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Preventing Exercise-Related Injuries in Old Age

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Abstract

Exercise is the strongest defense against age-related biological decay, yet in older adults the same mechanical loading that drives adaptation also risks structural failure. Traditional injury prevention relies on qualitative heuristics that insufficiently address the physiological realities of aging. This narrative review proposes a Load-Capacity Discrepancy framework for understanding geriatric musculoskeletal vulnerability. We examine how the asynchronous degradation of tissues, characterized by muscle anabolic resistance and tendon stiffness changes, creates a narrow therapeutic window for mechanical loading. Psychosocial factors, including kinesiophobia and self-efficacy, are positioned as primary modulators that directly influence acute mechanical stress through behavioral pathways. The review evaluates three intervention strategies for navigating this discrepancy: adapting the Acute:Chronic Workload Ratio for geriatric populations, prioritizing velocity-based training to preserve neuromuscular kinetics and reduce fall risk, and using objective readiness metrics derived from wearable sensor technology for daily autoregulation. We identify critical frontiers for future research, including real-time mechanotransduction biomarkers, sex-stratified hormonal considerations, the adoption of bootstrap methods for mediational analysis, and the institutional barriers to implementing precision loading protocols in clinical settings.

Keywords: Aging, Physical Activity, Exercise, Sport, İnjuries, Old Age.

1. INTRODUCTION

Subjecting the aging body to physical training initiates a difficult physiological balancing act. While exercise remains the most potent countermeasure against cellular and structural decay, the intervention itself relies on mechanical overload to force adaptation, and this carries a sharply elevated risk of morbidity. In young cohorts, structural failure requires high-kinetic energy transfer; in older adults, the severe attenuation of physiological reserve means tissue failure can result from sub-maximal, low-velocity loading (Sherrington et al., 2019). The margin between an anabolic stimulus and a mechanical rupture narrows with age, though the precise rate of this narrowing remains an open empirical question. When this threshold is breached, the consequences extend beyond localized tissue damage. Exercise-induced injuries compromise functional independence, accelerating the transition from autonomy to institutional dependency (Gillespie et al., 2012).

The psychological sequelae, including depression, social isolation, and kinesiophobia, create a feedback loop where the fear of injury predicts further physical decline (Paterson & Warburton, 2010; Zijlstra et al., 2007). The failure to manage geriatric mechanical load translates to an unsustainable demand on acute care resources. The economic imperative for injury prevention is driven by macroscopic healthcare constraints: meta-regression analyses of public hospital efficiency demonstrate that resource allocation is strictly bounded, with technical efficiency varying significantly across institutions (Kaya & Algin, 2022; Toros, 2025). Preventive exercise programming that actively reduces fall-related orthopedic admissions serves to alleviate immediate pressure on clinical systems operating near their maximum efficiency thresholds (Lord et al., 2007; Buman et al., 2010; Pekgör et al., 2025d).

Optimal load management, by contrast, preserves longevity, mitigates cardiovascular and metabolic pathologies, and sustains systemic function (Warburton & Bredin, 2017). The challenge is not whether older adults should exercise, but how to calibrate the mechanical stimulus to remain within the narrowing therapeutic window that separates adaptation from failure.

2. BIOLOGICAL SUBSTRATES OF VULNERABILITY: THE LOAD-CAPACITY DISCREPANCY

Traditional literature attributes geriatric vulnerability to generalized descriptions of reduced elasticity and diminished physical reserve. This descriptive taxonomy is insufficient for a mechanistic understanding of injury. Vulnerability is more precisely defined as a Load-Capacity Discrepancy: tissue failure occurs when acute mechanical load exceeds the tissue's tensile or compressive capacity. In aging, this capacity is not merely reduced; it is asynchronously degraded across structures, creating a mismatch that standard linear models fail to capture.

Skeletal muscle undergoes sarcopenia, characterized by selective type II muscle fiber atrophy and anabolic resistance, a blunting of the myofibrillar protein synthesis response to mechanical tension (Cruz-Jentoft et al., 2019; Pérez-Castillo et al., 2025). Meanwhile, tendons accumulate advanced glycation end-products (AGEs) and exhibit altered collagen cross-linking, changing their Young's modulus and creating a stiff, non-compliant architecture (Epro et al., 2017; Pekgor et al., 2025a). The result is a structural mismatch: muscle loses force-generating capacity while the tendon loses energy-absorbing compliance. Kinetic forces that would normally be attenuated by compliant tendons instead transfer directly to the myotendinous junction or joint capsule. Because each tissue type loses capacity at a different rate, the overall discrepancy between applied load and structural tolerance widens unevenly with age. This framework differs from existing tissue tolerance models, such as Dye's (1996) envelope of function, in a specific respect: it emphasizes the asynchronous rate of degradation across tissue types rather than treating the musculoskeletal system as a single unit with a uniform capacity threshold. In younger populations, muscle, tendon, and bone degrade at broadly comparable rates under overuse conditions. In aging populations, the differential rates of degradation mean that the weakest structural link shifts unpredictably, making injury location and mechanism less predictable from external load parameters alone.

Systemic neural degradation compounds local tissue fragility. Age-related proprioceptive and vestibular decay sever the neuromuscular feedback loops required for dynamic stabilization, establishing balance impairment as a primary vector for high-impact fall trauma (Gillespie et al., 2012; Pekgor et al., 2025b). Targeted resistance and balance training alter this trajectory, reducing fall incidence while driving neurogenesis and expanding hippocampal volume (Erickson et al., 2011; Sherrington et al., 2019). Table 1 summarizes these degradation patterns and load management implications.

In the past, injury prevention relied on vague heuristics like gradual progression and generalized supervision (World Health Organization, 2020; Demirli et al., 2024). Prescribing load while ignoring physiological states, particularly polypharmacy-induced orthostatic hypotension, elevates acute failure risk (Nelson et al., 2007).

Table 1: Load-Capacity Discrepancy: Tissue-Specific Degradation Patterns in Aging

Tissue	Age-Related Degradation Mechanism	Functional Consequence	Implication for Load Management
Skeletal Muscle	Sarcopenia: selective type II fiber atrophy, anabolic resistance (blunted MPS response to mechanical tension)	Reduced force-generating capacity, impaired RFD, diminished stumble recovery	VBT to recruit type II fibers; protein timing around training; ACWR to prevent overload on weakened contractile tissue
Tendon	AGE accumulation, altered collagen cross-linking, increased Young's modulus	Stiff, non-compliant architecture; reduced energy absorption; increased stress transfer to myotendinous junction	Avoid heavy eccentric loading; favor lighter loads at higher velocity; monitor tendon stiffness via elastography (future)
Bone	Decreased mineral density, cortical thinning, trabecular deterioration	Reduced compressive and bending strength; increased fracture risk from falls	Progressive weight-bearing exercise within ACWR limits; fall prevention through VBT and balance training
Neural / Proprioceptive	Vestibular decline, proprioceptive decay, reduced nerve conduction velocity	Impaired dynamic stabilization, delayed postural corrections, increased fall frequency	Balance-specific training; sensorimotor integration exercises; wearable monitoring for gait quality

Note. ACWR = Acute:Chronic Workload Ratio; VBT = Velocity-Based Training; AGE = Advanced Glycation End-products; MPS = Myofibrillar Protein Synthesis; RFD = Rate of Force Development

3. PSYCHOSOCIAL MODULATORS OF LOAD: A BIO-BEHAVIORAL FRAMEWORK

Classical literature isolates physical capacity from psychological state, treating frameworks like the Biopsychosocial Model (Stathi et al., 2004) or Social Cognitive Theory (Bandura, 1997) as parallel rather than intersecting variables. In the context of geriatric exercise, this separation obscures a direct causal pathway: behavior is the mechanism through which tissue capacity is either preserved or compromised. Psychology does not merely accompany the loading process; it regulates it.

Motivation and self-efficacy (Deci & Ryan, 2000) function as regulators of mechanical loading. When an older adult possesses high self-efficacy, they are more likely to engage in the consistent, progressive loading required to maintain muscle mass and tendon stiffness. If this confidence is miscalibrated without professional monitoring, it can trigger acute load spikes that exceed tissue capacity and precipitate structural failure (Rhodes et al., 2017; McAuley et al., 2011). The empirical pathway from self-efficacy to measurable load parameters remains incompletely mapped; accelerometer-derived training volume data linked to psychological assessments would strengthen this proposed mechanism.

The inverse scenario is equally destructive. Following a minor injury or fall, the onset of kinesiophobia initiates a catabolic feedback loop. Driven by anxiety, the individual severely restricts physical activity (Paterson &

Warburton, 2010; Zijlstra et al., 2007). This behavioral withdrawal induces rapid detraining, lowering the baseline capacity of muscle and bone. When the individual is subsequently forced to execute an unavoidable daily task, the mechanical load of that movement exceeds the depleted structural threshold, producing a more severe injury than the initial event. The fear of injury, in this framing, fosters the biological conditions for its occurrence.

Sustaining exercise adherence in older adults requires strategies that maintain motivational engagement without triggering the erratic loading patterns associated with unsupervised enthusiasm. The application of game-design elements to non-game contexts, has gained traction in clinical and nursing settings as an adherence tool, with bibliometric analyses confirming its rapid growth as a research domain in health-related disciplines (Algin, 2024; Pekgor et al., 2024c). Applied to geriatric exercise, gamification principles such as incremental goal-setting, progress visualization, and milestone rewards may function as behavioral pacing mechanisms that sustain the consistency required to elevate chronic workload baselines. The approach warrants empirical testing in load-managed exercise programs, where adherence directly determines whether the tissue capacity threshold is maintained or allowed to decay.

The integration of objective biofeedback into psychosocial interventions offers a mechanism for calibrating self-efficacy against physiological capacity. Wearable health monitoring systems, increasingly used in sport psychology education contexts, provide users with real-time physiological data that can anchor subjective confidence to measurable output (Pekgor et al., 2024b; Gulgosteren et al., 2025). For older adults caught between kinesiophobic avoidance and overconfident loading, this external calibration may narrow the gap between perceived and actual capacity, reducing the probability of both behavioral withdrawal and acute load spikes.

To prevent long-term decline, paradigms like Successful Aging (Rowe & Kahn, 1997) and Active Aging (Walker, 2002) warrant operationalization as active, lifelong load-management strategies rather than aspirational categories. The Lifespan Development Theory (Baltes & Baltes, 1990) implies that the accumulation of micro-adaptations over decades creates a physiological buffer in senescence (Warburton & Bredin, 2017). Group-based interventions and environmental support systems act as pacing mechanisms, preventing erratic spikes in mechanical loading while maintaining the consistency necessary to keep the tissue capacity threshold elevated (Chodzko-Zajko et al., 2009; Yıldız Öztürk et al., 2025).

4. REDEFINING PREVENTATIVE PARADIGMS: THE MODERN INTERVENTION

The clinical standard of prescribing gradual progression is a qualitative heuristic. In high-performance athletics, tissue failure is mitigated through the strict, objective quantification of mechanical load. The aging musculoskeletal system stands to benefit from a comparable degree of rigor, adapted to the specific physiological constraints of senescence.

5. QUANTIFYING THE STIMULUS: THE GERIATRIC ACWR

Traditional protocols rely on linear progression models that fail to account for the erratic recovery curves of older adults. There is a strong rationale for adapting the Acute:Chronic Workload Ratio (ACWR) for the geriatric physiological profile. In athletic populations, an acute workload (one week) that exceeds the chronic workload (four-week rolling average) by a ratio above 1.5 sharply increases injury probability (Gabbett, 2016; Alkan et al., 2025). In sedentary older adults, the baseline chronic load is effectively zero, meaning even a seemingly benign intervention represents a significant ACWR spike. Consider a hypothetical scenario: a sedentary 72-year-old begins a resistance training program at two sessions per week, each consisting of three exercises at three sets of ten repetitions with light resistance bands. Using session rating of perceived exertion (RPE) as a proxy metric, if each session generates a load score of 150 arbitrary units, the first-week acute load is 300 arbitrary units against a chronic base of effectively zero. The ACWR is incalculable at a zero baseline and disproportionately elevated by week two. The prevention of initial tissue rupture requires micro-dosing: beginning with a single exercise at a single set, building the chronic base over eight to twelve weeks before introducing standard programming volumes. Progression is better guided by the stabilized elevation of the chronic base over months, not by calendar-driven increments.

6. VELOCITY OVER VOLUME: REVERSING NEUROMUSCULAR DECAY

The prevailing reliance on slow, low-intensity movements overlooks a primary vector of geriatric injury: falls. Older adults fall because they lack the Rate of Force Development (RFD) necessary to rapidly reposition their center of mass when equilibrium is lost. Two distinct mechanisms converge here. First, age-related sarcopenia selectively destroys type II (fast-twitch) muscle fibers, blunting the neuromuscular kinetic response (Pérez-

Castillo et al., 2025; Sherrington et al., 2019). Second, the stiffened, AGE-laden tendons in older adults cannot absorb rapid eccentric loads during stumble recovery (Epro et al., 2017; Pekgor et al., 2024c).

To mitigate fall-related trauma, interventions should incorporate velocity, and Velocity-Based Training (VBT) offers a practical framework for doing so. By using lighter loads moved at maximal intended concentric speeds, VBT selectively recruits dormant type II fibers and enhances central nervous system drive without exposing vulnerable tendons to heavy, high-tension loads. The distinction is clinically relevant: the approach addresses the neuromuscular speed deficit while leaving stiff connective tissue within its tolerance threshold.

7. AUTOREGULATION AND OBJECTIVE READINESS

Biological readiness in senescence fluctuates daily, driven by systemic inflammation, sleep architecture, and polypharmacy effects. Rigid, pre-planned exercise regimens force individuals to load a system that may be acutely compromised, increasing the likelihood of tissue failure (Demirli et al., 2024). Modern preventive paradigms are increasingly reliant on autoregulation, where intensity and volume are adjusted per session based on objective readiness markers. The feasibility of continuous load monitoring in geriatric populations has expanded with advances in wearable sensor technology. Accelerometers, inertial measurement units, and optical heart rate sensors now enable real-time tracking of movement quality, training volume, and autonomic recovery status outside laboratory settings (Pekgor et al., 2024a). Simple metrics derived from these platforms, such as daily grip strength dynamometry or resting heart rate variability (HRV), provide immediate insight into central nervous system fatigue and systemic recovery. For older adults, this shift from laboratory-based assessment to continuous ambulatory monitoring is particularly relevant: it captures the day-to-day variability that fixed protocols miss.

Sleep architecture exerts a direct influence on next-day tissue recovery and neuromuscular readiness, yet older adults frequently underreport or fail to recognize disordered sleep patterns. Passive monitoring technologies utilized for athlete sleep disorder detection, offer a non-intrusive paradigm adaptable for geriatric populations (Toros & Şekeroğlu, 2026). By capturing sleep quality data without requiring active user engagement, such systems feed directly into autoregulatory decision-making, flagging sessions where loading should be reduced due to compromised overnight recovery. This dynamic adjustment prevents the accumulation of micro-trauma, keeping the threshold of tissue capacity secure. Table 2 summarizes the three proposed intervention strategies, their mechanisms, current evidence levels, and priority research questions.

Table 2: Summary of Proposed Intervention Strategies for Precision Geriatric Loading

Intervention	Mechanism of Action	Current Evidence Level	Geriatric RCT Evidence	Priority Research Questions
ACWR Adaptation	Tracks acute-to-chronic workload ratio to prevent load spikes exceeding tissue tolerance	Strong in athletic populations (Gabbett, 2016); conceptual for geriatrics	None specific to older adults	What ACWR thresholds apply to deconditioned older adults? How should chronic baselines be established from near-zero?
Velocity-Based Training (VBT)	Light-load, high-velocity concentric movements to recruit type II fibers and improve RFD without heavy eccentric tendon loading	Moderate; supported by neuromuscular physiology and fall prevention literature	Limited; pilot studies in older adults exist but no large-scale geriatric RCTs	Can VBT reduce fall incidence independently of traditional balance training? What velocity thresholds are safe for stiffened tendons?

Objective Autoregulation (HRV, grip dynamometry, wearables)	Daily adjustment of training load based on real-time central nervous system fatigue and recovery markers	Moderate; established in sports science, emerging in clinical populations	Minimal; feasibility studies but no efficacy RCTs in geriatric exercise	Which readiness metrics best predict next-day tissue tolerance in older adults? What are validated decision thresholds?

Note. HRV = Heart Rate Variability; RCT = Randomized Controlled Trial; VBT = Velocity-Based Training; ACWR = Acute:Chronic Workload Ratio; RFD = Rate of Force Development

8. FUTURE FRONTIER: METHODOLOGICAL AND BIOLOGICAL GAPS

8.1. Biomolecular Blind Spot

Current autoregulation protocols rely on macroscopic proxy metrics. The literature lacks real-time, non-invasive biomarkers capable of tracking acute mechanotransduction and tissue fatigue at the cellular level. We understand that anabolic resistance and collagen cross-linking drive the Load-Capacity Discrepancy, but we cannot yet measure the point at which a specific tendon shifts from functional adaptation to micro-failure during a training session. The future likely lies in identifying fluid biomarkers or using advanced elastography to monitor acute structural deformations in vivo. Until such tools are validated, autoregulation will remain dependent on systemic proxy measures (HRV, grip strength) rather than tissue-specific indicators.

8.2. Monolithic Cohort Fallacy

Geriatric exercise literature consistently treats "older adults" as a single biological entity. This ignores the endocrinological cliff of menopause. The rapid withdrawal of estrogen alters female connective tissue architecture, accelerating collagen degradation and tendon stiffness at a rate distinct from age-matched males. Future paradigms should stratify load-management protocols by investigating how specific endocrine profiles modulate the acute mechanical tolerance of the myotendinous junction. Without sex-stratified data, the Load-Capacity Discrepancy framework risks over-generalizing thresholds that may differ by 20–30% between sexes in the post-menopausal cohort. This represents a testable hypothesis, not an established finding.

8.3. Statistical Fragility in Mediation

Theoretical models proposing psychosocial variables as mediators of injury risk require robust statistical validation. The literature has historically relied on the Baron and Kenny framework (1986), which imposes highly restrictive distributional assumptions and lacks power in skewed clinical samples. To overcome this methodological limitation, researchers are encouraged to transition to Bootstrap analysis. By utilizing resampling to directly test the indirect effect and generate bias-corrected confidence intervals, bootstrapping bypasses normality constraints and delivers a highly reliable evaluation of mediational pathways. When the confidence interval cleanly excludes zero, the mediating effect is robustly supported, establishing a modern, resilient standard for evaluating behavioral mechanisms in geriatric exercise. The field should adopt bootstrap methods as standard practice while recognizing that statistical significance in mediation does not substitute for causal evidence from randomized designs.

9. INSTITUTIONAL ADOPTION AND IMPLEMENTATION

The transition from heuristic-based exercise prescription to precision load management faces significant institutional friction. Research on organizational responses to evidence-based protocols in commercial settings indicates that a commitment to systematic, data-driven practices, rather than ad hoc compliance, drives sustained operational success (Algin & Sarvan, 2024; Serin et al., 2025).). Healthcare and rehabilitation facilities follow a comparable adoption curve: embedding precision geriatric loading requires the same administrative commitment to objective monitoring systems that industries utilize to secure operational advantage. Identifying the organizational factors that accelerate or impede this adoption remains an open question bridging implementation science and geriatric exercise physiology.

This narrative review has limitations consistent with its scope. The literature selection reflects the authors' judgment rather than a systematic search protocol, and selection bias cannot be excluded. The Load-Capacity Discrepancy framework is proposed as a conceptual model; its integrated clinical utility has not been tested prospectively. The three intervention strategies (ACWR adaptation, VBT, autoregulation) are extrapolated primarily from athletic and younger adult populations, and geriatric-specific randomized controlled trials remain sparse. These proposals should be regarded as evidence-informed directions requiring empirical validation.

CONCLUSION

Exercise is a potent biological intervention whose therapeutic window narrows with age. Vague, calendar-based progression correlates with either tissue failure or systemic detraining; the alternative is precise, day-to-day management of mechanical load calibrated to fluctuating tissue capacity. When the Load-Capacity Discrepancy is successfully managed, the yield extends beyond orthopedic resilience: regulated mechanical tension counters sarcopenia and bone mineral decay (Cruz-Jentoft et al., 2019; Warburton & Bredin, 2017), promotes hippocampal neurogenesis (Erickson et al., 2011), and reduces kinesiophobia and depressive isolation (Mikkelsen et al., 2017; Buman et al., 2010). These outcomes follow from keeping mechanical stress within the anabolic threshold through integrated physical and psychosocial management (Paterson & Warburton, 2010). Clinicians should consider replacing subjective pacing with objective readiness metrics, incorporating velocity-based training to address fall risk, and applying ACWR monitoring to prevent load spikes. Researchers should adopt bootstrap mediation methods embedded within longitudinal or experimental designs capable of supporting causal inference.

REFERENCES

Algin, A. (2024). Bibliometric analysis of research on gamification in nursing via visual mapping technique. Cadernos De Educação Tecnologia E Sociedade, 17(se5), 219–229.

Algin, A., & Sarvan, F. (2024). The effects of environmentally sensitive business practices on competitive advantage: A study on Antalya Organised Industrial Zone Companies. International Journal of Sports Technology and Science, 2(1), 66–81.

Alkan, İ., Algin, A., Toros, T., & Serin, E. (2025). Social Inclusion and Sports: Strategies to Promote Participation of People with Disabilities (Last 10 years). *Cuestiones de Fisioterapia*, *54*(3), 4849-4858.

Baltes, P. B., & Baltes, M. M. (Eds.). (1990). *Successful aging: Perspectives from the behavioral sciences.* Cambridge University Press. https://doi.org/10.1017/CBO9780511665684

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W H Freeman/Times Books/ Henry Holt & Co.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of personality and social psychology*, *51*(6), 1173–1182. https://doi.org/10.1037//0022-3514.51.6.1173

Buman, M. P., Hekler, E. B., Haskell, W. L., Pruitt, L., Conway, T. L., Cain, K. L., Sallis, J. F., Saelens, B. E., Frank, L. D., & King, A. C. (2010). Objective light-intensity physical activity associations with rated health in older adults. *American journal of epidemiology*, *172*(10), 1155–1165. https://doi.org/10.1093/aje/kwq249

Chodzko-Zajko, W. J., Proctor, D. N., Fiatarone Singh, M. A., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S. (2009). American College of Sports Medicine position stand: Exercise and physical activity for older adults. *Medicine and Science in Sports and Exercise*, 41(7), 1510–1530. https://doi.org/10.1249/MSS.0b013e3181a0c95c

Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A. A., Schneider, S. M., Sieber, C. C., Topinkova, E., Vandewoude, M., Visser, M., Zamboni, M., & Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2 (2019). Sarcopenia: revised European consensus on definition and diagnosis. *Age and ageing*, *48*(1), 16–31. https://doi.org/10.1093/ageing/afy169

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. https://doi.org/10.1207/S15327965PLI1104_01

Demirli, A., Yıldırım, S., Akyüz, Ö., & Özkara, A. B. (2024). Exercise and Health in the Elderly: Effective Approaches and Outcomes. *Journal of Sports and Science*, *2*(2), 89-104. https://izlik.org/JA98EY64GF

Dye S. F. (1996). The knee as a biologic transmission with an envelope of function: a theory. *Clinical orthopaedics and related research*, (325), 10–18. https://doi.org/10.1097/00003086-199604000-00003

Epro, G., Mierau, A., Doerner, J., Luetkens, J. A., Scheef, L., Kukuk, G. M., Boecker, H., Maganaris, C. N., Brüggemann, G. P., & Karamanidis, K. (2017). The Achilles tendon is mechanosensitive in older adults: adaptations following 14 weeks versus 1.5 years of cyclic strain exercise. *The Journal of experimental biology*, *220*(Pt 6), 1008–1018. https://doi.org/10.1242/jeb.146407

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., Kim, J. S., Heo, S., Alves, H., White, S. M., Wojcicki, T. R., Mailey, E., Vieira, V. J., Martin, S. A., Pence, B. D., Woods, J. A., McAuley, E., & Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(7), 3017–3022. https://doi.org/10.1073/pnas.1015950108

Gabbett T. J. (2016). The training-injury prevention paradox: should athletes be training smarter and harder?. *British journal of sports medicine*, *50*(5), 273–280. https://doi.org/10.1136/bjsports-2015-095788

Gillespie, L. D., Robertson, M. C., Gillespie, W. J., Sherrington, C., Gates, S., Clemson, L. M., & Lamb, S. E. (2012). Interventions for preventing falls in older people living in the community. *The Cochrane database of systematic reviews*, *2012*(9), CD007146. https://doi.org/10.1002/14651858.CD007146.pub3

Gulgosteren, E., Agrali Ermis, S., Algin Toros, A., Toros, T., Serin, E., Sekeroglu, M. O., & Bahadır Kayisoglu, N. (2025). Sweat, tears, and beyond: advanced wearable sensors for personalized health and athletic performance. *Frontiers in Bioengineering and Biotechnology*, *13*, 1684674. https://doi.org/10.3389/fbioe.2025.1684674

Kaya, N., & Algin, A. (2022). Technical efficiency in public hospitals: A meta-regression analysis. Eskişehir Osmangazi University Journal of Economics and Administrative Science, 17(3), 810–821.

Lord, S. R., Sherrington, C., Menz, H. B., & Close, J. C. T. (2007). *Falls in Older People: Risk Factors and Strategies for Prevention* (2nd ed.). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511722233

McAuley, E., Szabo, A., Gothe, N., & Olson, E. A. (2011). Self-efficacy: Implications for Physical Activity, Function, and Functional Limitations in Older Adults. *American journal of lifestyle medicine*, *5*(4), 10.1177/1559827610392704. https://doi.org/10.1177/1559827610392704

Mikkelsen, K., Stojanovska, L., Polenakovic, M., Bosevski, M., & Apostolopoulos, V. (2017). Exercise and mental health. *Maturitas*, *106*, 48–56. https://doi.org/10.1016/j.maturitas.2017.09.003

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., Macera, C. A., & Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and science in sports and exercise*, *39*(8), 1435–1445. https://doi.org/10.1249/mss.0b013e3180616aa2

Paterson, D. H., & Warburton, D. E. (2010). Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *The international journal of behavioral nutrition and physical activity*, *7*, 38. https://doi.org/10.1186/1479-5868-7-38

Pekgor, M., Algin, A., & Toros, T. (2025). RFID-embedded mattress for sleep disorder detection for athletes in sports psychology. *Scientific Reports*, *15*(1), 14697.

Pekgor, M., Algin, A., Toros, T., & Serin, E. (2024a). Wearable sensors in sports and healthcare: Technological advancements, applications, and future perspectives. *Nanotechnology Perceptions*, *20*(6), 1866–1877.

Pekgor, M., Algin, A., Toros, T., & Serin, E. (2024b). Wearable Sensors in Health and Sports Psychology. *Nanotechnology Perceptions*, *20*(6), 1900-1915

Pekgor, M., Algin, A., Toros, T., Serin, E., Kulak, A., & Tek, T. (2024c). Wearable sensor technology in health monitoring and sport psychology education. *Cadernos de Educação Tecnologia e Sociedade*, *17*(se5), 202–218.

Pekgor, M., Algin, A., Toros, T., Serin, E., Kulak, A., & Tek, T. (2025a). RFID sensor technology in health and sports education. *Cadernos de Educação Tecnologia e Sociedade*, *18*(se3), 29-43. https://doi.org/10.14571/brajets.v18.nse3.29-43

Pekgor, M., Algin, A., & Toros, T. (2025b). RFID-embedded mattress for sleep disorder detection for athletes in sports psychology. *Scientific Reports*, *15*(1), 14697. https://doi.org/10.1038/s41598-025-96311-0

Pekgör, M., Algın, A., Serin, E., & Toros, T. (2025c). Applications of wearable sensor technology for health monitoring in sports: Laboratory setup and requirements and future perspectives. *International Journal of Eurasia Social Sciences/Uluslararasi Avrasya Sosyal Bilimler Dergisi*, *16*(20).

Pekgör, M., Algın Toros, A., Toros, T., & Serin, E. (2025d). Review on university laboratory applications of RFID sensor technology in health and sports education. The International Journal of Eurasia Social Sciences, 16 (62), 2269- 2289. https://doi.org/10.14571/brajets.v18.nse3.29-43

Pérez-Castillo, Í. M., Rueda, R., Pereira, S. L., Bouzamondo, H., López-Chicharro, J., Segura-Ortiz, F., & Atherton, P. J. (2025). Age-related anabolic resistance: Nutritional and exercise strategies, and potential relevance to life-long exercisers. *Nutrients*, *17*(22), 3503. https://doi.org/10.3390/nu17223503

Rhodes, R. E., Janssen, I., Bredin, S. S. D., Warburton, D. E. R., & Bauman, A. (2017). Physical activity: Health impact, prevalence, correlates and interventions. *Psychology & health*, *32*(8), 942–975. https://doi.org/10.1080/08870446.2017.1325486

Rowe, J. W., & Kahn, R. L. (1997). Successful aging. *The Gerontologist*, *37*(4), 433–440. https://doi.org/10.1093/geront/37.4.433

Serin, E., Algin, A., & Toros, T. (2025). The Relationship Between Exercise and Sport and Epigenetics. *Cuestiones de Fisioterapia*, *54*(3).

Sherrington, C., Fairhall, N. J., Wallbank, G. K., Tiedemann, A., Michaleff, Z. A., Howard, K., Clemson, L., Hopewell, S., & Lamb, S. E. (2019). Exercise for preventing falls in older people living in the community. *The Cochrane database of systematic reviews*, *1*(1), CD012424. https://doi.org/10.1002/14651858.CD012424.pub2

Stathi, A., McKenna, J., & Fox, K. R. (2004). The experiences of older people participating in exercise referral schemes. *The journal of the Royal Society for the Promotion of Health*, *124*(1), 18–23. https://doi.org/10.1177/146642400312400108

Toros, A. A. (2025). The development and importance of gamification in nurse managers. *International Journal of Sports Technology and Science*, *3*(1), 195-206.

Toros, A. A., & Şekeroğlu, M. Ö. (2026). Teknolojinin ve Küreselleşmenin Kesişiminde Klinik Otorite ve Bakım Paradigması: Hemşirelik ve Sağlık Tarihine Sistemik Bir Bakış. *Journal of History School*, *19*(LXXX), 186-197. http://dx.doi.org/10.29228/joh.88740

Walker, A. (2002), A strategy for active ageing. International Social Security Review, 55: 121-139. https://doi.org/10.1111/1468-246X.00118

Warburton, D. E. R., & Bredin, S. S. D. (2017). Health benefits of physical activity: a systematic review of current systematic reviews. *Current opinion in cardiology*, *32*(5), 541–556. https://doi.org/10.1097/HCO.0000000000000437

World Health Organization. (2020). *WHO guidelines on physical activity and sedentary behaviour*. https://www.who.int/publications/i/item/9789240015128

Yıldız Öztürk, R., Pekgor, M., Algin, A., Toros, T., Serin, E., Tek, T., & Ergun, S. (2025). Enhancing athletic performance and well-being: The role of RFID Technology in health monitoring and sports psychology. *SPORT TK-EuroAmerican Journal of Sport Sciences*, *14*, 157.

Zijlstra, G. A., van Haastregt, J. C., van Eijk, J. T., van Rossum, E., Stalenhoef, P. A., & Kempen, G. I. (2007). Prevalence and correlates of fear of falling, and associated avoidance of activity in the general population of community-living older people. *Age and ageing*, *36*(3), 304–309. https://doi.org/10.1093/ageing/afm021