

Reference: Alexiou, H., & Coutts, A. J. (2008). A Comparison of Methods Used for Quantifying Internal Training Load in Women Soccer Players. *International Journal of Sports Physiology and Performance*, 3(3), 320-330.

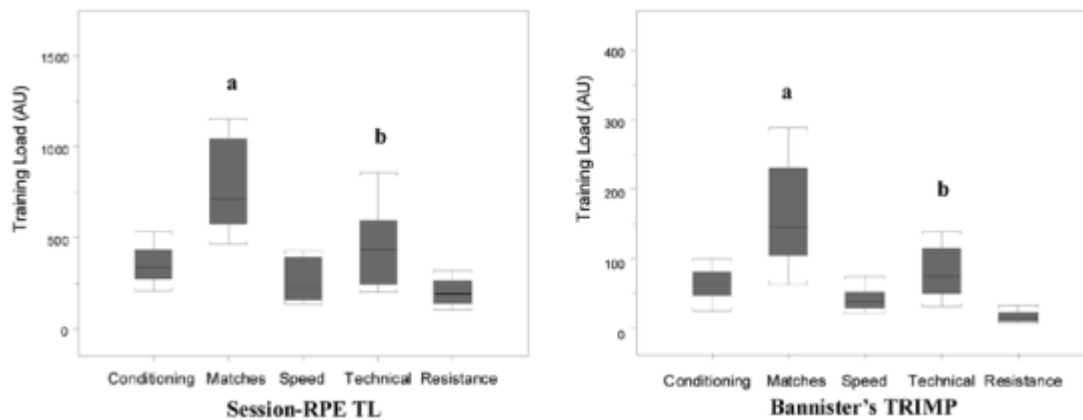


Figure 1: Box plots for session-RPE (left) and the Heart Rate-based training load quantification Bannister's TRIMP (right). The edges of the box plots represent the quartile range and the whiskers show the 10th and 90th percentiles. a = Significant different to resistance training, speed training, and conditioning training ($P < .001$); b = Significantly different to resistance training sessions ($P < .001$).

Table 3: Correlation Coefficients for Session-RPE Training Load (TL) and HR-Based TL Methods Separated by Session Type

	Bannister's TRIMP		
	<i>r</i>	N	P
Conditioning	0.74	139	<0.001
Matches	0.49	65	<0.001
Speed	0.61	59	<0.001
Technical	0.68	230	<0.001
Resistance	0.25	242	<0.001

Context: Figure 1 and Table 3 are extracted from the study by Alexiou & Coutts (2008), which examined the use of different internal training load (TL) measures in elite women's soccer. The study compared a subjective method; session Rating of Perceived Exertion (sRPE) with an objective, heart rate-based method (Bannister's TRIMP).

Figure 1 presents the internal load values for both sRPE and Bannister's TRIMP across different session types: conditioning, speed, technical, resistance, and matches. In this context, "conditioning" refers specifically to aerobic conditioning sessions, while "resistance" refers to strength training sessions. Table 3 presents the correlation coefficients (r-values) between sRPE and TRIMP for each session type, illustrating how closely aligned these two metrics are depending on the type of session.

Question:

1. Using Figure 1, describe and interpret how session type (conditioning, speed, technical, resistance, match play) influences the magnitude of internal training load, as reflected by both sRPE-TL and TRIMP. What does the pattern across the two panels suggest about how these two methods compare to one another in capturing training load?
2. Discuss possible explanations for the observed differences (Table 3) in correlation between conditioning training and resistance training.

Sensor guide:

1. The magnitude of internal TL as measured by both session-RPE (sRPE) and Banister's TRIMP is clearly influenced by the type of training session, as shown in Figure 1. Figure 1 shows a consistent pattern across both internal load measures: match play produced the greatest training load, significantly higher than conditioning, speed, and resistance sessions ($P < .001$, label "a"). Technical training produced the second-highest load, significantly greater than resistance training alone (label "b"). Conditioning and speed sessions elicited intermediate, broadly similar loads to one another. Resistance training consistently produced the lowest load on both panels, with the narrowest interquartile range, indicating both a lower average load and less session-to-session variability compared with the other training types.

This ranking — matches > technical > conditioning $\approx$ speed > resistance — holds for both sRPE-TL and TRIMP, indicating that session type influences the two methods in a similar way. This suggests that, at the level of average load across session types, sRPE and TRIMP broadly agree on which training modes are most and least demanding.

2. The difference in correlation between sRPE and TRIMP for conditioning ($r = 0.74$) and resistance training ($r = 0.25$) can be explained by the nature of the physiological load in each session type. Aerobic conditioning sessions leads to a sustained and proportional increase in heart rate. As a result, TRIMP, which is based on heart rate data, aligns closely with perceived exertion (sRPE), resulting in a strong correlation. In contrast, resistance training relies heavily on muscular and neuromuscular load, often without a corresponding rise in heart rate. TRIMP could therefore underestimate the load compared to sRPE, leading to a weaker correlation. In addition, the narrow range in training load values for resistance training (shown in Figure 1) reflects low variability in this session type, which can potentially limit the strength of the correlation coefficient, as correlation depends on sufficient spread across the data to detect a consistent relationship between sRPE and TRIMP.

Rubric/points:

	Component	Points	What earns full mark
Question:			
Q1	Ranking identified	1	States matches highest, technical second, resistance lowest, on both panels
Q1	Significance interpretation	1	Correctly explains "a" (matches > resistance, speed, conditioning) and "b" (technical > resistance) — 1 mark each
Q1	Consistency across methods	1	Notes the ranking pattern holds for both sRPE and TRIMP
Q1	Spread/variability	1	Notes resistance training has the narrowest IQR/whiskers
Q1	Comparison between sRPE and TRIMP	2	Notes that level of average load across session types, sRPE and TRIMP broadly agree on which training modes are most and least demanding.
Q2	Correctly states the contrast	1	Identifies $r = 0.74$ (conditioning) vs $r = 0.25$ (resistance) as the pattern to explain
Q2	Explains why HR-based TRIMP may not track effort well in resistance training	2	HR less responsive to intermittent/muscular strain vs sustained aerobic work
Q2	Methodological explanation	1	Restricted range/lower variability in resistance training load as a statistical reason correlation weakens

The physiology of high-intensity exercise

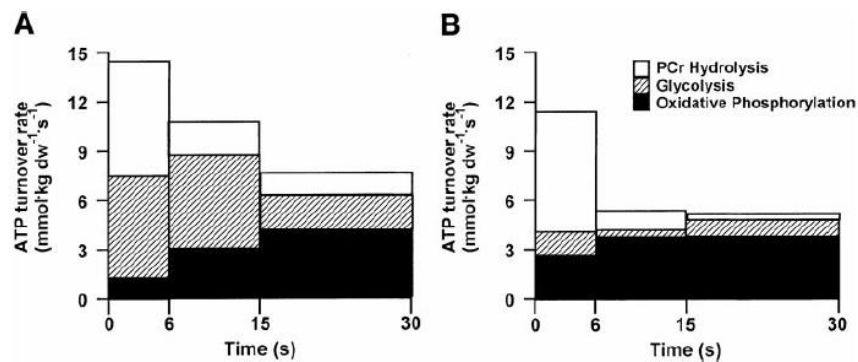
Reference :

Parolin, M. L., Chesley, A., Matsos, M. P., Spriet, L. L., Jones, N. L., & Heigenhauser, G. J. (1999). Regulation of skeletal muscle glycogen phosphorylase and PDH during maximal intermittent exercise. *American Journal of Physiology*, 277(5), E890-900.

Article excerpt:

Parolin et al (1999):

Fig. 7. ATP turnover rates from PCr hydrolysis, glycolysis, and oxidative phosphorylation during each time interval in the first (A) and third (B) bouts of maximal isokinetic cycling.



Context

In Parolin et al. (1999), participants performed three 30-second all-out cycling bouts separated by 4 minutes of passive recovery. Muscle biopsies were obtained before exercise and after 6, 15 and 30 seconds during the first (Figure 7A) and third bout (Figure 7B). Using muscle metabolite measurements, the authors estimated ATP turnover from:

- Phosphocreatine (PCr) hydrolysis
- Glycolysis
- Oxidative phosphorylation

Figure 7 shows the ATP turnover rates from these three energy systems during different periods of the first and third exercise bout.

Questions

Using Figure 7 in Parolin et al. (1999), answer the following:

1. During the first 6 seconds of the first 30-second sprint (Figure 7A), which energy system contributes most to ATP turnover? Approximately how large is the contribution from each of the three energy systems?
2. How does the relative contribution of PCr hydrolysis, glycolysis, and oxidative phosphorylation change from the beginning (0–6 s) to the end (15–30 s) of the first sprint? Explain the physiological reasons for these changes.
3. Compare the first 6 seconds of sprint 1 (Figure 7A) and sprint 3 (Figure 7B). Which ATP-producing pathway shows the largest reduction, and why?

Answer guide

Exact numbers are not needed to get full score, but directional changes and approximations are needed.

1. During the first 6 seconds of sprint 1, ATP turnover is supplied mainly by PCr hydrolysis and glycolysis, while the oxidative contribution is relatively small.
 - PCr hydrolysis: 48% or $\sim 7 \text{ mmol ATP} \cdot \text{kg dw}^{-1} \cdot \text{s}^{-1}$
 - Glycolysis: 43% or $\sim 6 \text{ mmol ATP} \cdot \text{kg dw}^{-1} \cdot \text{s}^{-1}$
 - Oxidative phosphorylation: 9% or $\sim 1\text{--}1.5 \text{ mmol ATP} \cdot \text{kg dw}^{-1} \cdot \text{s}^{-1}$
2. From the start to the end of sprint 1:
 - ATP turnover from **PCr hydrolysis decreases markedly** because PCr stores become depleted.
 - ATP turnover from **glycolysis decreases** because glycogenolysis/glycolytic flux is progressively inhibited and because a greater proportion of pyruvate is oxidized in the mitochondria rather than converted to lactate.
 - ATP turnover from **oxidative phosphorylation increases** as mitochondrial ATP production becomes more fully activated.
 - Summary: As a result, the relative importance of oxidative phosphorylation increases throughout the sprint, whereas the contribution from anaerobic pathways declines.

3. The pathway showing the largest reduction from sprint 1 to sprint 3 is **glycolysis**.

During sprint 3:

- Glycolytic ATP production is greatly reduced.
- PCr hydrolysis is reduced, but not as dramatically.
- Oxidative phosphorylation is increased.

The main explanation is that metabolites accumulated during previous sprints (particularly H^+ /acidosis) inhibit glycogenolysis and glycolytic ATP production. At the same time, mitochondrial metabolism is already activated, allowing a greater proportion of pyruvate to be oxidized rather than converted to lactate. Lastly, 4 minutes rest between sprints allows PCr stores to be recovered well.

Seminar title: The application of sport science knowledge in elite sport practice

Reference: Fullagar HHK, McCall A, Impellizzeri FM, Favero T, Coutts AJ. The Translation of Sport Science Research to the Field: A Current Opinion and Overview on the Perceptions of Practitioners, Researchers and Coaches. *Sports Med.* 2019 Dec;49(12):1817-1824. doi: 10.1007/s40279-019-01139-0. PMID: 31214978.

Club- or organisation-embedded research is generally considered to have greater impact on professional practice, whereas laboratory studies lay the foundation of EBP in many areas of sport science [1]. For instance, well-controlled randomised trials produce a much higher level of evidence than applied investigations conducted in the field [17]; however, the former has reduced ecological validity. Field-based investigations have been reported as difficult to implement in high-performance settings [18] due to experimental control requirements, training interference and randomisation issues [1]. Indeed, balancing the need for efficacious research (i.e. does the intervention work?) with effective research (i.e. does it work in practice?) is paramount [19]. In addition, due consideration needs to be given to the efficiency of such measures (cost vs. benefit [19]). Practitioners and researchers also need to consider that the organisation or club will prioritise a competitive advantage over research dissemination. Although difficult, it is important for sport scientists to strive for appropriate scientific design where possible when performing research in applied settings (recommendations regarding this issue are offered in Sect. 5). Such optimised design may increase the rigour and subsequent uptake of sport science research, which in turn will influence the areas researchers and practitioners view as important. Ideally, if better-quality research is designed and conducted, this will strengthen the evidence from which applied sport science practice is based [3].

Context: This text is part of the chapter “2.2 Researchers’ and Practitioners’ Perceived Importance of Research Areas” describing the advantages and disadvantages of embedded scientists in clubs / teams vs research conducted externally in a scientific institution.

Questions: Based on the text explain the arguments for and against the embedding of scientists in the sport practice in terms of

- 1) the rooting of the research question in research practice
- 2) the validity of the research process
- 3) the implementation of the research findings.

Answer guide:

The central trade-off is between practical relevance and ecological validity on one side, and scientific control and generalisability on the other. Fullagar et al. describe evidence-based practice as the integration of research evidence, practitioner expertise, and athlete values—not simply the application of research findings. [Fullagar et al. \(2019\)](#)

1. Rooting the research question in sport practice

Argument for embedding scientists:

An embedded scientist works closely with coaches, athletes, and support staff and therefore understands the organisation's actual performance problems, culture, resources, and operational constraints. This makes it more likely that research questions will address relevant issues and examine interventions that are feasible, useful, and cost-effective in that particular setting. Close interaction can also help align research with the information coaches value and reduce the risk of investigating questions that have little practical application.

Argument against embedding scientists:

The club's immediate performance priorities may determine which questions are investigated. Research may consequently become narrow, short-term, and specific to one team rather than theory-driven or broadly relevant. Because clubs seek competitive advantage, they may favour projects that promise an immediate benefit while neglecting fundamental or mechanistic research. External or laboratory research is less constrained by these priorities and can investigate foundational questions that later support applied evidence-based practice.

2. Validity of the research process

Argument for embedding scientists:

Research conducted in the real training and competition environment has high **ecological validity**. It examines real athletes, coaching practices, schedules, and performance pressures. It

can therefore establish whether an intervention is effective and efficient under normal sporting conditions—not merely whether it can work under ideal laboratory conditions.

Argument against embedding scientists:

Applied settings make rigorous experimental control difficult. Coaches may be unwilling to randomise athletes, create a control group, or modify training solely for research purposes. Training schedules, competitions, injuries, athlete availability, and performance priorities may interfere with the protocol. These factors can introduce confounding variables and weaken internal validity, making causal conclusions less certain. In contrast, controlled laboratory studies and randomised trials generally provide stronger internal validity and a higher level of evidence, although their findings may be less representative of elite sport practice.

Thus, embedded research tends to answer “Does it work in this real setting?”, whereas controlled research is often better suited to answering “Does the intervention itself produce the effect?”

3. Implementation of the research findings

Argument for embedding scientists:

Embedded research generally has greater potential to influence practice. The scientist can communicate findings directly to coaches and athletes, adapt recommendations to the club’s circumstances, and provide continuing support during implementation. Personal relationships may increase trust, staff and athlete “buy-in,” and ownership of the research. Findings are also more likely to be viewed as relevant because they were produced with the club’s athletes and within its normal environment.

Argument against embedding scientists:

Implementation is not guaranteed. Lack of time, funding, resources, and coach, athlete, or staff buy-in can still prevent findings from being used. Methodological weaknesses may also reduce confidence in the results. Furthermore, clubs may keep useful findings confidential to preserve a competitive advantage, limiting publication, independent evaluation, and implementation elsewhere. Because results may depend strongly on one club’s athletes and context, they may not transfer readily to other organisations.

Seminar title: Stretching exercise. What is it good for?

Acute and long-term effects of stretching in relation to function, performance and injury risk

Reference: Anthony D Kay, Anthony J Blazeovich. Effect of acute static stretch on maximal muscle performance: a systematic review. *Med Sci Sports Exerc.* 2012 Jan;44(1):154-64.

Figure A:

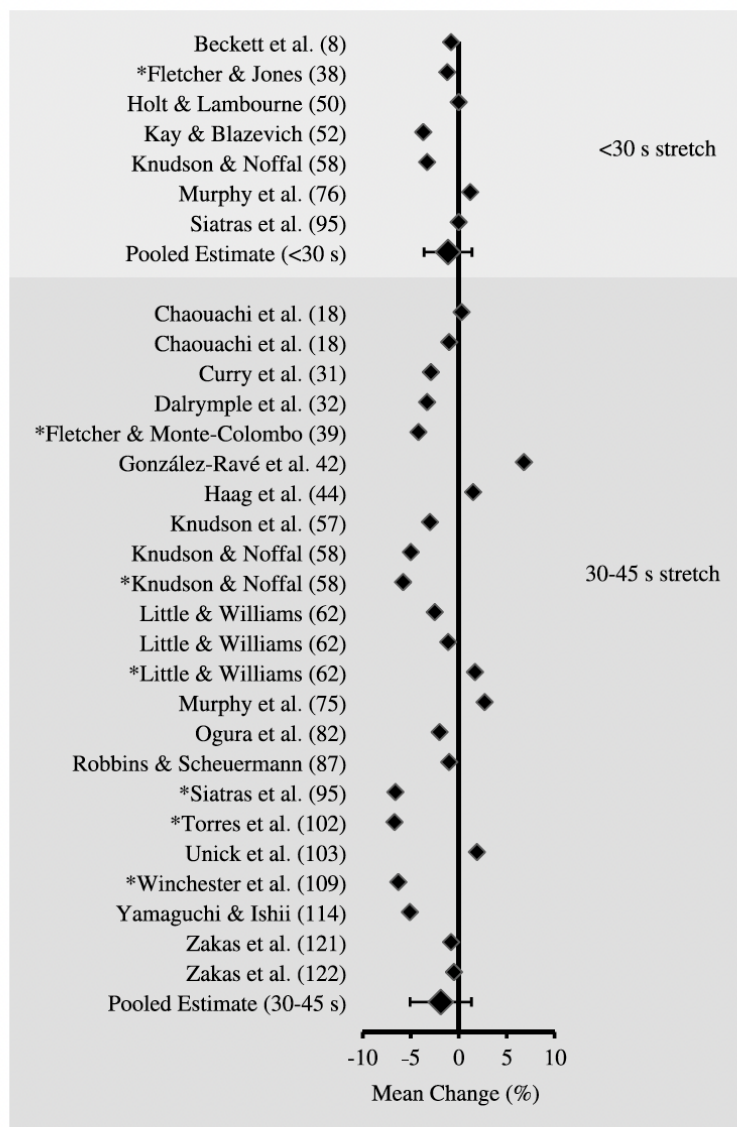
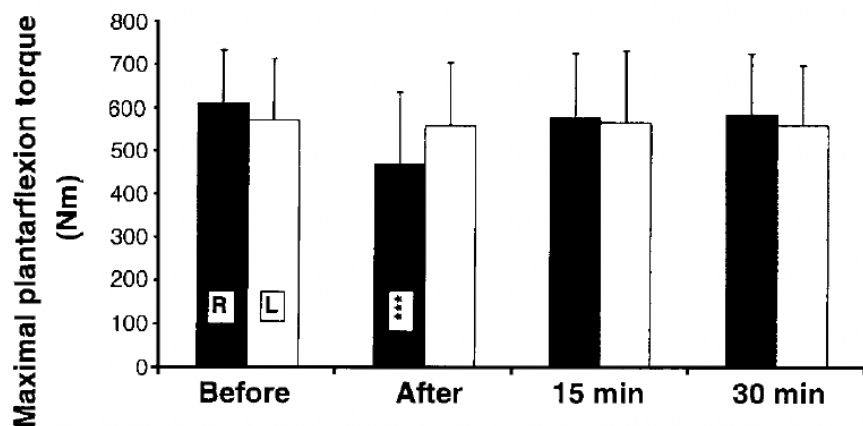


FIGURE 1—Mean percentage change (* $P < 0.05$, significant) in strength-, power-, and speed-dependent task performances after stretches of <30 s (*top*) or 30–45 s (*bottom*) in duration. Most studies found no significant reduction in muscle performance after shorter stretch durations, with small mean reductions calculated across studies indicating no meaningful change in performance.

Figure B:



Context: Despite that stretching is routinely applied as part of warm-up routines, it has in been questioned if stretching exercise should be performed prior to maximal performance efforts (e.g. competition). This discussion is based on a number of studies that demonstrated reduced muscle-contraction performance following stretching. Figure B above, is one such study that measured leg strength (maximal plantarflexion torque) prior to, acutely, and 15 and 20 min after 1 hr of cyclic stretching performed unilaterally for the right (R) leg (L, left leg served as control) (J Avela, H Kyröläinen, P V Komi. Altered reflex sensitivity after repeated and prolonged passive muscle stretching. J Appl Physiol 1999 Apr;86(4):1283-91). More recently a review was conducted that examined the acute effect of stretching on strength, power and speed performance after stretching of less duration (Figure A above).

Question: Discuss briefly the effects of acute and habitual stretching. Explain the findings that are summarized in the two figures above (A & B) and based on this, give your recommendation to if and specifically how athletes should include stretching as part of their training/warm up routines prior to competition.

Answer: *Habitual* stretching (e.g. repeated stretching exercise conducted regularly (daily or 3-4/week) for 3-8 weeks +) is well known to increase joint range of motion (ROM) over time, an effect that is mainly attributed to stretch tolerance, and reversible if stretching exercise is terminated. Similarly, it is known that one stretching bout *acutely* increases range of motion (ROM), but also reduces maximal voluntary contraction strength, sprint speed, jump height. However, the acute reduction in contractile performance is mostly observed following longer stretches +1-5 min, are transitory and last only minutes following the stretch. As shown in figure B, 1 hr. of stretching reduced maximal plantarflexion torque approximately 20% (R, right leg) following the stretch, but 15 min later the maximal torque was restored. Figure A is a Forest plot, summarizing the acute effect of brief stretching efforts (duration <30 sec and 30-45 sec) on strength and power performance. It seems, from the single studies and from the pooled estimate that brief stretching has no meaningful negative effect on contractile performance. As a

coach or trainer, the recommendation would consequently be that stretching can be a part of the warm-up routine prior to performance, but excessive stretching (duration above 1 min) for the single joint/muscle should be avoided.

Seminar title MA461- Influence of sex and female hormones on performance and response to training

Reference: M M Samson 1, I B Meeuwsen, A Crowe, J A Dessens, S A Duursma, H J Verhaar (2000). Relationships between physical performance measures, age, height and body weight in healthy adults. *Age Ageing*. May;29(3):235-42.

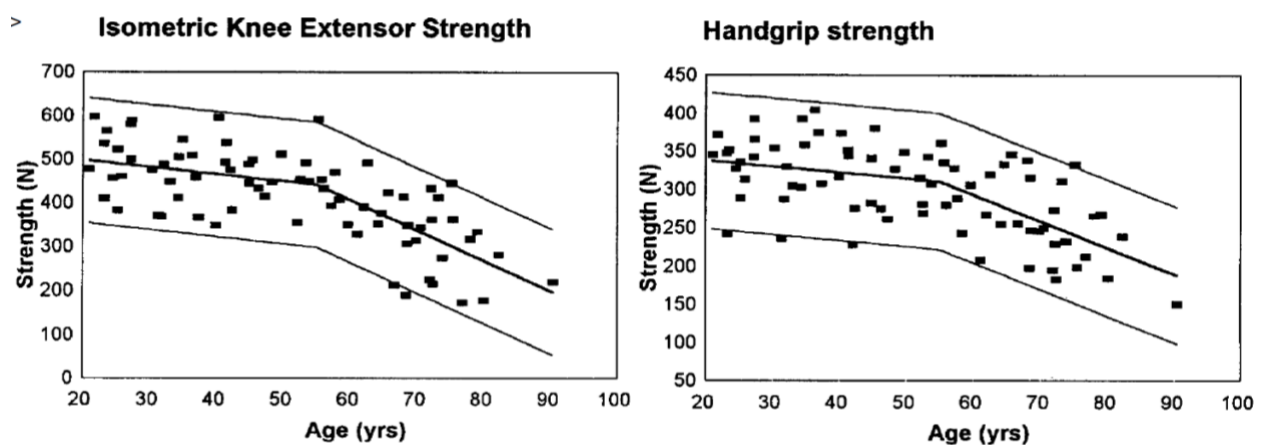


Figure : 1. Line of best fit with 95% confidence limits for the isometric knee extensor strength and handgrip strength among 74 healthy women aged between 20 and 90 years.

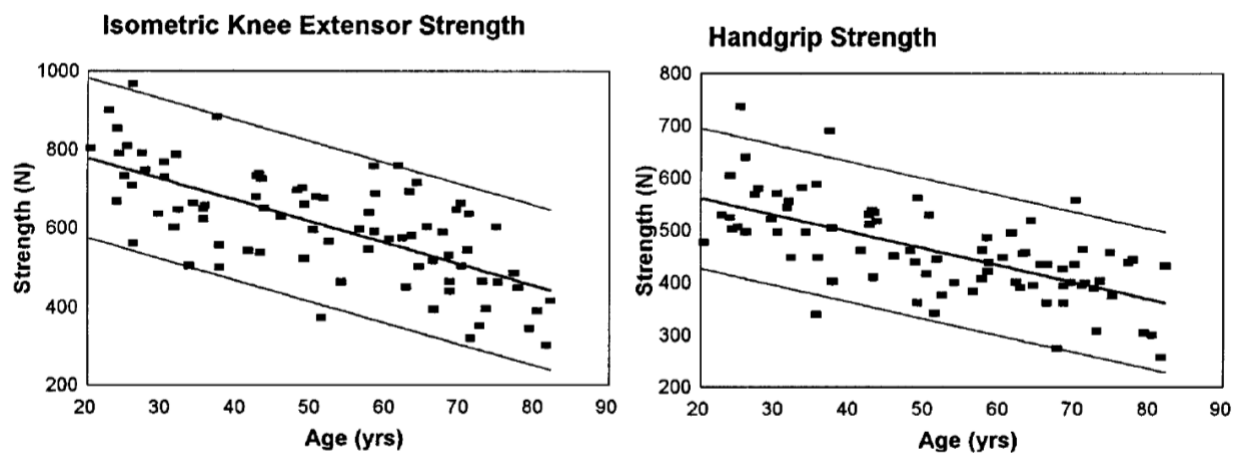


Figure 2. Line of best fit with 95% confidence limits for the isometric knee extensor strength and handgrip strength among 81 healthy men aged between 20 and 90 years.

Context: The figures are based on data from a cross-sectional study. The aim was to measure strength and functional mobility in healthy men and women over the adult age range to investigate the changes with age and sex. They were particularly interested in whether the menopause had any influence on muscle strength

Questions: Based on the results shown in the figures, what will you conclude in relation to their aim. Further, with reference to the curriculum for the present seminar, discuss potential mechanisms which can explain the observations in Samson et al (2000)

Answer guide:

Based on the figures from Samson et al. (2000), and the curriculum:

Conclusion from the figures:

The figures show isometric knee extensor and handgrip strength in men and women across different age ranges. Both strength parameters decline with age in men and women, but the decline is steeper in women, especially after the age of 50, likely around the menopause. This suggests that menopause may exacerbate muscle strength loss in women, as seen in the steeper decline in their muscle performance measures post-menopause compared to men.

Discussion of potential mechanisms:

The observed decline in muscle strength with aging, particularly in women post-menopause, can be explained by changes in hormonal levels, specifically the reduction in estrogen. According to the curriculum:

1. **Muscle Protein Metabolism:** Hansen (2018) highlighted that estrogen influences muscle protein metabolism, playing a protective role in maintaining muscle mass. With the reduction in estrogen during menopause, there is a decline in muscle protein synthesis, which may explain the accelerated strength loss.

2. **Satellite Cell Regulation:** Oxfeldt et al. (2022) discussed that sex hormones, including estrogen, regulate satellite cell activity, which is crucial for muscle repair and growth. The decrease in estrogen could impair satellite cell function, further contributing to muscle weakness and atrophy in postmenopausal women.
3. **Tendon and Connective Tissue:** Hansen et al. (2009) examined how estrogen affects tendon collagen synthesis and biomechanical properties. Estrogen decline could lead to weaker tendons and reduced force transmission efficiency, exacerbating the strength loss seen in aging women compared to men.

In summary, the menopause-related reduction in estrogen may lead to declines in muscle protein synthesis, impaired satellite cell function, and weakened tendon properties, all contributing to the observed steeper decline in muscle strength in women post-menopause, as seen in the figures from Samson et al. (2000).

Curriculum references used:

Oxfeldt M, Dalgaard LB, Farup J, Hansen M. "Sex Hormones and Satellite Cell Regulation in Women". Translational Sports Medicine. 14. April:2022:9065923

Hansen M, "Female hormones: do they influence muscle and tendon protein metabolism?", Proc Nutr Soc. 2018, vol 77, nr 1 (02), s 32-41

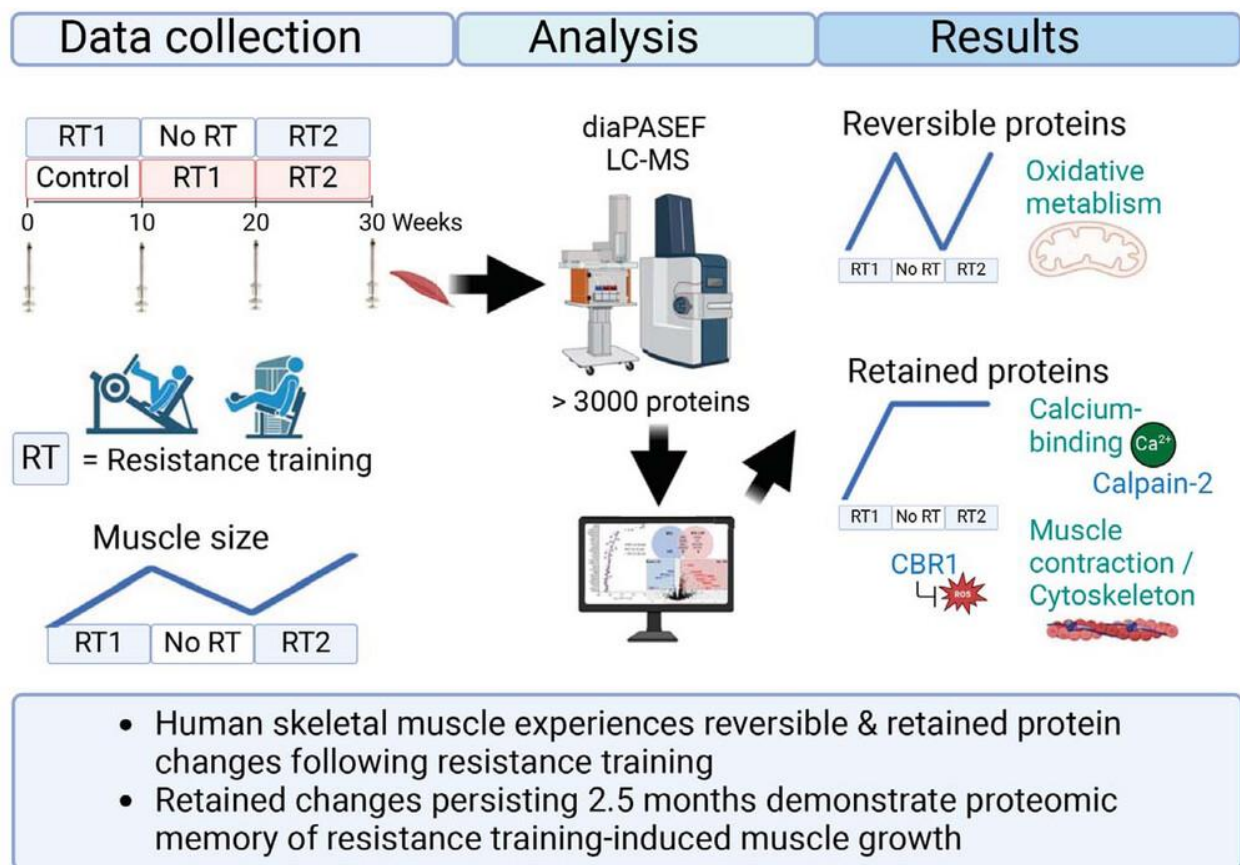
Hansen M, Kongsgaard M, Holm L, Skovgaard D, Magnusson SP, Qvortrup K, Larsen JO, Dahl M, Serup A, Frystyk J, Flyvbjerg A, Langberg H, Kjaer M, "Effect of estrogen on tendon collagen synthesis, tendon structural characteristics, and biomechanical properties in postmenopausal women", J Appl Physiol, 2009 Apr;106(4):1385-93

Seminar title: Does Skeletal Muscle have a Memory?

Reference:

Hulmi, J. J., Halonen, E. J., Sharples, A. P., O'Connell, T. M., Kuikka, L., Lappi, V. M., Salokas, K., Keskitalo, S., Varjosalo, M., & Ahtiainen, J. P. (2025). Human skeletal muscle possesses both reversible proteomic signatures and a retained proteomic memory after repeated resistance training. *The Journal of Physiology*, 603(9), 2655–2673. <https://doi.org/10.1113/JP288104>

Figure and Context:



The Journal of
Physiology

A schematic illustrating positive skeletal muscle memory at the proteomic level following training and detraining.

Question:

Using the figure as a guide, explain how evidence for skeletal muscle memory has evolved from epigenetic observations to transcriptional and most recently proteomic discoveries. Discuss the molecular mechanisms that may enable the persistence of training-induced adaptations during detraining and describe how these mechanisms could contribute to responses during retraining. Refer to evidence from resistance training studies and, where relevant, high-intensity interval training studies.

Answer guide:

- Define positive skeletal muscle memory as the retained capacity of previously trained muscle to maintain molecular signatures during detraining and/or exhibit an enhanced response during retraining.
- Explain that resistance training induces DNA hypomethylation in genes linked to muscle growth, structural remodelling, mechanotransduction and cytoskeletal organisation.
- Describe how some hypomethylated loci remain hypomethylated during detraining, providing an epigenetic memory of previous training.
- Explain that retained hypomethylation can maintain gene expression or prime genes for a larger transcriptional response during retraining.
- Discuss evidence from high-intensity interval training showing retained hypomethylation and transcriptional signatures in pathways related to metabolic regulation, mitochondrial adaptation, calcium signalling and lactate transport.
- Describe how transcriptional memory represents retention of exercise-responsive gene expression profiles that persist beyond the initial training period.
- Explain recent proteomic evidence showing both reversible and retained protein responses after resistance training.
- Identify that many metabolic proteins increase during training, decline during detraining and increase again during retraining.

- Describe how a subset of proteins involved in structural integrity, cytoskeletal organisation and calcium regulation remain elevated through detraining, providing evidence of proteomic memory.
- Mention examples such as CAPN2 and other proteins retained across molecular layers as evidence for integration between epigenetic, transcriptional and proteomic memory.
- Explain how the field has progressed from epigenetic observations, to transcriptional evidence, and now to direct proteomic evidence.
- Conclude that skeletal muscle appears capable of retaining molecular signatures of previous exercise at multiple biological levels, which may contribute to maintained responsiveness and/or enhanced adaptation during retraining.

Modelling of Human Movement

Reference: Frankston, N., Ellison, M., Riise, J. N. R., Seynnes, O., Farris, D., & Rice, H. (2025). Second Metatarsal Bone Stress During Running Is Independently Influenced by Running Speed and Load Carriage. *Scandinavian Journal of Medicine & Science in Sports*, 35(10), e70152.

Context

The purpose of this study was to quantify how running speed influenced the mechanical loading (stress) of the second metatarsal bone in the foot.

Twenty-eight runners ran over a pressure plate and force plate whilst video cameras recorded the location of reflective markers positioned on the leg and foot of each runner. Three running speeds were assessed which corresponded to each participant's preferred running speed (i.e. self-selected), 90% of preferred (i.e. slower) and 110% of preferred (i.e. faster).

Metatarsal bone stress was calculated at the surface of the bone, halfway along the length of the bone. The bone was modelled in two-dimensions at the midshaft of the second metatarsal using a two-dimensional beam theory model. The main inputs to the model were the bone geometries and forces (Figure 1).

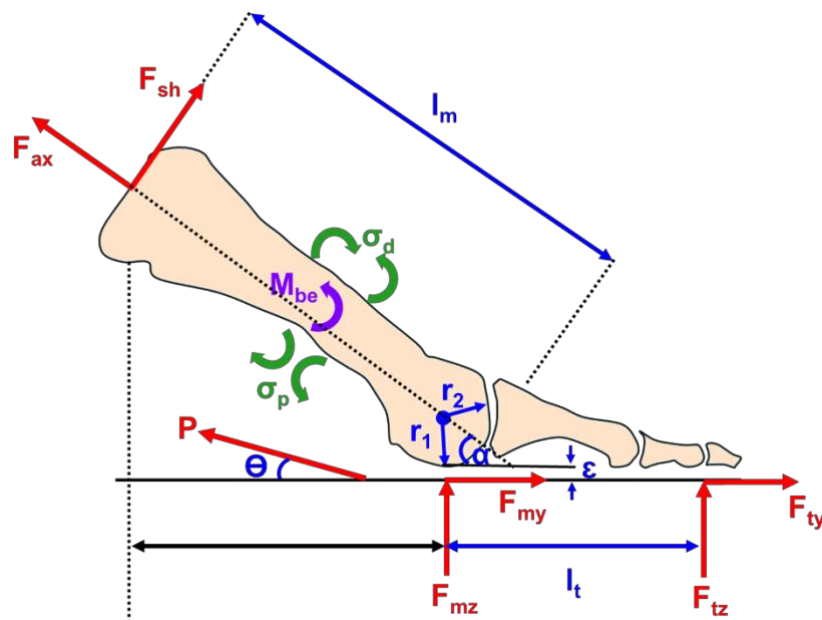


Figure 1: Inputs into the model to calculate metatarsal bone stress. Bone geometries (l_m , l_t , r_1 , r_2 , ϵ , θ) and forces (F_{my} , F_{mz} , F_{ty} , F_{tz} , P , F_x , F_{sh}). The main outcomes are the bending moment (M_{be}), and dorsal and plantar stress (σ_d and σ_p , respectively).

The metatarsal bone in this model is assumed to be a solid cylinder. The results of the influence of running at different speeds on peak dorsal bone stress (σ_d) are presented in Figure 2 below.

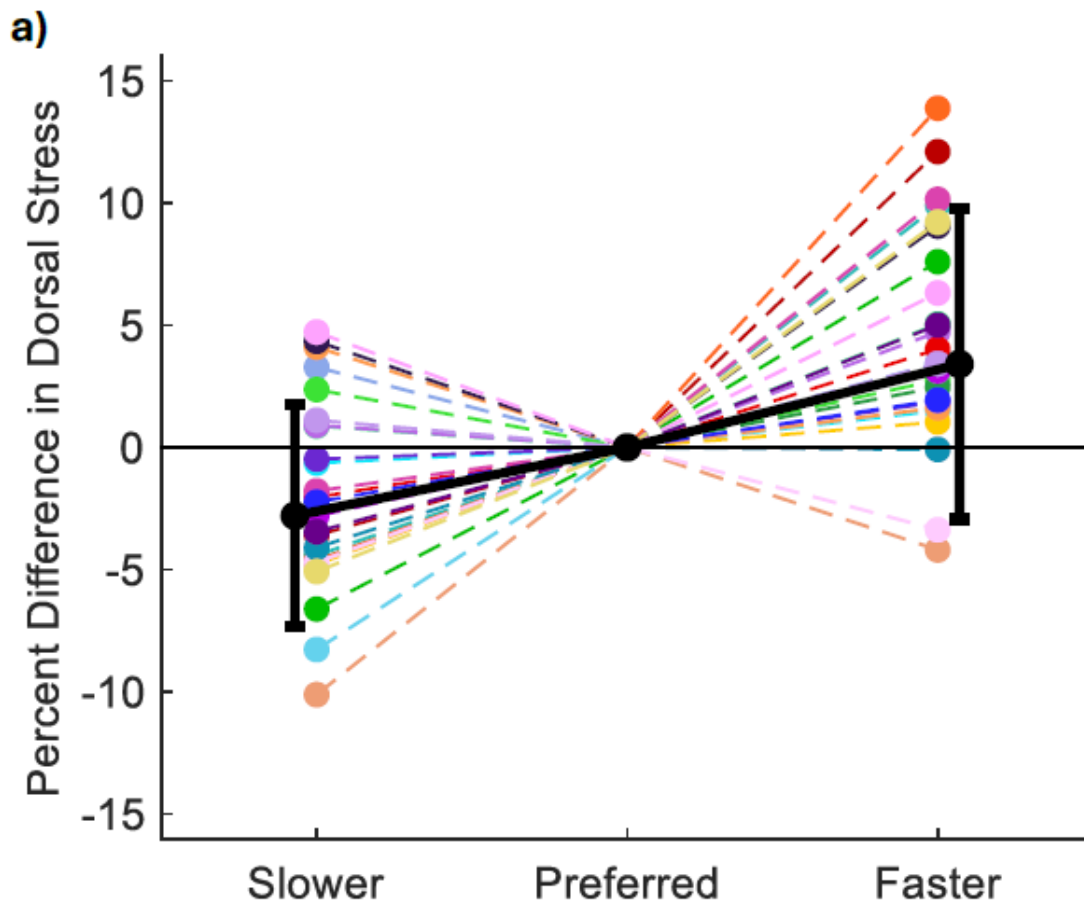


Figure 2: Percent difference in peak dorsal stress between speed conditions, relative to the Preferred Speed condition. Colored circles represent average percent difference in dorsal stress for each participant. Black circles represent means for each condition averaged across participants. Black error bars represent $\pm$ standard deviation. An asterisk indicates a significant difference from the preferred speed condition.

Questions

- 1) What was the influence of running speed on peak dorsal stress? Comment on both the group average and individual results.
- 2) Suggest two ways in which the complexity of the model could be increased?
- 3) Name one advantage and one disadvantage of increasing the model complexity.

Answer guide

- 1) Increasing running speed increased the peak dorsal stress on average across the group. This trend was observed for the majority of individuals, but there were exceptions. There were more exceptions when comparing slower and preferred speed than preferred and faster.
- 2) Three dimensional model, participant-specific geometries, non-hollow bone, indication of bone material properties, indication of the fact bone is deformable (e.g. finite element) accounting for deformation, accounting for bone remodelling/fatigue.
- 3) Advantages: more participant-specific values; can be more valid; can allow better detection of between- participant differences; can reduce error from assumptions and oversimplifications. Disadvantages: may result in unnecessary increase in computation time, resource requirement, new error sources.

Exercise and cancer

Reference: Courneya KS, Vardy JL, O'Callaghan CJ, Gill S, Friedenreich CM, Wong RKS, Dhillon HM, Coyle V, Chua NS, Jonker DJ, Beale PJ, Haider K, Tang PA, Bonaventura T, Wong R, Lim HJ, Burge ME, Hubay S, Sanatani M, Campbell KL, Arthuso FZ, Turner J, Meyer RM, Brundage M, O'Brien P, Tu D, Booth CM; CHALLENGE Investigators. Structured Exercise after Adjuvant Chemotherapy for Colon Cancer. *N Engl J Med*. 2025 Jul 3;393(1):13-25. doi: 10.1056/NEJMoa2502760. Epub 2025 Jun 1. PMID: 40450658.

Context: Courneya et al 2025 published a paper with the main aim to demonstrate the effects of a structured exercise program for disease-free survival after adjuvant chemotherapy for colon cancer.

In this phase 3, randomized trial conducted at 55 centers from 2009-2024, 889 patients with resected colon cancer who had completed adjuvant chemotherapy were randomized to participate in a structured exercise program (exercise group) or to receive health-education materials alone (health-education group) over a 3-year period. The primary end point was disease-free survival.

Questions: Consider the information given in Figure 1 and Figure 2, give a short description of the main findings and reflect on implications of these results.

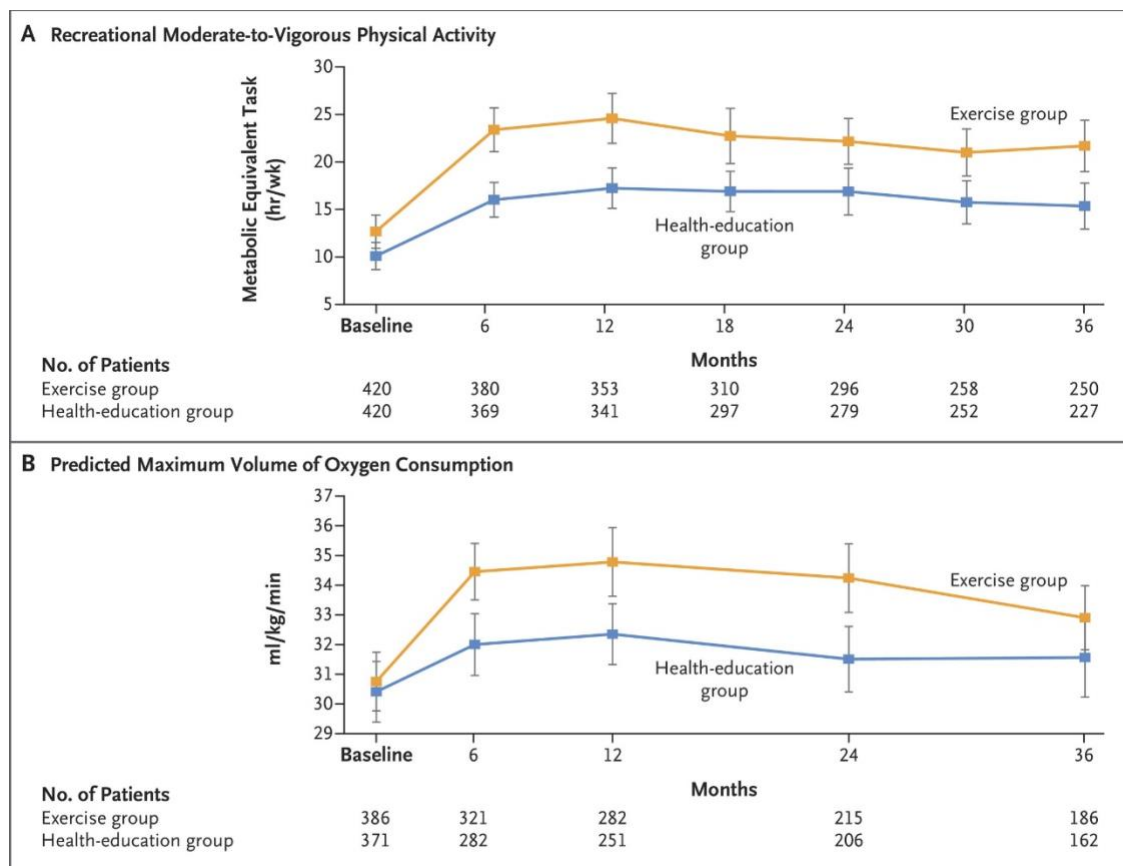


Figure 1. Measures of Physical Activity, Fitness, and Functioning.

Shown are results in the group assigned to participate in a structured exercise program (exercise group) and those assigned to receive health-education materials (health-education group) with respect to measures of recreational moderate-to-vigorous physical activity (Panel A) and the predicted maximum volume of oxygen consumption (Panel B).

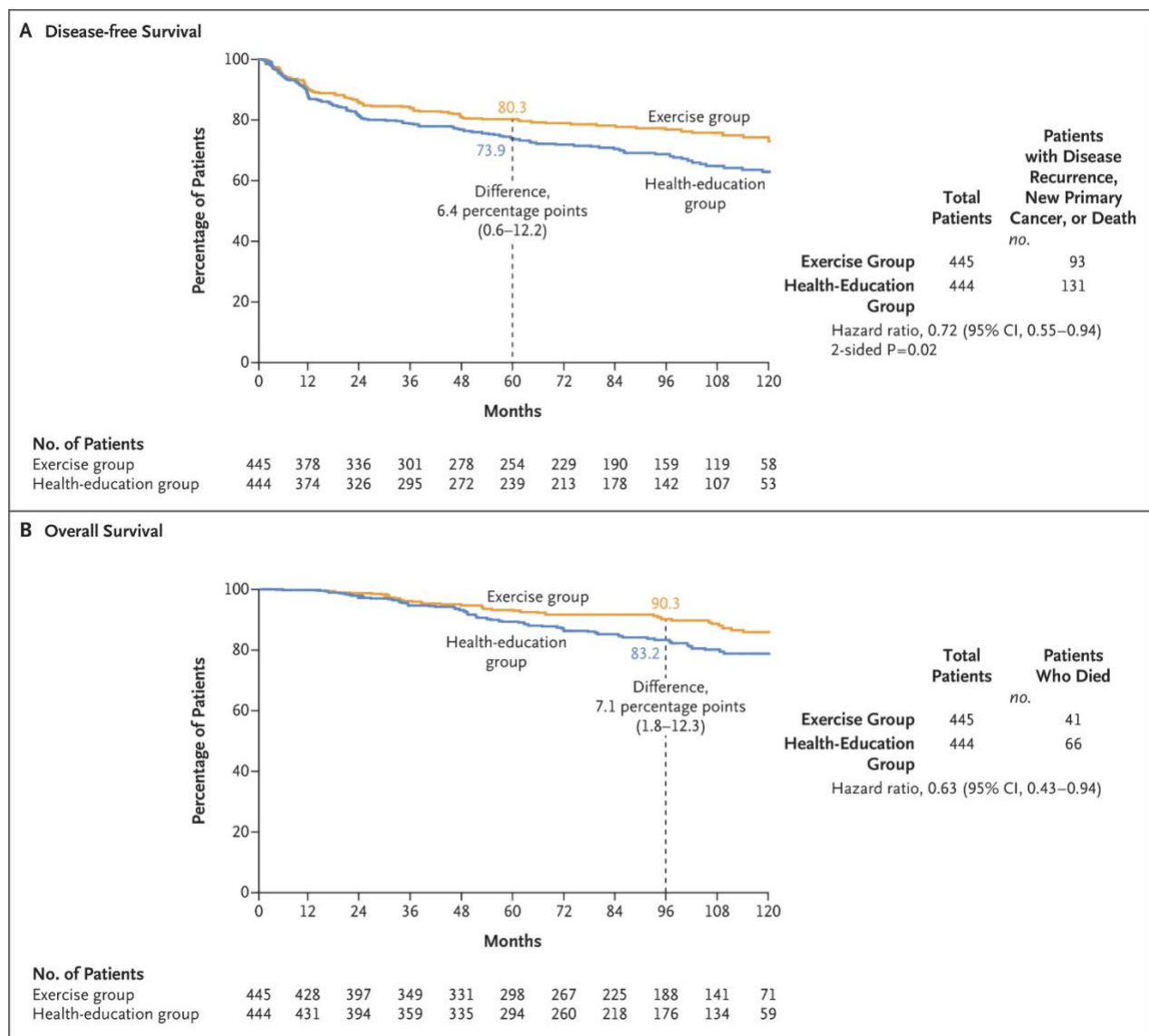


Figure 2. Disease-free and Overall Survival (Intention-to-Treat Population).

Shown is the probability of disease-free survival according to investigator assessment (Panel A) and overall survival (Panel B) in the exercise group and the health-education group.

Answer guide:

Main findings

Figure 1. The structured exercise program successfully changed behavior. Participants in the exercise group increased and maintained higher levels of moderate-to-vigorous physical activity throughout the intervention compared with the health-education group. They also showed better cardiorespiratory fitness (higher predicted VO_2max). These findings indicate that the intervention was effective in producing meaningful and sustained improvements in exercise behavior and fitness.

Figure 2. The exercise group had significantly better disease-free survival than the health-education group. The risk of recurrence, a new primary cancer, or death was reduced by about **28%** (HR 0.72, 95% CI 0.55-0.94). Overall survival was also improved, with about a **37% lower risk of death** (HR 0.63, 95% CI 0.43-0.94). Five-year disease-free survival was 80.3% versus 73.9%, and eight-year overall survival was 90.3% versus 83.2% in favor of the exercise group.

Reflection and implications

This study is important because it provides randomized phase III evidence that exercise is not only beneficial for quality of life and physical fitness, but may also improve clinically important cancer outcomes. The improved survival curves suggest that exercise should be considered an integral component of colon cancer survivorship care alongside surgery and chemotherapy. The findings support implementing supervised and structured exercise programs in oncology settings. However, the intervention required long-term support and resources.

The main weaknesses are limited generalizability, lack of blinding, and challenges in implementing such an intensive 3-year exercise program in routine cancer care, although the randomized design provides strong evidence for a causal effect of the intervention.

Conclusion: Figure 1 demonstrates that the intervention successfully increased physical activity and fitness, while Figure 2 shows that these changes were associated with improved disease-free and overall survival. Together, the results provide strong evidence that structured exercise can be considered a therapeutic strategy after treatment for colon cancer.

Seminar title: Musculoskeletal connective tissue: function and adaptation to training

Reference: Stäudle, B., Seynnes, O., Laps, G., Göll, F., Brüggemann, G.-P., & Albracht, K. (2021). Recovery from Achilles Tendon Repair: A Combination of Postsurgery Outcomes and Insufficient Remodeling of Muscle and Tendon. *Medicine and Science in Sports and Exercise*, 53(7), 1356–1366.

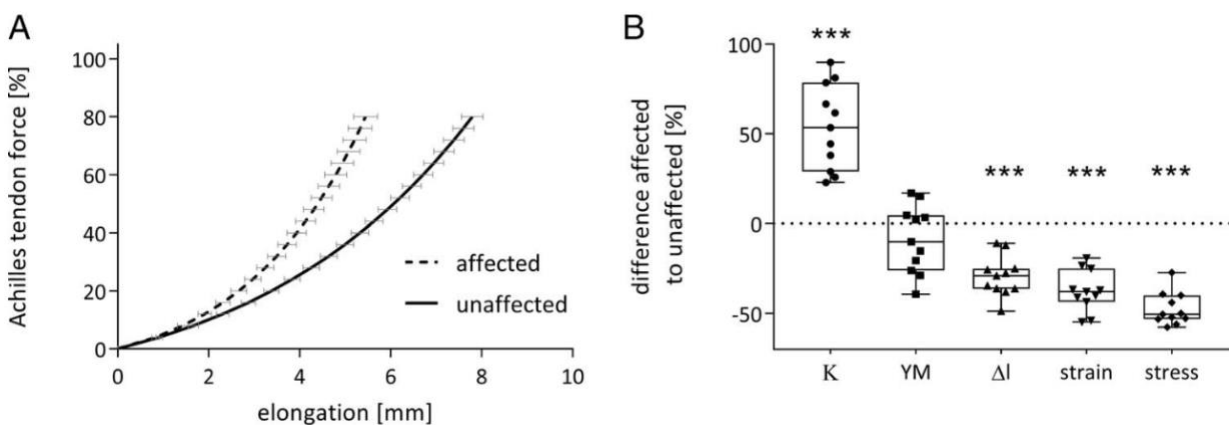


Figure 1. A, Achilles tendon force–deformation relation for the affected (dashed line) and unaffected (solid line) side. Achilles tendon force (ATF) is expressed relative to the maximum of the affected side for each individual subject (80% of maximum ATF = 3503 ± 518 N). B, Boxplots of relative differences between the affected and the unaffected side, representing minimum, 25th percentile, median, 75th percentile, and maximum. Significant difference between sides: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. K, tendon stiffness; YM, Young's modulus; Δl , tendon elongation..

Context: This figure was published in a study on patients who had ruptured their Achilles tendon and undergone surgery (≈ 5 yrs post-surgery). It depicts the differences in properties of the Achilles tendon between the operated (affected) and non-operated (unaffected) sides.

Questions:

- Based on the differences illustrated in Figure 3 (Panels A and B), describe the changes in tendon properties after surgery.
- An additional observation was that the operated Achilles tendon was longer than the non-operated one. How would this morphological alteration theoretically affect tendon strain? Does this prediction fit with the data from the figure? Which variable from the figure (other than strain) could explain this?
- Another observation was that the repaired tendon is thicker than the unaffected one. What would the effect of such a modification be for the stiffness of the tendon? What other variable from the figure affect tendon stiffness? Based on the figure, does this variable have a stronger or weaker influence than tendon thickening?

Answer:

- Panels A and B of the figure show that the tendon on the affected side undergoes less strain and displays a larger stiffness than the unaffected side. Panel B also indicates an unchanged or reduced Young's modulus, and reduced elongation, strain and stress. (3 points)
- A lengthened tendon would theoretically display more strain, which is the opposite of the findings shown in the figure. The greater stiffness reported in the figure explains this discrepancy. (3 points)
- A thicker tendon typically has greater stiffness due to its larger cross-sectional area, which increases its ability to resist deformation. However, tendon stiffness also depends on the material properties of the tendon, represented by the Young's modulus. According to Figure 3, the Young's modulus did not change significantly. Therefore, the observed increase in stiffness is primarily attributable to tendon thickening, rather than changes in material properties. (4 points)