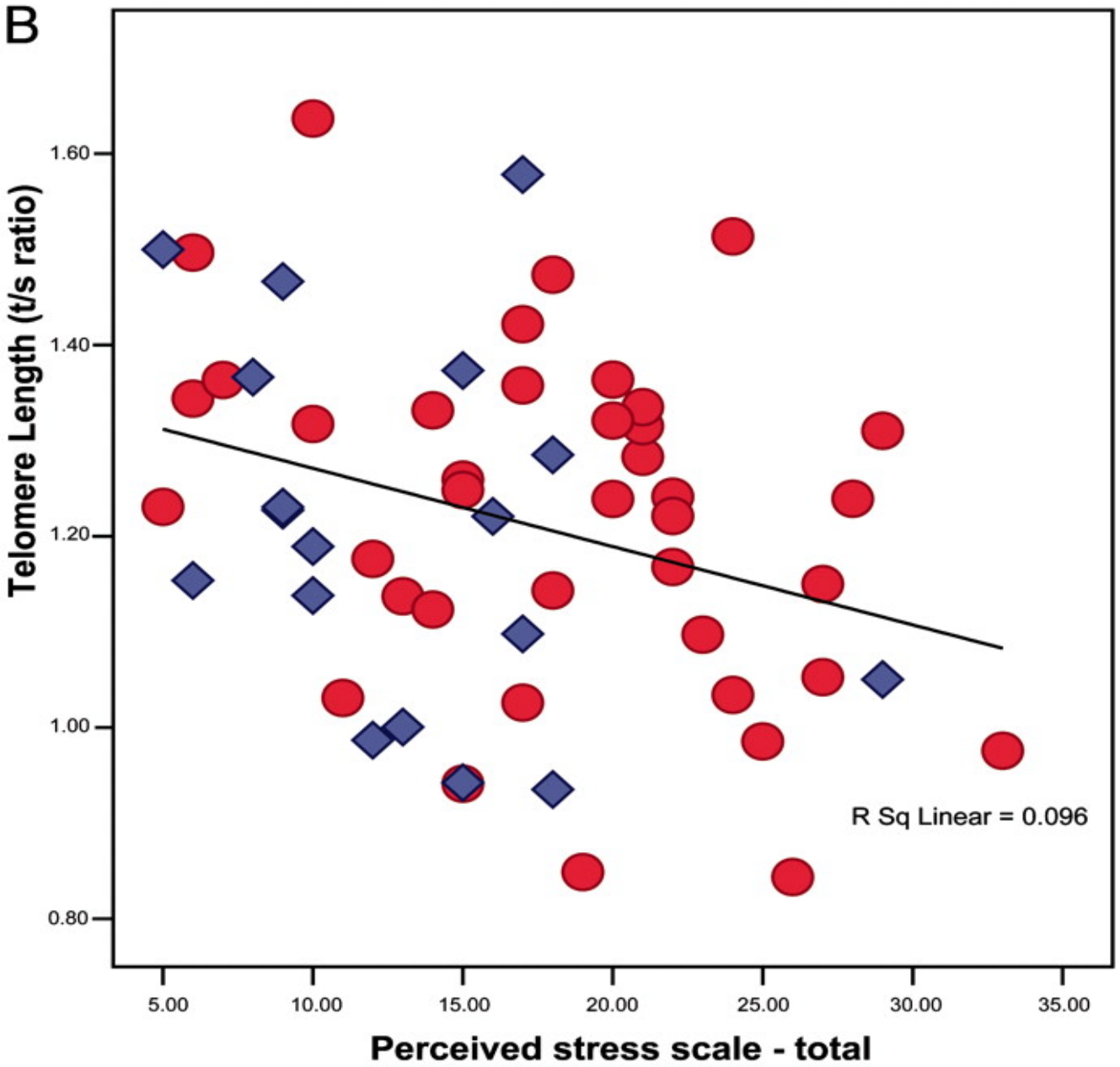
Accelerated telomere shortening in response to life stress

Elissa S. Epel*†, Elizabeth H. Blackburn‡, Jue Lin‡, Firdaus S. Dhabhar§, Nancy E. Adler*, Jason D. Morrow¶, and Richard M. Cawthon‖

*Department of Psychiatry, University of California, 3333 California Street, Suite 465, San Francisco, CA 94143; ‡Department of Biochemistry and Biophysics, University of California, San Francisco, CA 94143; §Department of Oral Biology, College of Dentistry, and Department of Molecular Virology, Immunology, and Medical Genetics, College of Medicine, Ohio State University, Columbus, OH 43210; ¶Department of Medicine and Pharmacology, Vanderbilt University School of Medicine, Nashville, TN 37232; and ‖Department of Human Genetics, University of Utah, 15 North 2030 E Street, Room 2100, Salt Lake City, UT 84112



Epel et al. PNAS, 2004



Epel, PNAS, 2004

Caregiving

Epel, 2004; Damjanovic, 2007; Puterman, 2010

Domestic violence

Humphreys, 2012

Socioeconomic disadvantage

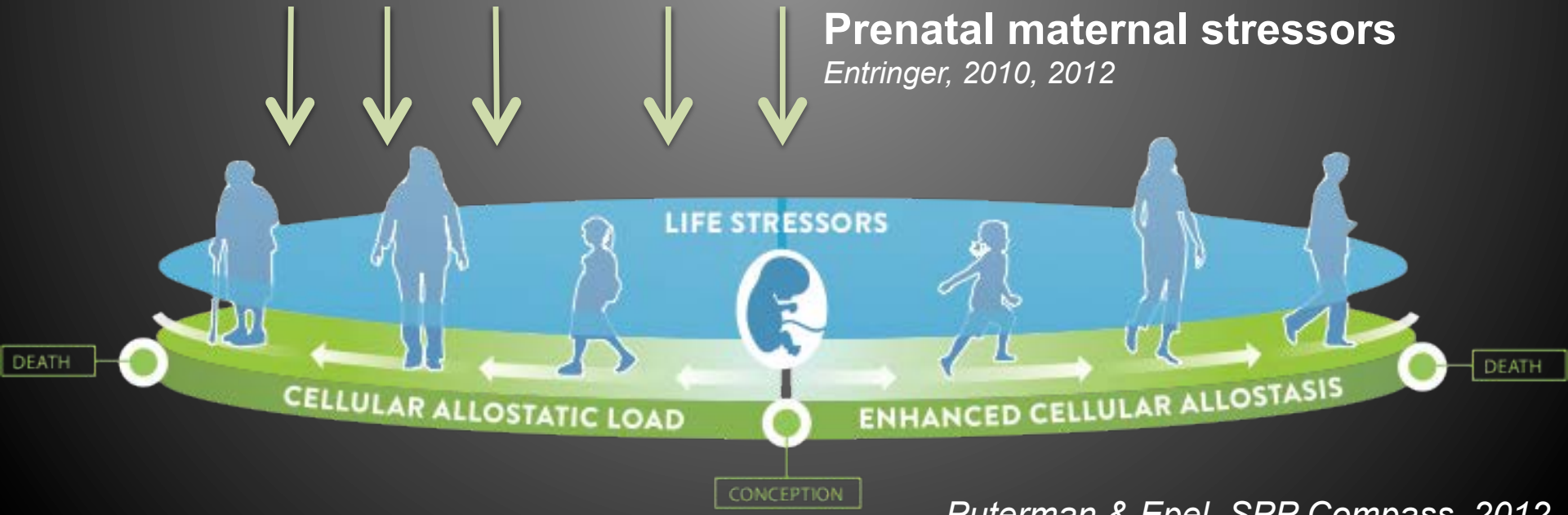
Adler, 2013; Batty , 2009; Cherkas , 2006; Diez-Roux, 2009; Shiels , 2011; Steptoe, 2011; Surtees, 2012

Early childhood adversity

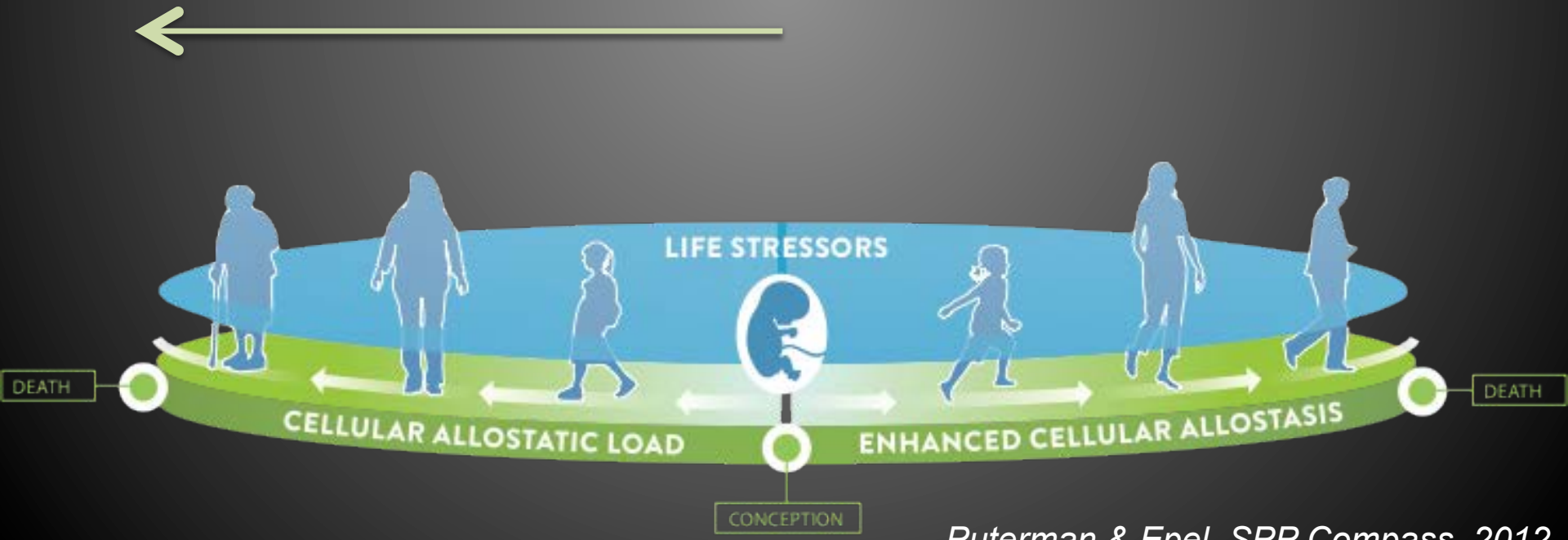
Kanenan, 2010, Kiecolt-Glaser, 2010; O'Donovan, 2011l Shalev, 2012; Surtees, 2011; Tyrka, 2010

Prenatal maternal stressors

Entringer, 2010, 2012



Puterman & Epel, SPP Compass, 2012



Puterman & Epel, SPP Compass, 2012

PNAS

PNAS PLUS

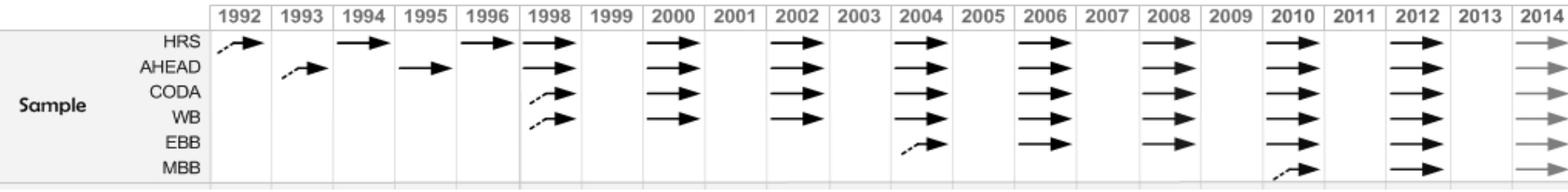
Lifespan adversity and later adulthood telomere length in the nationally representative US Health and Retirement Study

Eli Puterman[a,1], Alison Gemmill[b], Deborah Karasek[c], David Weir[d], Nancy E. Adler[e], Aric A. Prather[e], and Elissa S. Epel[e,1]

[a]School of Kinesiology, University of British Columbia, Vancouver, BC, Canada V6T 1Z3; [b]Department of Demography, University of California, Berkeley, CA 94720-2120; [c]Division of Epidemiology, School of Public Health, University of California, Berkeley, CA 94720-7360; [d]Survey Research Center, Institute for Social Research, University of Michigan, Ann Arbor, MI 48106; and [e]Department of Psychiatry, University of California, San Francisco, CA 94118

HRS | HEALTH AND RETIREMENT STUDY
A Longitudinal Study of Health, Retirement, and Aging
Sponsored by the National Institute on Aging

Telomere data
N = ~ 5000



N= ~ 20,000

Puterman et al, PNAS, 2016

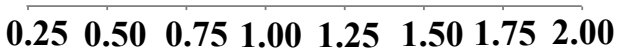
Total lifespan adversity

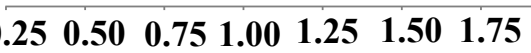
Childhood adversities

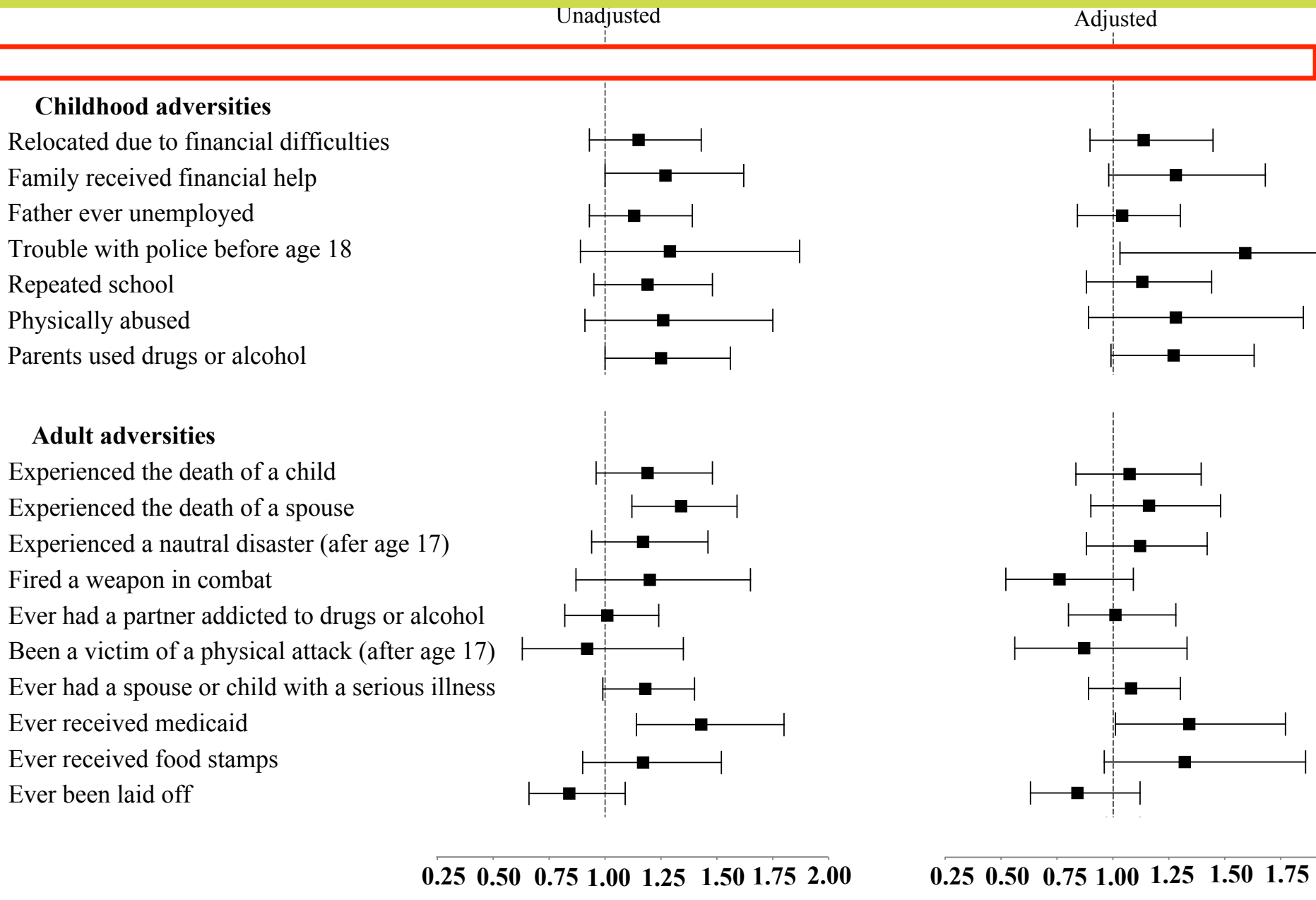
Relocated due to financial difficulties
Family received financial help
Father ever unemployed
Trouble with police before age 18
Repeated school
Physically abused
Parents used drugs or alcohol

Adult adversities

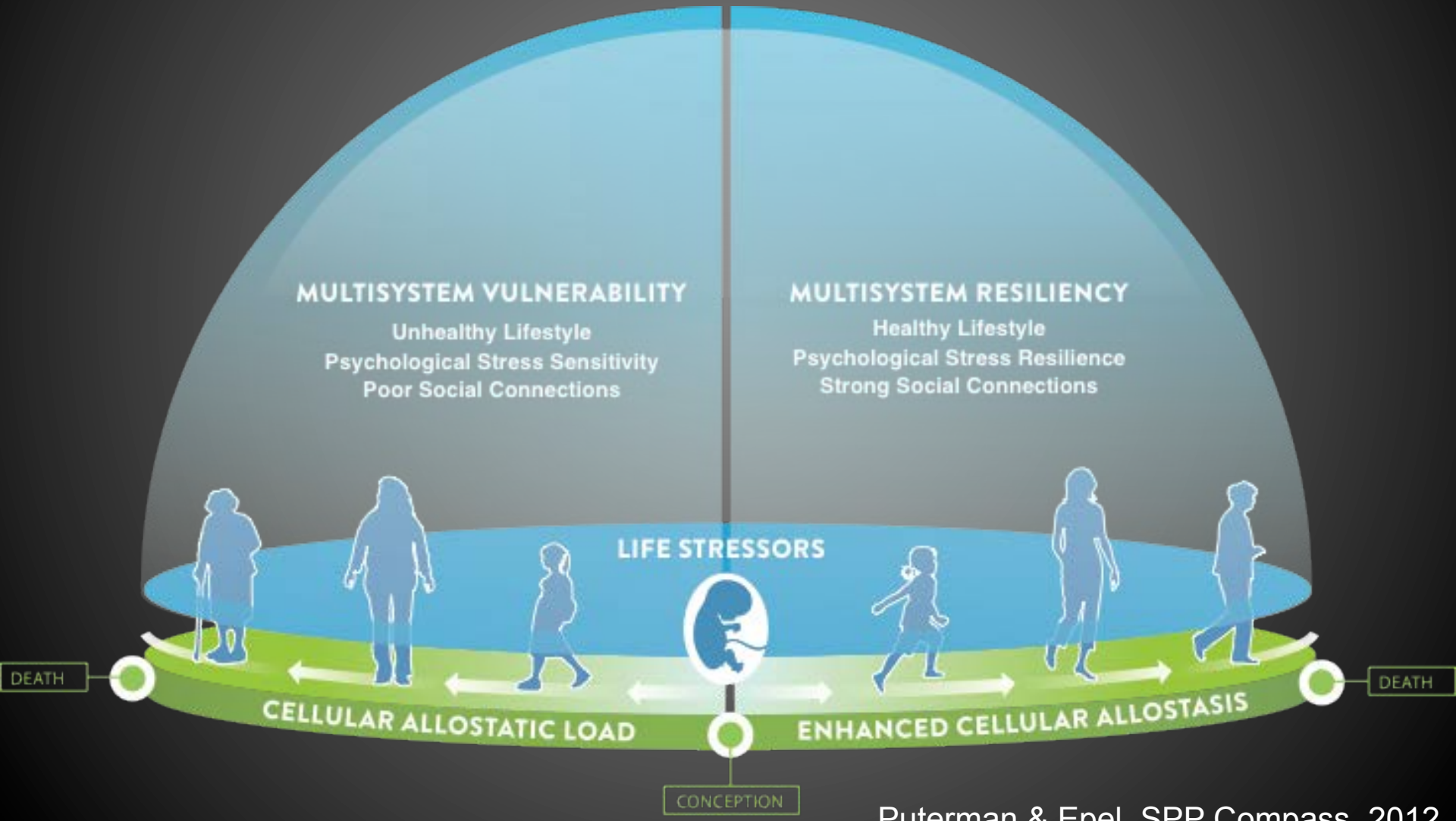
Experienced the death of a child
Experienced the death of a spouse
Experienced a nautral disaster (afer age 1
Fired a weapon in combat
Ever had a partner addicted to drugs or al
Been a victim of a physical attack (after a
Ever had a spouse or child with a
Ever received medicaid
Ever received food stamps
Ever been laid off






Unadjusted
Adjusted
Childhood adversities
Relocated due to financial difficulties
Family received financial help
Father ever unemployed
Trouble with police before age 18
Repeated school
Physically abused
Parents used drugs or alcohol
Adult adversities
Experienced the death of a child
Experienced the death of a spouse
Experienced a nautral disaster (afer age 17)
Fired a weapon in combat
Ever had a partner addicted to drugs or alcohol
Been a victim of a physical attack (after age 17)
Ever had a spouse or child with a serious illness
Ever received medicaid
Ever received food stamps
Ever been laid off
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
0.25 0.50 0.75 1.00 1.25 1.50 1.75

Puterman & Epel, SPP Compass, 2012



Puterman & Epel, SPP Compass, 2012

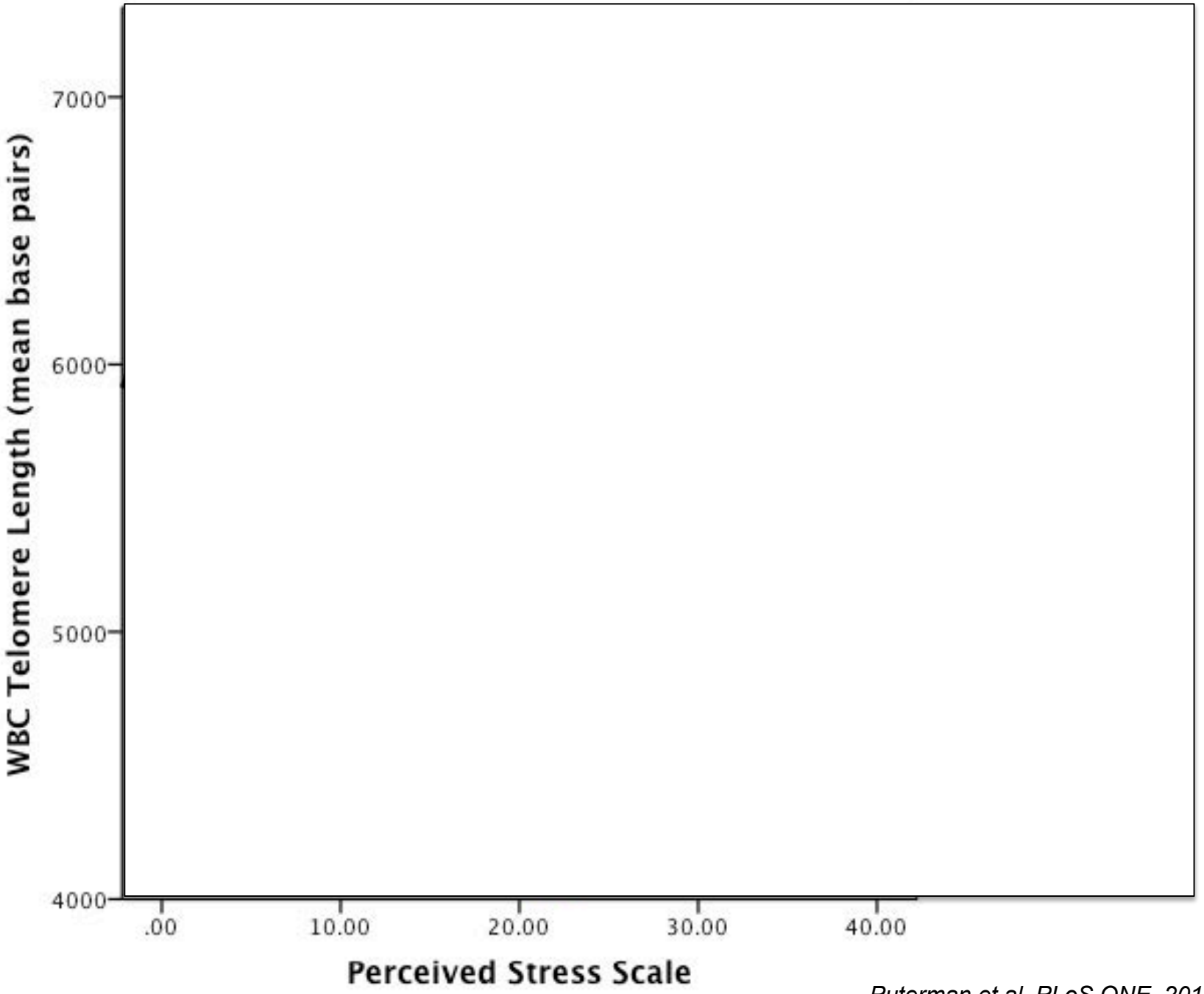
OPEN ACCESS Freely available online

PLoS one

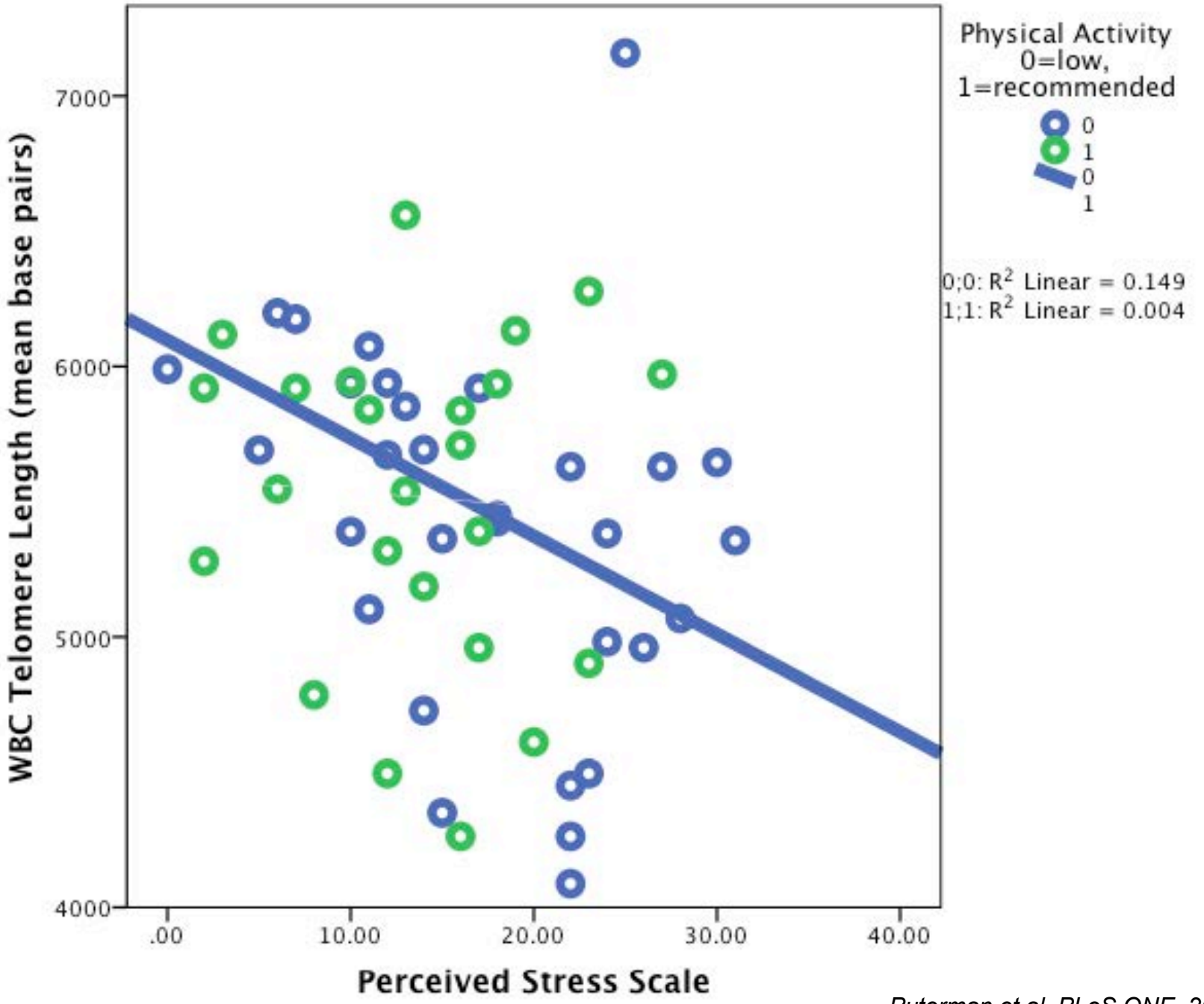
The Power of Exercise: Buffering the Effect of Chronic Stress on Telomere Length

Eli Puterman[1]*, Jue Lin[2], Elizabeth Blackburn[2], Aoife O'Donovan[1,3], Nancy Adler[1], Elissa Epel[1]

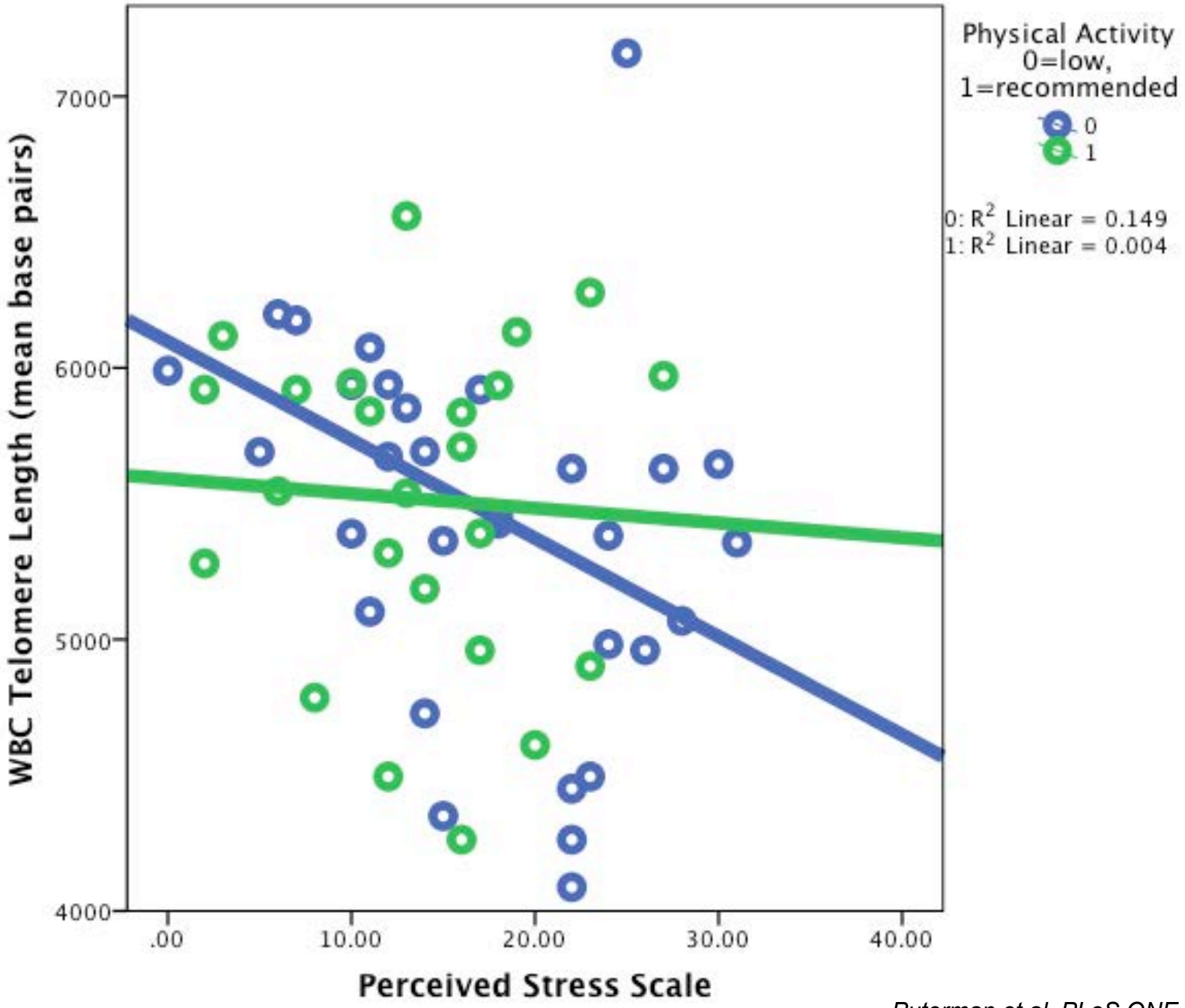
1 Department of Psychiatry, University of California San Francisco, San Francisco, California, United States of America, 2 Department of Biochemistry and Biophysics, University of California San Francisco, San Francisco, California, United States of America, 3 Veterans Affairs Medical Center, San Francisco, California, United States of America



Puterman et al, PLoS ONE, 2010



Puterman et al, PLoS ONE, 2010



Puterman et al, PLoS ONE, 2010

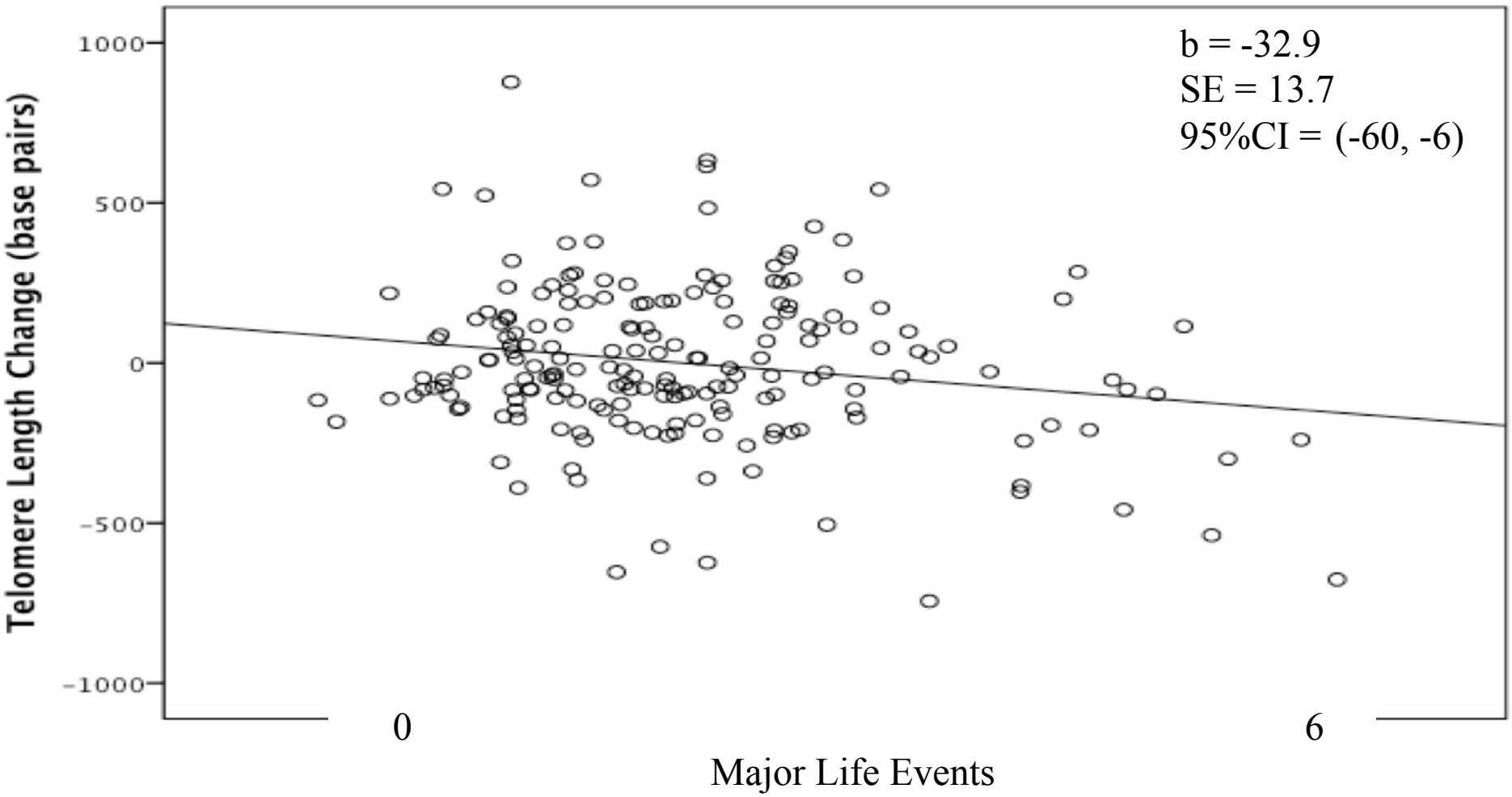
Molecular Psychiatry (2014), 1–7

www.nature.com/mp

ORIGINAL ARTICLE

Determinants of telomere attrition over 1 year in healthy older women: stress and health behaviors matter

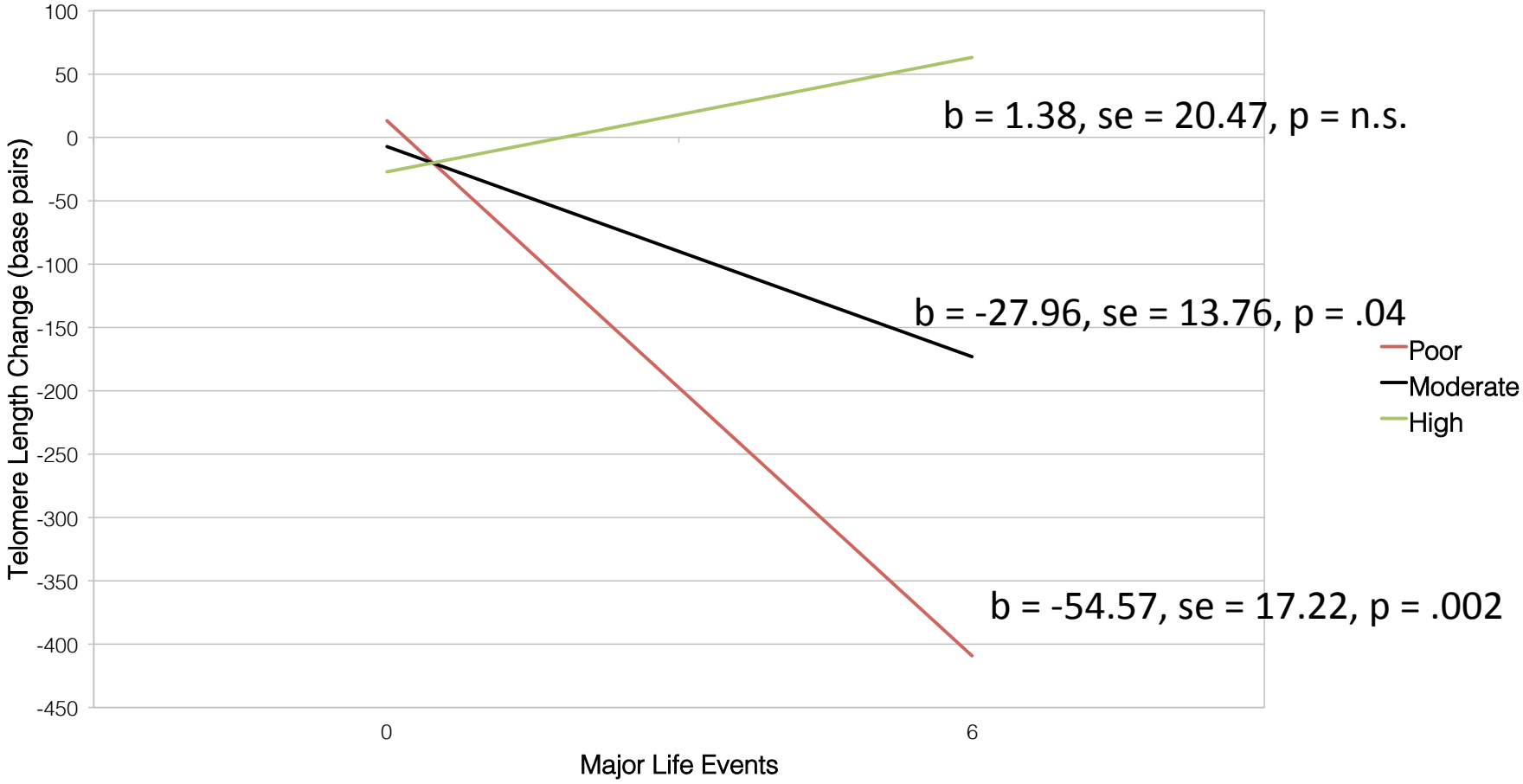
E Puterman[1], J Lin[2], J Krauss[3], EH Blackburn[2] and ES Epel[1]



*Covariates: Baseline TL, Age, Income, Education, Ethnicity, BMI, Medication Use

Puterman et al., Molecular Psychiatry, 2015

Exercise, Diet, and Sleep Mitigate Stress Effects



Brain, Behavior, and Immunity 33 (2013) 65–73

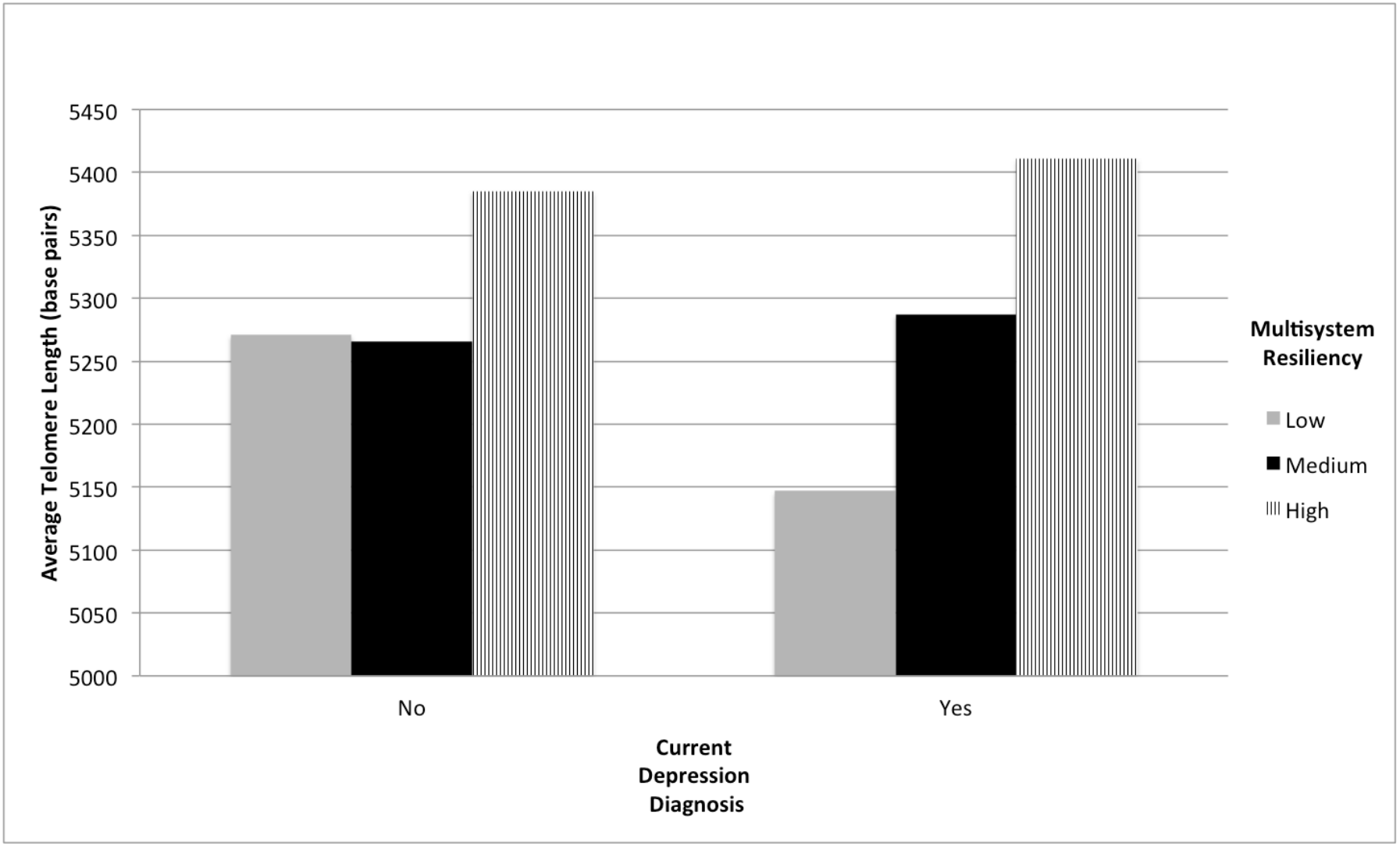
Contents lists available at SciVerse ScienceDirect

Brain, Behavior, and Immunity

journal homepage: www.elsevier.com/locate/ybrbi

Multisystem resiliency moderates the major depression–Telomere length association: Findings from the Heart and Soul Study

Eli Puterman [a,*], Elissa S. Epel [a], Jue Lin [a], Elizabeth H. Blackburn [a], James J. Gross [b], Mary A. Whooley [a,c], Beth E. Cohen [a,c]


5450
5400
5350
5300
5250
5200
5150
5100
5050
5000
Average Telomere Length (base pairs)
No
Yes
Current Depression Diagnosis
Multisystem Resiliency
Low
Medium
High

Take Home

Stress accumulates and reduces telomere length

Exercise, and other health behaviours, matter

FASTSTUDY

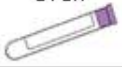
FITNESS, AGING, & STRESS

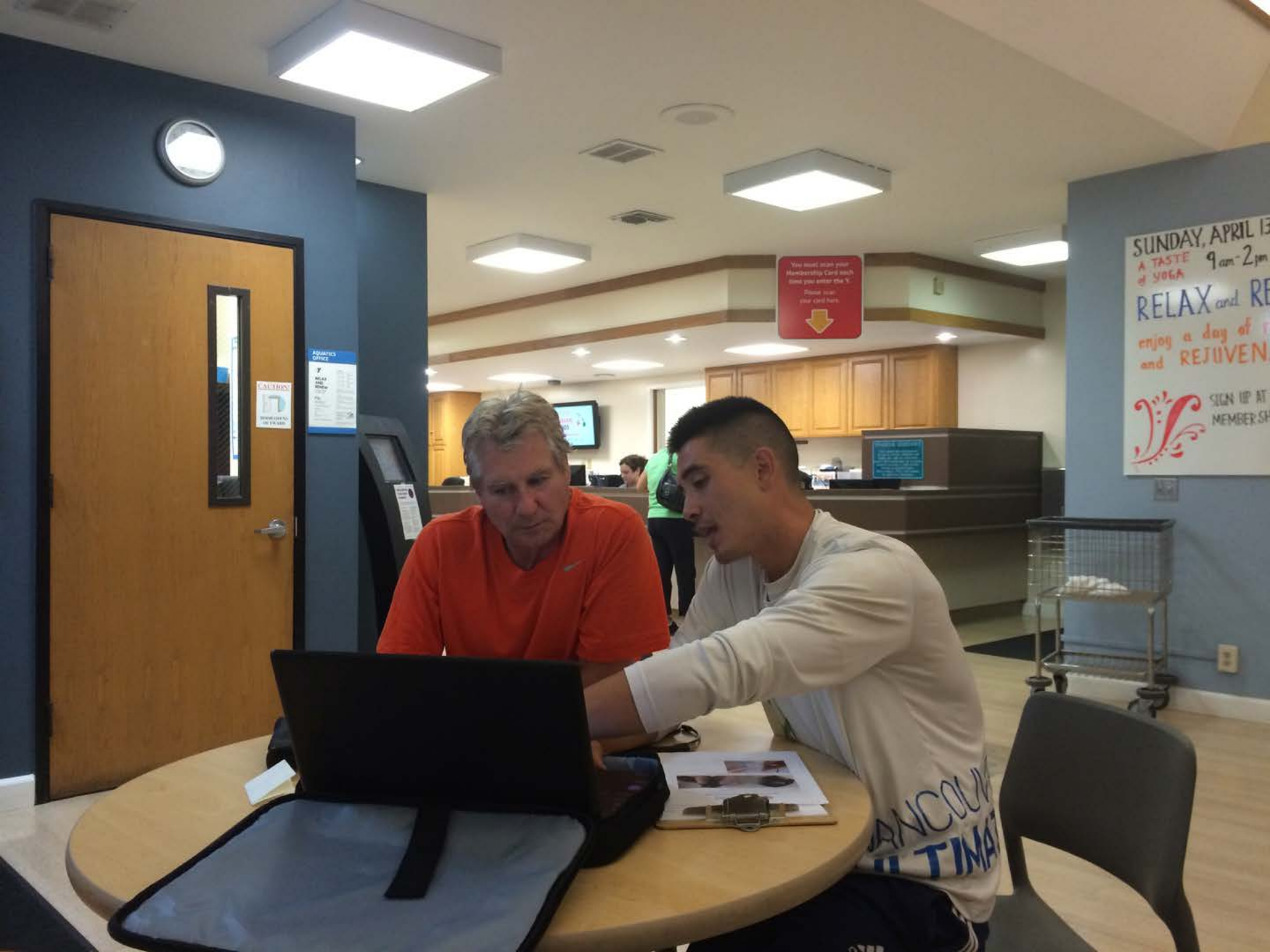
Improving fitness in family caregivers

UCSF
University of California
San Francisco

FITNESS, AGING, AND STRESS
STUDY TIMELINE

FASTSTUDY
FITNESS, AGING, & STRESS

MONTH 1				MONTH 2 — MONTH 7	MONTH 8	
Week 1	Week 2	Week 3	Week 4	Week 5-Week28	Week 29	Week 30
Study Orientation & Enrollment 	Pre-Study Blood Draw  Baseline Questionnaire  Ecological Week 	Stretching Trial 	UCSF Clinic Visit 	RANDOMIZE 6-Month Exercise Intervention  6-Month Activity Maintenance 	Follow-Up Questionnaire  Ecological Week 	Pre-Visit Blood Draw  UCSF Clinic Visit 
• Decision to Participate in the FAST Study.... • Sign Consent Forms	• Pre-Study Blood Draw • Complete Questionnaires Online • 7 Days of	• 7 Days of Stretching	• 3 Hour Clinical Visit at UCSF Parnassus • Randomization into Study group	• 6 months of aerobic training, fitness instruction, and coaching. OR • 6 months maintaining your normal lifestyle.	• Complete Questionnaires Online • 7 Days of "Ecological Week"	• Pre-Visit Blood Draw • 3 Hour Clinical Visit at UCSF Parnassus


SUNDAY, APRIL
A TASTE of YOGA
9 am - 2 pm
RELAX and
enjoy a day of
and REJUVEN
SIGN UP AT
MEMBER SH
CAUTION
AQUATICS OFFICE

Weekly Exercise and Heart Rate Goals

Numbers in each column under Day 1, 2, 3, and 4 indicate how many minutes of aerobic exercise should be completed. Your weekly minimum target heart rate is displayed in "**red**". This is your goal to maintain each time you exercise.

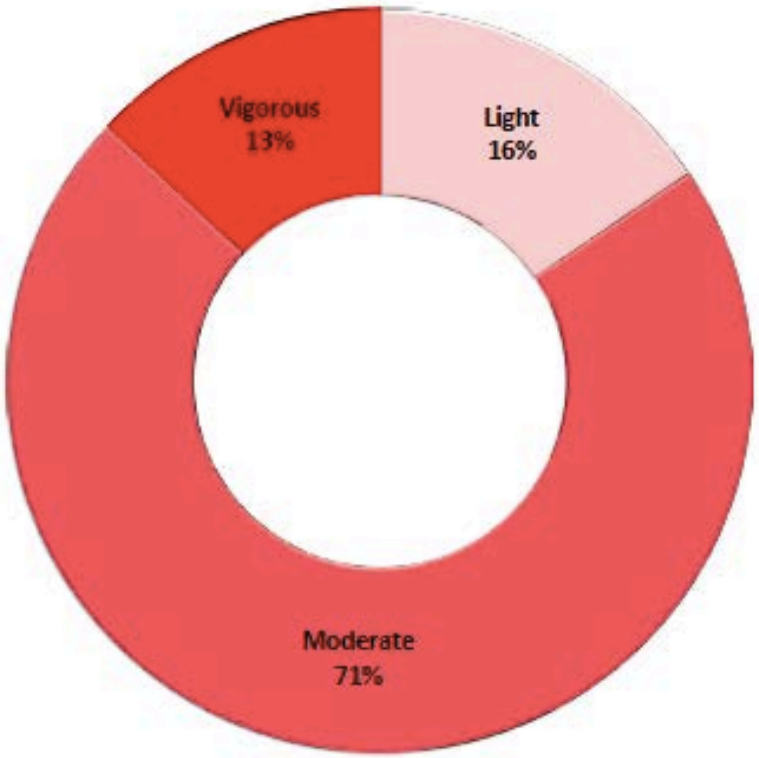
Week	Day 1	Day 2	Day 3	Day 4	% Heart Rate Reserve	Minimum Target Heart Rate	Total time/notes
1	20	20	20	-	40%	**109**	60 minutes –brisk walking
2	20	30	20	-	45%	**115**	70 minutes –brisk walking, one stationary bike session
3	20	30	20	-	45%	**115**	70 minutes –brisk walking, one stationary bike session
4	30	20	30	-	50%	**121**	80 minutes – brisk walking, one stationary bike session
5	30	30	30	-	50%	**121**	90 minutes – brisk walking, one stationary bike session. Consider beginning a jog/walk session
6	20	30	20	30	55%	**127**	100 minutes –brisk walking, one stationary bike session. Consider a jog/walk session.
7	30	30	30	30	55%	**127**	120 minutes – Brisk walking, consider one stationary bike session. Consider 2 jog/walk sessions.
8	30	35	30	40	60%	**133**	135 minutes – Brisk walking, consider one stationary bike session. Consider 2 jog/walk sessions.
9-24	40	35	35	40	60%	**133**	150 minutes – Brisk walking, consider one stationary bike session. Consider 2 jog/walk sessions.

Below is your Heart Rate and how it matches the CDC categories of intensity.

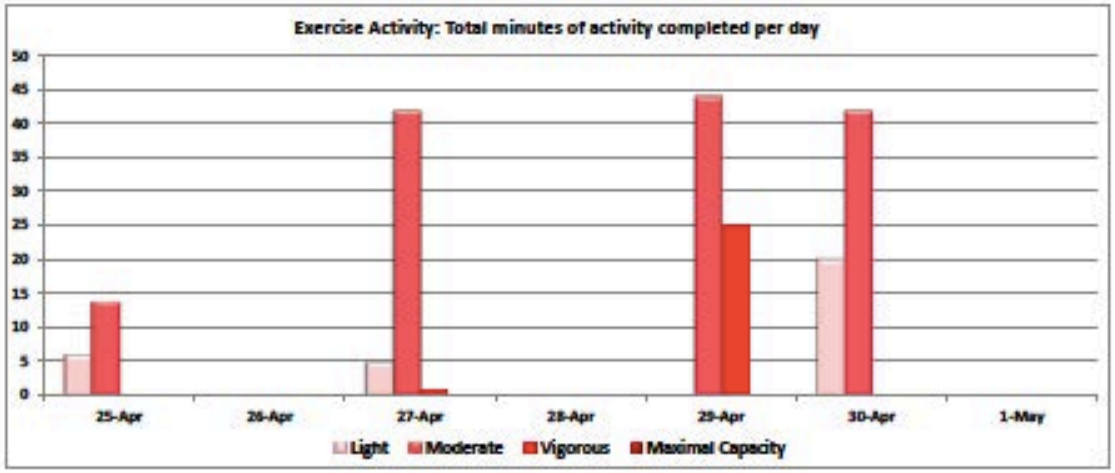
Resting HR	Light Activity: 39% and Below	Moderate Activity: 40%-59%	Vigorous Activity: 60%-89%	Maximal Capacity: 90% and above	Maximum HR
63 BPM	63-108 BPM	109-132 BPM	133-167 BPM	168-179 BPM	179 BPM

Congratulations on exceeding your 150 minute exercise goal by 49 minutes this week!

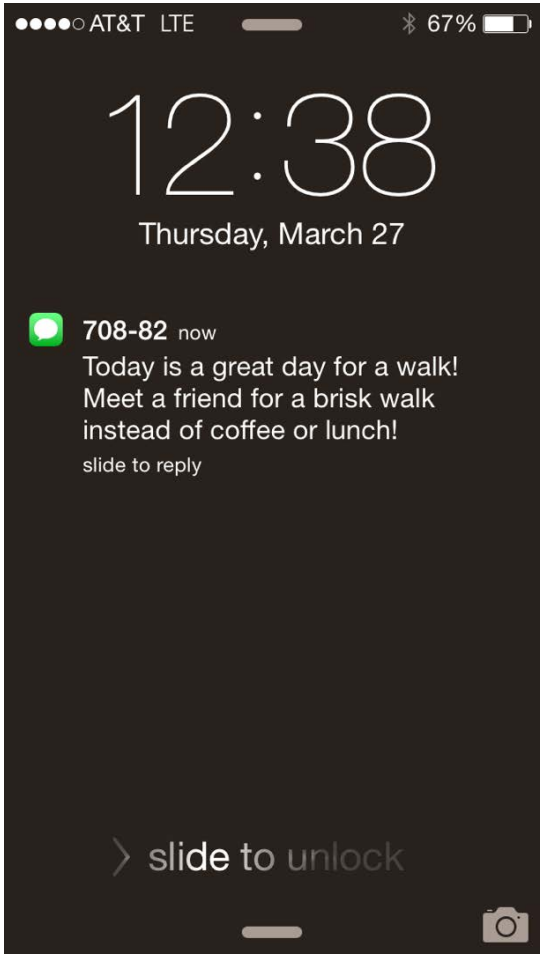
Workout intensity for week 17

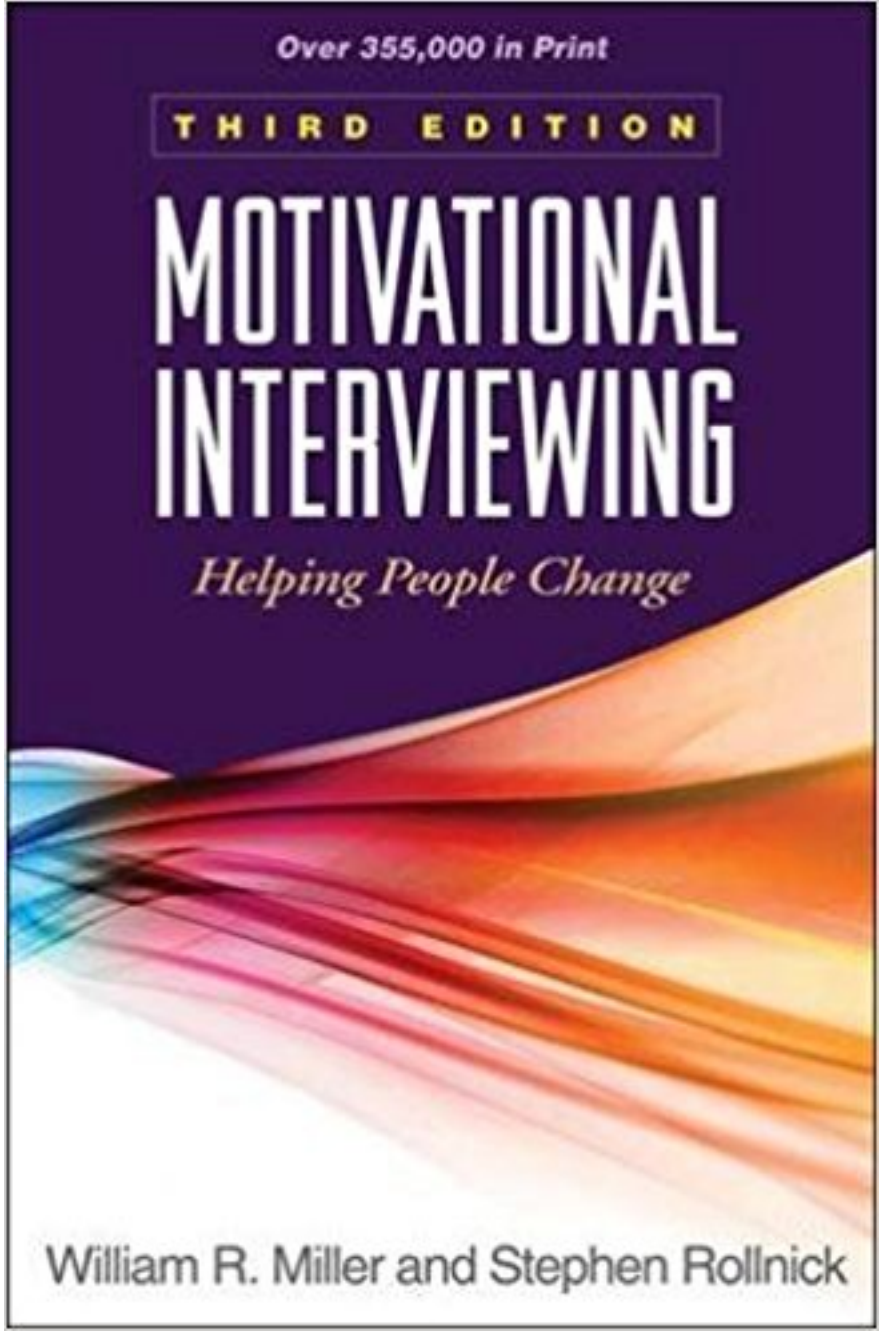


Workout intensity in minutes for Week 17	
Intensity	Minutes
Light	31
Moderate	142
Vigorous	26
Maximal Capacity	0
Total	199


Exercise Activity: Total minutes of activity completed per day
50
45
40
35
30
25
20
15
10
5
0
25-Apr
26-Apr
27-Apr
28-Apr
29-Apr
30-Apr
1-May
Light
Moderate
Vigorous
Maximal Capacity

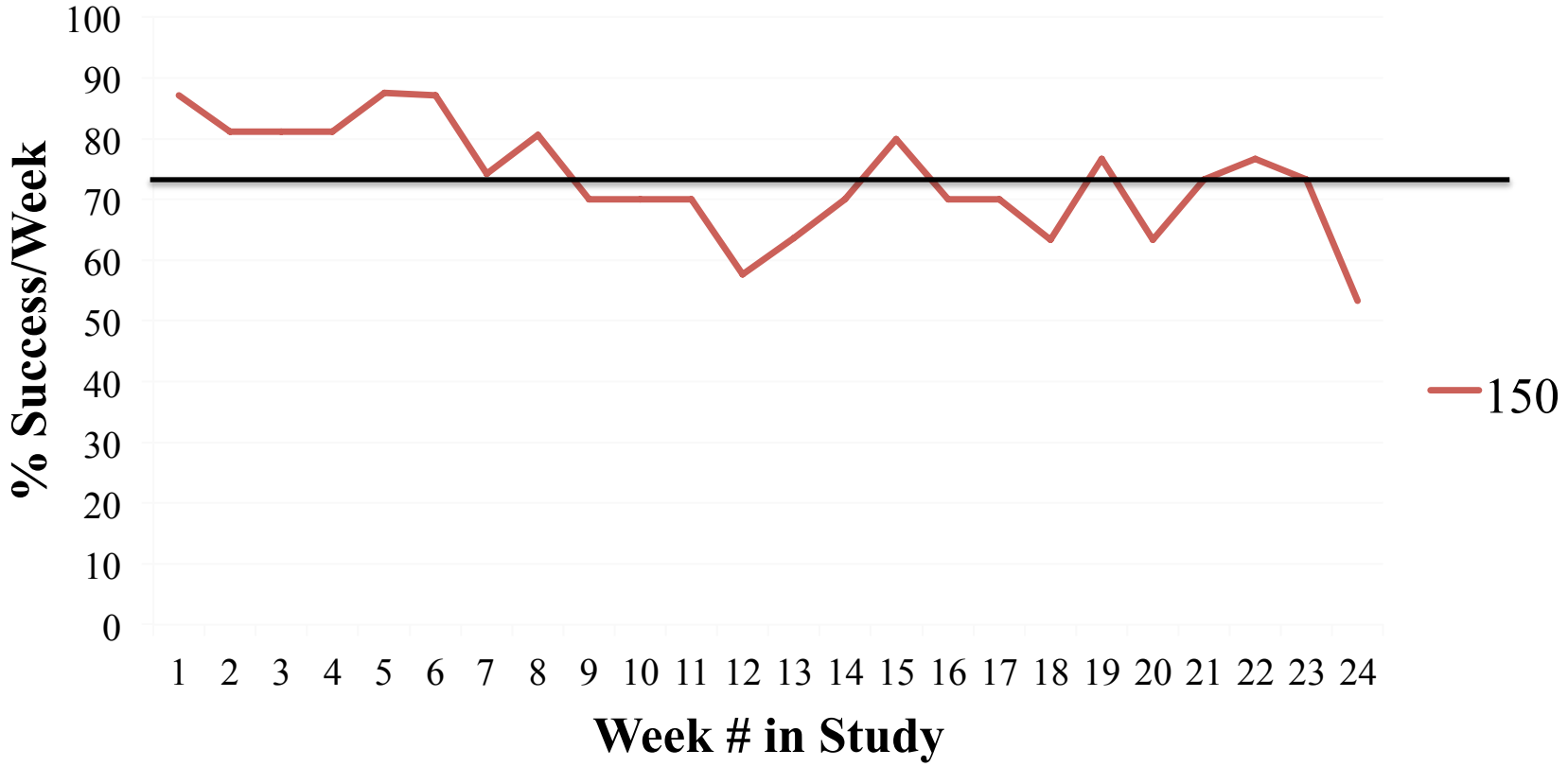

Steps: Total number of steps completed per day
14000
12000
10000
8000
6000
4000
2000
0
25-Apr
26-Apr
27-Apr
28-Apr
29-Apr
30-Apr
1-May


AT&T LTE
67%
12:38
Thursday, March 27
708-82 now
Today is a great day for a walk!
Meet a friend for a brisk walk
instead of coffee or lunch!
slide to reply
slide to unlock

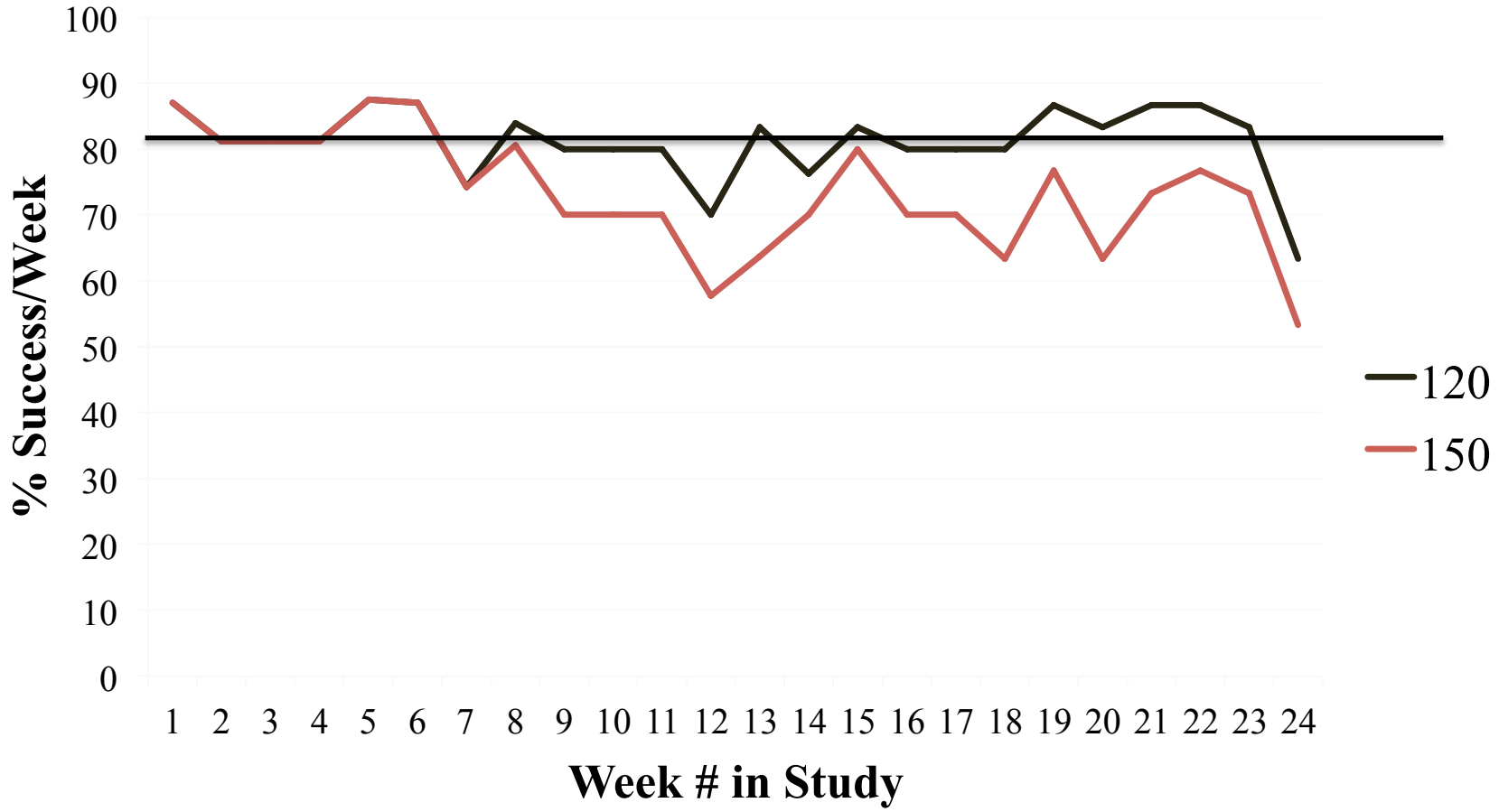

Over 355,000 in Print
THIRD EDITION
MOTIVATIONAL INTERVIEWING
Helping People Change
William R. Miller and Stephen Rollnick

Results

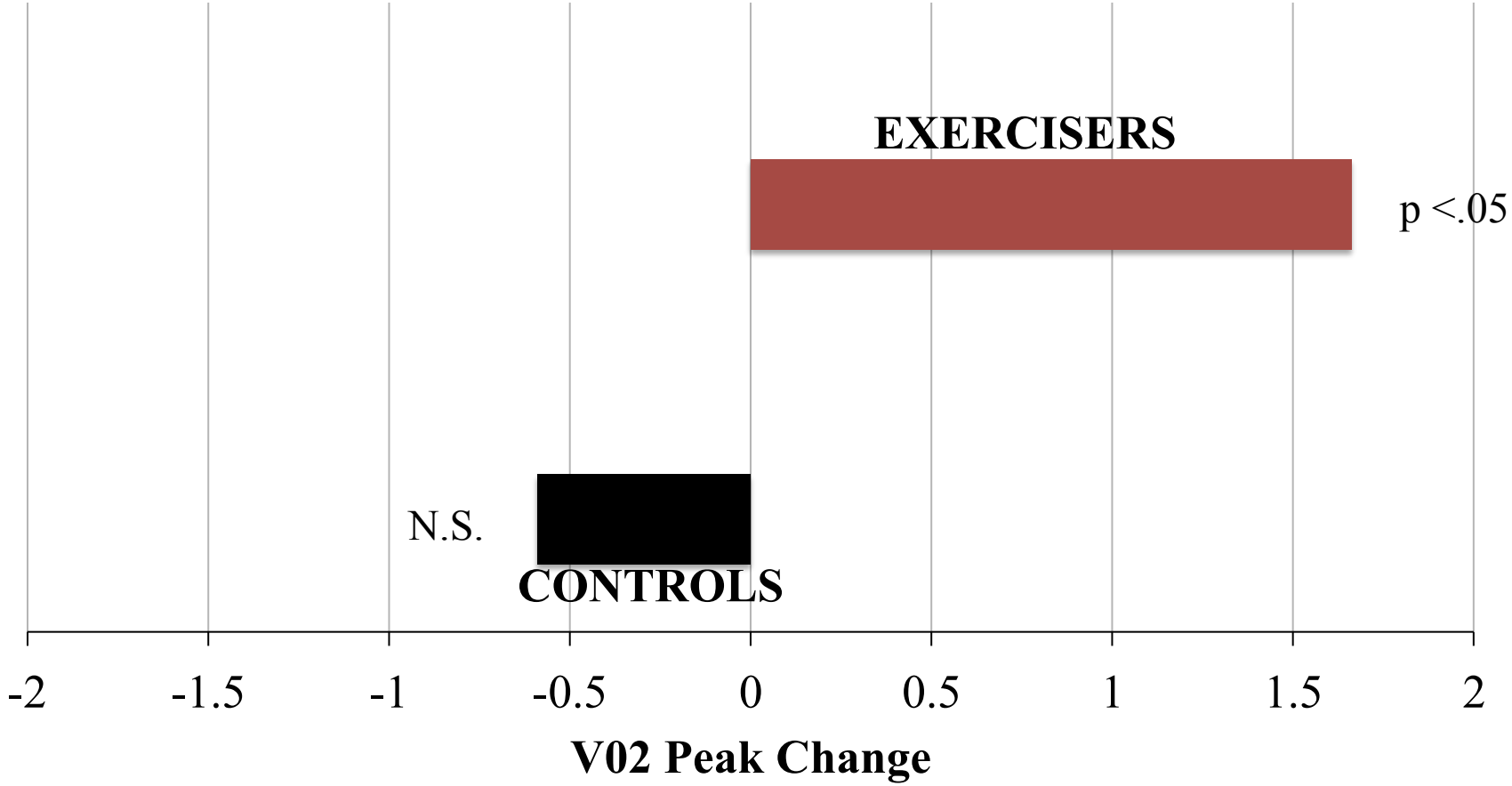
Success per week



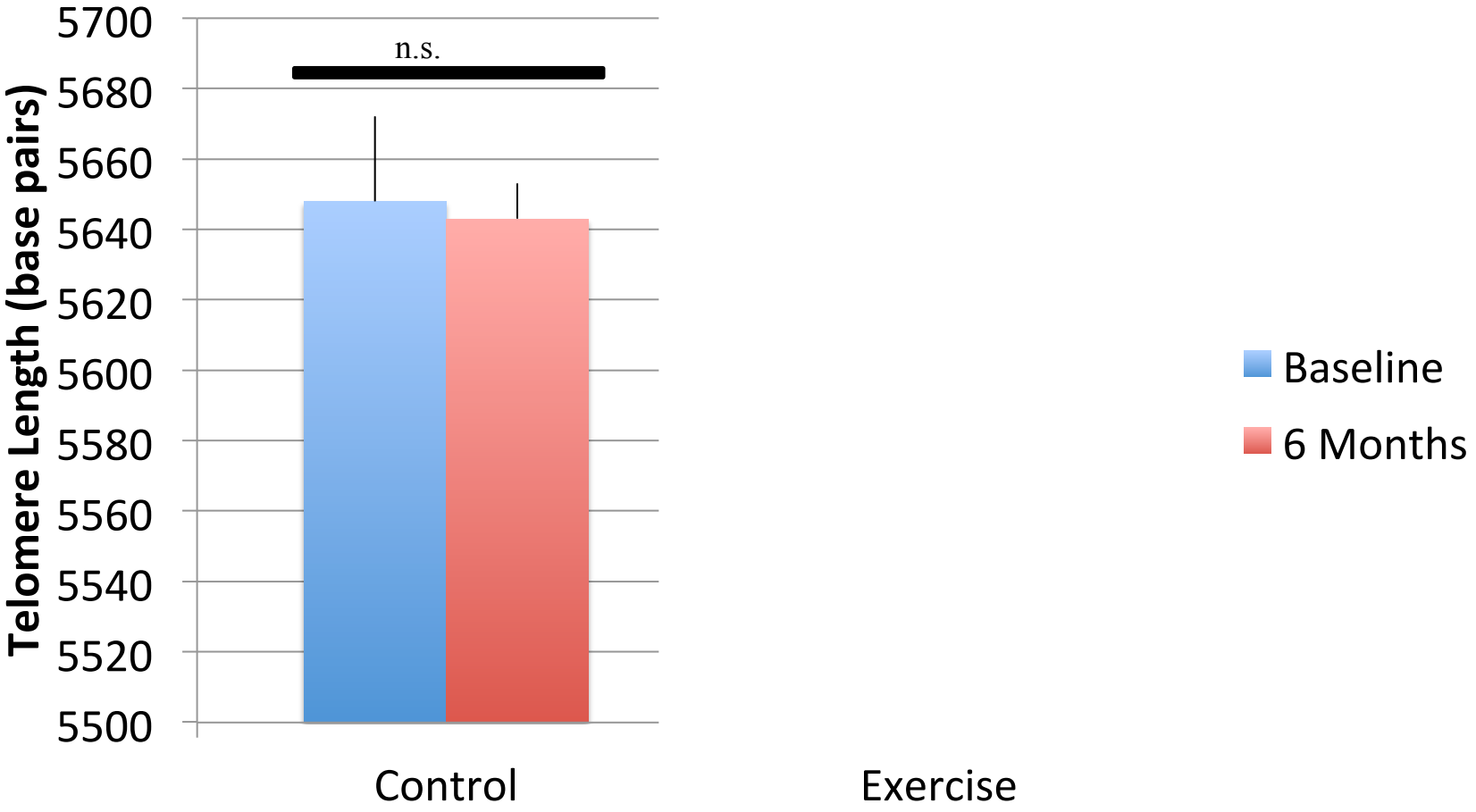
Success per week



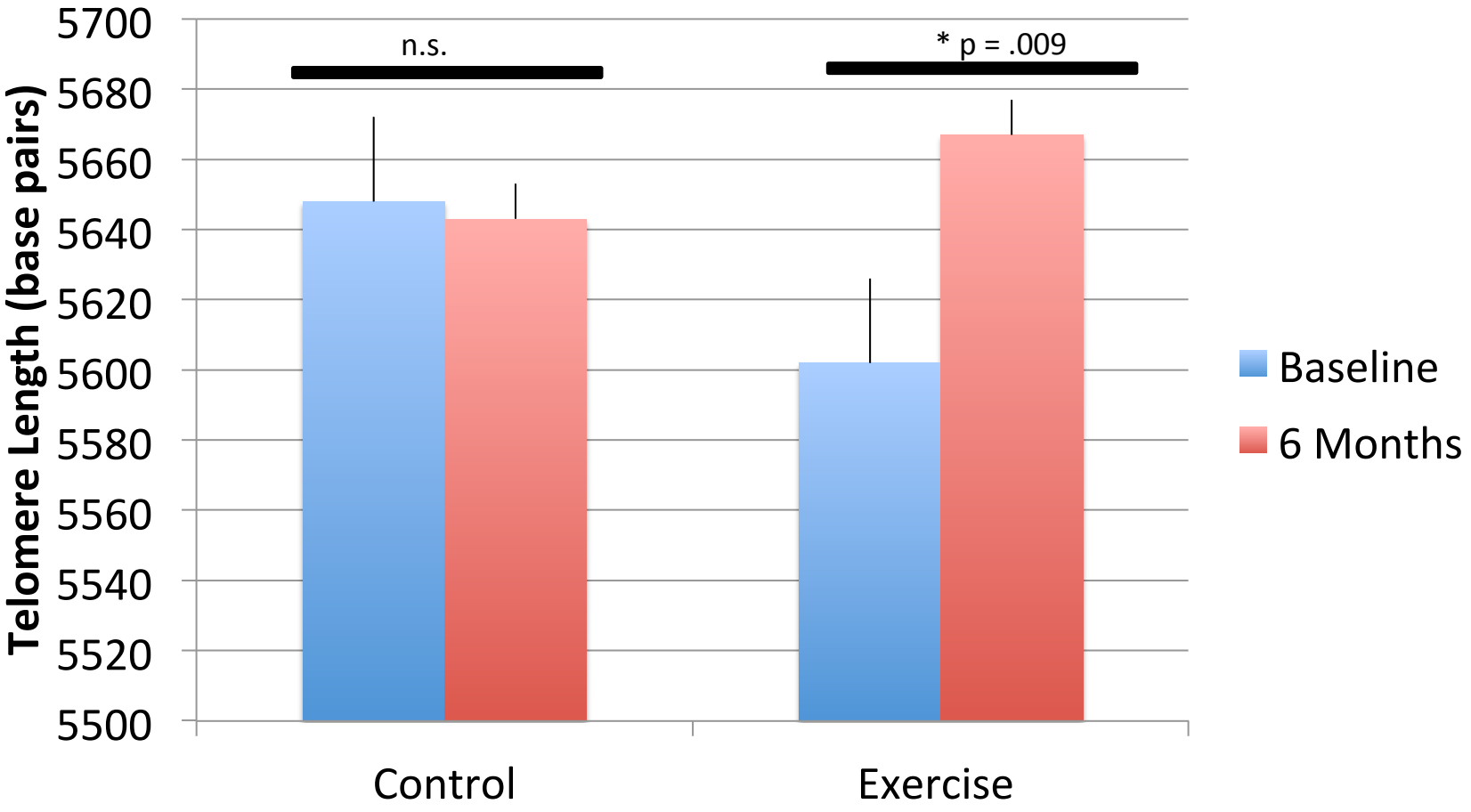
Cardiorespiratory Fitness (V02peak)



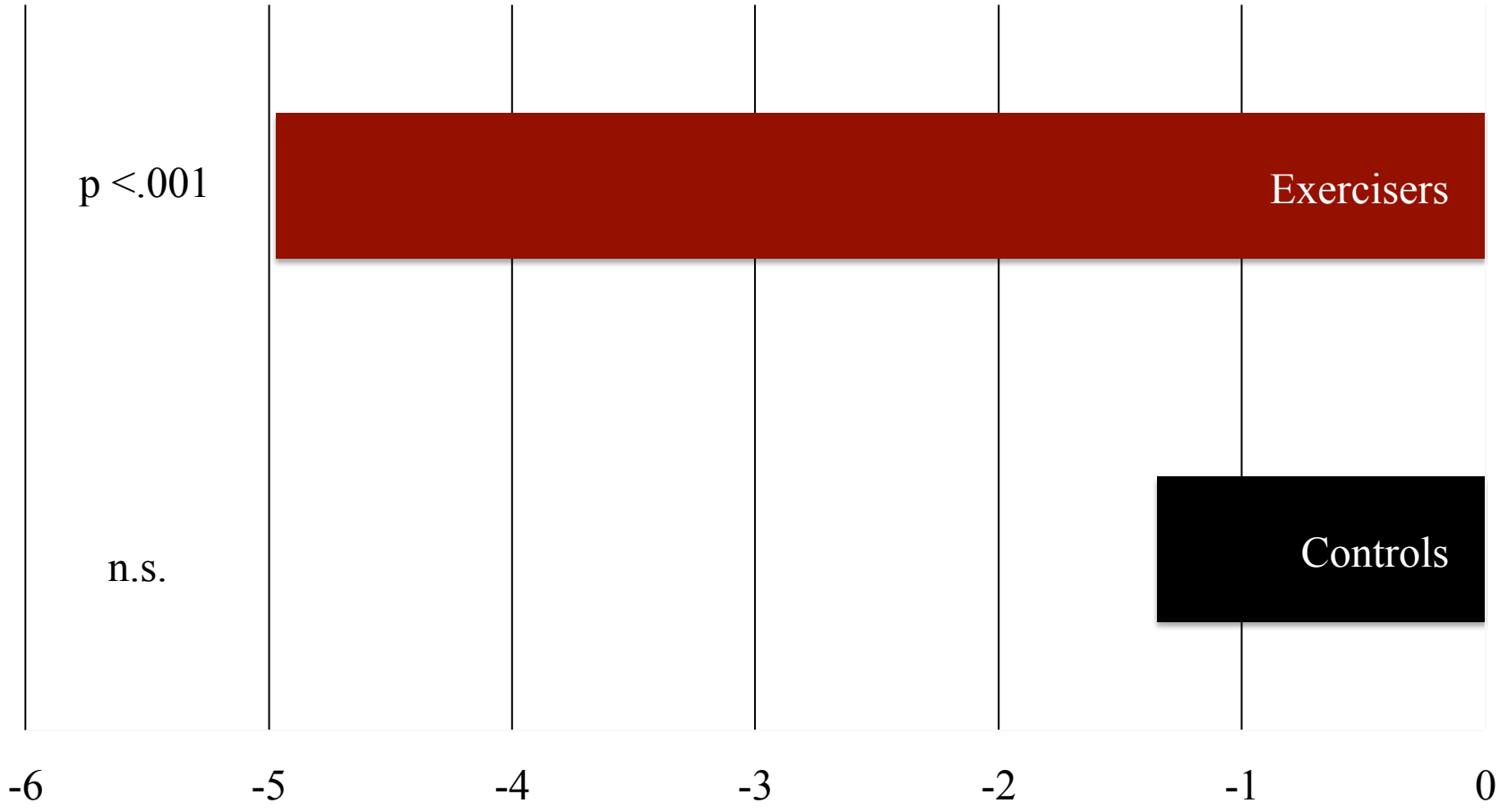
Telomere length (base pairs)



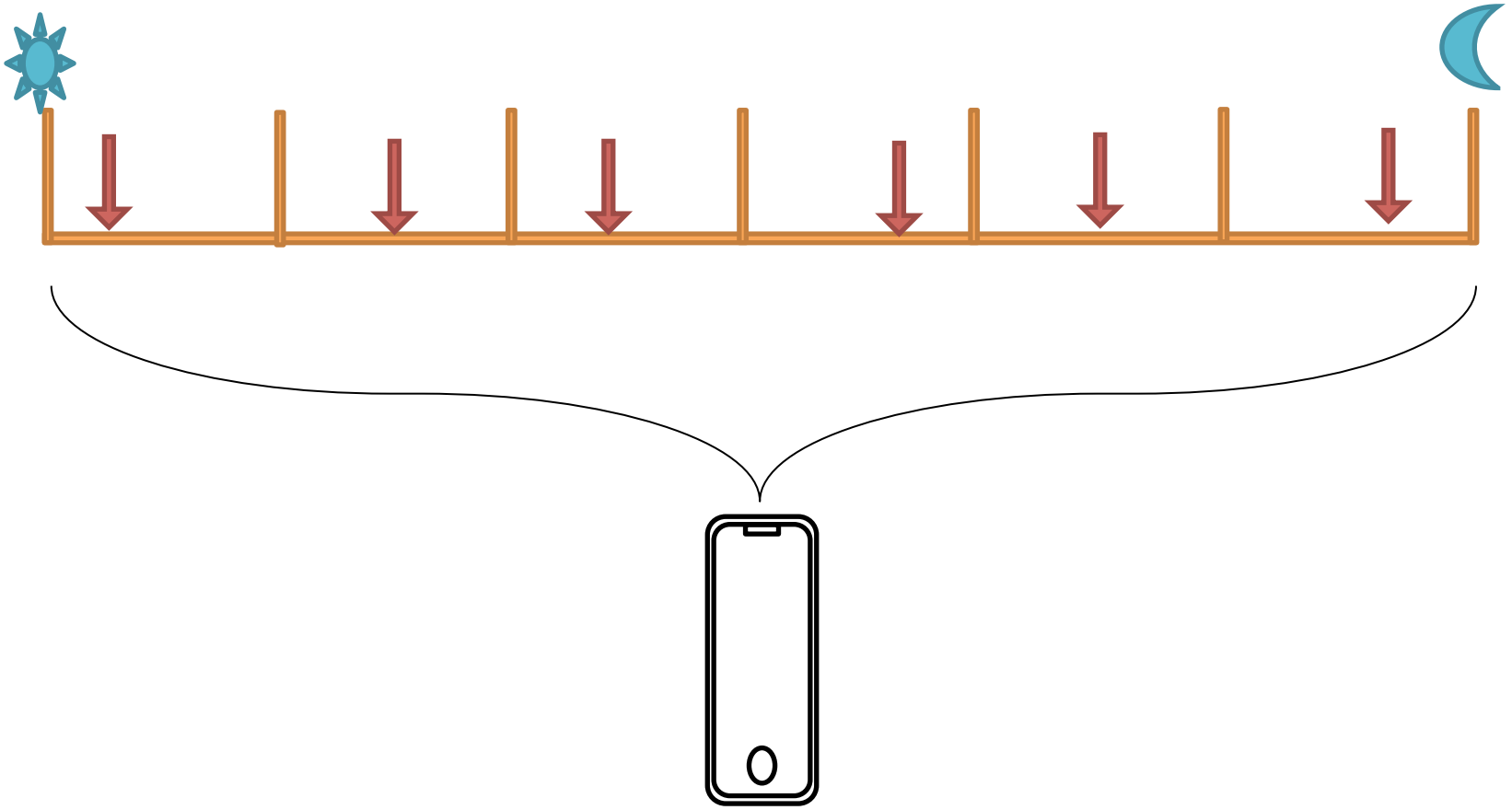
Telomere length (base pairs)



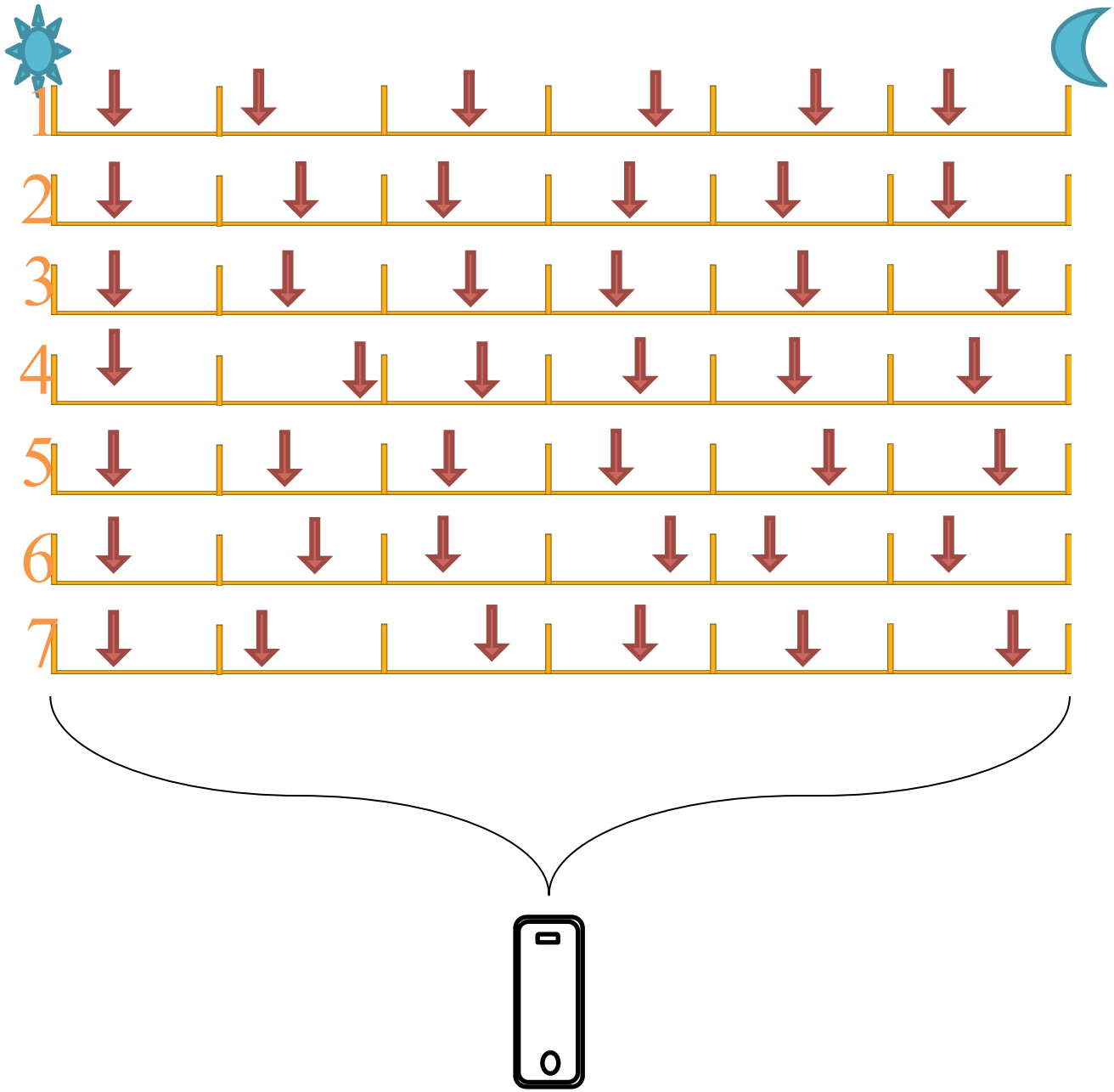
Perceived Stress Change



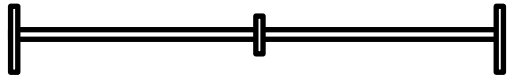
Measures:
Ecological Momentary Assessments



Measures:
Ecological
Momentary
Assessments

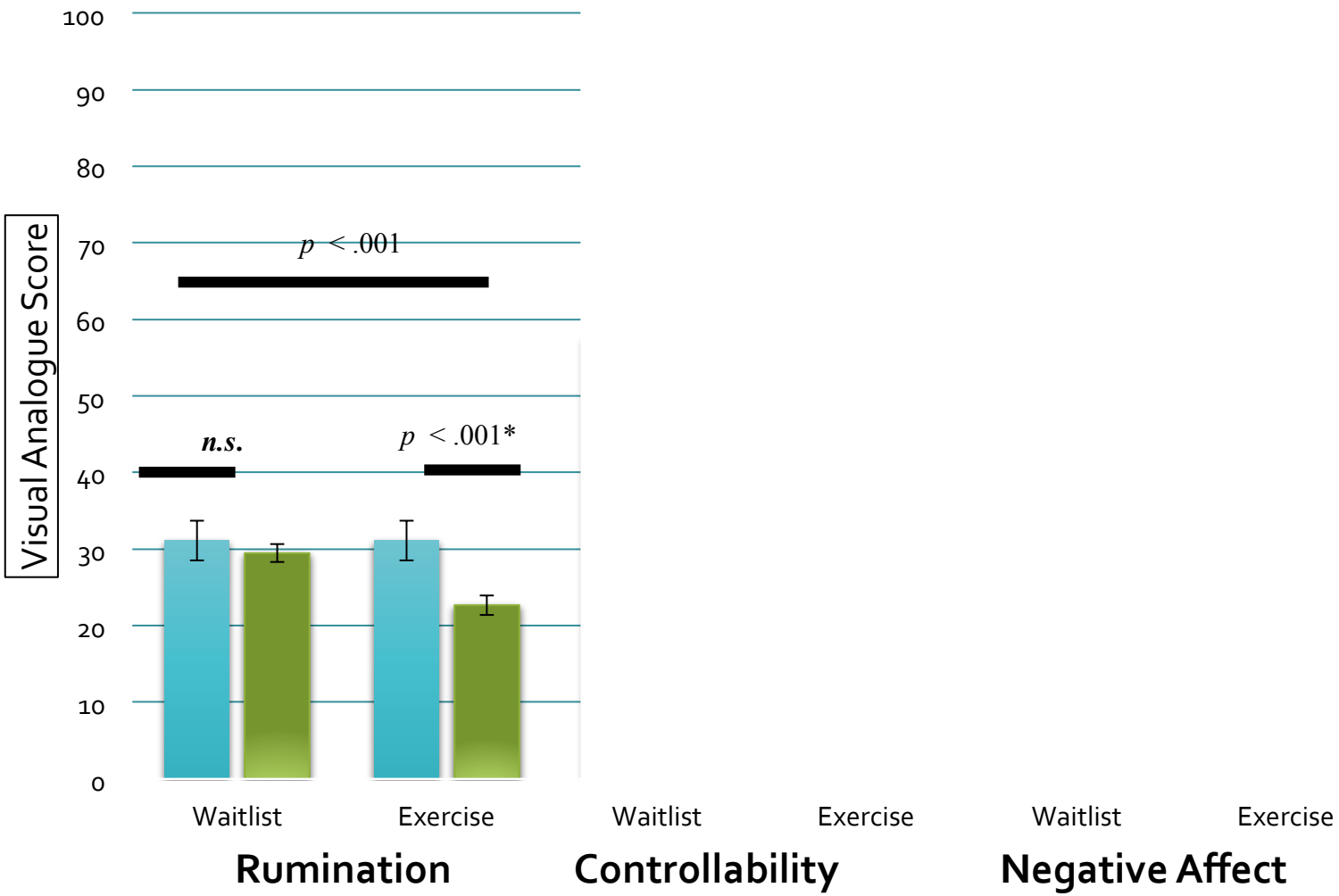


At each ”ping!”:

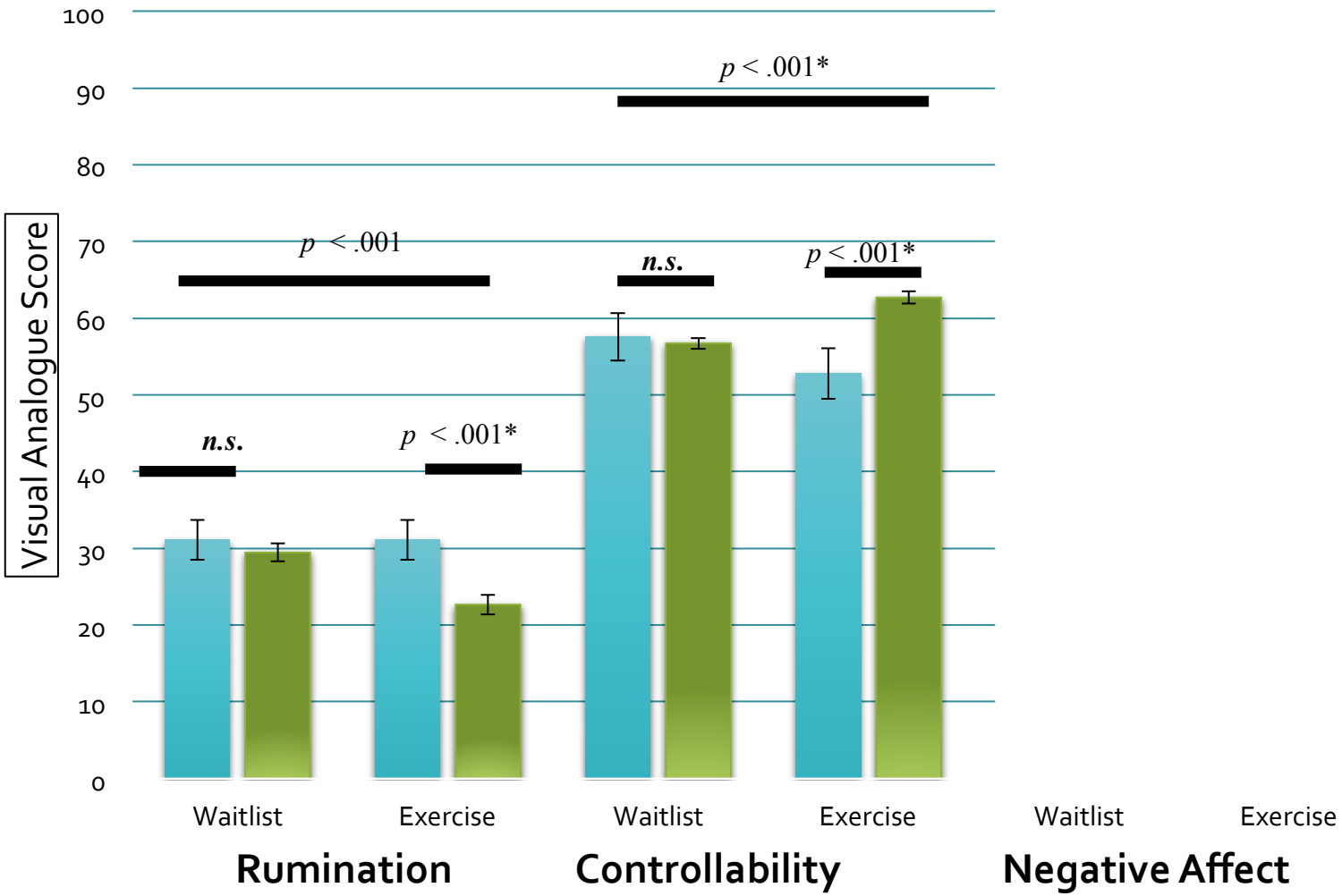


Controllability:
Do you feel that you could control important things in your life today?
Rumination:
Have you been unable to stop thinking about stressful situations?
Negative Affect:
Please rate the extent to which you are feeling: • Angry, anxious, embarrassed, sad, fatigued, frustrated, lonely

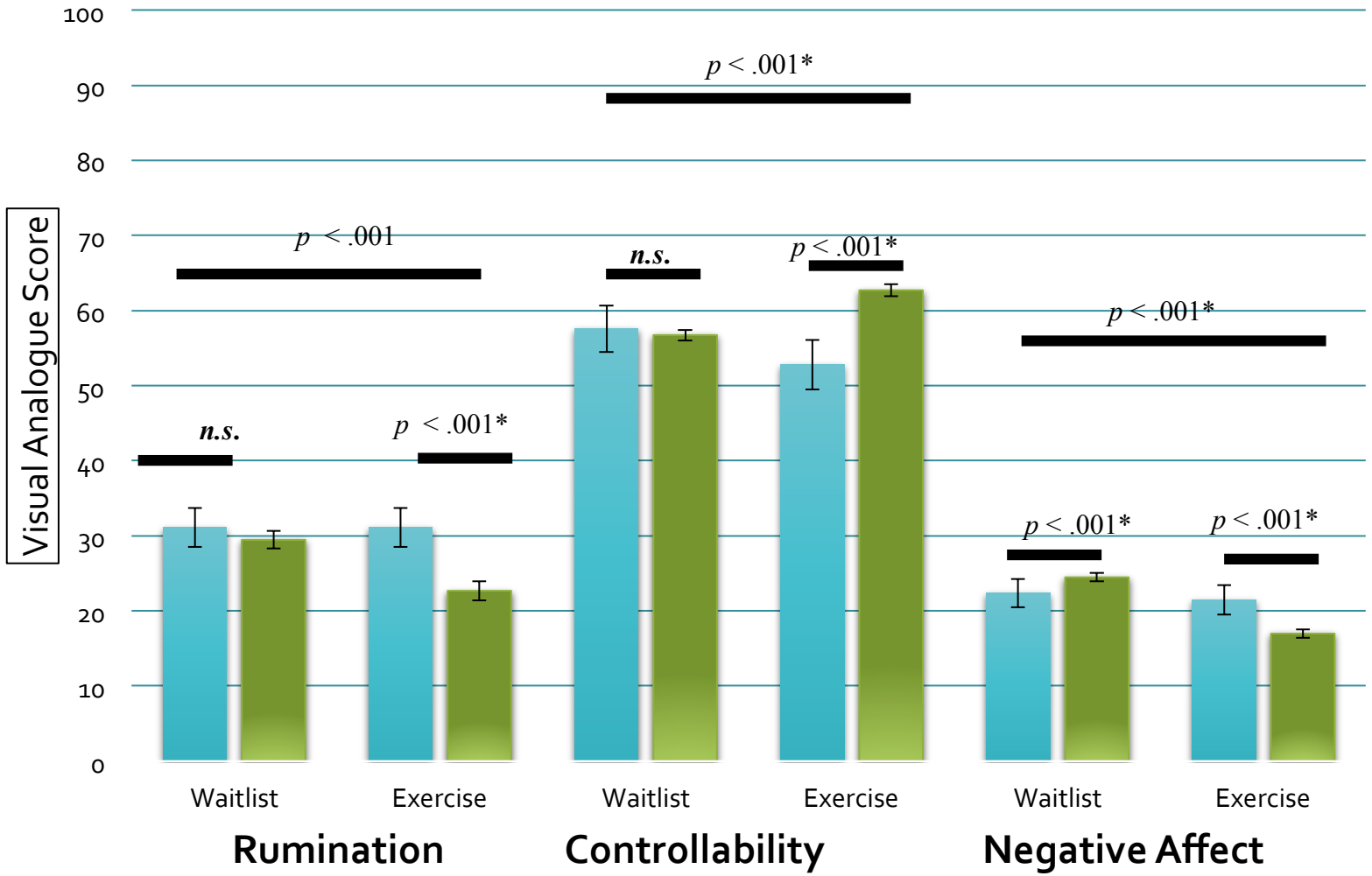
Cognitions and Negative Affect



Cognitions and Negative Affect



Cognitions and Negative Affect



Take Home

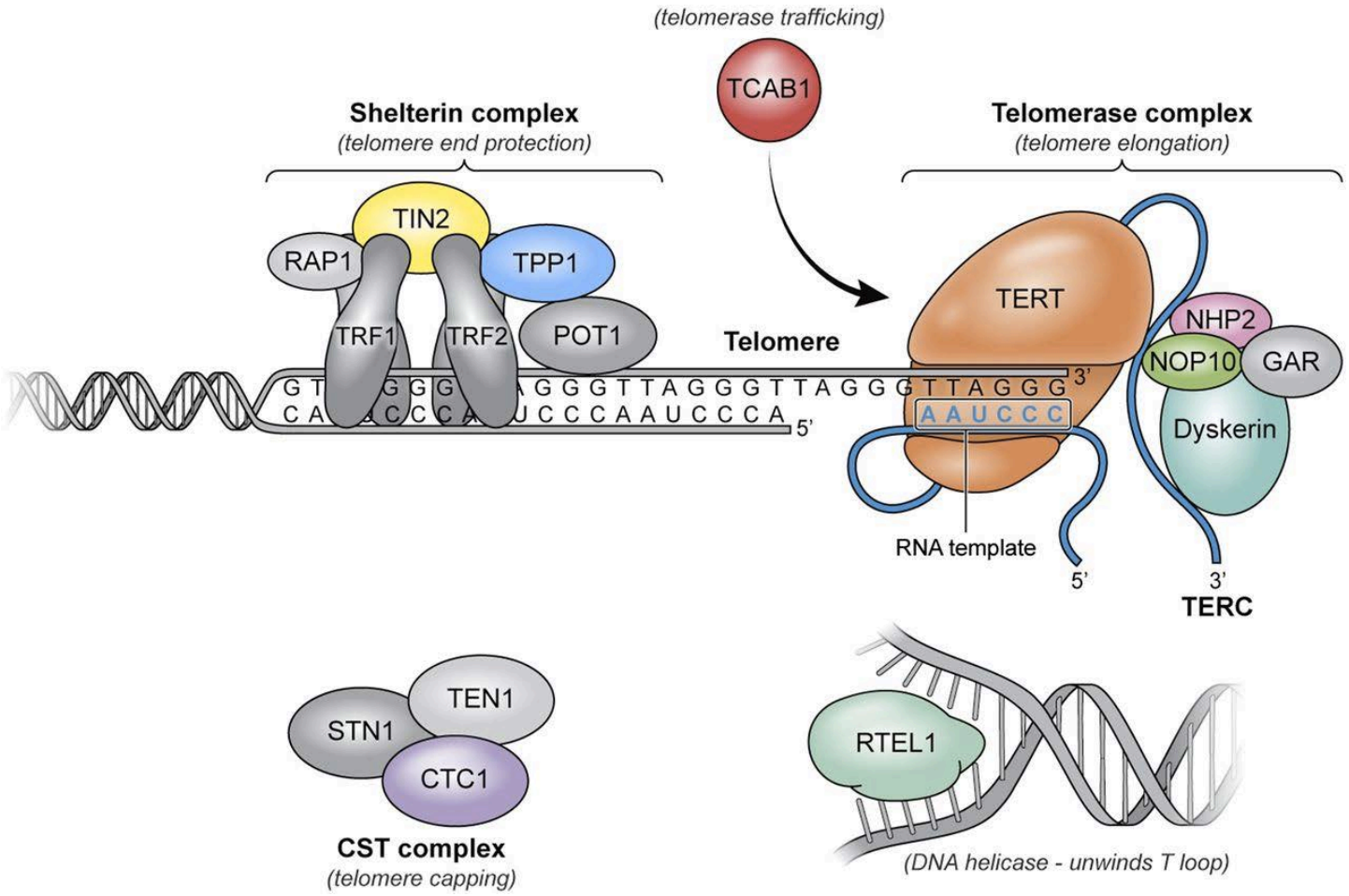
Exercise improves traditional and novel markers of health in high stressed individuals

Exercise improves how we experience our days

Understanding our motivation, barriers and facilitators for health behaviour change essential

NEXT STEPS

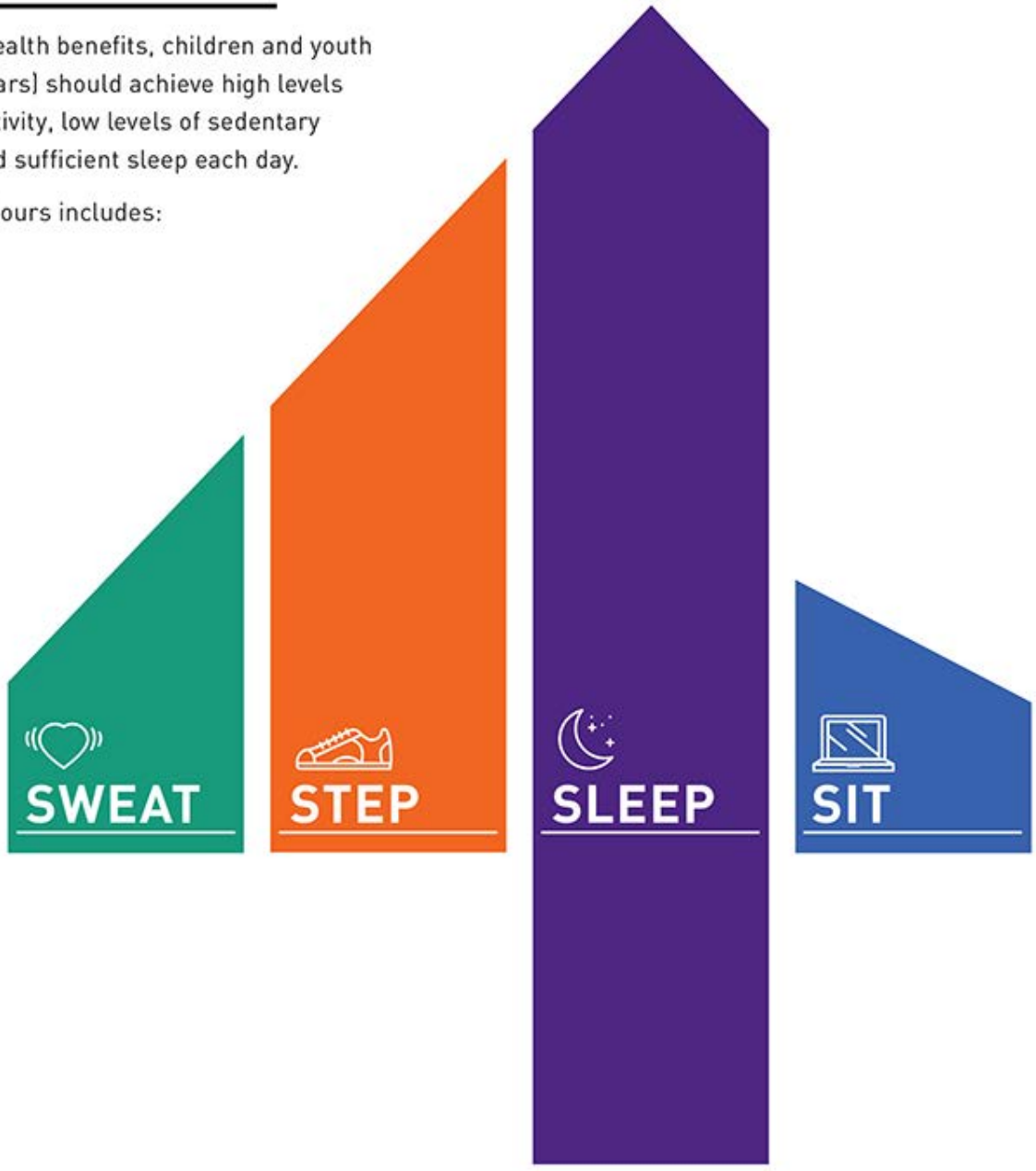
Telomere protectors



GUIDELINES

For optimal health benefits, children and youth (aged 5–17 years) should achieve high levels of physical activity, low levels of sedentary behaviour, and sufficient sleep each day.

A healthy 24 hours includes:



SWEAT

MODERATE TO VIGOROUS PHYSICAL ACTIVITY

An accumulation of at least 60 minutes per day of moderate to vigorous physical activity involving a variety of aerobic activities. Vigorous physical activities, and muscle and bone strengthening activities should each be incorporated at least 3 days per week;

STEP

LIGHT PHYSICAL ACTIVITY

Several hours of a variety of structured and unstructured light physical activities;

SLEEP

SLEEP

Uninterrupted 9 to 11 hours of sleep per night for those aged 5–13 years and 8 to 10 hours per night for those aged 14–17 years, with consistent bed and wake-up times;

SIT

SEDENTARY BEHAVIOUR

No more than 2 hours per day of recreational screen time;

Limited sitting for extended periods.

Preserving sufficient sleep, trading indoor time for outdoor time, and replacing sedentary behaviours and light physical activity with additional moderate to vigorous physical activity can provide greater health benefits.

Conclusions

Start moving!

UCSF
Elissa Epel
Elizabeth Blackburn
Aric Prather
Jue Lin
Nancy Adler

UBC
Mark Beauchamp
Guy Faulkner
Robert Boushel
Anne Lasinsky
Sarah Koch
Adam Caplin
Ben Hives
Renee Reimer

INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION

CIHR IRSC
Canadian Institutes of Health Research | Instituts de recherche en santé du Canada

NIH National Heart, Lung, and Blood Institute

alzheimer's association

Eli.puterman@ubc.ca
http://kin.educ.ubc.ca/research/labs/fastlab/