Promoting physical activity with wearables

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SMART AGEING AND HEALTHY LIFE Summer School, 20th Sept. 2021

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Why older adults should exercise?

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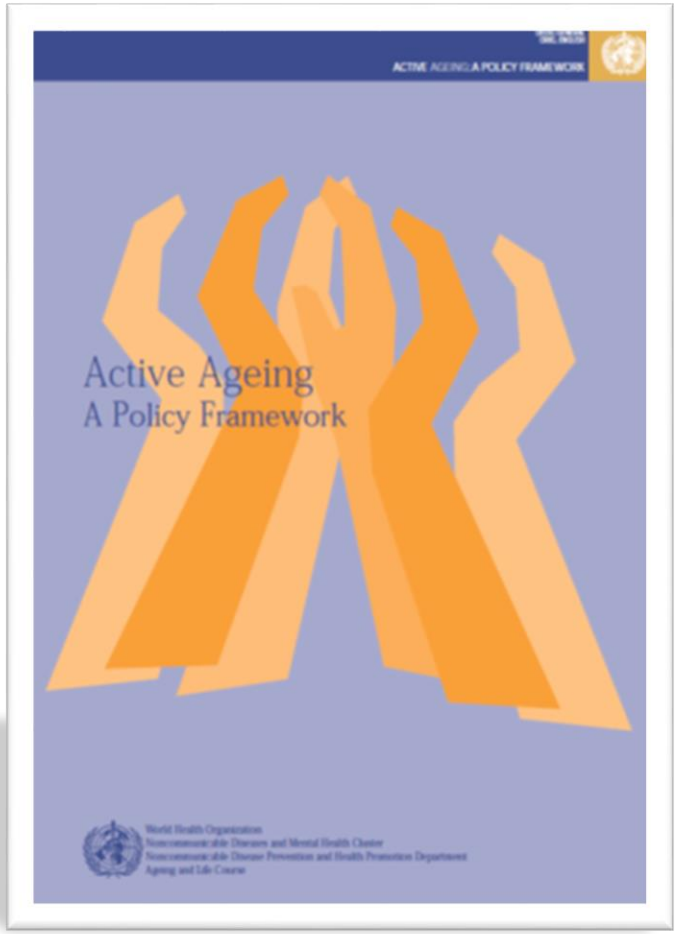
Active aging

- In 2025, there will be a total of about 1.2 billion people over the age of 60.
- Active ageing is the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age.



- https://apps.who.int/iris/handle/10665/67215

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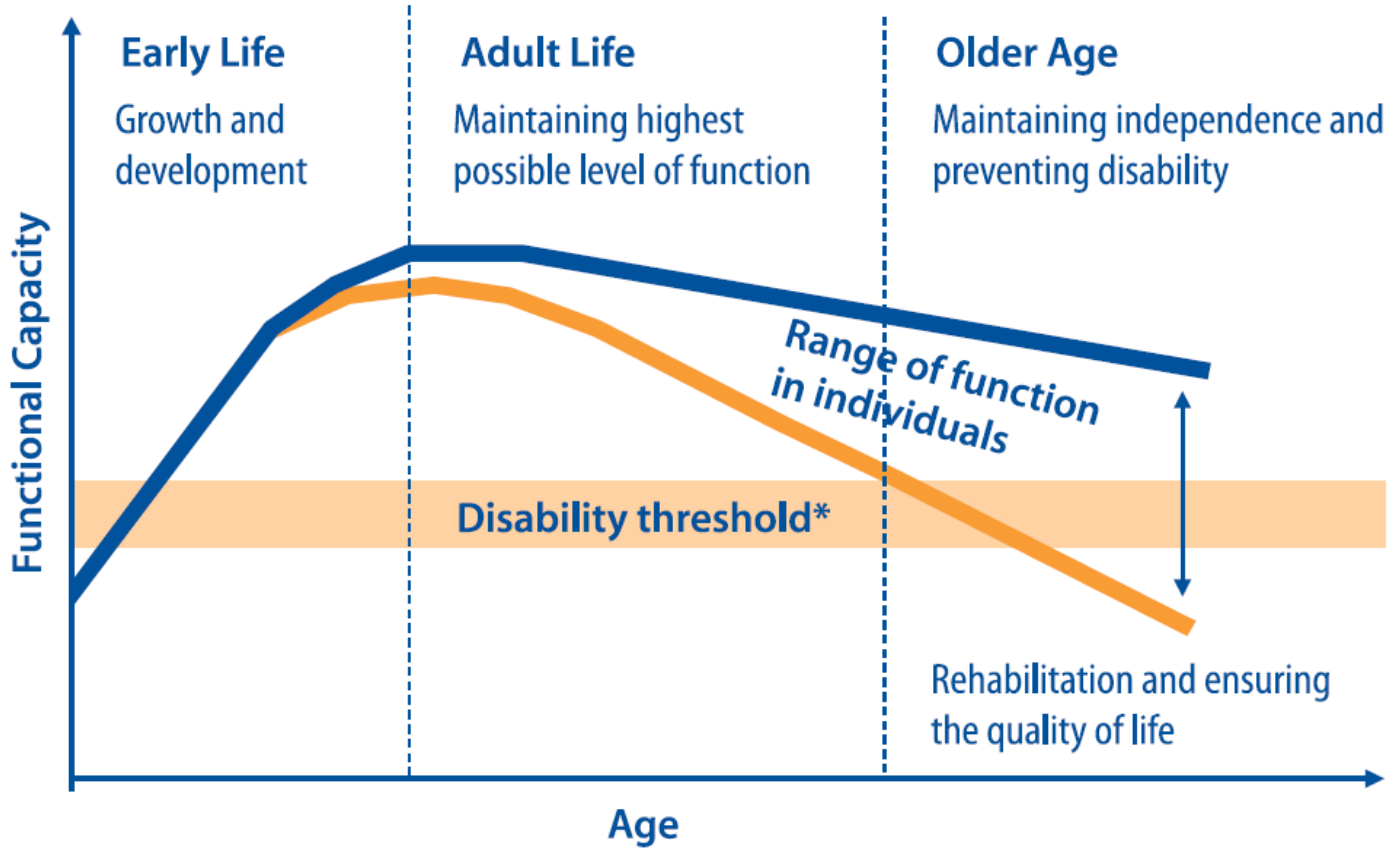
Figure 4. Maintaining functional capacity over the life course



Source: Kalache and Kickbusch, 1997

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Structural and functional decline with advancing age

- Declines in **maximal aerobic capacity** ($\dot{V}O_{2max}$) and **skeletal muscle performance** with advancing age are two examples of physiological aging
- Changing body composition is another hallmark of the physiological aging process, which has profound effects on health and physical function among older adults.
- Specific examples include the gradual **accumulation of body fat** and its redistribution to central and **visceral depots** during middle age and **the loss of muscle** (sarcopenia) during middle and old age.
- https://pubmed.ncbi.nlm.nih.gov/19516148/

TABLE 2. Summary of typical changes in physiological function and body composition with advancing age in healthy humans.

Variables	Typical Changes	Functional Significance[a]
Muscular function		
Muscle strength and power	Isometric, concentric, and eccentric strength decline from age ~40 yr, accelerate after age 65–70 yr. Lower body strength declines at a faster rate than upper body strength. Power declines at faster rate than strength.	Deficits in strength and power predict disability in old age and mortality risk.
Muscle endurance and fatigability	Endurance declines. Maintenance of force at a given relative intensity may increase with age. Age effects on mechanisms of fatigue are unclear and task-dependent.	Unclear but may impact recovery from repetitive daily tasks.
Balance and mobility	Sensory, motor, and cognitive changes alter biomechanics (sit, stand, locomotion). These changes + environmental constraints can adversely affect balance and mobility.	Impaired balance increases fear of falling and can reduce daily activity.
Motor performance and control	Reaction time increases. Speed of simple and repetitive movements slows. Altered control of precision movements. Complex tasks affected more than simple tasks.	Impacts many IADL and increases risk of injury and task learning time.
Flexibility and joint ROM	Declines are significant for hip (20%–30%), spine (20%–30%), and ankle (30%–40%) flexion by age 70 yr, especially in women. Muscle and tendon elasticity decreases.	Poor flexibility may increase risks of injury, falling, and back pain.
Cardiovascular function		
Cardiac function	Max HR (208 − 0.7 × age), stroke volume, and cardiac output decline. Slowed HR response at exercise onset. Altered diastolic filling pattern (rest, ex). Reduced left ventricular ejection fraction %. Decreased HR variability.	Major determinant of reduced exercise capacity with aging.
Vascular function	Aorta and its major branches stiffen. Vasodilator capacity and endothelium-dependent dilation of most peripheral arteries (brachial, cutaneous) decrease.	Arterial stiffening and endothelial dysfunction increase CVD risk.
Blood pressure	BP at rest (especially systolic) increases. BP during submaximal and maximal exercise are higher in old vs young, especially in older women.	Increased systolic BP reflects increased work of the heart
Regional blood flow	Leg blood flow is generally reduced at rest, submaximal, and maximal exercise. Renal and splanchnic vasoconstriction during submaximal exercise may be reduced with age.	May influence exercise, ADL, and BP regulation in old age
O_2 extraction	Systemic: same at rest and during submaximal exercise, same or slightly lower at maximal exercise. Legs: no change at rest or during submaximal exercise exercise; decreased slightly at maximal exercise.	Capacity for peripheral O_2 extraction is relatively maintained.
Blood volume and composition	Reduced total and plasma volumes; small reduction in hemoglobin concentration.	May contribute to reduced max stroke volume via reduced cardiac preload.
Body fluid regulation	Thirst sensation decreases. Renal sodium- and water-conserving capacities are impaired. Total body water declines with age.	May predispose to dehydration and impaired exercise tolerance in the heat.
Pulmonary function		
Ventilation	Chest wall stiffens. Expiratory muscle strength decreases. Older adults adopt different breathing strategy during exercise. Work of breathing increases.	Pulmonary aging not limiting to exercise capacity, except in athlete.
Gas exchange	Loss of alveoli and increased size of remaining alveoli; reduces surface area for O_2 and CO_2 exchange in the lungs.	Arterial blood gases usually well-maintained up to maximal exercise.
Physical functional capacities		
Maximal O_2 uptake	Overall decline averages 0.4–0.5 $mL \cdot kg^{-1} \cdot min^{-1} \cdot yr^{-1}$ (9% per decade) in healthy sedentary adults. Longitudinal data suggest rate of decline accelerates with advancing age.	Indicates functional reserve; disease and mortality risk factor.
O_2 uptake kinetics	Systemic O_2 uptake kinetics at exercise onset is slowed in old vs young, but this may be task specific. Prior warm-up exercise may normalize age difference.	Slow $\dot{V}O_2$ kinetics may increase O_2 deficit and promote early fatigue.
Lactate and ventilatory thresholds	Ventilatory thresholds (expressed as a percentage of $\dot{V}O_{2max}$) increase with age. Maximal lactate production, tolerance, and clearance rate postexercise decline.	Indicative of reduced capacity for high intensity exercise.
Submaximal work efficiency	Metabolic cost of walking at a given speed is increased. Work efficiency (cycling) is preserved, but O_2 debt may increase in sedentary adults.	Implications for caloric cost and $\dot{V}O_2$ prediction in older adults.
Walking kinematics	Preferred walking speed is slower. Stride length is shorter; double-limb support duration is longer. Increased gait variability. These age differences are exaggerated when balance is perturbed.	Implications for physical function and risk of falling.
Stair climbing ability	Maximal step height is reduced, reflects integrated measure of leg strength, coordinated muscle activation, and dynamic balance.	Implications for mobility and physically demanding ADL.
Body composition/metabolism		
Height	Height declines approximately 1 cm per decade during the 40s and 50s, accelerated after age 60 yr (women > men). Vertebral disks compress; thoracic curve becomes more pronounced.	Vertebral changes can impair mobility and other daily tasks.
Weight	Weight steadily increases during the 30s, 40s, and 50s, stabilizes until ~age 70 yr, then declines. Age-related changes in weight and BMI can mask fat gain/muscle loss.	Large, rapid loss of weight in old age can indicate disease process.
FFM	FFM declines 2%–3% per decade from 30 to 70 yr of age. Losses of total body protein and potassium likely reflect the loss of metabolically active tissue (i.e., muscle).	FFM seems to be an important physiological regulator.
Muscle mass and size	Total muscle mass declines from age ~40 yr, accelerated after age 65–70 yr (legs lose muscle faster). Limb muscles exhibit reductions in fiber number and size (Type II > I).	Loss of muscle mass, Type II fiber size = reduced muscle speed/power.
MQ	Lipid and collagen content increase. Type I MHC content increases, type II MHC decreases. Peak-specific force declines. Oxidative capacity per kg muscle declines.	Changes may be related to insulin resistance and muscle weakness.
Regional adiposity	Body fat increases during the 30s, 40s, and 50s, with a preferential accumulation in the visceral (intra-abdominal) region, especially in men. After age 70 yr, fat (all sites) decreases.	Accumulation of visceral fat is linked to CV and metabolic disease.
Bone density	Bone mass peaks in the mid to late 20s. BMD declines $0.5\% \cdot yr^{-1}$ or more after age 40 yr. Women have disproportionate loss of bone ($2\%–3\% \cdot yr^{-1}$) after menopause.	Osteopenia (1–2.5 SD below young controls) elevates fracture risk.
Metabolic changes	RMR (absolute and per kg FFM), muscle protein synthesis rates (mitochondria and MHC), and fat oxidation (during submaximal exercise) all decline with advancing age.	These may influence substrate utilization during exercise.

Typical changes generally reflect age-associated differences on the basis of cross-sectional data, which can underestimate changes followed longitudinally.
[a] The strength of existing evidence for the functional associations identified in the far right column ranges between A and D.
BMI, body mass index; BP, blood pressure; CVD, cardiovascular disease; IADL, instrumental ADL; MHC, myosin heavy chain; Peak, peak or maximal exercise responses; RMR, resting metabolic rate.

Physical activity promotes healthy aging

- Physical activity and sedentary behavior are modifiable risk factors for non-communicable disease and healthy ageing
- Physical activity prevents sarcopenia, osteoporosis, falls, and many other conditions that hinder healthy aging.
- Physical activity improves mobility, cognition, and independent functioning.
- Older adults benefit from aerobic, strength, flexibility, and balance training.

Table 1
Benefits of different types of exercise to various older adult–specific conditions

	Aerobic Exercise	Strength Exercise	Balance and Flexibility Exercise	Highest Impact Recommendation
Mobility	✓	✓	✓	Well-balanced exercise program!
Sarcopenia	✓	✓	✓	
Osteoporosis	✓[a]	✓	✓	
Falls	✓	✓	✓	
Pain	✓	✓	✓	
Cognition	✓	✓	✓	

[a] Only if weight-bearing or impact aerobic exercise.

https://www.sciencedirect.com/science/article/pii/S0749069020300513?via%3Dihub

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Physical activity vs. inactivity vs. sedentary behavior

Terminology: what is physical activity

- Types of physical activity
  - Occupational
  - Leisure
  - Transportation
  - Daily (household)
- Physical activity has
  - **Intensity**
  - Duration
  - Frequency

  } VOLUME
- Voluntary, planned
- Repetative, recovery

} EXERCISE > fitness

WHO defines physical activity as 'any bodily movement produced by skeletal muscles that requires energy expenditure'.

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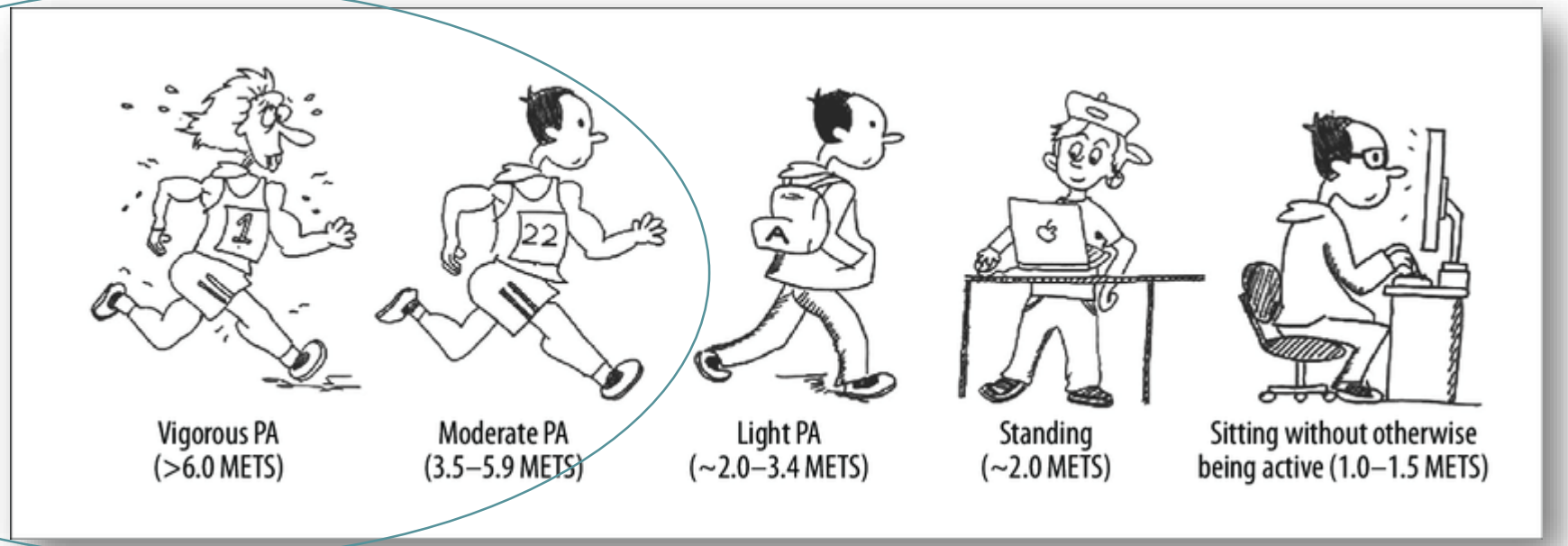
ACTIVITY SPECTRUM

- How to measure physical activity?
  - MET=metabolic equivalent
  - 1 MET = 3.5 ml/kg/min ~ 1 kcal/kg/h (energy consumption)



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Classification of exercise intensity: relative and absolute exercise intensity for cardiorespiratory endurance and resistance exercise.

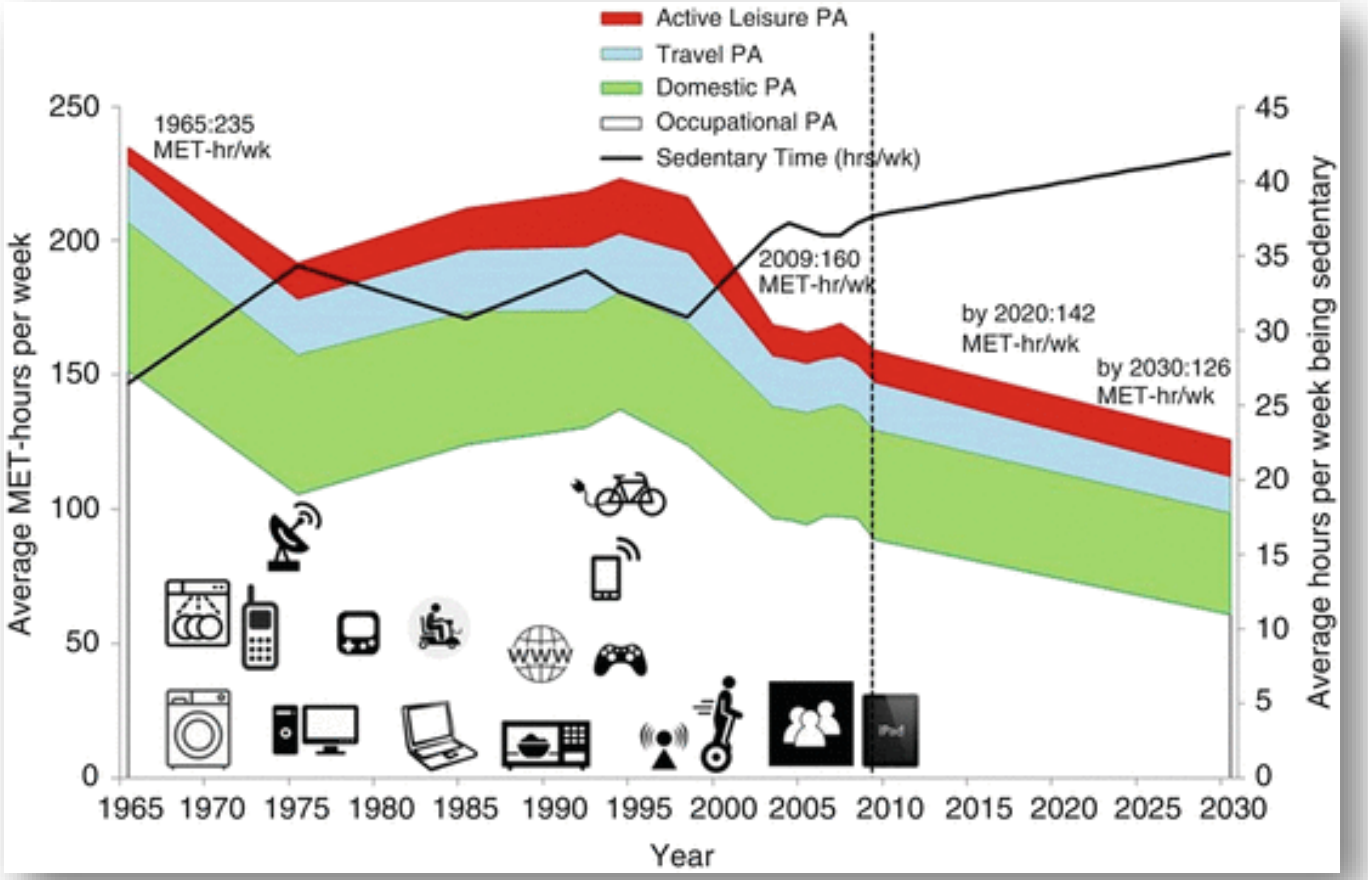
	Cardiorespiratory Endurance Exercise										Resistance Exercise
	Relative Intensity				Intensity (%$\dot{V}O_{2max}$) Relative to Maximal Exercise Capacity in METs			Absolute Intensity	Absolute Intensity (MET) by Age			Relative Intensity
Intensity	%HRR or %$\dot{V}O_2R$	%HR_{max}	%$\dot{V}O_{2max}$	Perceived Exertion (Rating on 6–20 RPE Scale)	20 METs %$\dot{V}O_{2max}$	10 METs %$\dot{V}O_{2max}$	5 METs %$\dot{V}O_{2max}$	METs	Young (20–39 yr)	Middle-aged (40–64 yr)	Older (≥65 yr)	% 1RM
Very light	<30	<57	<37	<Very light (RPE < 9)	<34	<37	<44	<2	<2.4	<2.0	<1.6	<30
Light	30–39	57–63	37–45	Very light–fairly light (RPE 9–11)	34–42	37–45	44–51	2.0–2.9	2.4–4.7	2.0–3.9	1.6–3.1	30–49
Moderate	40–59	64–76	46–63	Fairly light to somewhat hard (RPE 12–13)	43–61	46–63	52–67	3.0 to 5.9	4.8–7.1	4.0–5.9	3.2–4.7	50–69
Vigorous	60–89	77–95	64–90	Somewhat hard to very hard (RPE 14–17)	62–90	64–90	68–91	6.0–8.7	7.2–10.1	6.0–8.4	4.8–6.7	70–84
Near–maximal to maximal	≥90	≥96	≥91	≥Very hard (RPE ≥ 18)	≥91	≥91	≥92	≥8.8	≥10.2	≥8.5	≥6.8	≥85

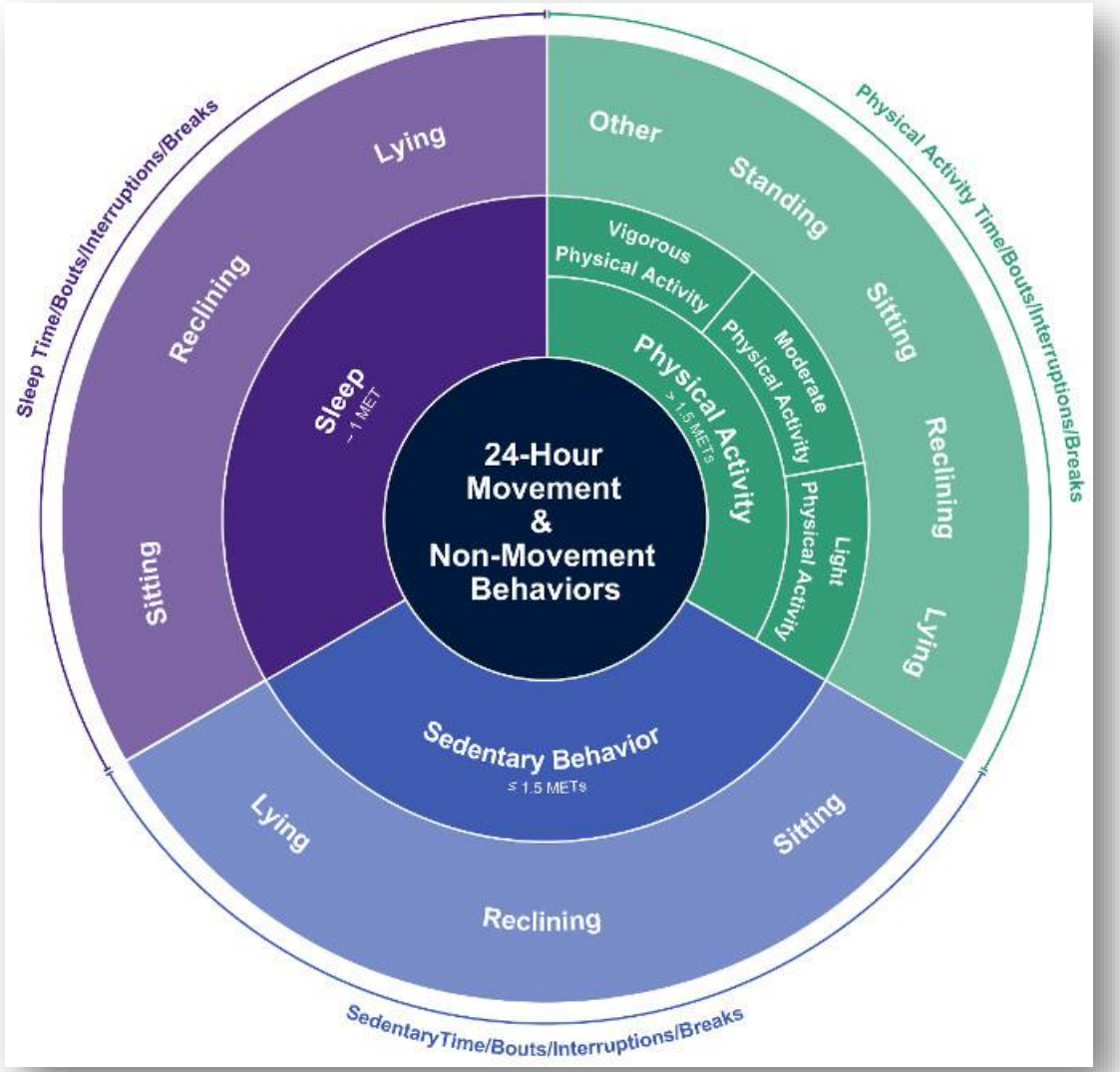
Table adapted from the American College of Sports Medicine (14), Howley (173), Swain and Franklin (344), Swain and Leutholtz (346), Swain et al. (347), and the US Department of Health and Human Services (370).
HR_{max}, maximal HR; %HR_{max}, percent of maximal HR; HRR, HR reserve; $\dot{V}O_{2max}$, maximal oxygen uptake; %$\dot{V}O_{2max}$, percent of maximal oxygen uptake; $\dot{V}O_2R$, oxygen uptake reserve; RPE, ratings of perceived exertion (48).

https://journals.lww.com/acsm-msse/Fulltext/2011/07000/Quantity_and_Quality_of_Exercise_for_Developing.26.aspx

The other end of the spectrum: SEDENTARY BEHAVIOR

- Sedentary behavior is defined as *'any waking behavior with and energy expenditure of no more than **1.5 METs in sitting, reclining or lying posture***'.
- Standing (~2 METs) is defined as stationary, non-sedentary activity.
- https://www.ncbi.nlm.nih.gov/pubmed/22694051





https://www.sedentarybehaviour.org/

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Sitting kills you….

https://www.ncbi.nlm.nih.gov/pubmed/27475271

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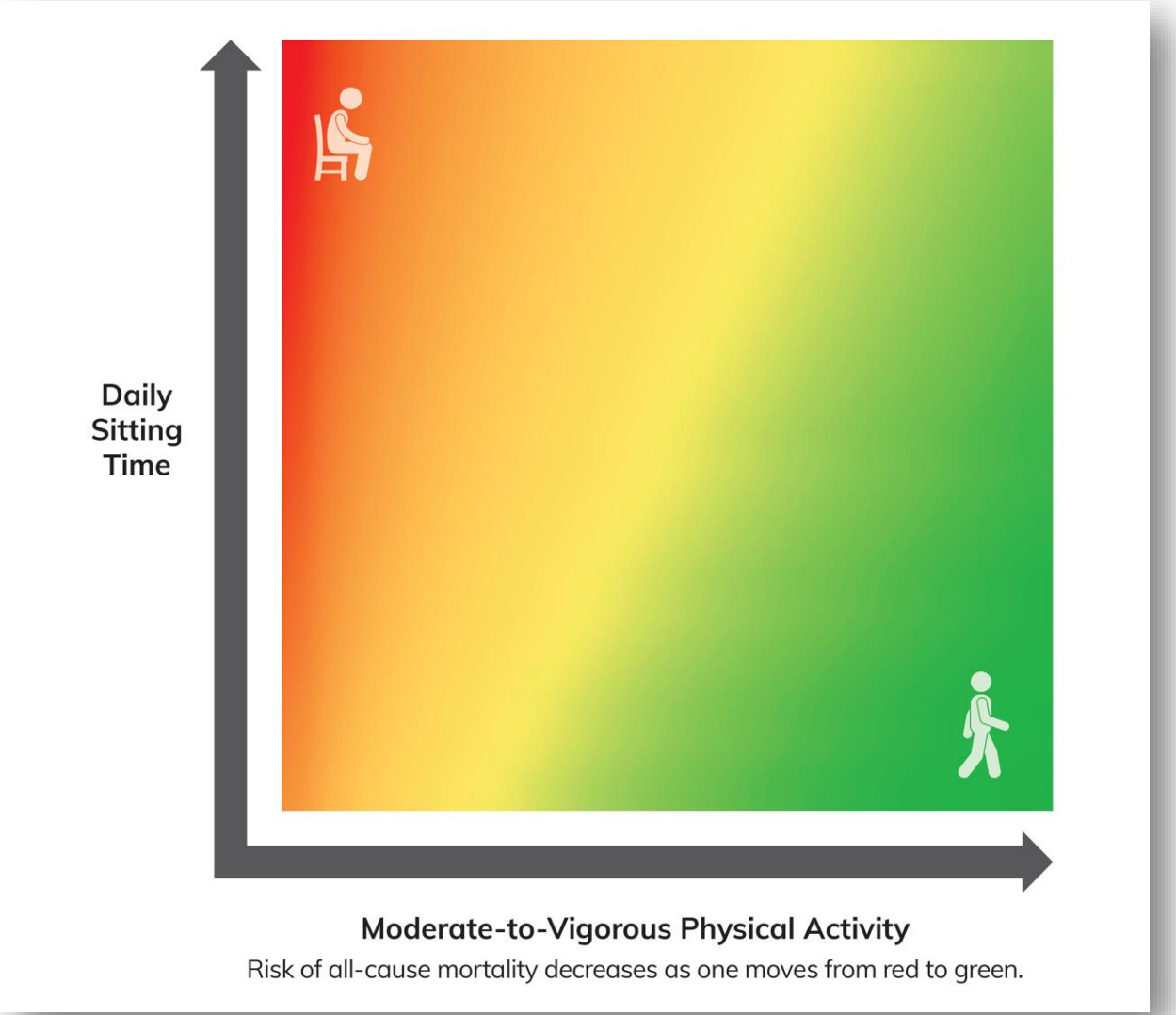
Sit less!



Move more!

https://health.gov/our-work/nutrition-physical-activity/physical-activity-guidelines

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How much physical activity is enought?

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BURDEN of PHYSICAL INACTIVITY

- Worldwide, more than 1.4 billion adults **do not get recommended levels of physical activity** and are, therefore, at risk of developing physical inactivity-related non-communicable diseases (NCDs).
- The global pandemic of physical inactivity is responsible for more than 5 million deaths and at least $67.5 billion of economic burden per year.

- https://www.thelancet.com/series/physical-activity
- https://www.thelancet.com/series/physical-activity-2016
- https://pubmed.ncbi.nlm.nih.gov/31562122/

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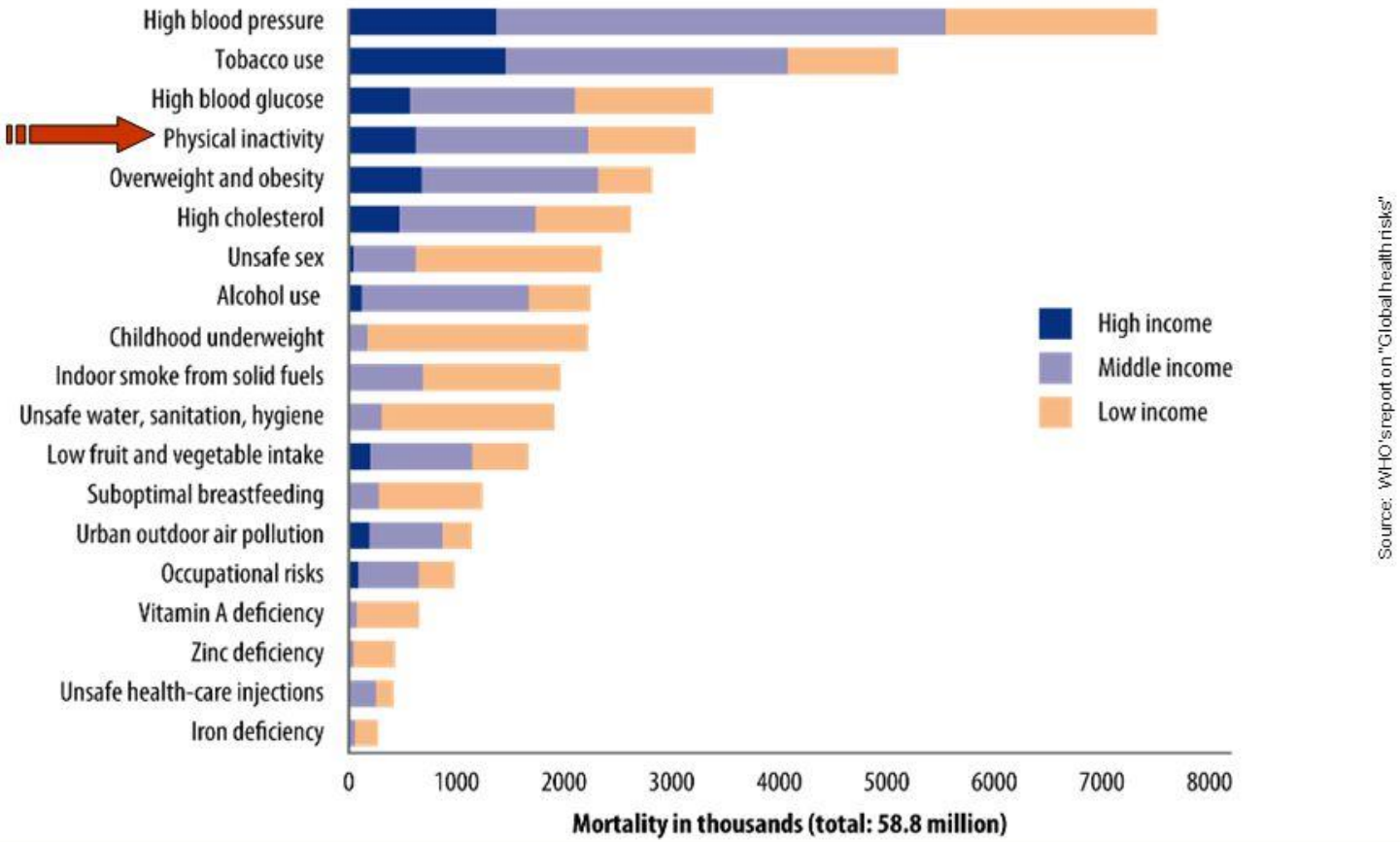
Physical inactivity - 4th leading risk factor for global mortality



Source: WHO's report on "Global health risks"

60% of global deaths due to NCDs

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Physical activity recommendations

- The WHO **Guidelines on physical activity and sedentary behaviour** provide evidence-based public health recommendations for children, adolescents, adults and older adults on the amount of physical activity (frequency, intensity and duration) **required to offer significant health benefits and mitigate health risks**.
- For the first time, recommendations are provided on the associations between sedentary behaviour and health outcomes, as well as for subpopulations, such as pregnant and postpartum women, and people living with chronic conditions or disability.
- Recommended levels of physical activity
  - for children aged 5 - 17 years
  - for adults aged 18 - 64 years
  - **for adults aged 65 and above**

https://health.gov/paguidelines/second-edition/report/
https://www.who.int/publications/i/item/9789240015128

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OLDER ADULTS
(aged 65 years and older)

In older adults, physical activity confers benefits for the following health outcomes: improved all-cause mortality, cardiovascular disease mortality, incident hypertension, incident site-specific cancers, incident type-2 diabetes, mental health (reduced symptoms of anxiety and depression), cognitive health, and sleep; measures of adiposity may also improve. In older adults, physical activity helps prevent falls and falls-related injuries and declines in bone health and functional ability.

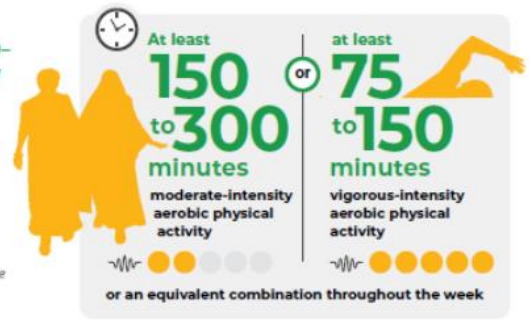
It is recommended that:

› **All older adults should undertake regular physical activity.**

Strong recommendation, moderate certainty evidence

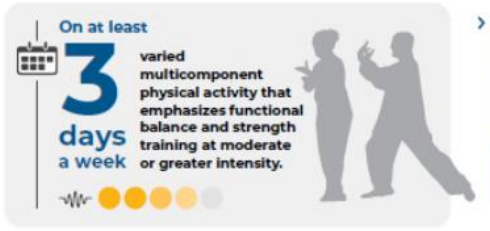
› **Older adults should do at least 150–300 minutes of moderate-intensity aerobic physical activity; or at least 75–150 minutes of vigorous-intensity aerobic physical activity; or an equivalent combination of moderate- and vigorous-intensity activity throughout the week, for substantial health benefits.**

Strong recommendation, moderate certainty evidence



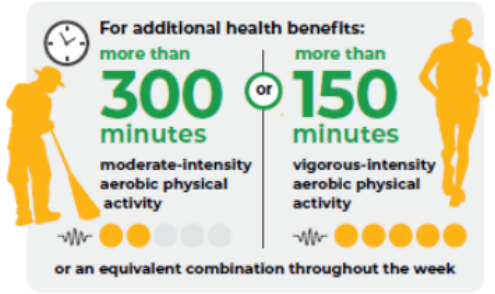
› **Older adults should also do muscle-strengthening activities at moderate or greater intensity that involve all major muscle groups on 2 or more days a week, as these provide additional health benefits.**

Strong recommendation, moderate certainty evidence



› **As part of their weekly physical activity, older adults should do varied multicomponent physical activity that emphasizes functional balance and strength training at moderate or greater intensity, on 3 or more days a week, to enhance functional capacity and to prevent falls.**

Strong recommendation, moderate certainty evidence



› **Older adults may increase moderate-intensity aerobic physical activity to more than 300 minutes; or do more than 150 minutes of vigorous-intensity aerobic physical activity; or an equivalent combination of moderate- and vigorous-intensity activity throughout the week, for additional health benefits.**

Conditional recommendation, moderate certainty evidence

GOOD PRACTICE STATEMENTS

- Doing some physical activity is better than doing none.
- If older adults are not meeting the recommendations, doing some physical activity will bring benefits to health.
- Older adults should start by doing small amounts of physical activity, and gradually increase the frequency, intensity and duration over time.
- Older adults should be as physically active as their functional ability allows, and adjust their level of effort for physical activity relative to their level of fitness.

In older adults, higher amounts of sedentary behaviour are associated with the following poor health outcomes: all-cause mortality, cardiovascular disease mortality and cancer mortality, and incidence of cardiovascular disease, cancer and incidence of type-2 diabetes.

It is recommended that:

› **Older adults should limit the amount of time spent being sedentary. Replacing sedentary time with physical activity of any intensity (including light intensity) provides health benefits.**

Strong recommendation, moderate certainty evidence

› **To help reduce the detrimental effects of high levels of sedentary behaviour on health, older adults should aim to do more than the recommended levels of moderate- to vigorous-intensity physical activity.**

Strong recommendation, moderate certainty evidence

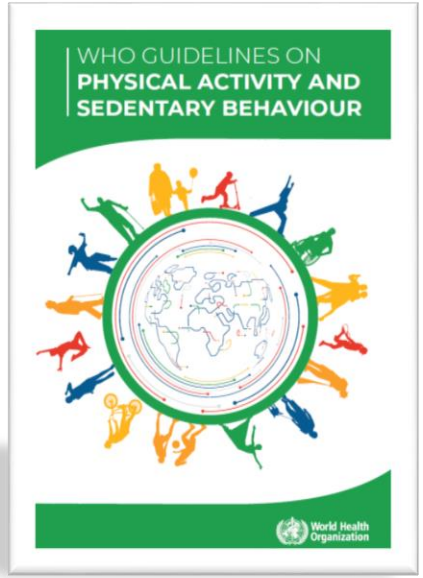


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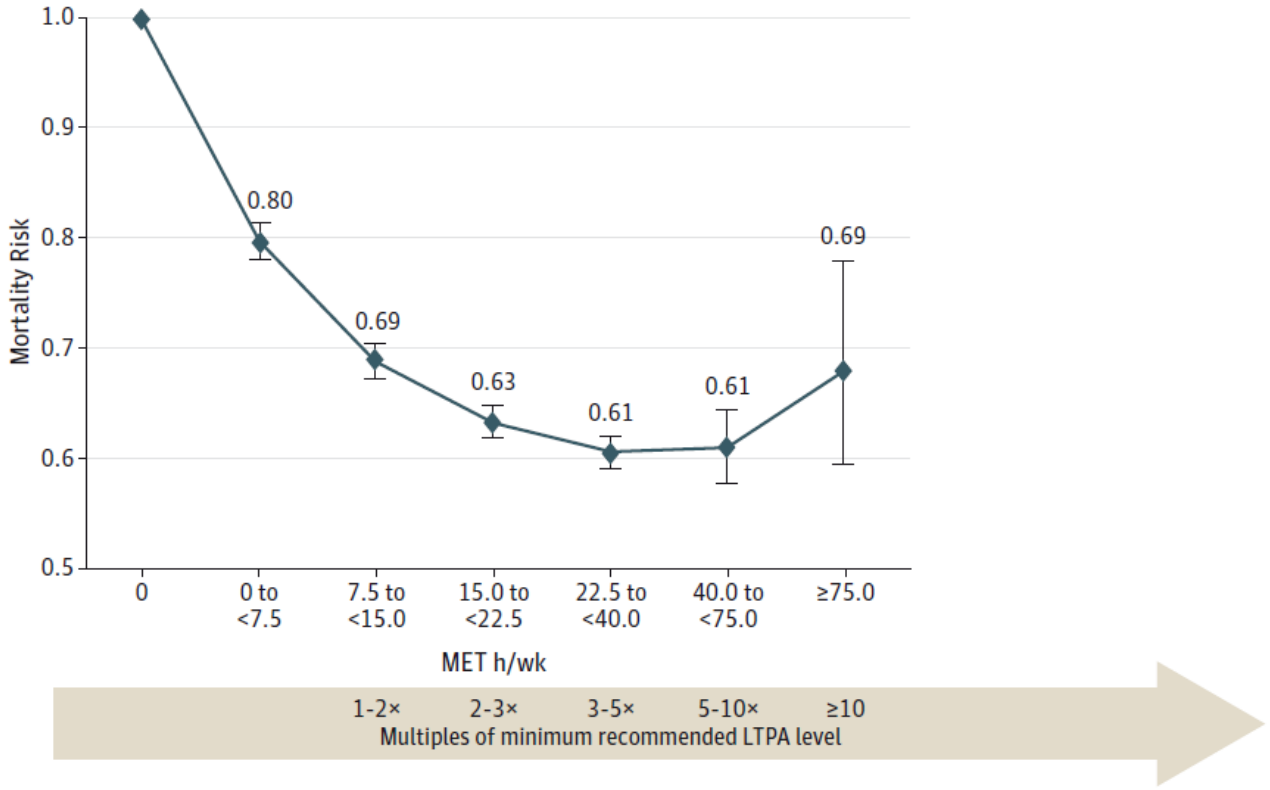
Figure. Hazard Ratios (HRs) and 95% CIs for Leisure Time Moderate- to Vigorous-Intensity Physical Activity and Mortality



The dose-response curve and category-specific HR estimates of exercise levels compared with the federally recommended minimum of 7.5 metabolic equivalent (MET) hours per week. Models were stratified by cohort and use age as the underlying time scale. The model was adjusted for sex, smoking (never, former, current, or missing), alcohol (none, <15 g/day, 15 to <30 g/day, or ≥30 g/day), educational level (dropout, high school, post–high school training, some college, college graduate, postcollege, or missing), marital status (married, divorced, widowed, single, or missing), history of cancer, history of heart disease, and body mass index (calculated as weight in kilograms divided by height in meters squared) (<18.5, 18.5 to <25.0, 25.0 to <30.0, 30.0 to <35.0, or ≥35.0).The dotted line between categories illustrates an assumed dose-response curve rather than individual data points. Crude and adjusted risk estimates are presented in eTable 3 in the Supplement.

https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2212267

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How to promote physical activity among older adults?

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PROMOTING PHYSICAL ACTIVITY AMONG OLDER ADULTS

- Older aduls are the most sedentary age group
- Barriers to physical activity may be different from younger adults (disability, weather, fear, environment)
- Needs tailoring; personalized interventions/programs
- Social support is important, resources?

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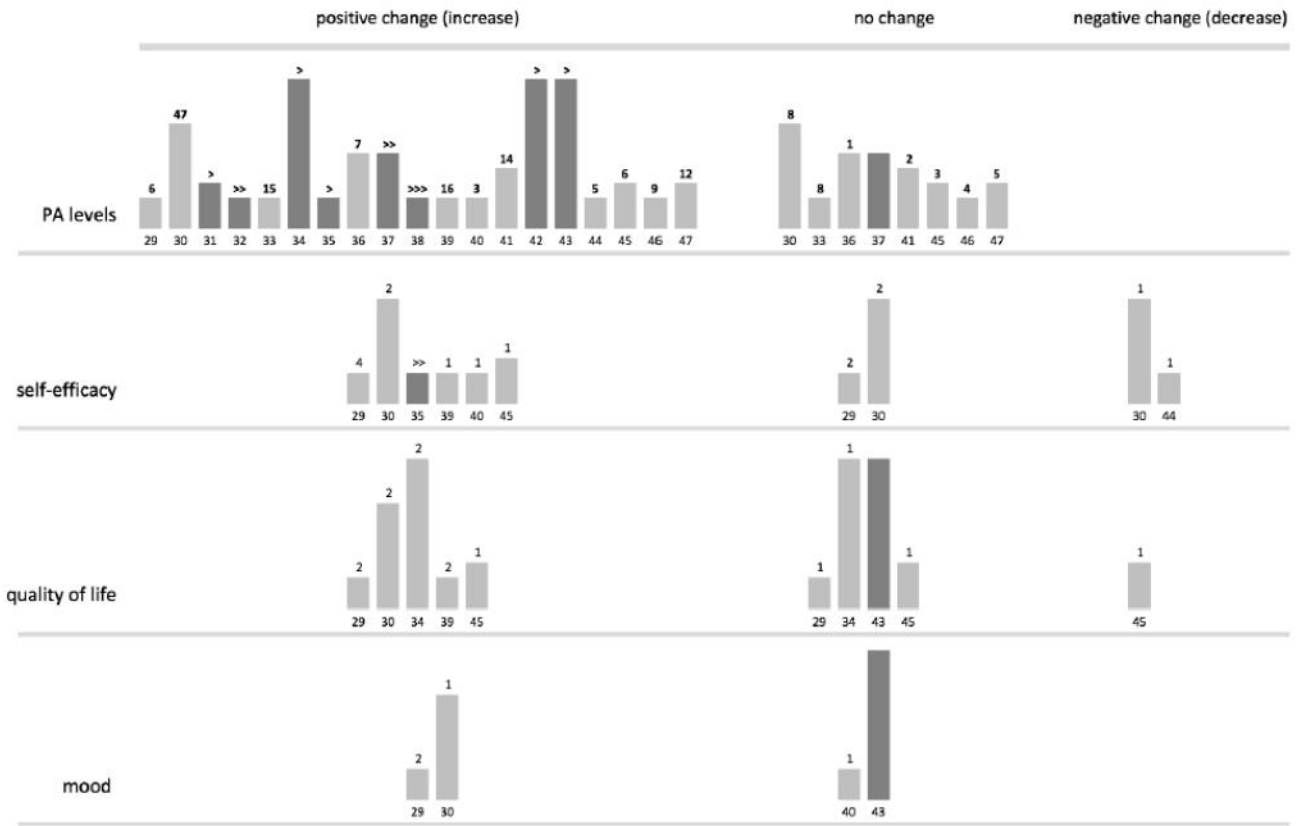

Fig 2. Harvest plot: Evidence for PA and psychological outcomes. Columns represent individual reviews with reference numbers below. Column height represents risk of bias assessed on four domains—higher columns represent lower risk of bias. Lighter shade designates narrative evidence, darker shade designates evidence from meta-analysis. Numbers above columns indicate number of studies reporting effect (for narrative reviews). Arrows indicate effect size (for meta-analyses: > small effect, >> mixed effects, >>> moderate effect).

https://doi.org/10.1371/journal.pone.0180902.g002

The interventions frequently incorporated **lifestyle counselling and health education** elements and typically took the form of a face-to-face **group/individual counselling** or **training session** followed by a scheduled remote **contact** to encourage further involvement in PA

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5507305/

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However, ….

- Traditional face-to-face approaches promoting health behaviors are typically
  - resource intensive,
  - time-limited,
  - require participants to travel to specific locations and
  - lack appropriate techniques for monitoring daily fluctuations in health behaviors
- In addition, behavior change interventions require professional expertise in delivering behavior change techniques (BCTs).
- Thus, there is a need for potentially scalable, low cost and less staff intensive interventions.

- https://www.sciencedirect.com/science/article/pii/S0531556519300877?via%3Dihub

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ADVANTAGES OF WEARABLES

- Individualized programs for large population
- Easy to use and well accepted, commercially available, expensive?
- Can be used as intervention method and for monitoring (and feedback)
- Include behavioral change techniques -> nudge to be active
- No face-to-face communication needed

Behavioral change techniques (BCTs)

- Behaviour change interventions to promote physical activity can include several behaviour change strategies and components—so-called behavior change techniques (BCTs).
- TAXONOMY https://pubmed.ncbi.nlm.nih.gov/23512568/
- BCT Taxonomy v1 (BCTTv1) is a cross-domain, hierarchically structured taxonomy of 93 distinct BCTs with labels, definitions and examples.
- Higher intervention effectiveness with the use of self-regulation techniques (self-monitoring, feedback and goal setting).

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Techniques

1. **Goals and planning**
2. **Feedback and monitoring**
3. **Social support**
4. Shaping knowledge
5. Natural consequences
6. Comparison of behavior
7. Associations
8. Repetition and substitution
9. Comparison of outcomes
10. Reward and threat
11. Regulation
12. Antecedents
13. Identity
14. Scheguled consequences
15. Self-belief
16. Covert learning

Electronic Supplementary Materials Table 3. BCT Taxonomy (v1): 93 hierarchically-clustered techniques

Page	Grouping and BCTs
1	**1. Goals and planning**
	1.1. Goal setting (behavior) 1.2. Problem solving 1.3. Goal setting (outcome) 1.4. Action planning 1.5. Review behavior goal(s) 1.6. Discrepancy between current behavior and goal 1.7. Review outcome goal(s) 1.8. Behavioral contract 1.9. Commitment
3	**2. Feedback and monitoring**
	2.1. Monitoring of behavior by others without feedback 2.2. Feedback on behaviour 2.3. Self-monitoring of behaviour 2.4. Self-monitoring of outcome(s) of behaviour 2.5. Monitoring of outcome(s) of behavior without feedback 2.6. Biofeedback 2.7. Feedback on outcome(s) of behavior
5	**3. Social support**
	3.1. Social support (unspecified) 3.2. Social support (practical) 3.3. Social support (emotional)
6	**4. Shaping knowledge**
	4.1. Instruction on how to perform the behavior 4.2. Information about Antecedents 4.3. Re-attribution 4.4. Behavioral experiments
7	**5. Natural consequences**
	5.1. Information about health consequences 5.2. Salience of consequences 5.3. Information about social and environmental consequences 5.4. Monitoring of emotional consequences 5.5. Anticipated regret 5.6. Information about emotional consequences
8	**6. Comparison of behaviour**
	6.1. Demonstration of the behavior 6.2. Social comparison 6.3. Information about others' approval
9	**7. Associations**
	7.1. Prompts/cues 7.2. Cue signalling reward 7.3. Reduce prompts/cues 7.4. Remove access to the reward 7.5. Remove aversive stimulus 7.6. Satiation 7.7. Exposure 7.8. Associative learning
10	**8. Repetition and substitution**
	8.1. Behavioral practice/rehearsal 8.2. Behavior substitution 8.3. Habit formation 8.4. Habit reversal 8.5. Overcorrection 8.6. Generalisation of target behavior 8.7. Graded tasks
11	**9. Comparison of outcomes**
	9.1. Credible source 9.2. Pros and cons 9.3. Comparative imagining of future outcomes
12	**10. Reward and threat**
	10.1. Material incentive (behavior) 10.2. Material reward (behavior) 10.3. Non-specific reward 10.4. Social reward 10.5. Social incentive 10.6. Non-specific incentive 10.7. Self-incentive 10.8. Incentive (outcome) 10.9. Self-reward 10.10. Reward (outcome) 10.11. Future punishment
15	**11. Regulation**
	11.1. Pharmacological support 11.2. Reduce negative emotions 11.3. Conserving mental resources 11.4. Paradoxical instructions
16	**12. Antecedents**
	12.1. Restructuring the physical environment 12.2. Restructuring the social environment 12.3. Avoidance/reducing exposure to cues for the behavior 12.4. Distraction 12.5. Adding objects to the environment 12.6. Body changes
17	**13. Identity**
	13.1. Identification of self as role model 13.2. Framing/reframing 13.3. Incompatible beliefs 13.4. Valued self-identify 13.5. Identity associated with changed behavior
18	**14. Scheduled consequences**
	14.1. Behavior cost 14.2. Punishment 14.3. Remove reward 14.4. Reward approximation 14.5. Rewarding completion 14.6. Situation-specific reward 14.7. Reward incompatible behavior 14.8. Reward alternative behavior 14.9. Reduce reward frequency 14.10. Remove punishment
19	**15. Self-belief**
	15.1. Verbal persuasion about capability 15.2. Mental rehearsal of successful performance 15.3. Focus on past success 15.4. Self-talk
19	**16. Covert learning**
	16.1. Imaginary punishment 16.2. Imaginary reward 16.3. Vicarious consequences

WEARABLES' TOP BCTs

- Electronic activity monitor systems include a variety of evidence-based BCTs.
  - **Goal setting**
  - **Feedback of behavior**
  - **Self-monitoring of behavior**
  - Adding object to the environment

- https://www.jmir.org/2014/8/e192/
- https://mhealth.jmir.org/2019/7/e12768/?utm_campaign=JMIR_TrendMD_0&utm_medium=cpc&utm_source=TrendMD

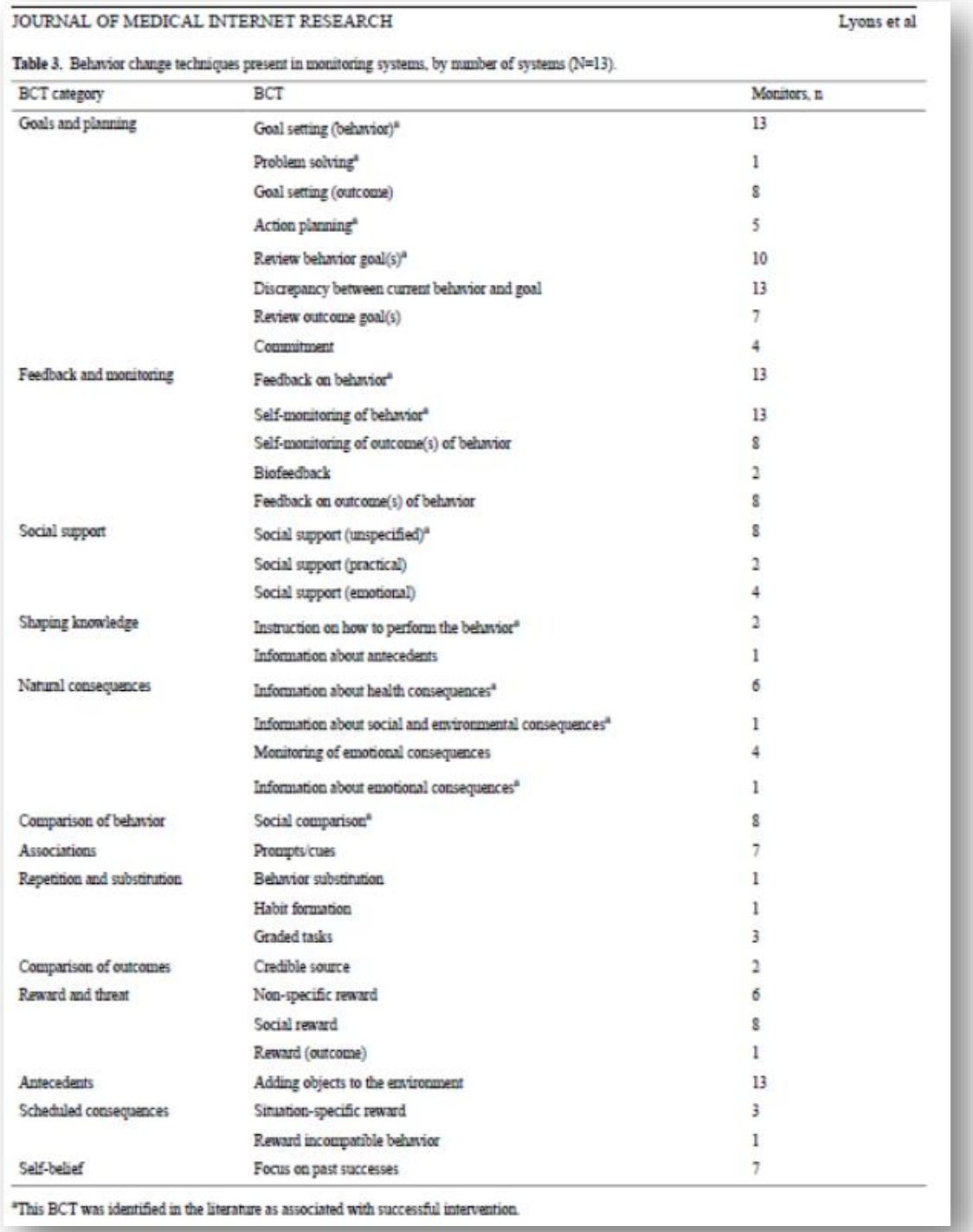

Table 3. Behavior change techniques present in monitoring systems, by number of systems (N=13).

BCT category	BCT	Monitors, n
Goals and planning	Goal setting (behavior)[a]	13
	Problem solving[a]	1
	Goal setting (outcome)	8
	Action planning[a]	5
	Review behavior goal(s)[a]	10
	Discrepancy between current behavior and goal	13
	Review outcome goal(s)	7
	Commitment	4
Feedback and monitoring	Feedback on behavior[a]	13
	Self-monitoring of behavior[a]	13
	Self-monitoring of outcome(s) of behavior	8
	Biofeedback	2
	Feedback on outcome(s) of behavior	8
Social support	Social support (unspecified)[a]	8
	Social support (practical)	2
	Social support (emotional)	4
Shaping knowledge	Instruction on how to perform the behavior[a]	2
	Information about antecedents	1
Natural consequences	Information about health consequences[a]	6
	Information about social and environmental consequences[a]	1
	Monitoring of emotional consequences	4
	Information about emotional consequences[a]	1
Comparison of behavior	Social comparison[a]	8
Associations	Prompts/cues	7
Repetition and substitution	Behavior substitution	1
	Habit formation	1
	Graded tasks	3
Comparison of outcomes	Credible source	2
Reward and threat	Non-specific reward	6
	Social reward	8
	Reward (outcome)	1
Antecedents	Adding objects to the environment	13
Scheduled consequences	Situation-specific reward	3
	Reward incompatible behavior	1
Self-belief	Focus on past successes	7

[a]This BCT was identified in the literature as associated with successful intervention.

Results from interventions, older adults

Stockwell et al. 2019

- *Digital behavior change interventions* have potential to increase physical activity and reduce sedentary time in older adults. Studies are still rather **short-term**.
- The meta-analyses suggest that among RCT studies, DBCI increased total PA (**SMD = 0.28**, $p = 0.04$), increased MVPA by 52 min/week (**SMD = 0.47**, $p < 0.001$; MD = 52, $p < 0.001$) and reduced sedentary time by 58 per day (**SMD = −0.44**, $p < 0.001$; MD = −58, $p < 0.001$) when compared with control conditions.
- Digital behavior change interventions may **improve physical functioning** and **reduce systolic blood pressure, no change in weight.**
- A minimum of 3 behavior change technique clusters were required for significant effects on physical activity
- https://www.sciencedirect.com/science/article/pii/S0531556519300877?via%3Dihub

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Results from interventions, adults

Laranjo et al., 2021

- Interventions using contemporary *mobile apps or physical activity trackers* **are effective in promoting physical activity**, with a statistically significant effect size of public health relevance.
- These interventions were more effective when including text-messaging or personalisation features.
- A major challenge with apps and trackers is **their high drop-off rate,** a third of users of activity trackers abandon their device in the first 6 months
- These results are valuable to clinicians, who may prescribe apps and trackers as part of a shared decision-making process **to individuals who seem ready to make behavioral changes**.

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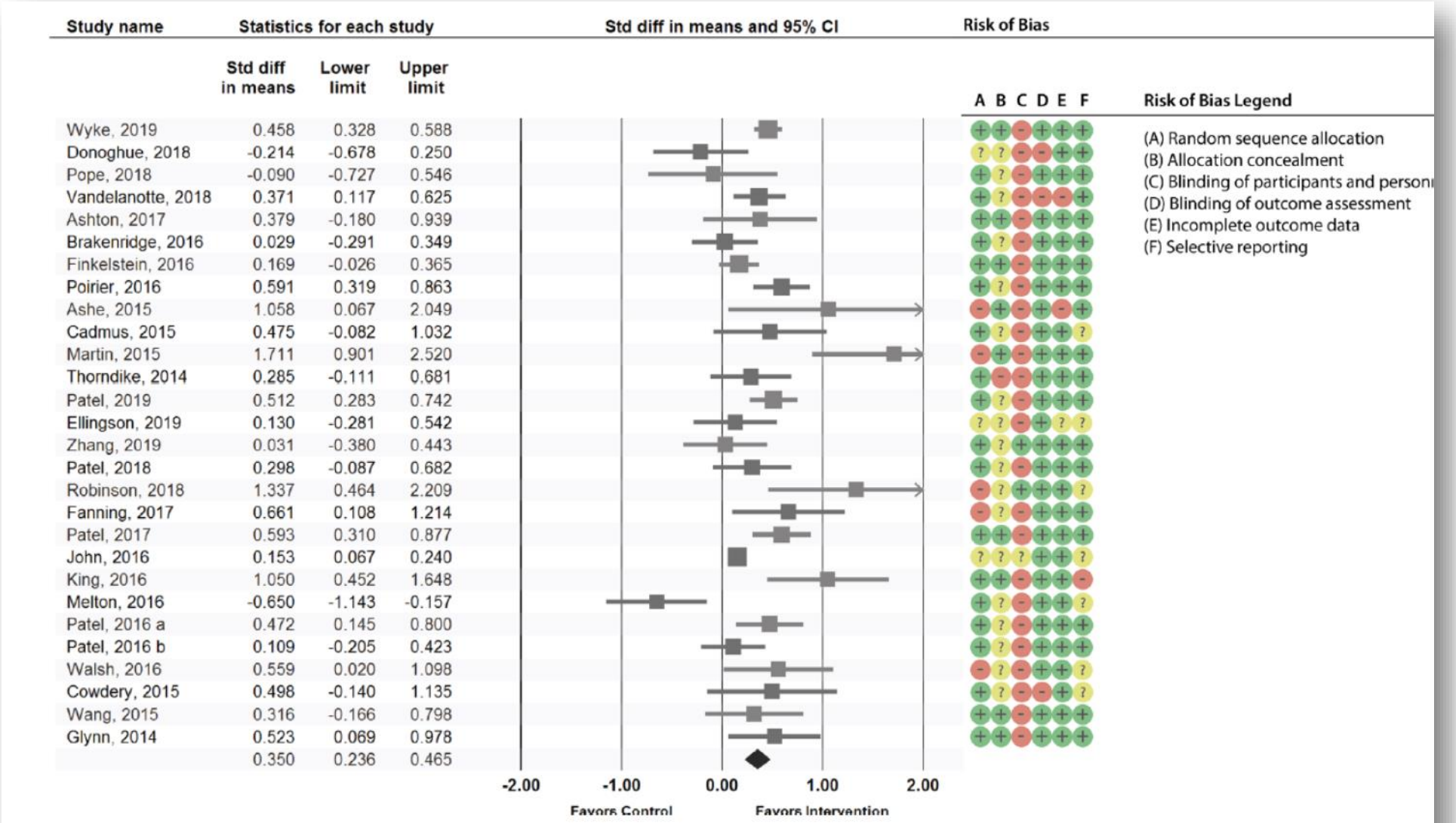

Figure 3 Forest plot of effect sizes and 95% CIs representing the effect of interventions involving mobile applications or activity trackers in increasing physical activity (random effects model) with risk of bias assessment. The meta-analysis showed a positive effect on physical activity favouring interventions, including smartphone apps or activity trackers (SDM 0.350, 95% CI 0.236 to 0.465, p<0.0001, I^2=69%, T^2=0.051), corresponding to an increase of 1850 steps per day (95% CI 1247 to 2457). Note: size of squares is proportional to study sample size. SDM, standardised difference in means.

Interventions using apps or trackers have small-to-moderate effects on physical activity at a mean follow-up of 13 weeks, with an average increase of 1850 steps per day, compared with control.

https://bjsm.bmj.com/content/55/8/422.abstract

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Results from interventions, adults
Brickwood et al. 2019

- Utilizing a *consumer-based wearable activity tracker* as **either the primary component of an intervention or as part** of a broader physical activity intervention has the **potential to increase physical activity participation**.
- Consumer-based wearable activity trackers can be effective on their own, but **when combined with other behavior change techniques**, such as telephone counseling or group-based education, the improvement in physical activity participation is greater.
- As the effects of physical activity interventions are **often short term**, the inclusion of a consumer-based wearable activity tracker may provide an **effective tool to** assist health professionals to provide ongoing monitoring and support to patients **with minimal resource expenditure**.
- https://pubmed.ncbi.nlm.nih.gov/30977740/

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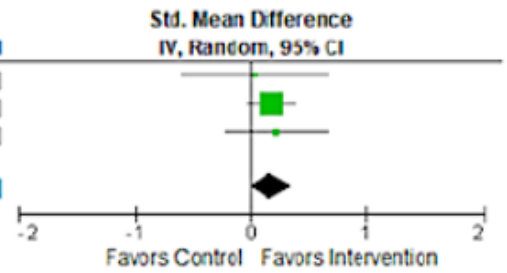
2. Minutes per week of moderate and vigorous physical activity – Wearable-Based Interventions

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Duncan (2016) [33] (1)	529.2	34	19	527.6	51.2	19	7.3%	0.04 [-0.60, 0.67]
Finkelstein (2016) [34] (2)	0	93.9	203	-16	93.5	201	77.4%	0.17 [-0.02, 0.37]
Slootmaker (2009) [48] (3)	436.7	575.1	38	335.7	290.4	42	15.3%	0.22 [-0.22, 0.66]
Total (95% CI)			**260**			**262**	**100.0%**	**0.17 [-0.00, 0.34]**

Heterogeneity: Tau² = 0.00; Chi² = 0.23, df = 2 (P = 0.89); I² = 0%
Test for overall effect: Z = 1.92 (P = 0.05)

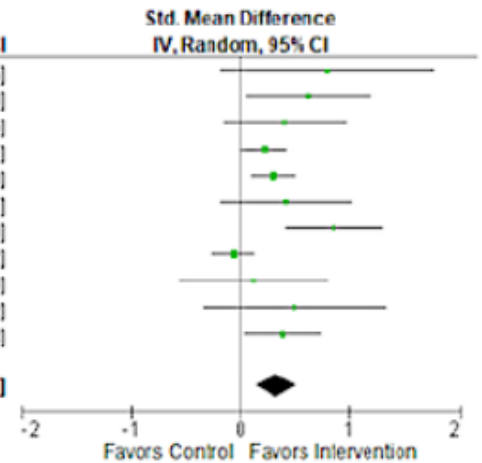


Footnotes
(1) Unpublished data.
(2) Fitbit only group. Data presented as mean change and 95% CI
(3) Data presented as median and IQR. Mean and SD provided by author.

3. Minues per week of moderate and vigorous physical activity – Multi-Faceted Interventions

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Ashe (2015) [29]	231.4	201.8	12	94.43	56.2	7	2.8%	0.79 [-0.18, 1.76]
Ashton (2017) [30] (1)	154.1	205.7	26	26.1	199.2	24	6.5%	0.62 [0.05, 1.19]
Cadmus-Bertram (2015) [21]	234	119	25	189	98	26	6.7%	0.41 [-0.15, 0.96]
Finkelstein (2016) [34] (2)	5	100.1	199	-16	93.5	201	16.1%	0.22 [0.02, 0.41]
Finkelstein (2016) [34] (3)	13	99.6	197	-16	93.5	201	16.0%	0.30 [0.10, 0.50]
Hartman (2016) [35]	224	179.9	33	154	132.3	17	6.2%	0.42 [-0.18, 1.01]
Hartman (2018) [36]	195.3	105.9	43	104.3	105.8	44	8.9%	0.85 [0.41, 1.29]
Jakicic (2016) [37] (4)	5.5	458.7027	237	35.5	455.5	233	16.6%	-0.07 [-0.25, 0.12]
Li (2017) [39] (5)	64.2	70.5	17	56	60.1	17	5.1%	0.12 [-0.55, 0.80]
Unick (2012) [51] (6)	133	217	11	44.8	124.6	12	3.7%	0.49 [-0.35, 1.32]
van der Weegen (2015) [53] (7)	337.1	166.6	65	277.27	136.5	68	11.4%	0.39 [0.05, 0.73]
Total (95% CI)			**865**			**850**	**100.0%**	**0.33 [0.16, 0.51]**

Heterogeneity: Tau² = 0.04; Chi² = 23.60, df = 10 (P = 0.009); I² = 58%
Test for overall effect: Z = 3.69 (P = 0.0002)



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Acceptance and use of wearables among older adults

- Activity trackers may be an effective technology to encourage physical activity among older adults, especially those who have **never tried it**.
- Initial positive response to tracker use does not guarantee tracker use maintenance.
- Maintenance depends on **recognizing the long-term benefits of tracker use, social support, and internal motivation**.
- Nonadoption and relapse may occur because of **technology's limitations and gaining awareness of one's physical activity** without changing the physical activity level itself.
- https://pubmed.ncbi.nlm.nih.gov/30950807/

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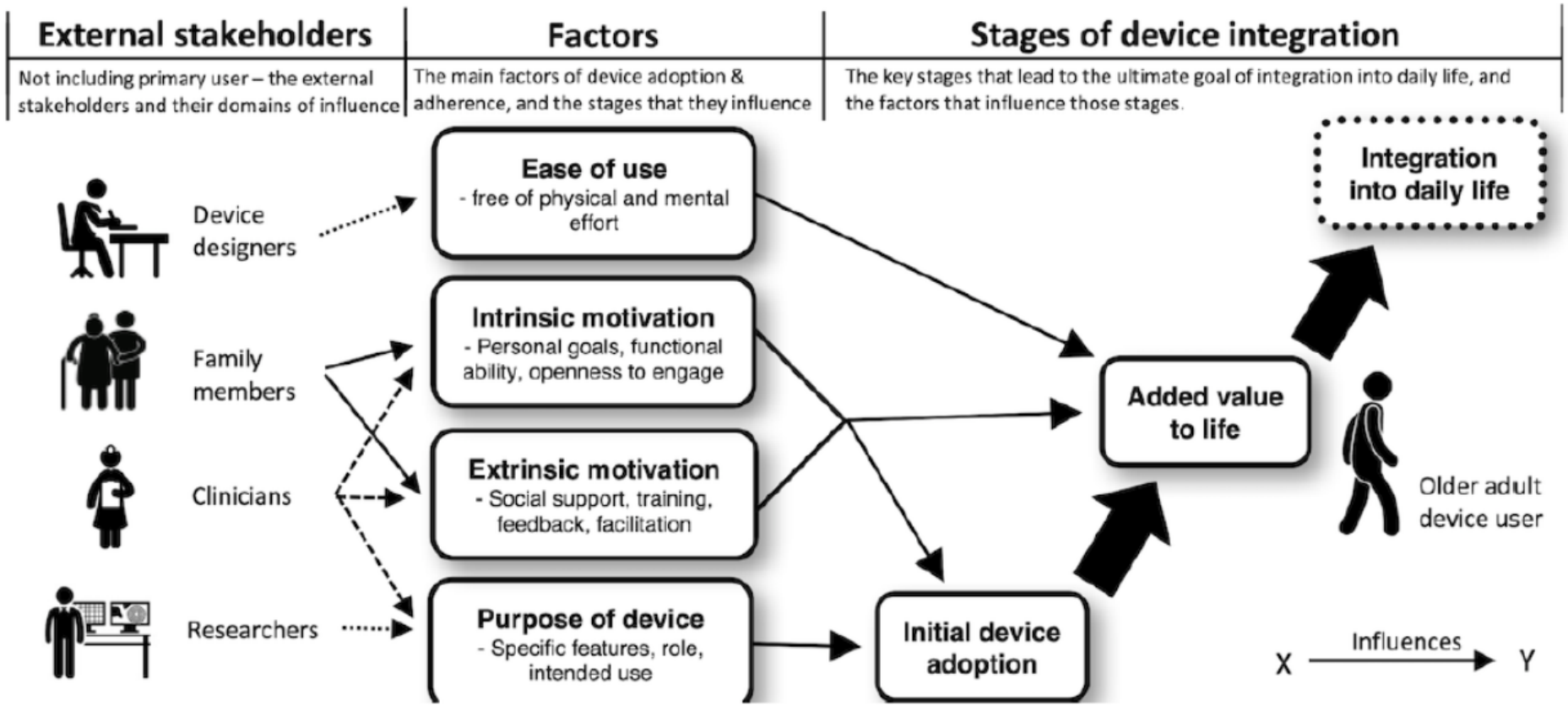
Figure 2. Conceptual model developed from the line-of-argument synthesis.



Take home message

- There is an urgent need to promote physical activity among older adults.
  - Especially inactive older adults
- Aim is not only to increase MVPA, but also to reduce sedentary behavior with LPA (WHO guidelines, *every minute counts*)
- The use of wearebles is promising yet suffers from short-term adherence, other resourses may be needed to gain significant results (social support, text-messages)
  - New users, inactive users, person who is motivated to make a change may benefit
  - Long-term usage?, how to develop physical activity as a habit
- Changing behavior is not easy
  - Motivation, skills, readiness to change
  - Multidisciplinary research is needed

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Retirement and physical activity

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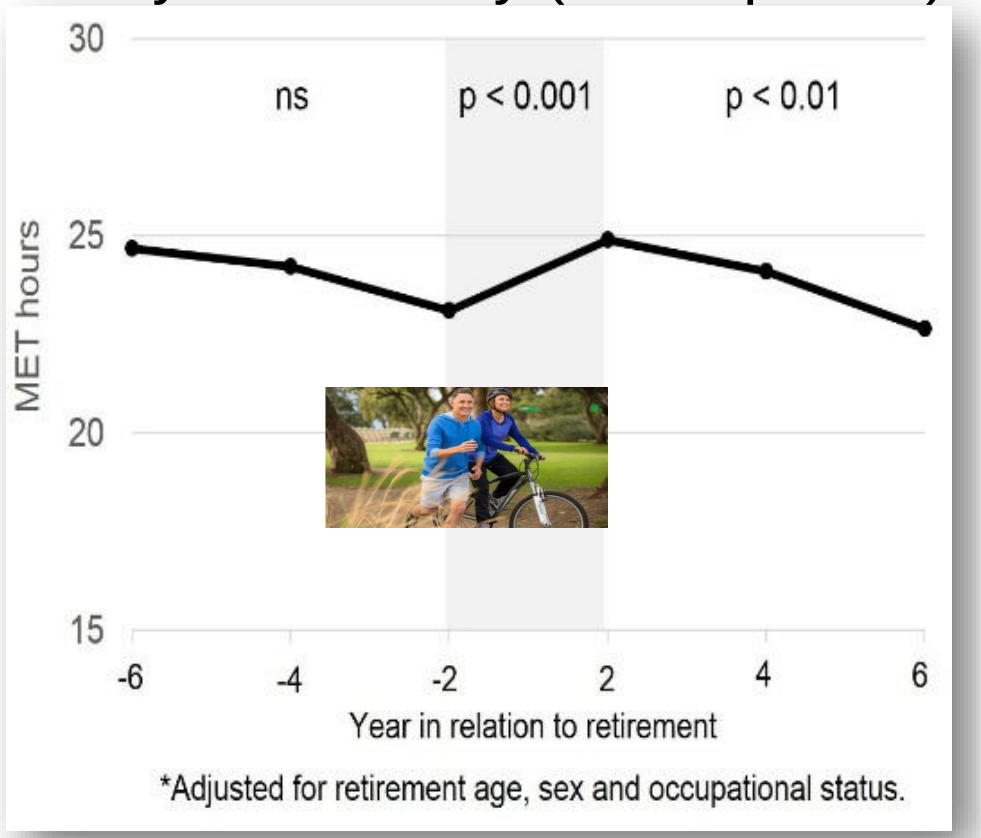
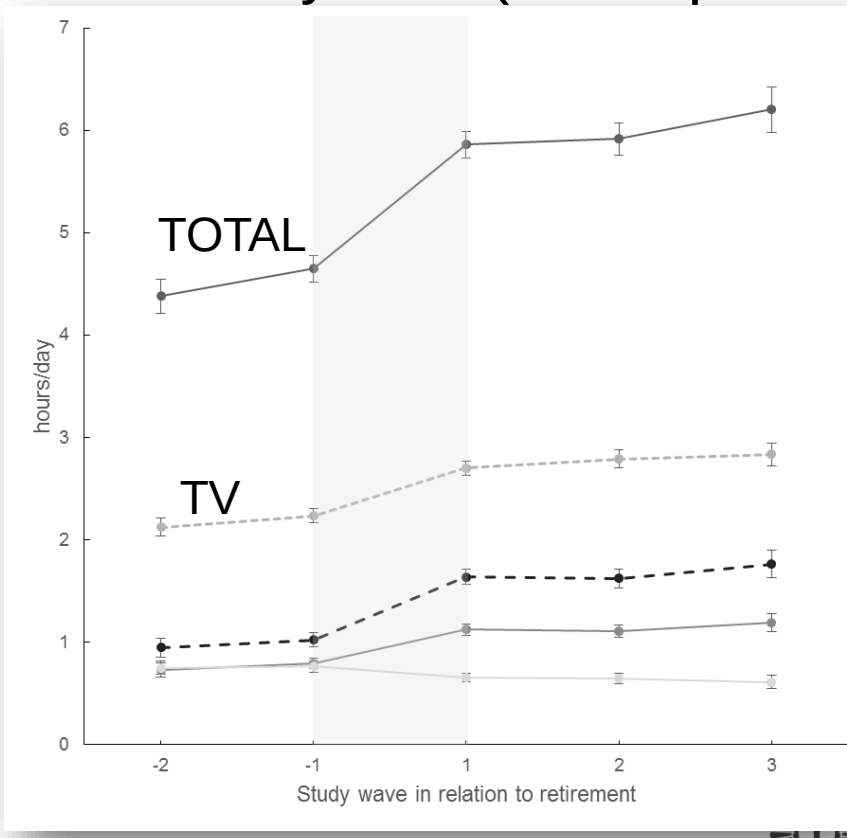
Our previous findings from the retirement transition

- Physical activity (self-reported)



https://pubmed.ncbi.nlm.nih.gov/27084334/

- Sedentary time (self-reported)



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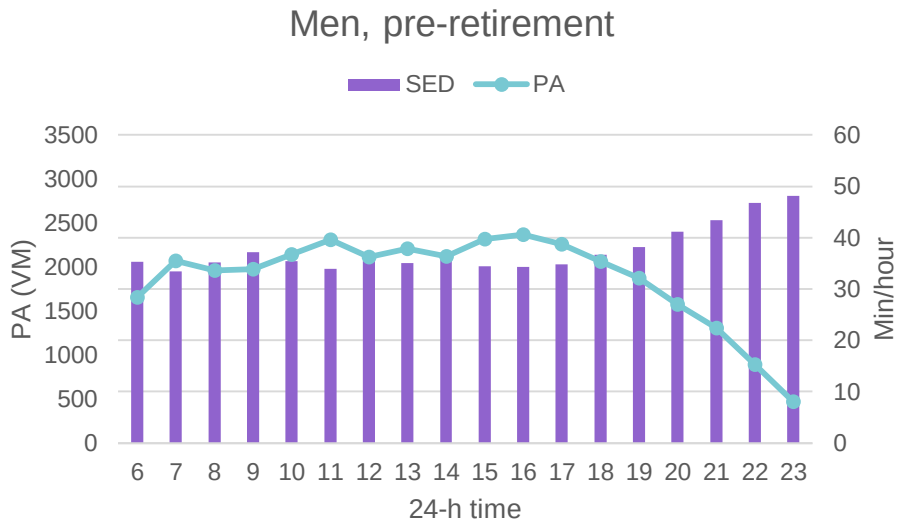
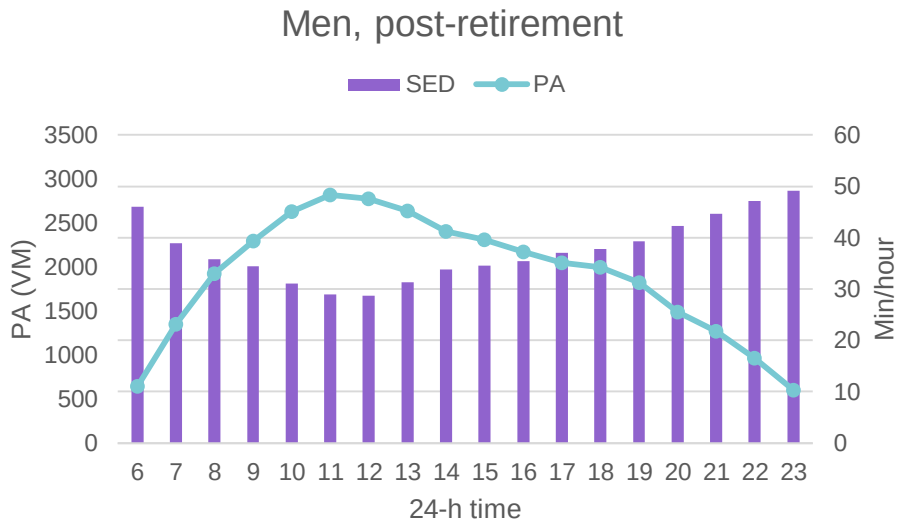
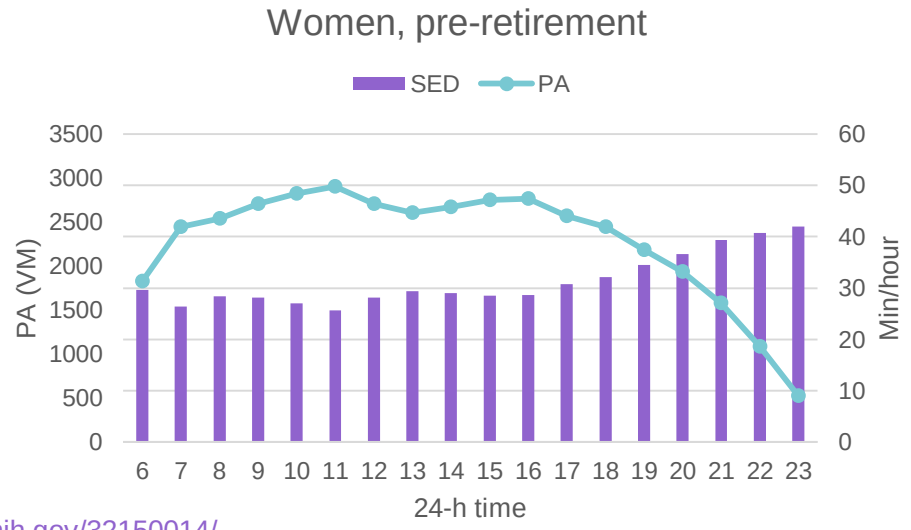
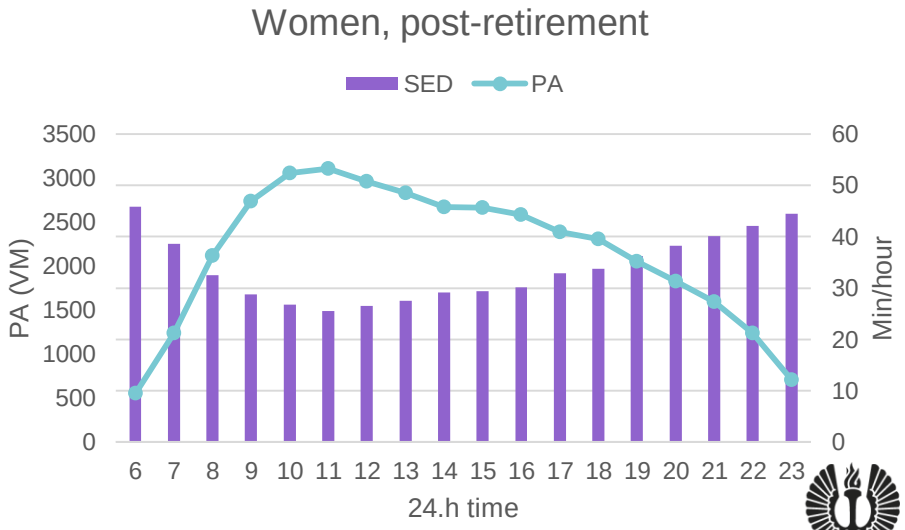
RETIREMENT AND PHYSICAL ACTIVITY









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https://pubmed.ncbi.nlm.nih.gov/32150014/
https://pubmed.ncbi.nlm.nih.gov/31095675/

REACT trial

NCT03320746

- **Enhancing physical ACTivity and healthy aging among recent REtirees (REACT)**
- To examine the efficacy of 12-month wearable technology based intervention on physical activity and sedentary time, and other health-related outcomes among recent retirees.
- REACT trial was among the first physical activity trials targeted to a time window immediately after retirement.
- Because, the independent effect of commercial activity trackers on daily physical activity is not known.

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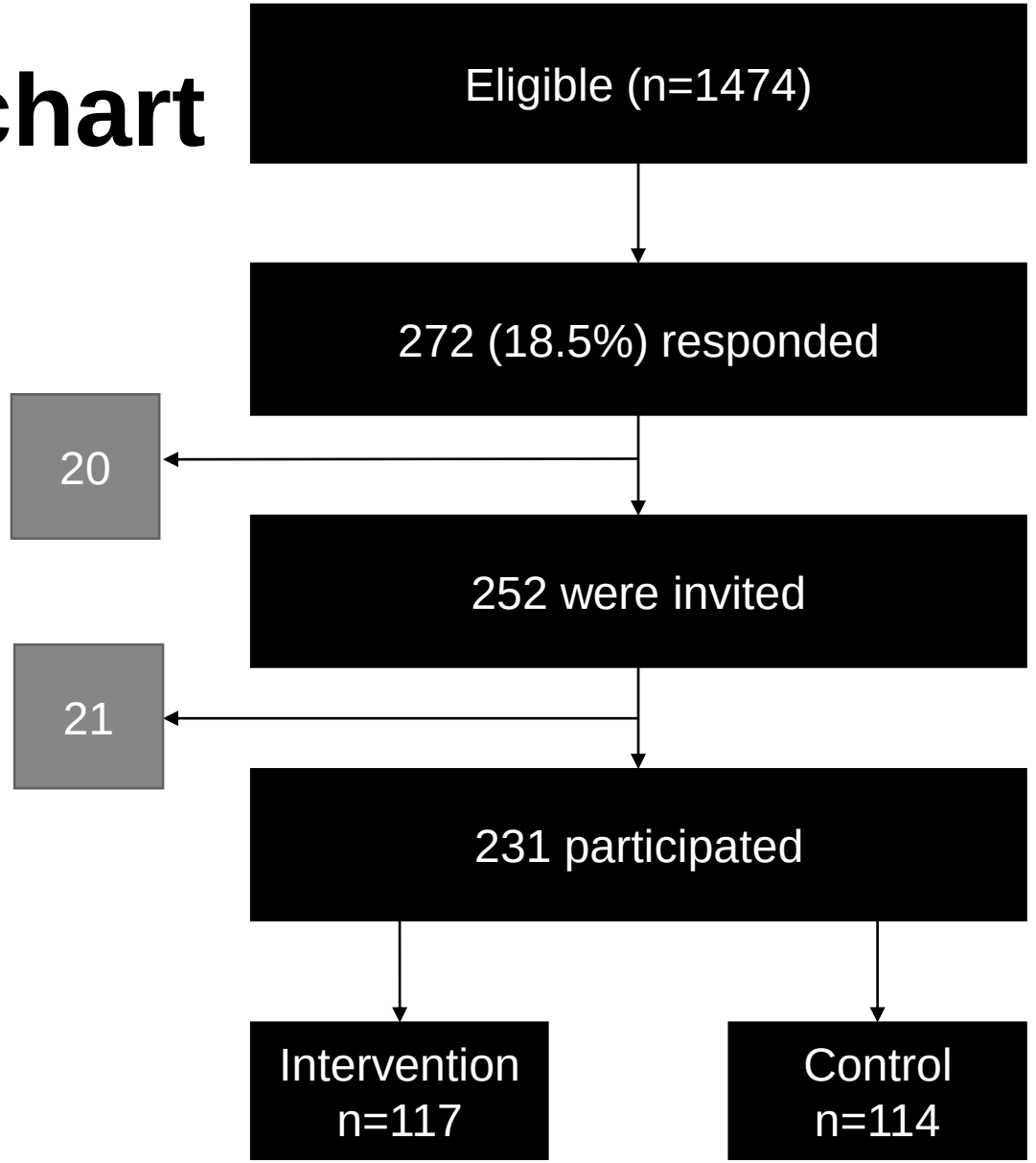
REACT design: flow chart

<u>The inclusion criteria</u>

- Statutory retirement date between January 2016 and December 2018
- No major functional limitations
- No current post-operative state or no known surgery within the next 6 months
- No malign cancer or recent myocardial infraction
- Basic knowledge on how to use computer
- Internet access at home

- Former public sector workers
- Mean age 65.2 years (SD 1.1), 83% women



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Intervention

- Polar Loop 2 activity tracker, wrist-worn, waterproof
- To wear every day and preferable nights for 12 months
- Features for daily activity:
  - Daily activity goal - - -- - - - - - - - - - - - - - ->
  - Daily steps - - - - - - - - - - - - >
  - Daily calories
  - Inactivity alerts (*vibration after 55 min of non-movement period*)

- Activity data was uploaded at least once a week to personalized account to Polar's web-based program (Polar Flow)
- If a participant frequently exceeded the daily activity goal, a higher goal was suggested by the researcher via e-mail.
- No further counselling or guidance on how to achieve the daily activity goal was given to the participants.
- No intervention for controls.

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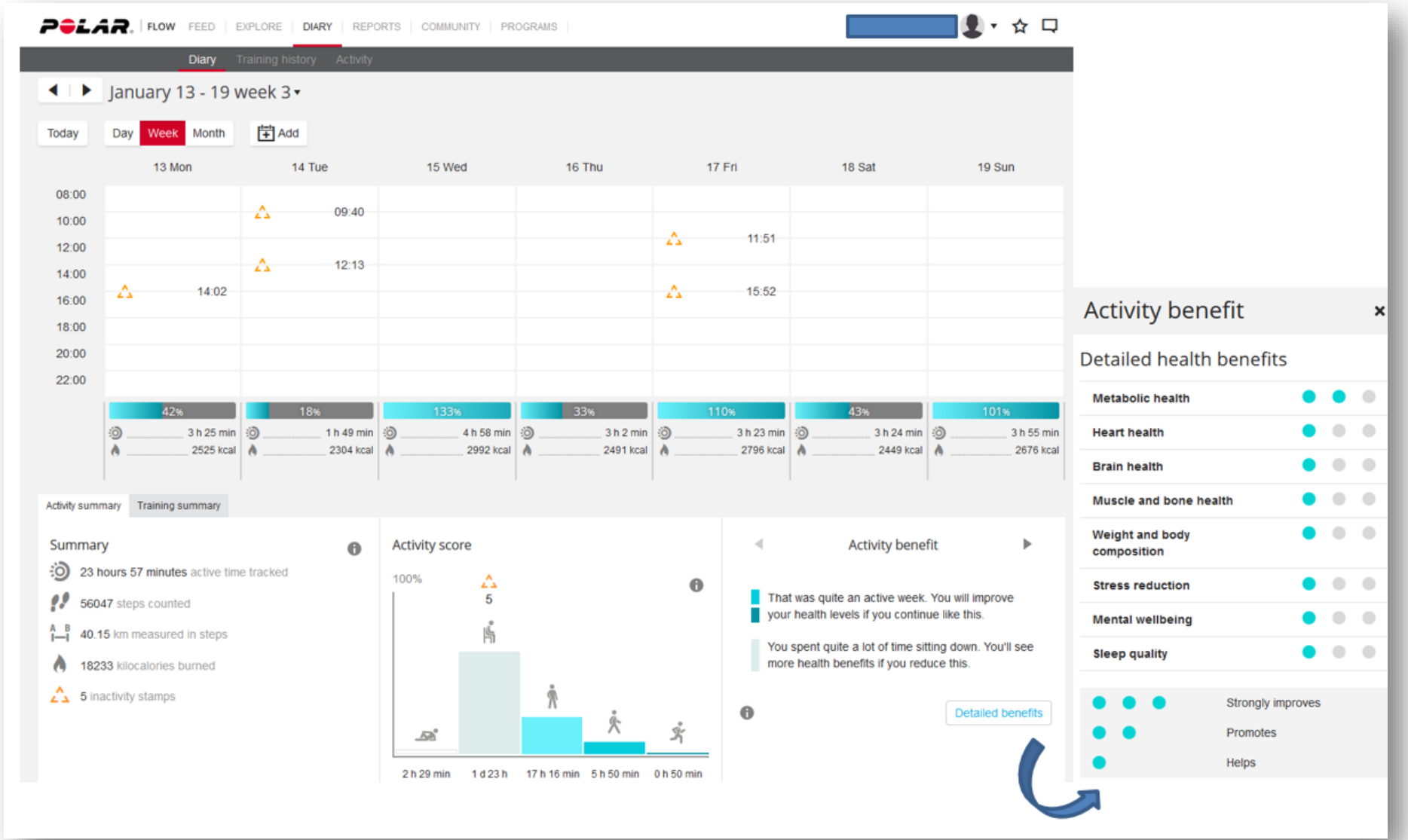
BCTs

- Adding objects to the environment *(the tracker)*
- Goal Setting (behavior) *(daily activity goal)*
- Review behavioral goals *(progression of the goal)*
- Discrepancy between current behavior and goal *(how much to go)*
- Self-monitoring of behavior *(e.g., daily steps)*
- Feedback on behavior *(level of attainment)*
- Prompts/Cues *(inactivity alerts)*
- Social rewards *(congratulation of the 100% attainment of the goal)*
- Information about health consequences *(from Polar flow program)*



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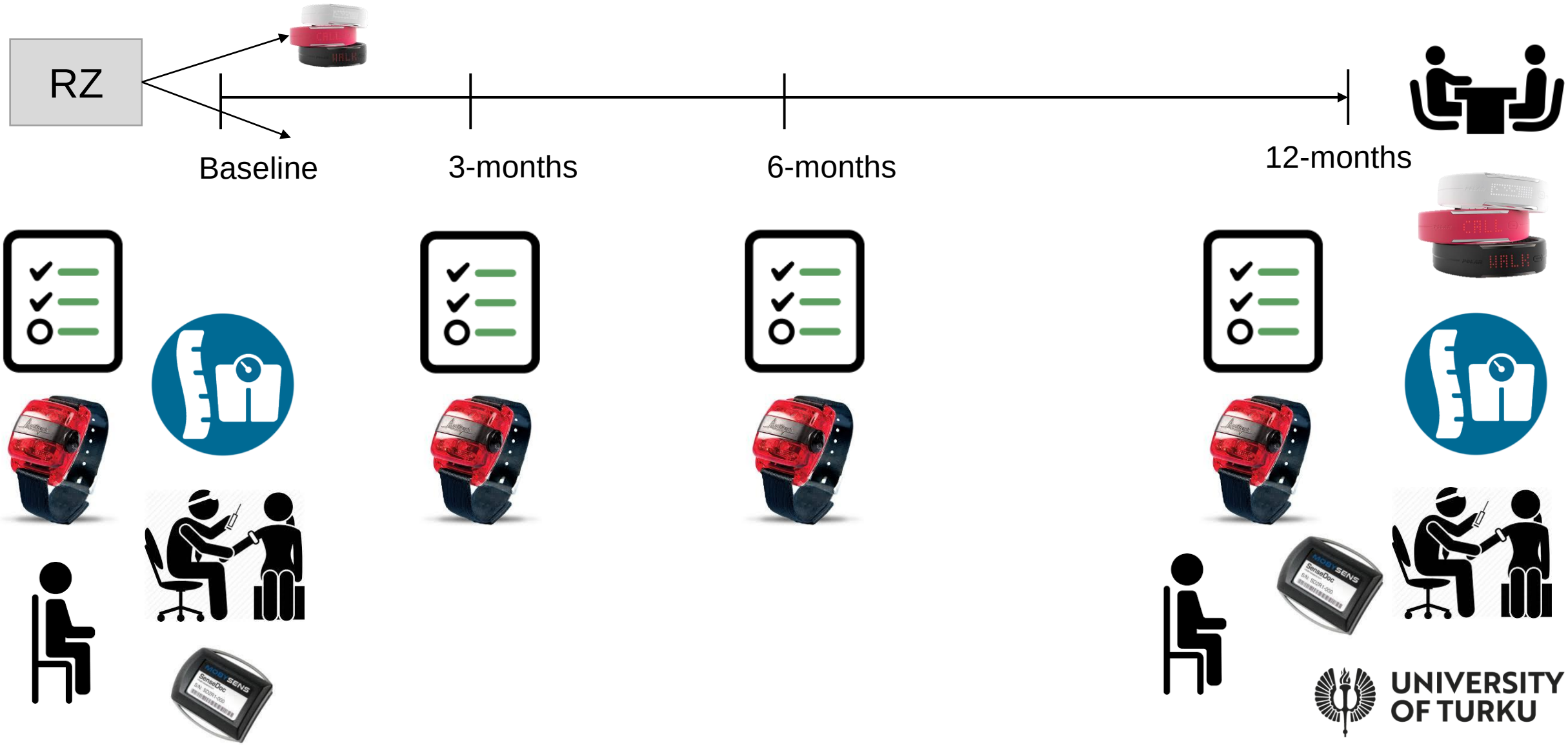
REACT design: timeline of the measurements



Results: daily physical activity patterns

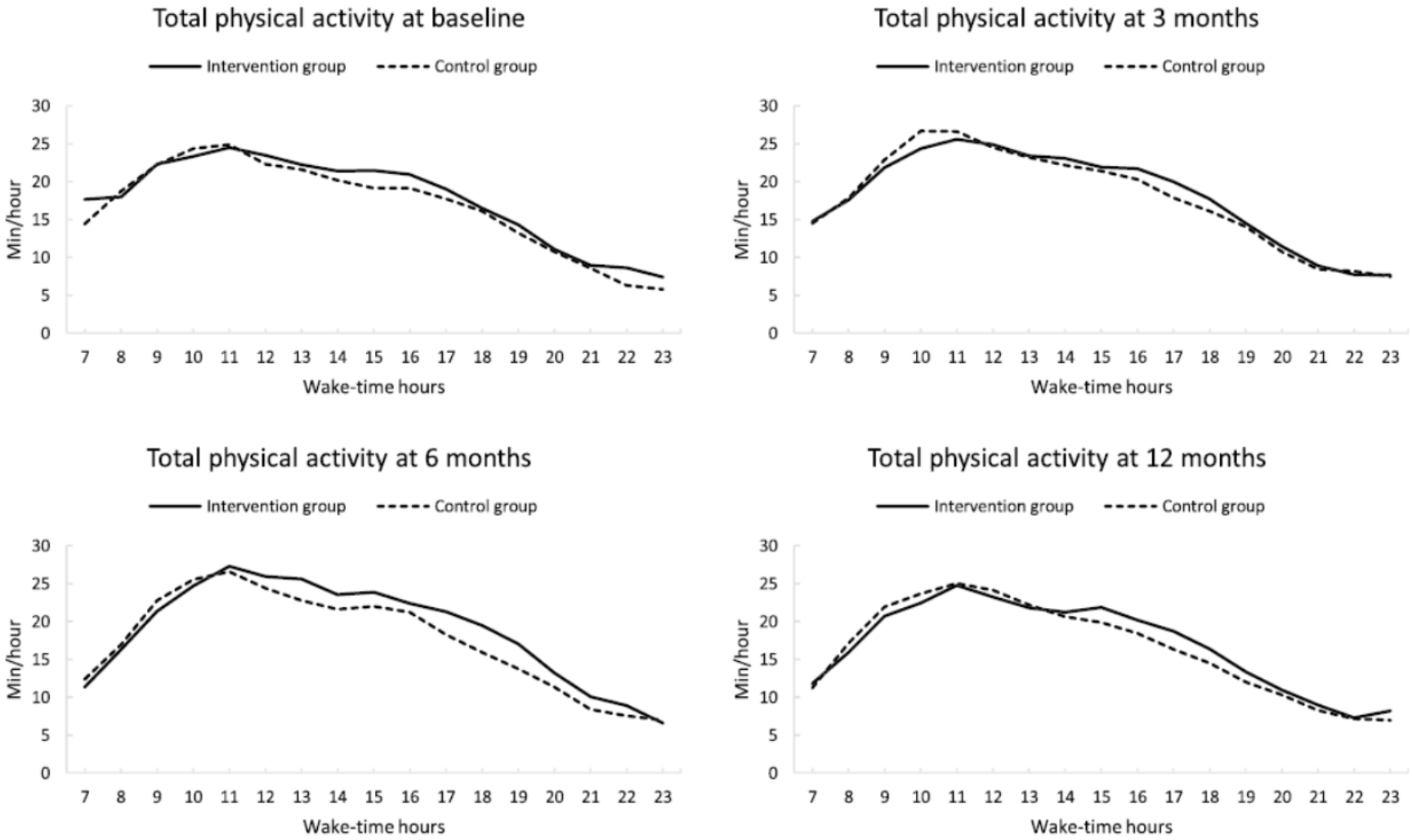


FIGURE 3—Daily profiles of the mean values of hourly total physical activity at each follow-up time point for the intervention (*solid line*) and control (*dotted line*) groups. Average values are based on mixed models.

https://pubmed.ncbi.nlm.nih.gov/34261997/

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Results: physical activity, all

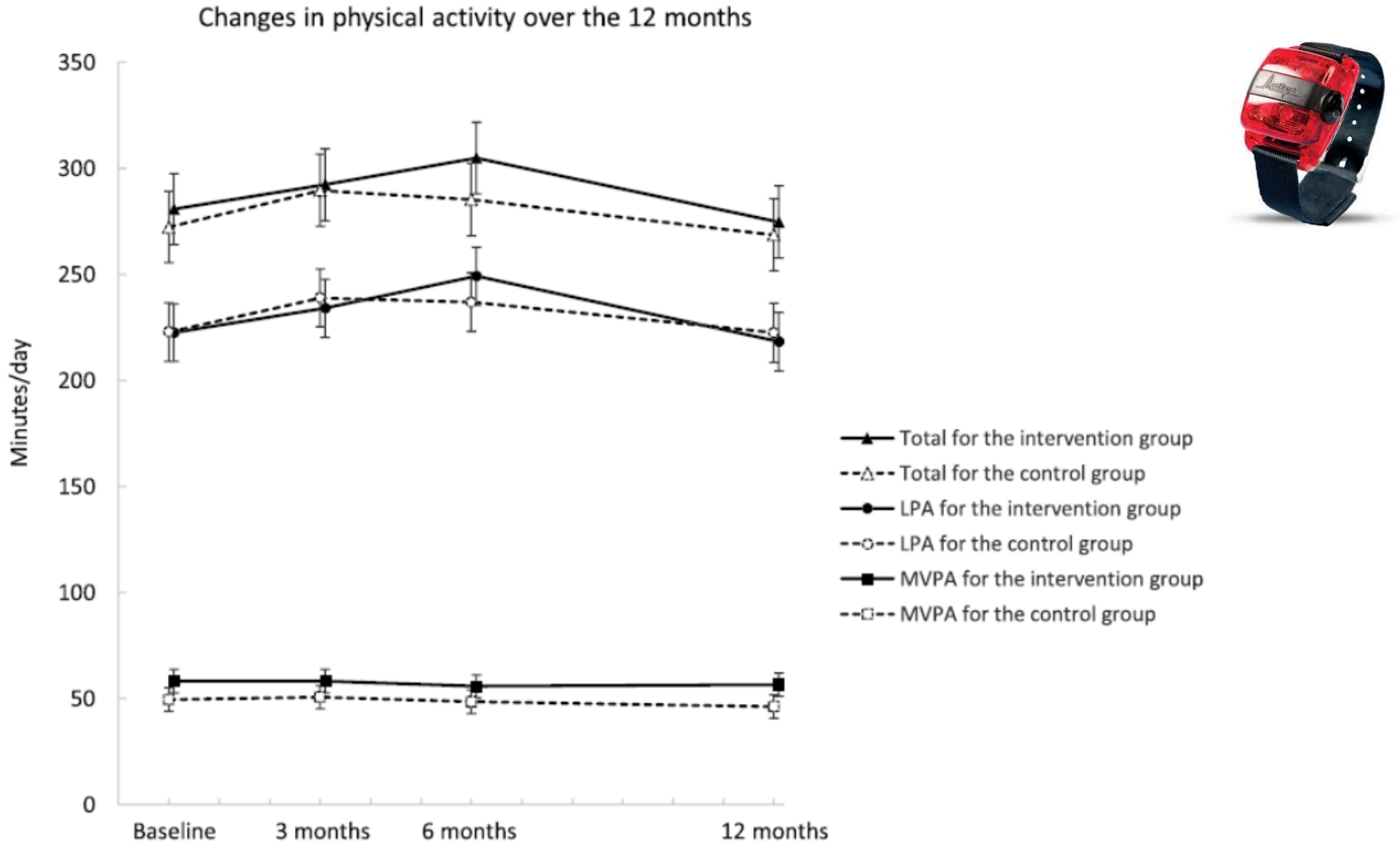
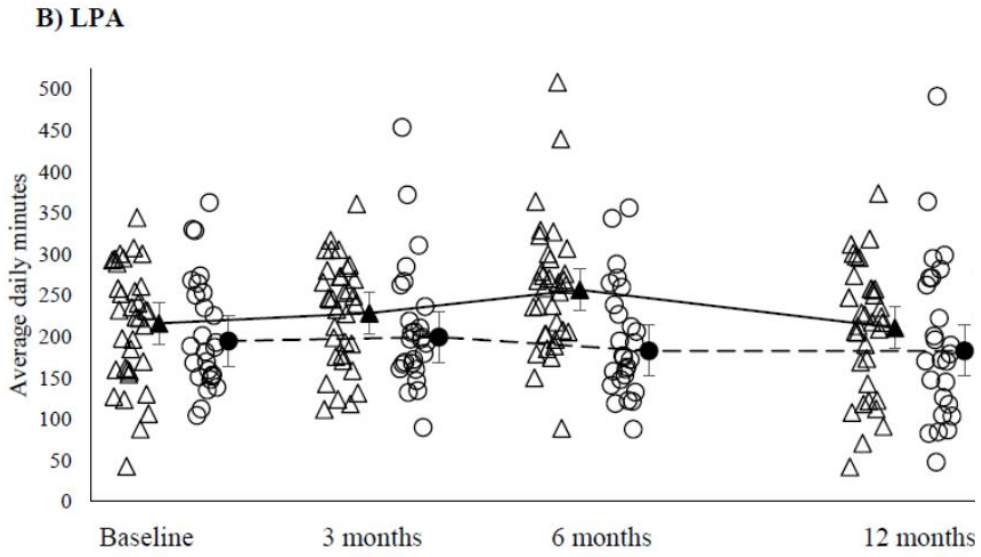
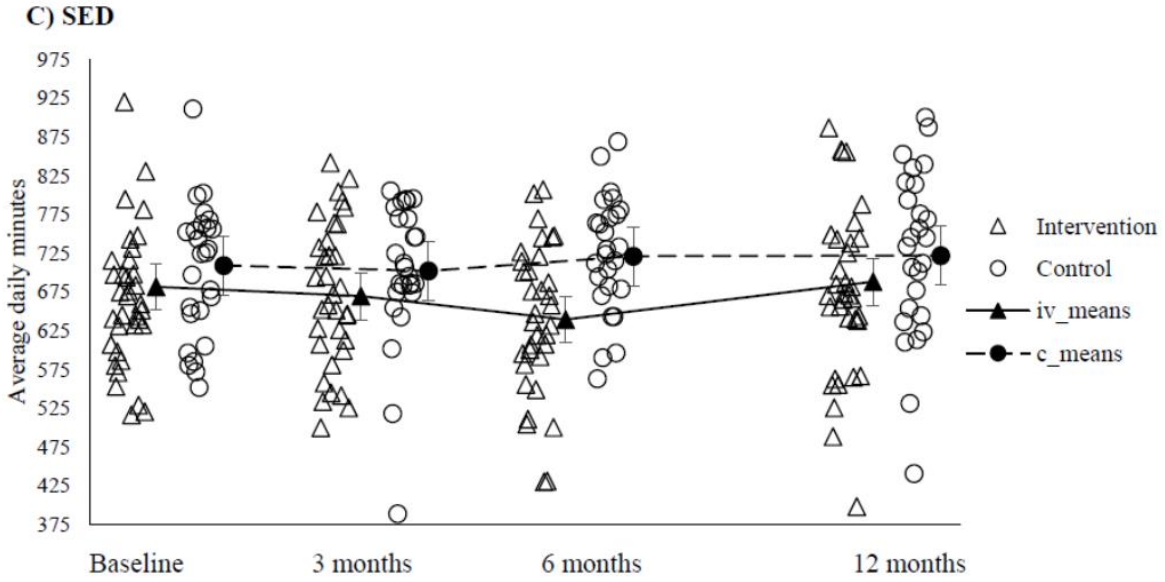


FIGURE 2—The change in total physical activity, LPA, and MVPA during the follow-up for the intervention (*solid line*) and control (*dotted line*) groups. Results are expressed as mean values and 95% CI based on mixed models.

https://pubmed.ncbi.nlm.nih.gov/34261997/

Results: physical activity, obese





Tuominen M. et al., 2021, JPAH, accepted

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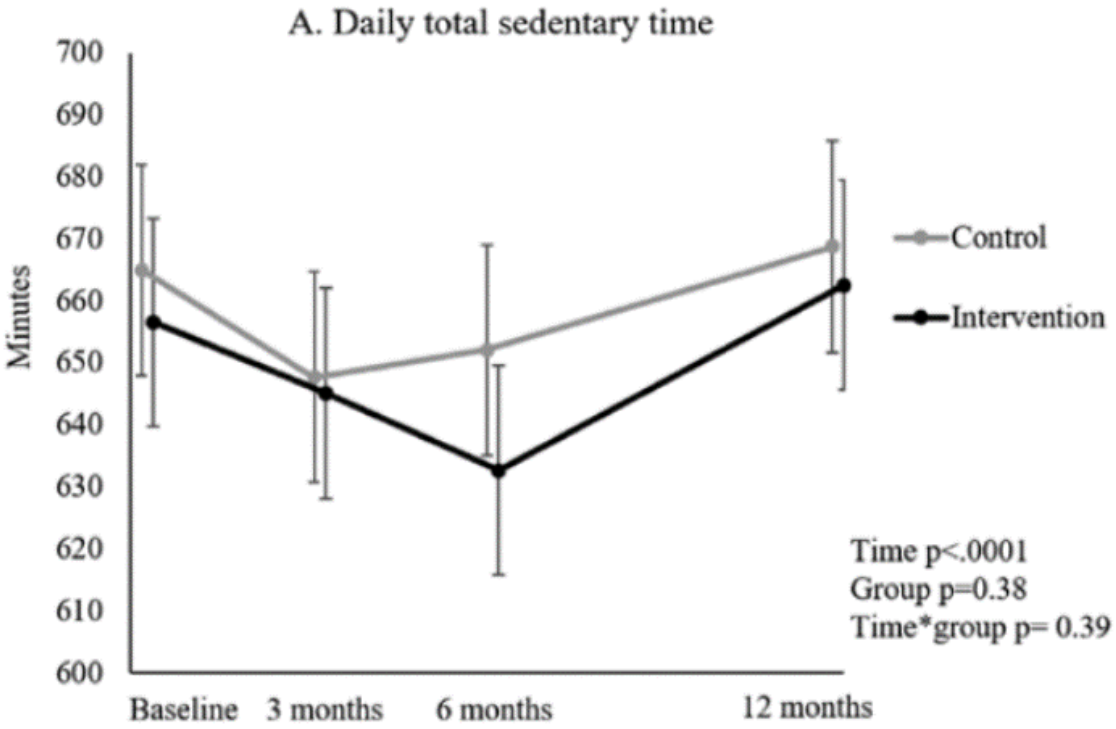
Results: sedentary time, prolonged (>60 mins)



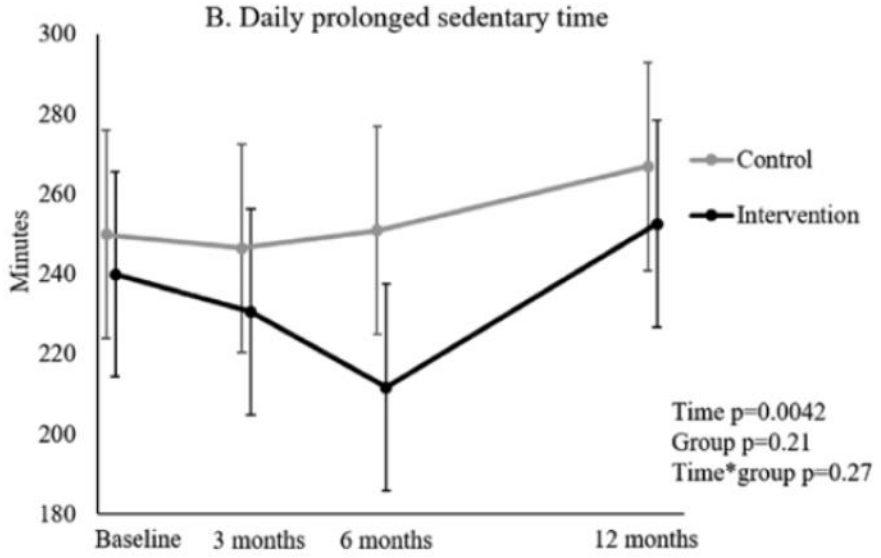


Figure 1. Changes in (A) daily total sedentary time and (B) daily prolonged sedentary time during the follow-up.

https://pubmed.ncbi.nlm.nih.gov/33839766/

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Results: spatial physical activity

		Mean	95% CL		P
All contexts					
Total PA	Baseline	297.8	276.4	319.3	0.74
	12-months	295.7	275.7	315.8	
Light PA	Baseline	272.5	253.3	291.7	0.04
	12-months	258.1	240.5	275.6	
MVPA	Baseline	25.3	18.2	32.4	<0.001
	12-months	37.9	29.2	46.5	
Home					
Total PA	Baseline	181.1	158.6	203.6	0.22
	12-months	191.9	165.5	218.2	
Light PA	Baseline	174.2	152.6	195.7	0.62
	12-months	178.2	153.5	202.9	
MVPA	Baseline	6.9	3.5	10.3	<0.001
	12-months	13.7	9.2	18.2	
Non-home					
Total PA	Baseline	86.6	72.6	100.6	0.09
	12-months	73.5	55.3	91.7	
Light PA	Baseline	80.3	66.8	93.7	0.06
	12-months	66.9	49.4	84.4	
MVPA	Baseline	6.3	3.9	8.6	0.73
	12-months	6.6	4.0	9.2	

Active travel					
Total PA	Baseline	20.8	15.9	25.7	0.59
	12-months	22.1	16.1	28.1	
Light PA	Baseline	9.5	6.9	12.1	0.01
	12-months	5.7	3.7	7.6	
MVPA	Baseline	11.3	7.1	15.4	0.03
	12-months	16.5	11.0	21.9	
Passive travel					
Total PA	Baseline	9.4	6.9	11.9	0.58
	12-months	8.8	6.3	11.3	
Light PA	Baseline	8.6	6.2	10.9	0.24
	12-months	7.7	5.4	9.9	
MVPA	Baseline	0.8	0.3	1.3	0.46
	12-months	1.2	0.5	1.9	
Adjusted for age, gender, wear time and measurement season					

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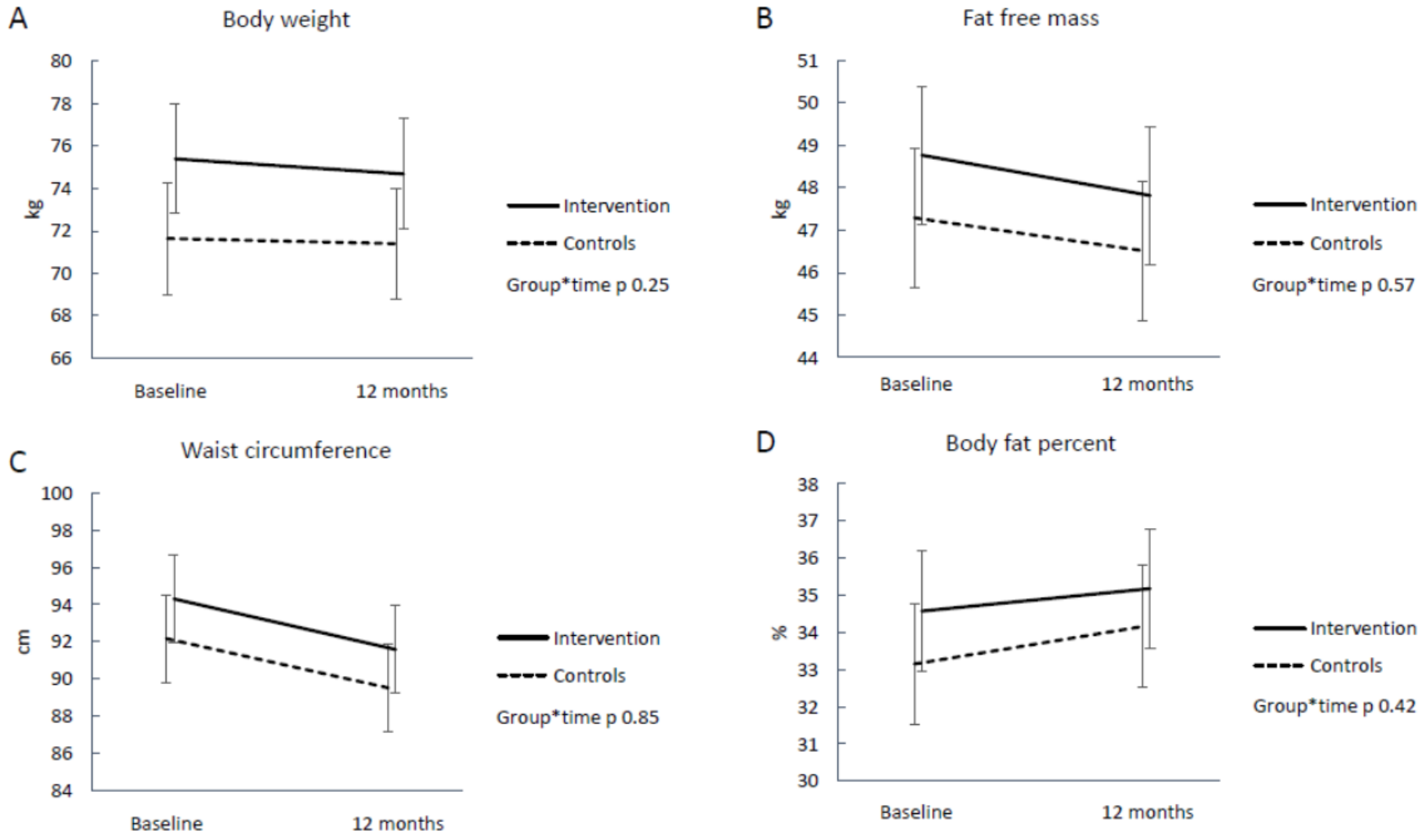
Pasanen S. et al., 2021, under review

Results: body composition



Leskinen T. et al., 2021, under review

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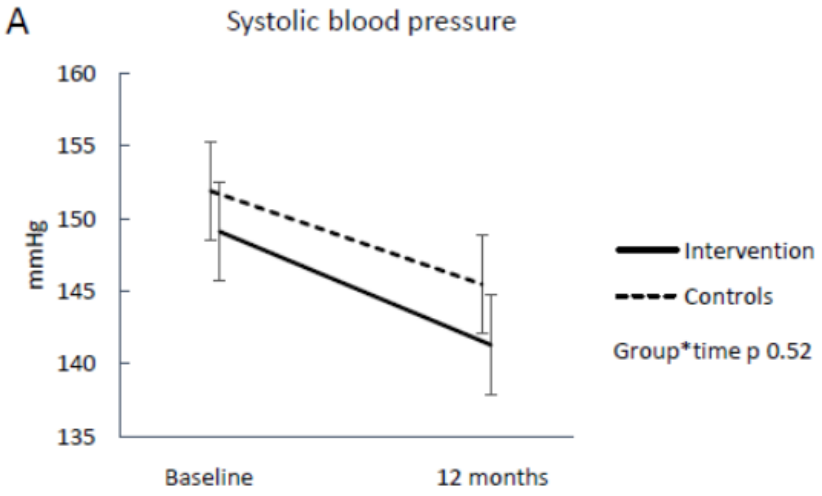
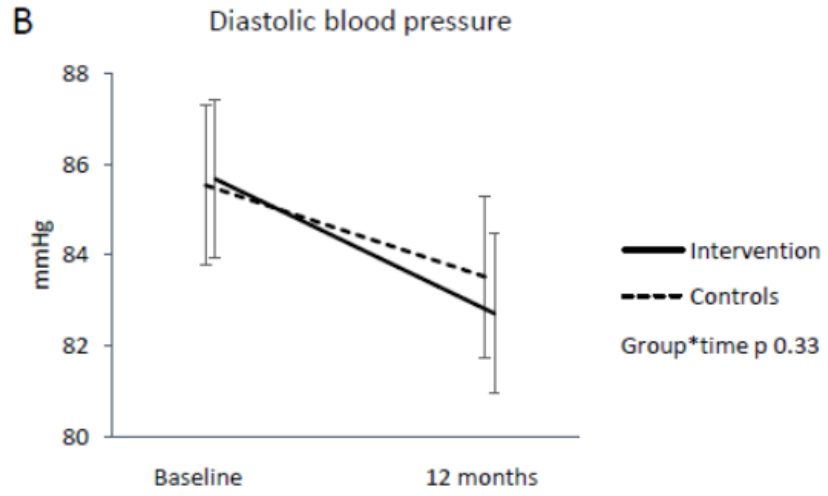
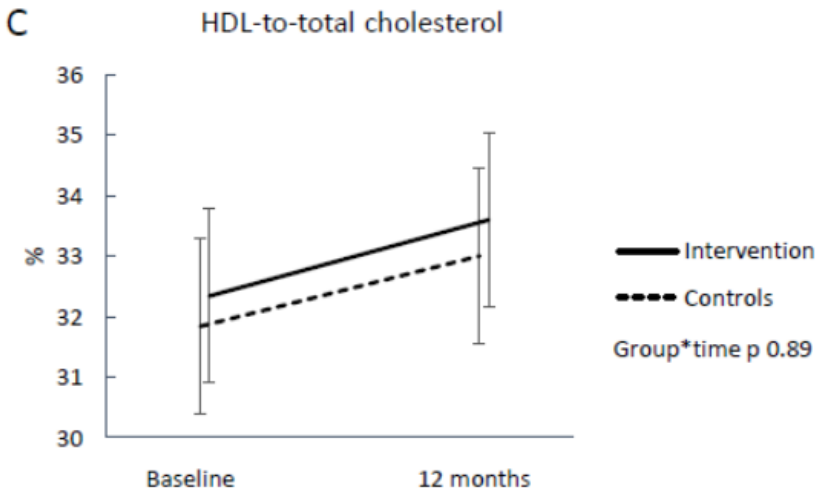
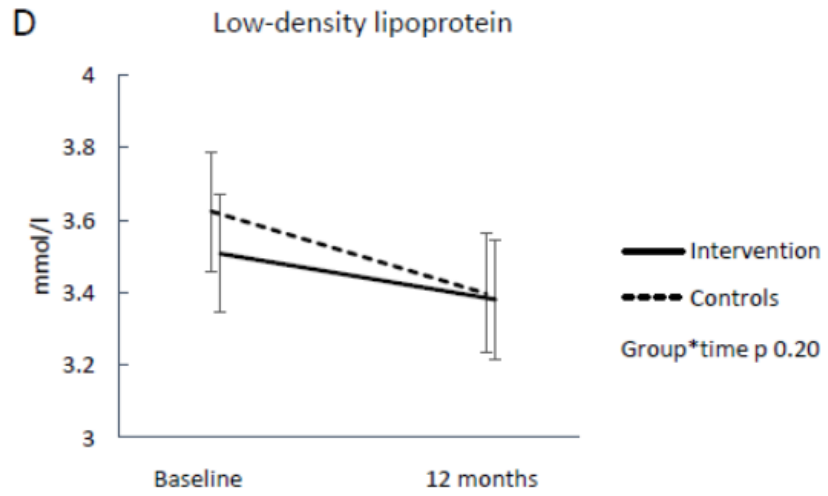
Results: metabolic health









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Leskinen T. et al., 2021, under review

Conclusions from REACT

- Short-term use up to 6 months, inactive and obese may benefit the most
- May decrease prolonged sedentary time, replaced with LPA
- No increase in / loss of daily MVPA
- No significant health effects, MVPA needed
- The long-term use of commercial activity tracker **alone** is not effective enought, more components are needed
- *Goal was too easy?*
- *Controls' "wear effect" / baseline measurements*
- *Thematic analysis in process….*

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