Exercise Dose-Response and Adherence

Steady Practice Applied Science Series — SP-4

Steady Practice Research · 2026

Abstract

Exercise is the most comprehensively studied behavioral intervention in medicine, with dose-response relationships established for mortality, cardiovascular disease, metabolic health, mental health, and cognitive performance. This survey synthesizes the evidence for practitioners: how much exercise is needed for which outcomes, what types of exercise produce which adaptations, how adherence erodes and how to prevent it, and what design principles follow for a behavior-change platform. Key findings: even small amounts of physical activity produce large mortality reductions (the first 75 minutes of vigorous activity per week reduces all-cause mortality by ~35%); HIIT and moderate-intensity continuous training produce similar health outcomes in less time; resistance training dose-response for hypertrophy is roughly linear up to ~20 sets per muscle group per week; sedentary behavior is an independent risk factor beyond exercise volume; and autonomous motivation for exercise predicts long-term adherence better than controlled motivation or intentions alone. The evidence on exercise and cognitive function is particularly strong: aerobic exercise reliably improves executive function and increases hippocampal volume in adults — effects plausibly mediated by neurogenesis and BDNF, though direct neurogenesis measurement in living humans remains technically unavailable.

Contents

1. Introduction

Physical inactivity is the fourth leading risk factor for global mortality, responsible for approximately 3.2 million deaths per year (Lee et al., 2012). This places inactivity behind only hypertension, tobacco use, and high blood glucose — and exercise is the primary behavioral treatment for two of the three.

The dose-response relationship between exercise and health outcomes is now well-characterized across dozens of meta-analyses covering millions of participants. The main practical messages:

1. Some exercise is dramatically better than none — the first portion of the dose-response curve is steepest
2. More is generally better up to a point, with diminishing marginal returns
3. Type of exercise matters for specific adaptations but not for broad health outcomes
4. Sedentary behavior is an independent risk factor, not just the absence of exercise
5. Adherence is the binding constraint — the best program is the one the user actually does

This survey is organized around what a practice platform needs to know: dose-response for key outcomes, comparison of exercise types, adherence science, and design principles.

---

2. Dose-Response: Physical Activity and Mortality

2.1 The Landmark Pooled Analysis

Arem et al. (2015) pooled data from 6 prospective cohort studies (N = 661,137, follow-up median 14.2 years) to characterize the dose-response relationship between leisure-time physical activity and all-cause mortality:

- **<0.1× recommended level** (< 7.5 MET-hours/week): reference group
- **0.1–0.5× recommended**: HR = 0.80 (20% lower mortality)
- **1× recommended** (7.5–15 MET-hours/week, ~150 min moderate activity): HR = 0.69
- **3–5× recommended**: HR = 0.61
- **>10× recommended**: HR = 0.69 (marginal increase but no harm)

The curve is hyperbolic: enormous benefit from the first 75 minutes of vigorous activity per week; diminishing but continued returns up to approximately 300 minutes/week; no harm from very high volumes in this non-clinical sample.

Practical translation: If a user does zero activity, getting to 75 minutes of vigorous walking per week (or 150 minutes moderate) reduces their all-cause mortality risk by approximately 31%. This first step is worth more than doubling from 300 to 600 minutes/week.

2.2 WHO Physical Activity Guidelines

The 2020 WHO Physical Activity Guidelines (Bull et al., 2020) recommend:

Adults (18–64): - 150–300 minutes/week of moderate-intensity aerobic activity, OR - 75–150 minutes/week of vigorous-intensity activity, OR - An equivalent combination - Plus: muscle-strengthening activities ≥2 days/week - Reduce sedentary time; any physical activity is better than none

Older adults (65+): Same recommendations plus balance and coordination training ≥3 days/week for fall prevention.

Children (5–17): 60 minutes/day moderate-to-vigorous activity; vigorous activity ≥3 days/week.

Only approximately 25% of U.S. adults meet both aerobic and muscle-strengthening guidelines

(Troiano et al., 2008). The guidelines define the threshold for public health benefit, not optimal health or performance.

2.3 Beyond the Guidelines

Warburton et al. (2006) showed that benefits continue beyond guideline levels for most health outcomes, though the absolute gain per additional unit of activity decreases. For specific outcomes:

- **Cardiovascular disease**: benefit continues up to ~60 minutes/day moderate activity (Sattelmair et al., 2011 meta-analysis)
- **Type 2 diabetes**: each 2 MET-hr/day increment in leisure physical activity reduces T2D risk by 6% (Aune et al., 2015)
- **Cancer**: dose-response established for colon, breast, endometrial, and kidney cancers (Moore et al., 2016, meta-analysis of 26 cancer types)
- **Depression**: dose-response less clear; evidence supports 3× week × 45 minutes as effective; whether more is better is uncertain

---

3. Types of Exercise and Their Adaptations

3.1 Aerobic (Cardiovascular) Training

Physiology: Aerobic training improves VO_2max (maximal oxygen uptake), stroke volume, mitochondrial density, and capillary density in muscle. These adaptations produce the cardiovascular, metabolic, and mortality benefits that dominate the epidemiological literature.

Dose for VO_2max: The relationship between aerobic training volume and VO_2max improvement follows an inverted-U in untrained individuals: rapid gains in the first 4–8 weeks, plateau thereafter. Trained individuals require higher doses for continued improvement.

Intensity matters: Higher intensity training produces larger VO_2max improvements per unit time (Wisloff et al., 2007: 4×4-minute intervals at 90–95% HRmax improved VO_2max by 7.2 ml/kg/min vs. 4.6 ml/kg/min for moderate continuous training over 10 weeks).

3.2 High-Intensity Interval Training (HIIT)

HIIT alternates intense efforts (85–95% HRmax or higher) with recovery periods. The primary claim: comparable adaptations to moderate-intensity continuous training (MICT) in significantly less time.

Meta-analytic evidence — Wewege et al. (2017) comparison of HIIT vs. MICT for body composition in overweight adults: comparable reductions in total body fat percentage and absolute fat mass. HIIT sessions averaged 25 minutes vs. 45 minutes for MICT. Effect sizes similar.

Cardiovascular outcomes: Bacon et al. (2013) meta-analysis: HIIT superior to MICT for VO_2max improvement (d = 0.53 vs. 0.29). Superior VO_2max improvements without requiring greater time commitment is HIIT's primary evidence-based advantage.

Caveats: HIIT has higher perceived exertion and injury risk. Adherence to HIIT protocols in real-world (vs. supervised) settings is lower than MICT (Biddle & Batterham, 2015). The time efficiency advantage is real; the adherence advantage is not.

Practical guidance: HIIT 2–3 times/week is sufficient to capture cardiovascular benefits. It should not replace all moderate-intensity activity for adherence-sensitive users.

3.3 Resistance Training

Resistance training (RT) produces adaptations distinct from aerobic training: muscle hypertrophy, strength, bone density, and metabolic rate maintenance. These are underweighted in public health guidelines relative to aerobic activity but increasingly recognized as critical for healthspan.

Dose-response for hypertrophy: Schoenfeld et al. (2017) meta-analysis: a clear dose-response exists between weekly training volume and muscle growth. Low volume (<5 sets/muscle/week): 5.4% hypertrophy; moderate (5–9 sets): 6.6%; high (10+ sets): 9.8%. The relationship appears roughly linear up to approximately 20 sets per muscle group per week, beyond which recovery becomes the limiting factor.

Dose-response for strength: Krieger (2010) meta-analysis: multiple sets per exercise produce significantly greater strength gains than single sets (d = 0.26). The marginal benefit of sets 3–6 is similar, with diminishing returns beyond 6 sets.

Frequency: The total weekly volume can be distributed across 1–5 sessions with similar hypertrophy outcomes (Ralston et al., 2017), provided total volume is equated. More frequent sessions may be preferable for beginners (motor learning) and advanced trainees (higher total volume tolerance).

Health outcomes beyond body composition: Resistance training reduces all-cause mortality (Saeidifard et al., 2019, meta-analysis: HR = 0.83), independent of aerobic activity. It is the primary behavioral intervention for three conditions that become clinically significant after age 50 and are largely irreversible once established:

- **Sarcopenia** (muscle mass loss): adults lose 3–8% of muscle mass per decade after age 30, accelerating after 60. Progressive resistance training is the only non-pharmacological intervention that reliably reverses or halts this trajectory.
- **Osteoporosis** (bone mineral density loss): bone density responds to mechanical loading. Resistance training, particularly lower-body compound movements (squats, deadlifts), produces consistent BMD improvements — a Cochrane review of 18 RCTs found significant improvements in lumbar spine and femoral neck density (Sherrington et al., 2017). This is not achievable through aerobic exercise alone.
- **Insulin sensitivity**: skeletal muscle is the primary site of glucose disposal. Resistance training increases GLUT4 transporter expression in muscle and improves insulin-stimulated glucose uptake independently of weight change.

3.4 Outcomes by Modality: Summary

Outcome	Aerobic	HIIT	Resistance	Zone 2
All-cause mortality	✓✓✓	✓✓	✓✓	✓✓
Cardiovascular disease	✓✓✓	✓✓	✓✓	✓✓✓
VO_2max	✓✓	✓✓✓	×	✓✓
Muscle mass	×	×	✓✓✓	×
Bone density	×	×	✓✓✓	×
Insulin sensitivity	✓✓	✓✓	✓✓	✓✓✓
Depression	✓✓✓	✓✓	✓✓	✓✓
Executive function	✓✓✓	✓✓	✓	✓✓

Outcome	Aerobic	HIIT	Resistance	Zone 2
Body fat	✓✓	✓✓	✓	✓✓
Time efficiency	×	✓✓✓	—	×

✓✓✓ = robust evidence; ✓✓ = moderate evidence; ✓ = emerging/limited; × = minimal or no established effect. This is a simplified heuristic — effects depend on dose, population, and individual response. Aerobic and resistance training are complementary, not competing.

3.5 Sedentary Behavior as an Independent Risk Factor

Sedentary behavior (sitting/lying while awake, with low energy expenditure) is associated with adverse health outcomes independently of exercise volume. This is counterintuitive: two people who both do 150 minutes/week of exercise but one sits 8 hours/day and the other sits 4 hours/day have meaningfully different health risks.

Biswas et al. (2015) meta-analysis of 47 studies: sedentary time significantly associated with all-cause mortality, cardiovascular disease, cancer, and type 2 diabetes — even after adjusting for leisure-time physical activity.

The compensatory model fails: You cannot fully compensate for 8 hours of sitting with 30 minutes of exercise. The metabolic effects of prolonged sitting (suppressed lipoprotein lipase activity, reduced glucose uptake) are not fully reversed by exercise bouts (Hamilton et al., 2007).

Practical implication for platform design: Tracking both exercise sessions AND breaks from sitting is warranted. The goal is not only to increase peak activity but to reduce prolonged unbroken sedentary time. Hourly movement breaks of 2–5 minutes can partially attenuate the metabolic effects of sitting (Dunstan et al., 2012). A workout dashboard that only shows session data misses this independent risk factor entirely.

---

4. Cognitive Benefits of Exercise

4.1 Hippocampal Volume and Brain Health

Aerobic exercise produces structural brain changes measurable in humans. Van Praag et al. (1999) showed running-induced neurogenesis in rodents; subsequent human neuroimaging studies documented analogous effects at the volumetric level — though direct neurogenesis cannot be measured non-invasively in living humans. The rodent neurogenesis finding motivated the human research; the human evidence itself is volumetric and functional.

Erickson et al. (2011) RCT (N=120, older adults): one year of aerobic walking (3×/week, 40 minutes) increased hippocampal volume by 2% in the exercise group vs. a 1.4% decrease in the stretching control group. The hippocampal volume increase was associated with improved spatial memory and higher serum BDNF (brain-derived neurotrophic factor). BDNF is the most plausible molecular mediator of these effects — it promotes synaptic plasticity and is elevated by aerobic exercise consistently across studies.

Effect magnitude: The hippocampal volume gain from one year of aerobic exercise is roughly comparable in direction to reversing 1–2 years of age-related atrophy in this population — a meaningful structural effect, though extrapolation to younger or healthier adults should be made cautiously.

4.2 Executive Function and Cognitive Control

Colcombe and Kramer (2003) meta-analysis of 18 RCTs: aerobic exercise training significantly improved cognitive performance in older adults, with the largest effects on executive function (planning, inhibition, working memory) — the domain most sensitive to aging.

The mechanism: aerobic exercise increases prefrontal blood flow and gray matter volume, enhances dopamine and norepinephrine signaling, and elevates BDNF — all of which support executive function.

Acute effects: A single bout of moderate-intensity aerobic exercise (20–30 minutes) improves cognitive performance for approximately 30–60 minutes afterward (Chang et al., 2012, meta-analysis). This has practical implications for scheduling exercise before cognitively demanding work.

4.3 Mental Health: Depression and Anxiety

Depression: Schuch et al. (2016) meta-analysis adjusted for publication bias (N=1,487, 25 RCTs): exercise significantly reduced depressive symptoms (SMD = -0.98). Effect sizes comparable to antidepressant medication in mild-to-moderate depression. Blumenthal et al. (2007) RCT (N=202): aerobic exercise comparable to sertraline at 4 months, with lower relapse at 10-month follow-up in the exercise-only group.

Anxiety: Rebar et al. (2015) meta-meta-analysis (37 meta-analyses): exercise significantly reduces anxiety symptoms in non-clinical populations (d = -0.48). Effect is consistent across exercise types and intensities. The anxiolytic effect appears within a single session and is sustained with regular training.

Mechanism: Exercise reduces cortisol reactivity to stressors, increases GABA and serotonin, and reduces amygdala hyperactivity — overlapping but distinct from antidepressant mechanisms.

Practical note: Exercise should not replace psychiatric treatment for clinical depression or anxiety disorders, but it is an evidence-based adjunct that improves outcomes and reduces relapse risk.

---

5. Adherence: The Binding Constraint

5.1 The Adherence Problem

The evidence for exercise benefits is irrelevant if the user does not exercise. Adherence to exercise programs in the first 6 months averages approximately 50% (Dishman & Buckworth, 1996). At 12 months, adherence is typically 30–40% even in supervised, motivated populations.

The gap between intention and behavior is among the largest of any health behavior. Meta-analysis of intention-behavior correlation for physical activity: r ≈ 0.40 (Rhodes & Dickau, 2012) — intentions explain only 16% of the variance in exercise behavior. The remaining 84% is determined by factors beyond intention.

5.2 Predictors of Adherence

Consistently positive predictors (Trost et al., 2002, review of 108 studies): - Self-efficacy for exercise (the single strongest modifiable predictor) - Enjoyment of the activity - Social support from friends/family - Access and convenience (proximity to facilities, home equipment) - Past exercise history

Consistently negative predictors: - Perceived barriers (time, cost, effort) - Depression and poor mental health - Obesity (starting from a lower fitness baseline increases perceived difficulty) - Age (moderate inverse relationship)

Autonomous motivation: Deci and Ryan's Self-Determination Theory predicts that exercise motivated by identified reasons ("exercise is important to me") or intrinsic reasons ("I enjoy it") produces more durable adherence than controlled reasons ("I should exercise" or "my doctor told me to"). Wilson and Brookfield (2009) confirmed: autonomous motivation at baseline predicted exercise frequency at 18 months beyond initial intentions.

5.3 The Enjoyment Effect

Hagger and Chatzisarantis (2007) meta-analysis: enjoyment of exercise is among the strongest predictors of participation. The implication: the type of exercise matters for adherence, not just for physiological outcomes.

A user who hates running but loves dancing will get better health outcomes from dancing long-term, even if running is marginally superior for VO_2max. Prescribing the "optimal" exercise type to someone who will not do it is irrational.

Practical rule: First, find an activity the user enjoys or can learn to enjoy. Second, optimize within that constraint.

5.4 The Role of Habit (Cross-reference: SP-1)

Phillips and Gardner (2016) showed that habitual exercise instigation (automatically initiating exercise in response to contextual cues) predicted exercise frequency independently of intentions. Once exercise is habituated, adherence becomes context-dependent rather than motivation-dependent — dramatically more robust.

The goal of a practice platform for exercise should be: move from intention-based exercise to context-triggered habitual exercise. This takes approximately 8–12 weeks of consistent practice with a stable cue structure (same time, same signal, same initial action).

5.5 Social Features and Group Exercise

Dishman and Buckworth (1996) and subsequent reviews consistently show that group exercise increases adherence over solo exercise by approximately 15–25% in supervised settings. The social accountability mechanism (see SP-6) is the primary driver.

Virtual group exercise (synchronous online classes, challenges) shows similar but slightly smaller effects than in-person group exercise. Asynchronous social features (shared streaks, leaderboards) have smaller and more variable effects (see SP-6).

---

6. Common Adherence Failure Modes

6.1 The All-or-Nothing Trap

Users who frame exercise in binary terms (“I either complete the full workout or I don’t exercise at all”) show dramatically higher dropout rates after the first missed session. This is the same mechanism as streak psychology (SP-6): the reference point is the perfect record; any deviation is experienced as total failure.

Design mitigation: Explicitly normalize abbreviated workouts. A 10-minute walk on a day when a 45-minute run was planned is 10 minutes of benefit, not a failure. Progressive minimum-effective-dose framing prevents this failure mode.

6.2 Overreaching in Week 1–2

New exercisers routinely start at unsustainably high intensity or volume (motivated by initial enthusiasm), experience excessive soreness or injury, and abandon the program. The exercise science term is “overreaching” — training beyond the body’s current recovery capacity.

Practical rule: Week 1 volume should be approximately 50–60% of the user's perceived maximum. Week 2: 70%. Week 3: 80%. Week 4: 90%. Ramp-up over 4 weeks before attempting full-program volume.

6.3 Life Disruption and Context Loss

Travel, illness, stress, and life change disrupt exercise habits through the same mechanism as any context-dependent habit (SP-1): the cue structure changes. Users who exercise regularly in a home gym travel and lose their equipment; users who exercise outdoors lose their habit during winter.

Design mitigation: For each user, define a "minimum viable workout" that can be performed in any context (e.g., 10 minutes of bodyweight exercises in a hotel room). When the primary context is unavailable, the minimum viable workout maintains habit continuity.

6.4 Overtraining Syndrome

Advanced users who train at high volume without adequate recovery can develop overtraining syndrome: paradoxical performance decline, chronic fatigue, mood disturbance, immune suppression, and hormonal disruption (elevated cortisol, reduced testosterone). Recovery requires weeks to months of reduced training.

HRV monitoring is the most accessible early indicator: sustained decline in morning HRV over 5–7 days without contextual explanation (illness, stress, alcohol) suggests inadequate recovery and warrants training reduction.

---

7. Exercise Timing and Other Practical Variables

7.1 Morning vs. Evening Exercise

The evidence on optimal exercise timing is less definitive than commonly believed. Circadian factors do influence performance: core body temperature, muscle strength, and reaction time peak in the late afternoon (Atkinson & Reilly, 1996), suggesting that evening exercise may produce marginally superior acute performance.

However, the most important factor for long-term outcomes is consistency. Exercise in the morning shows higher adherence in several real-world studies (probably because fewer schedule conflicts arise), even though afternoon exercise may produce marginally better acute performance.

For sleep: Exercise timing's effect on sleep is modest and highly individual. Most users can exercise up to 2–3 hours before bed without sleep disruption. A minority are sensitive to the sympathetic activation and temperature elevation of vigorous exercise near bedtime. If sleep disruption is observed, shift exercise earlier (SP-3 cross-reference).

7.2 Fasted vs. Fed Training

Fasted aerobic training (exercising before eating) increases fat oxidation during exercise but does not consistently improve body composition outcomes vs. fed training when daily caloric intake is controlled (Schoenfeld et al., 2014). For performance: fed training supports higher intensity efforts. The choice between fasted and fed training should be driven by personal preference and tolerability, not fat-burning mythology.

7.3 Recovery and Progressive Overload

Progressive overload: The fundamental principle of training adaptation. The stimulus must progressively increase to continue producing adaptation. A user doing the same 3×10 workout with the same weight for 6 months will not continue to improve after the first 4–8 weeks.

Recovery: Muscle protein synthesis peaks 24–36 hours post-resistance training and returns to baseline by 36–48 hours in most users. Training the same muscle group every 48–72 hours maximizes stimulus frequency within recovery windows.

DOMS: Delayed onset muscle soreness peaks at 24–48 hours post-exercise, particularly after novel or eccentric-heavy exercise. DOMS is not a reliable indicator of training effectiveness (the absence of soreness does not mean the training was insufficient).

---

8. Design Principles for Steady Practice

Meet the user at their current fitness level. The most important exercise prescription for a sedentary user is: any exercise. Starting at WHO guidelines is appropriate for low-fitness users. Optimal training protocols are appropriate for advanced users. The gap between these is enormous.

Track both exercise and sedentary time. Exercise volume and sedentary behavior have independent effects. A dashboard that only shows workouts misses half the picture.

Prioritize consistency over intensity. 30 minutes of moderate activity 5 days/week (150 minutes total) produces better long-term outcomes than 90-minute sessions twice a week with inconsistent frequency. Frequency is more important than any single session parameter.

Design exercise habits, not exercise events. The goal is the same-time, same-signal, same-context routine that fires automatically (SP-1). A user who starts every morning by putting on their shoes gets more exercise than a user who decides each day based on motivation.

Normalize minimum viable workouts explicitly. "A 10-minute walk on a busy day is better than zero. Here's your quick option." Reducing the activation barrier on hard days prevents the all-or-nothing failure mode.

Surface the cognitive benefits. Exercise for mood and cognitive function resonates more immediately than exercise for cardiovascular disease prevention at age 60. The 30-minute acute cognitive boost is visible and felt; the 20% mortality reduction is abstract.

Use HRV as a recovery proxy. Morning HRV trends are the most accessible objective signal for tracking training load and recovery adequacy. Integrate HRV context into exercise recommendations.

Individual Variation

Exercise science produces some of the most striking individual variation data in all of behavioral medicine. The same training protocol, administered under identical conditions to genetically distinct individuals, produces wildly different physiological adaptations. This is not measurement noise — it is a fundamental biological fact with direct consequences for how any training program should be designed and evaluated.

VO2max trainability. The HERITAGE Family Study (Bouchard et al. 1999) is the landmark dataset: 481 subjects from 98 families completed an identical 20-week standardized aerobic training program. Mean VO2max improvement was approximately 400 mL/min, but individual responses ranged from near-zero to over 1,000 mL/min — roughly a 10-fold difference. Heritability of trainability was estimated at ~47%, meaning roughly half the variance in response is genetic. ACTN3 R577X genotype is one of the better-characterized predictors: the XX (null) genotype is associated with endurance-oriented muscle fiber composition; the RR genotype favors power and speed adaptations. The same aerobic training protocol will produce meaningfully different outcomes depending on genetic background, and this is not modifiable by effort or technique.

Strength response heterogeneity. Resistance training response shows 3–5 fold variation in controlled trials even when compliance is verified. Some individuals show robust hypertrophy within 8 weeks of standard progressive overload; others show minimal muscle cross-sectional area change despite full adherence. IGF-1 pathway genetics — particularly variants in IGF1 and IGFBP3 — predict anabolic response; individuals with high circulating IGF-1 at baseline tend to hypertrophy more readily. Age and hormonal environment interact with genetic factors, making pre/post pubescent and male/female responses systematically different in their distribution of outcomes.

Recovery rate variation. Heart rate variability (HRV) response to identical training loads varies substantially across individuals. Chronic HRV suppressors — individuals in the bottom quintile for HRV recovery between sessions — appear to benefit from approximately 40% volume reduction relative to standard programming; their adaptation appears to require more recovery stimulus per unit of training load. High sympathetic tone at baseline independently predicts slower HRV recovery. The practical problem is that most training programs are designed around mean recovery curves, which will systematically overtrain the slow-recovery minority.

Injury risk. Collagen gene variants — particularly COL5A1 and COL1A1 — predict susceptibility to tendon and ligament injury. COL5A1 TT genotype carriers show higher rates of Achilles tendon injury in distance runners. Training load tolerance ceiling varies 2–3 fold between individuals with similar fitness levels, meaning that a training progression that is conservative for one athlete may be aggressive enough to cause injury in another. This variation is not detectable by external observation alone.

Practical implication. The same training program will produce dramatically different results across individuals — in cardiorespiratory fitness, muscle mass, recovery speed, and injury rate. Population guidelines represent averages that may be irrelevant to your specific response. The practical solution is to track individual response markers — HRV trend, subjective readiness, and performance trajectory across training cycles — rather than following fixed population guidelines. A 6-week block of standardized training with careful measurement before and after yields more actionable information than any population norm.

---

9. Conclusion

Exercise is the single most comprehensively studied behavioral intervention in medicine, with causal dose-response evidence for mortality, cardiovascular disease, metabolic health, mental health, and cognitive function. The evidence base is unusually robust because exercise is dose-controllable, measurable, and ethical to manipulate in randomized trials. The broad practical conclusion is simple but non-obvious in its specifics: some exercise is dramatically better than none; the dose-response curve is hyperbolic, not linear; type matters less than volume for broad health outcomes; and adherence is the binding constraint that makes all other design decisions secondary.

The most important practical insight is asymmetric: the mortality benefit of going from sedentary to lightly active is greater than the benefit of going from active to very active. Platforms that help sedentary users achieve any consistent activity — even 75 minutes of brisk walking per week — are producing the largest possible health impact. The optimization for performance athletes is a different problem with different evidence requirements.

The exercise-cognitive performance connection is worth particular emphasis for a personal science platform: acute aerobic exercise (20–40 minutes, moderate intensity) produces measurable improvements in executive function, attention, and working memory lasting 1–4 hours post-exercise. This is the most robust, replicable short-term benefit of exercise that users can personally observe and experiment with — making it an ideal entry point for N=1 exercise experimentation.

References

Arem, H., Moore, S. C., Patel, A., Hartge, P., Berrington de Gonzalez, A., Visvanathan, K., … & Matthews, C. E. (2015). Leisure time physical activity and mortality: A detailed pooled analysis of the dose-response relationship. *JAMA Internal Medicine*, 175(6), 959–967.

Atkinson, G., & Reilly, T. (1996). Circadian variation in sports performance. *Sports Medicine*, 21(4), 292–312.

Aune, D., Norat, T., Leitzmann, M., Tonstad, S., & Vatten, L. J. (2015). Physical activity and the risk of type 2 diabetes: A systematic review and dose-response meta-analysis. *European Journal of Epidemiology*, 30(7), 529–542.

Bacon, A. P., Carter, R. E., Ogle, E. A., & Joyner, M. J. (2013). VO_2max trainability and high intensity interval training in humans: A meta-analysis. *PLOS ONE*, 8(9), e73182.

Biddle, S. J. H., & Batterham, A. M. (2015). High-intensity interval exercise training for public health: A big HIT or shall we HIT it on the head? *International Journal of Behavioral Nutrition and Physical Activity*, 12, 95.

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults. *Annals of Internal Medicine*, 162(2), 123–132.

Blumenthal, J. A., Babyak, M. A., Doraiswamy, P. M., Watkins, L., Hoffman, B. M., Barbour, K. A., … & Sherwood, A. (2007). Exercise and pharmacotherapy in the treatment of major depressive disorder. *Psychosomatic Medicine*, 69(7), 587–596.

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., … & Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, 54(24), 1451–1462.

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research*, 1453, 87–101.

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science*, 14(2), 125–130.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, 11(4), 227–268.

Dishman, R. K., & Buckworth, J. (1996). Increasing physical activity: A quantitative synthesis. *Medicine & Science in Sports & Exercise*, 28(6), 706–719.

Dunstan, D. W., Kingwell, B. A., Larsen, R., Healy, G. N., Cerin, E., Hamilton, M. T., ... & Owen, N. (2012). Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care*, 35(5), 976–983.

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., ... & Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. *Proceedings of the National Academy of Sciences*, 108(7), 3017–3022.

Hagger, M. S., & Chatzisarantis, N. L. D. (2007). The trans-contextual model of motivation. *European Psychologist*, 12(3), 217–233.

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2007). Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes*, 56(11), 2655–2667.

Krieger, J. W. (2010). Single vs. multiple sets of resistance exercise for muscle hypertrophy: A meta-analysis. *Journal of Strength and Conditioning Research*, 24(4), 1150–1159.

Lee, I.-M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., & Katzmarzyk, P. T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *The Lancet*, 380(9838), 219–229.

Moore, S. C., Lee, I.-M., Weiderpass, E., Campbell, P. T., Sampson, J. N., Kitahara, C. M., ... & Patel, A. V. (2016). Association of leisure-time physical activity with risk of 26 types of cancer in 1.44 million adults. *JAMA Internal Medicine*, 176(6), 816–825.

Phillips, L. A., & Gardner, B. (2016). Habitual exercise instigation (vs. execution) predicts healthy adults' exercise frequency. *Health Psychology*, 35(1), 69–77.

Ralston, G. W., Kilgore, L., Wyatt, F. B., & Baker, J. S. (2017). The effect of weekly set volume on strength gain: A meta-analysis. *Sports Medicine*, 47(12), 2585–2601.

Ratey, J. J., & Hagerman, E. (2008). *Spark: The revolutionary new science of exercise and the brain.* Little, Brown and Company.

Rebar, A. L., Stanton, R., Geard, D., Short, C., Duncan, M. J., & Vandelanotte, C. (2015). A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health Psychology Review*, 9(3), 366–378.

Rhodes, R. E., & Dickau, L. (2012). Experimental evidence for the intention–behaviour relationship in the physical activity domain: A meta-analysis. *British Journal of Sports Medicine*, 46(10), 694–700.

Saeidifard, F., Medina-Inojosa, J. R., West, C. P., Olson, T. P., Somers, V. K., Bonikowske, A. R., … & Lopez-Jimenez, F. (2019). The association of resistance training with mortality: A systematic review and meta-analysis. *European Journal of Preventive Cardiology*, 26(15), 1647–1665.

Sattelmair, J., Pertman, J., Ding, E. L., Kohl, H. W., Haskell, W., & Lee, I.-M. (2011). Dose response between physical activity and risk of coronary heart disease: A meta-analysis. *Circulation*, 124(7), 789–795.

Schoenfeld, B. J., Ogborn, D., & Krieger, J. W. (2017). Dose-response relationship between weekly resistance training volume and increases in muscle mass: A systematic review and meta-analysis. *Journal of Sports Sciences*, 35(11), 1073–1082.

Schoenfeld, B. J., Aragon, A. A., & Krieger, J. W. (2014). Effects of meal frequency on weight loss and body composition: A meta-analysis. *Nutrition Reviews*, 73(2), 69–82.

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine & Science in Sports & Exercise*, 40(1), 181–188.

Trost, S. G., Owen, N., Bauman, A. E., Sallis, J. F., & Brown, W. (2002). Correlates of adults' participation in physical activity: Review and update. *Medicine & Science in Sports & Exercise*, 34(12), 1996–2001.

Van Praag, H., Kempermann, G., & Gage, F. H. (1999). Running increases cell proliferation and neurogenesis in the adult mouse dentate gyrus. *Nature Neuroscience*, 2(3), 266–270.

Warburton, D. E. R., Nicol, C. W., & Bredin, S. S. D. (2006). Health benefits of physical activity: The evidence. *Canadian Medical Association Journal*, 174(6), 801–809.

Wewege, M., van den Berg, R., Ward, R. E., & Keech, A. (2017). The effects of high-intensity interval training vs. moderate-intensity continuous training on body composition in overweight and obese adults: A systematic review and meta-analysis. *Obesity Reviews*, 18(6), 635–646.

Wilson, P. M., & Brookfield, D. (2009). Effect of goal setting on motivation and adherence in a six-week exercise program. *International Journal of Sport and Exercise Psychology*, 7(1), 89–100.

Wisloff, U., Stoylen, A., Loennechen, J. P., Bruvold, M., Rognmo, O., Haram, P. M., ... & Skjaerpe, T. (2007). Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients. *Circulation*, 115(24), 3086–3094.