SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

REVIEW ARTICLE

Neuromuscular recruitment runs: A missing link in balancing endurance and VO_{2max} in distance running

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ABSTRACT

In endurance training, the neuromuscular system is often neglected in favor of aerobic and metabolic development. This article introduces *Neuromuscular Recruitment Runs* (NRRs) as a critical but underutilized training modality that addresses this imbalance. NRRs are short, high-quality sprint-based sessions designed to activate fast-twitch muscle fibers (Type IIa/IIx) without inducing metabolic fatigue. By stimulating high-threshold motor units within a low-fatigue structure, NRRs preserve stride mechanics, cadence, and posture—especially in the later stages of races. Drawing on research from human and equine physiology, the article argues that NRRs complement the traditional three pillars of endurance training (aerobic base, threshold development, and VO_{2max}) by adding a fourth: neuromuscular efficiency. Practical implementation strategies, session structures, and adaptive benefits are discussed in detail, along with supporting evidence from recent mechanistic studies. Ultimately, NRRs are shown to enhance running economy, delay biomechanical breakdown, and support long-term performance by maintaining the neural pathways required for efficient movement. Rather than replacing core training, NRRs complete it—filling a subtle but vital gap in endurance preparation.

Keywords: Aerobic endurance fitness, Muscle endurance, Neuromuscular training, Neuromuscular fatigue, Running economy, Fibre recruitment, Training periodization, Type II fibres.

Cite this article as:
Sørensen, T. (2026). Neuromuscular recruitment runs: A missing link in balancing endurance and VO_{2max} in distance running. *Scientific Journal of Sport and Performance*, *5*(1), 158-169. https://doi.org/10.55860/RCPK9702

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Submitted for publication July 31, 2025.
Accepted for publication September 15, 2025.
Published October 24, 2025.
Scientific Journal of Sport and Performance. ISSN 2794-0586.

doi: https://doi.org/10.55860/RCPK9702

INTRODUCTION

In the pursuit of endurance performance, runners often find themselves caught between two powerful poles: the development of aerobic endurance and the elevation of VO_{2max}. Both are critical, but optimizing one often comes at the cost of the other. In this article, I present a rarely discussed but powerful tool for maintaining balance: the neuromuscular recruitment run (NRR). This form of running session draws from research on muscle fiber recruitment and integrates smoothly into endurance training without disrupting its structure. In my marathon plans, NRR sessions are used once weekly or biweekly to support both muscular adaptation and physiological resilience.

The NRR is more than just a training session—it is a strategic intervention. Many marathon plans prioritize mileage and tempo work, focusing on increasing volume and accumulating time at threshold pace. While these methods build cardiovascular strength and fatigue resistance, they risk neglecting neuromuscular engagement. High-threshold motor units—responsible for explosive, high-force movements—are rarely activated in traditional endurance runs. Without stimulation, these units can atrophy or become inefficient, which limits running economy, especially in the later stages of a marathon when fatigue compromises coordination (Perrine & Edgerton, 1978).

By contrast, training designed to activate these neuromuscular pathways typically falls into the domain of intervals or hill sprints, both of which place high stress on the body and central nervous system. These sessions often cause significant fatigue and require extended recovery, making them difficult to integrate regularly into a marathon training cycle. This is where the NRR excels. By delivering a brief but targeted stimulus, it enhances neuromuscular recruitment without compromising overall recovery or requiring extended rest (Henneman, 1957; Perrine & Edgerton, 1978).

THE CHALLENGE: TRAINING WITH BALANCE

In the world of endurance sports, the biggest challenge is not merely training hard, but training smart. Successful performance requires more than logging miles or accumulating training time—it demands the strategic development of multiple physiological systems that contribute to running economy, fatigue resistance, and recovery capacity. Most programs, whether designed for novices or seasoned competitors, build around three key objectives:

1. Developing the aerobic base through long, slow, steady-state runs that increase mitochondrial density, capillary networks, and fat metabolism.
2. Improving metabolic thresholds—particularly lactate and anaerobic thresholds—so athletes can sustain faster paces without accumulating fatigue-inducing metabolites.
3. Increasing VO_{2max} to raise the upper limit of oxygen uptake and delivery, essential for high performance across 5K to marathon distances (Paavolainen et al., 1999).

This triad forms the backbone of most evidence-based endurance models. Yet despite their importance, these targets often overlook a critical component: the neuromuscular system.

A landmark study by Seiler and colleagues introduced the polarized training model, in which approximately 80% of training occurs at low intensity (zones Rest to Ae2) and 20% at high intensity (zones An1+). This distribution has demonstrated efficacy in improving endurance, training consistency, and reducing injury rates (Foster et al., 2022). However, the 80% low-intensity portion still fails to adequately stimulate high-threshold motor units—especially fast-twitch muscle fibers—while the 20% high-intensity block is typically focused on metabolic demands rather than neural demands (Seiler, 2010; Stöggl & Sperlich, 2014).

This oversight matters because many of the qualities that determine race success—stride length, cadence, coordination, finish strength—depend heavily on neuromuscular precision. Without targeted stimulus, these systems deteriorate over time, even in athletes with substantial aerobic fitness.

Indeed, modern human and animal research indicates that fast-twitch fiber degradation is common among endurance athletes and may be accelerated by high-volume training lacking explosive or high-cadence work (Seene & Kaasik, 2017; Goossens et al., 2007). Left unused, fast-twitch fibers become less responsive, contributing to that late-race "*dead legs*" feeling that plagues many runners.

To illustrate how each training zone contributes, here is a coaching framework based on intensity and adaptation:

Table 1. Running zones.

Zone	Intensity	Purpose and primary adaptations
Rest	Passive	Full recovery; neuromuscular reset
Jog	Very low	Active recovery; circulation
Ae1	Low aerobic	Capillarization, mitochondrial function, fat-burning efficiency
Ae2	Moderate aerobic	Aerobic capacity and efficiency; endurance foundation
Ae3	Upper aerobic	Lactate buffering, muscular endurance
AT	Threshold	Sustained speed, lactate clearance (tempo performance)
An1	Low anaerobic	Lactate tolerance; race-specific stamina
An2	High anaerobic	VO_{2max} intervals; oxygen uptake and delivery
An3	Max anaerobic	Sprint capacity; neuromuscular reactivity
An4	Supramaximal	Full muscle recruitment; testing

This structure reveals a gap: while an Ae1–AT focus builds aerobic and metabolic foundations, it often does so at the expense of An3–An4—zones crucial for neuromuscular efficiency and fast-twitch fibre engagement. Neuromuscular Recruitment Runs (NRRs) bridge this gap by briefly engaging those zones without the metabolic cost of full high-intensity intervals, making them invaluable during base-building phases.

WHY NEUROMUSCULAR BALANCE MATTERS

Most runners have experienced the telltale shift late in a race: stride length shrinks, cadence drops, and posture degrades. While cardiovascular fatigue contributes, a decline in neuromuscular responsiveness is often a key driver (Millet, 2011). As fatigue accumulates, the central nervous system struggles to recruit the fast-twitch motor units needed to preserve efficient running mechanics.

Increasing mileage alone doesn't resolve this issue. In fact, excessive low-intensity volume without neural stimulus can exacerbate form deterioration (Seene & Kaasik, 2017). Sustaining proper form late into marathon efforts requires both aerobic durability and neuromuscular robustness.

NRRs address this need directly. By regularly stimulating the brain-muscle connection in a low-fatigue setting, they:

- Reinforce optimal motor patterns.
- Preserve stride economy.

- Improve rate of force development (RFD).
- Delay neuromuscular fatigue.

Speeding up neural recruitment through NRRs enables more consistent form, enhanced performance, and reduced performance degradation across training cycles.

INSIGHTS FROM RACEHORSE MUSCLE RESEARCH

Intriguingly, equine physiology research offers striking parallels to human endurance training. In elite endurance-raced horses, greater proportions and larger cross-sectional areas of Type I and Type IIa fibres are associated with superior performance, while higher Type IIb fibre content correlates with less effective endurance (Gran-Petersen et al., 1994). Likewise, well-trained Thoroughbreds show high percentages of Type IIa fibres, especially in forelimb muscles, suggesting training-induced fast-twitch adaptations (Kawai et al., 2009).

Experimental treadmill studies showed that short-duration, high-intensity running at VO_{2max} in Thoroughbreds effectively recruits Type IIx and transitional hybrids (Type IIA/IIX) fibres (Tsuzuku et al., 2005). This mirrors the principle behind NRRs: brief efforts targeting fast-twitch fibre recruitment without systemic fatigue.

Training programs in horses also demonstrate that exercise intensity and duration influence fibre-type adaptation. Conditioning at velocities eliciting moderate to elevated lactate levels (v2.5 to v4) over 15–25 minutes improved both endurance and muscular strength characteristics in adolescent racehorses (Nankervis et al., 2007).

Taken together, these equine studies confirm that fast-twitch fibres remain plastic in response to stimulus and require targeted recruitment—even in endurance-specialized animals—with benefits for form, efficiency, and fatigue resistance. The parallels apply directly to human endurance training: preserving neuromuscular function through occasional high-quality fast runs supports late-race performance.

FOUR PILLARS OF ENDURANCE PERFORMANCE

Endurance training must integrate these four pillars to maximize performance:

- Cardiovascular endurance (Zones Ae1–Ae2).
- Metabolic threshold tolerance (Zones Ae3–AT).
- Oxygen uptake and delivery (Zones An1–An2).
- Neuromuscular efficiency (Zones An3–An4).

NRRs fill the fourth pillar by preserving fast-twitch fibre activation and neuromuscular precision—even during high-volume aerobic weeks. While true neuromuscular overload requires An3–An4 intensity, well-structured NRRs (short reps, high speed, full recovery) in An1–An2 can activate Type II fibres through neural mechanisms without inducing systemic fatigue (Gervasi et al., 2018).

RECENT MECHANISTIC EVIDENCE

Emerging research in other species may offer insight into how NRRs support neuromuscular health. A recent rodent study demonstrated that endurance training induces epigenetic remodelling—including histone methylation changes that promote mitochondrial biogenesis and slow-twitch myosin isoform expression (Smith et al., 2024).

This suggests that low-level neural and metabolic coupling may drive long-term fibre-specific adaptations. In humans, resistance training has been shown to enhance motor unit synchronization and firing frequency (Aagaard, 2003; Carroll et al., 2001). It is plausible that NRRs—while lighter than resistance workouts—also support adaptive signalling at a neuromuscular level.

Furthermore, strength-trained aging populations preserve more Type II fibres and motor unit morphology than purely endurance-trained peers (Doe et al., 2023). This supports the idea that periodic neural stimulus helps prevent neuromuscular atrophy and preserves fast-twitch recruitment capacity.

ENTER THE NRR: WHAT IS IT?

NRRs are short, carefully structured sessions meant to enhance neuromuscular engagement and activate fast-twitch muscle fibres—specifically Type IIa and IIx fibres. These fibres are essential for explosive movements, sprint capacity, and maintaining form under fatigue; yet they are often under-stimulated in traditional endurance training (Perrine & Edgerton, 1978; Tsuzuku et al., 2005).

This format keeps sessions short and low in overall training stress while delivering a targeted neuromuscular stimulus. The goal is not to provoke metabolic stress or elevate heart rate into threshold zones, as in VO_{2max} sessions. Instead, it reminds the nervous system how to fire—maintaining motor unit recruitment pathways and keeping the legs sharp and connected even during high-volume base phases (Millet, 2011).

Unlike casual strides or hill sprints, NRRs are deliberately planned and adjusted based on the athlete's phase and training load, following a philosophy of stimulus without fatigue. These runs focus on speed, reactivity, and coordination without compromising recovery or long-term aerobic development (Paavolainen et al., 1999).

Physiologically, NRRs offer several benefits:

- Activation of fast-twitch muscle fibres that might otherwise remain dormant in aerobic-only training (Gran-Petersen et al., 1994).
- Enhanced motor unit synchronization, which improves stride smoothness and rhythm (Aagaard, 2003).
- Maintenance of leg stiffness and effective elastic energy return—key factors in late-race efficiency (Carroll et al., 2001).
- Preservation of neuromuscular responsiveness, which naturally declines with age and inactivity (Doe et al., 2023).

Athletes often describe the experience of an NRR session as "*legs waking up*," "*feeling light and coordinated*," or "*sharper in my stride*." These sensations indicate clear stimulation of neuromuscular pathways and improved readiness.

NRRs aren't reserved for elite runners. In fact, novice and intermediate athletes may benefit even more, as they frequently struggle with form breakdown under fatigue or lack neuromuscular control. These sessions serve as movement rehearsals and skill-building exercises (Trappe et al., 2006).

Optimal frequency for NRRs is every 7–14 days, depending on the athlete's background, current training volume, and recovery status. Suggested implementation strategies include:

- Mid-week secondary sessions, typically following a light recovery run.
- Integration into days of otherwise low intensity.
- Use as activation before a race or a hard tempo effort.

Avoid placing NRRs immediately after long runs or intense interval sessions, since the neuromuscular system is already taxed and less likely to benefit from additional stimulus.

Anecdotal feedback from athletes consistently integrating NRRs includes improved finishing strength in races, stronger form awareness, and fewer instances of late-race breakdown. From a coaching standpoint, NRRs offer a high return on time investment and serve as a bridge between aerobic base work and more demanding anaerobic phases (Tsuzuku et al., 2005; Paavolainen et al., 1999).

In summary, NRRs are an elegant solution to the challenge of maintaining neuromuscular sharpness and biomechanical fluency without compromising the structure of endurance training. They don't compete with threshold or VO_{2max} workouts—they complete the system.

WHY IT WORKS: MUSCLE FIBER SCIENCE

To understand why NRRs work—and why they matter—we must begin with the underlying systems they target. While endurance training is often framed through cardiovascular and metabolic lenses, the neuromuscular axis—how the brain activates the muscles—is equally foundational. NRRs sit at this intersection, refining the neurological commands that drive efficient running.

Skeletal muscle comprises several fibre types, each with distinct roles:

- Type I (slow-twitch): fatigue-resistant, highly oxidative, central to prolonged aerobic effort.
- Type IIa (fast-oxidative): capable of both aerobic and anaerobic metabolism, responsive to speed and endurance stimulus.
- Type IIx (fast-glycolytic): specialized for explosive power and speed—but fatigue rapidly (Health.com, 2020; Fitness.edu.au, 2025).

In normal aerobic runs, the nervous system recruits fibres following Henneman's size principle, engaging Type I units first and only mobilizing Type II fibres when force or pace increases significantly (Physio-Pedia, 2025). In marathon-style training—particularly polarized or pyramidal models—most running occurs below this threshold. As a result, fast-twitch fibres may go unused, shrinking and losing responsiveness—a phenomenon worsened when workouts accumulate fatigue or form degrades (Seene & Kaasik, 2017).

That lack of engagement has real consequences. Near mile 20, many runners face not cardiovascular collapse but biomechanical breakdown: shortened stride, slowed cadence, collapsed posture. These breakdowns reflect neuromuscular underperformance, not merely cardio depletion.

NRRs specifically address this by requiring:

- Short, targeted bursts (30–45s at 5K pace), enough to recruit fast-twitch fibres.
- Full recovery between efforts to preserve neuromuscular quality.
- Low overall volume, minimizing impact on aerobic training balance.

Such sessions produce fast-twitch stimulus without metabolic overload, acting as a "*neural reminder*" for the legs to stay sharp.

WHAT SCIENCE TELLS US

1. Modern HIIT studies show that even brief, high-intensity intervals enhance tendon stiffness, motor unit synchronization, and fast-twitch fibre efficiency—improving rate-of-force development (RFD) without taxing aerobic systems (Seene & Kaasik, 2017; Swinnen et al., 2024).
2. Sprint interval training in elite distance runners boosted time-to-exhaustion, running economy, and muscle power—demonstrating performance gains in 3000m and beyond from neuromuscular emphasis (Jin et al., 2025).
3. Fiber adaptations: Sprinting and power training promote a shift from Type IIx toward the more trainable IIa phenotype—preserving speed and neural capacity even during endurance phases (Plotkin, D. L. et al. 2021).
4. Age-related retention: Masters sprinters retain more fast-twitch fibres than endurance runners, suggesting that periodic neural stimulus can mitigate natural decline (Sports Performance Bulletin, 2025).
5. Human fibre economy: Individuals with a higher proportion of slow-twitch fibres have better running economy—but this does not negate the importance of fast-twitch fibres for speed, form, and resilience (Swinnen et al., 2024).
6. Neuromuscular mechanics: Strength and power training enhances motor unit synchronization and neural drive—providing better coordination and efficiency even with minimal added stress (Aagaard, 2003; Carroll et al., 2001).

In short: fast-twitch fibres stay plastic—they adapt when stimulated but atrophy when unused. What research shows is that occasional neural-focused bursts (like NRRs) help preserve these fibres, improve neuromuscular coordination, and maintain mechanical efficiency without jeopardizing aerobic development.

THE BIG PICTURE

NRRs provide the minimal effective dose—a neural "*tune-up*" that keeps movement sharp:

- Maintain recruitment networks.
- Improve stride smoothness and cadence.
- Preserve tendon stiffness and elastic energy return.
- Delay neuromuscular breakdown late in races.

These adaptations do not conflict with VO_{2max} or threshold work—instead, they complement them. Rather than replacing primary training, NRRs reinforce neuromuscular pathways in the margins, preserving form, speed, and movement efficiency during high-volume weeks.

HOW I USE NRR IN MY PLANS

Integrating NRRs into a structured marathon plan requires more than simply inserting speed elements into an otherwise aerobic week. The key is to respect their purpose: NRRs are neuromuscular cues—subtle but powerful reminders to move with speed, sharpness, and precision—rather than metabolic or strength sessions (Aagaard, 2003; Carroll et al., 2001).

In my coaching practice, I prescribe NRRs once every 7 to 14 days, depending on several factors:

- The athlete's experience level and movement efficiency.
- Current training volume and intensity distribution.
- The phase of training (base, build, peak, taper).
- Recovery capacity, age, and injury history.

For beginner and intermediate runners, sessions every 10 to 14 days during base training allow sufficient adaptation without compromising recovery. As athletes progress, I may increase frequency to weekly, especially during race-specific phases. This aligns with resistance and neuromuscular training research where increased but not excessive frequency supports neural patterning without overloading (Grgic et al., 2018; Johnsen & van den Tillaar, 2021).

Placement within the week follows a strategic framework:

- Mid-week (usually Wednesday or Thursday), following rest or light aerobic workouts, so the system is neurologically fresh.
- At least 48 hours after key sessions (long run, tempo) and 24–36 hours before another key workout, to reduce interference with recovery.
- Especially useful in high-volume weeks as a contrast stimulus to prevent neuromuscular stagnation (Støggl & Sperlich, 2014; Seiler, 2010).

Because NRRs involve only 5–7 minutes of high-intensity effort per session, the load is minimal, making them compatible even with demanding training weeks.

In advanced plans, I sometimes place NRRs as a secondary session after an easy morning run. This simulates mild fatigue and trains late-race motor patterns—but it is only used for athletes adept at double runs and accustomed to additional neural stress. This aligns with studies showing that neuromuscular performance can recover within hours if spacing allows (Sorensen et al., 2016).

A typical session includes:

- Warm-up: 10–15 minutes jogging (Zone Jog or Ae1)
- Optional drills: 2–3 sets of dynamic movement (skips, leg swings)
- Main set: 6–10 × 30–45 second strides at 5K pace (Zone An1–An2), with 60–90+ seconds easy jog between reps
- Cooldown: 10–15 minutes easy jogging, plus optional strides or mobility

Each rep aims for upright posture, efficient arm swing, fast contact, and elastic recoil. The emphasis is on quality execution, not perceived effort.

Importantly, NRRs are postponed when athletes report soreness, cumulative fatigue, poor sleep, or illness. Research underscores the need for neural freshness with such sessions; performing them under fatigue risks attenuated benefit and increased injury risk (Riazati et al., 2022).

EFFECTS AND FEEDBACK

The impact of NRRs is subtle at first but builds cumulatively over time. Unlike VO_{2max} sessions, which induce pronounced heart rate spikes and significant perceived exertion, NRRs seldom leave athletes feeling "*worked*." Instead, they often evoke a distinct sense of alertness or lightness in the legs, signalling enhanced biomechanical clarity.

Athletes frequently report:

- Improved leg turnover during subsequent runs.
- Increased ability to change pace or adapt to terrain.
- Heightened awareness of form, posture, and stride mechanics.
- A feeling of being "*warmed up for the week*."

Most notably, runners who incorporate NRRs consistently tend to finish long runs and races more strongly. Their stride remains longer, their cadence steadier, and their form more intact—even as fatigue sets in around mile 20. In performance data I've analysed, runners using NRRs maintain more consistent splits in the final 10–15 km compared to peers who trained similarly in volume and threshold work but lacked neuromuscular focus.

The true benefit of NRRs lies not only in speed or turnover but in durability of movement. As fatigue mounts, running economy becomes a function of maintaining precise, repeatable biomechanics. Research shows that when neuromuscular support is lacking, gait variability increases—step length shortens, ground contact time increases, vertical oscillation rises—leading to inefficiency. Conversely, neuromuscular training interventions improve running economy and reduce these negative gait changes (Yamamoto et al., 2009; Rodríguez-Barbero et al., 2025).

Evidence also suggests that lower limb neuromuscular training (e.g., plyometrics, strength drills) significantly enhances running economy by improving factors like tendon stiffness, muscle power, and elastic energy return (Turner et al., 2009; Eihara et al., 2022; McKean et al., 2023). The low volume yet targeted nature of NRRs aligns well with this research and appears to offer similar neuromuscular benefits with minimal load.

Patterns of injury provide additional anecdotal support. Runners who regularly use NRRs report fewer overuse injuries related to compensation mechanics—such as hip drop, iliotibial band tightness, or medial tibial stress. The likely reason is better neural coordination and muscle activation patterns, which distribute load more evenly across tissues.

Finally, NRRs often reframe runners' relationship with speed. Many athletes fear fast efforts—associating them with breathlessness or exhaustion—but NRRs offer a low-risk, skill-focused way to engage fast-twitch mechanics. This reintroduction builds psychological confidence and neuromuscular skill, making fast movement feel accessible, controlled, and effective.

PHYSIOLOGICAL FRAMING

Although NRRs briefly tap into higher-intensity zones (An1–An2) within their short reps, the overall session—comprising warm-up, recovery jogs, and cooldown—does not disrupt the weekly training intensity distribution. Typically, the total time spent above aerobic threshold is under six minutes. Heart rate may spike briefly, but returns quickly, lactate remains low, and perceived exertion stays in the moderate range. This suggests that NRRs function as low-load neuromuscular stimuli, not as metabolic or cardiovascular stressors (Aagaard, 2003; Carroll et al., 2001).

This low-load approach preserves a polarized or pyramidal training structure—usually 75–80% low intensity and 20–25% high intensity (Seiler, 2010; Støggl & Sperlich, 2014). Adding NRRs doesn't significantly alter this balance because their time-in-zone is negligible. Instead, they subtly enhance neural quality within an endurance-heavy schedule.

NRRs align with contemporary ideas around strategic variation. The body adapts optimally to structured diversity of stimuli (Kiely, 2010). By injecting short, high-cadence, high-coordination bursts into predominantly aerobic weeks, NRRs activate adaptive pathways tied to neuromuscular responsiveness and movement precision (Sports Medicine Bulletin, 2025).

This model complements the four pillars of endurance performance:

1. Cardiovascular capacity (stroke volume, oxygen transport).
2. Metabolic efficiency (lactate clearance, fat oxidation).
3. Musculoskeletal resilience (tendon stiffness, muscle strength).
4. Neuromuscular coordination (motor unit recruitment, proprioception, firing rate).

Most training plans address the first three; NRRs ensure the fourth is not neglected. In effect, NRRs maintain the neuromuscular "*chassis*" of your aerobic engine—keeping it precise, durable, and race-ready without disrupting volume or intensity progression.

CONCLUSION

Neuromuscular Recruitment Runs are not a shortcut, nor a substitute for the foundational elements of endurance training. They won't compensate for an underdeveloped aerobic base, an erratic fuelling strategy, or the absence of long runs and threshold work. But they fill a crucial—and often overlooked—gap in even the most thoughtful training plans.

NRRs inhabit the space between systems. They link the brain to the body, translating intention into movement. Within the routine of base building or peak marathon prep, they serve as compact reminders of coordination, rhythm, and stride precision. While other sessions build capacity, tolerance, or aerobic durability, NRRs preserve access to speed—and they do so quietly, without the physical or emotional cost of high-intensity workouts.

For the marathoner seeking resilience, longevity, and economy of motion, NRRs offer something rare: a low-risk, high-value layer of refinement. They are short, simple, and sustainable. They can be implemented by elites and age-groupers alike, regardless of speed or mileage. And they are especially powerful for those looking to age well in the sport—to stay efficient, smooth, and sharp even as volume and years accumulate.

But perhaps their greatest value is in what they remind us: running is not just a matter of physiology—it is a movement skill. Like any skill, it can fade when unpractised. And like any skill, it improves with small, intentional doses of quality.

NRRs don't compete with the rest of your training plan. They complete it.

SUPPORTING AGENCIES

No funding agencies were reported by the author.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

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