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The Prince Rupert's drop paradigm in sports: *GiCheon's YeokGeun*

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Abstract

The Prince Rupert's drop, renowned for its unique interplay of tensile and compressive forces, serves as a metaphor for the biomechanical and physiological adaptations promoted by *GiCheon* practice of *YeokGeun*. As a cornerstone of *GiCheon* − a Korean discipline emphasizing the harmonization of mind and body through *ki* cultivation − *YeokGeun* focuses on extreme isometric joint-locking exercises. These exercises develop resilience, strength, and adaptability by transforming the musculoskeletal system through targeted neuromuscular, structural, and biochemical adaptations. While deeply rooted in traditional Korean health and martial systems, this work acknowledges that empirical validation of such holistic paradigms presents substantial methodological challenges. The manuscript proposes potential avenues for systematic study of physiological and biomechanical impact of *YeokGeun*, aiming to bridge conceptual insight and quantifiable research. The emphasis the practice places on balance and precision mirrors the capacity of the Prince Rupert's drop to withstand stress and highlights its role in enhancing athletic performance, injury prevention, and overall well-being. This paradigm bridges traditional Korean health systems with modern sports science, offering a holistic framework for fostering long-term physical and cognitive resilience. Key areas of focus include structural integrity, metabolic efficiency, and the application of biomechanical models like tensegrity to refine energy transfer across the kinetic chain. *GiCheon* method of *YeokGeun* emerges as a powerful tool for both athletes and individuals seeking holistic physical and mental development.

KEYWORDS: *GiCheon*, *YeokGeun*, *bahn tan*, Prince Rupert's drop, isometric training, Korean traditions, tensegrity model, athletic performance, holistic wellness.

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Introduction

The Prince Rupert's drop, a marvel of materials science, demonstrates a remarkable balance between resilience and vulnerability, two core concepts in sports as well (Figure 1). Formed by dripping molten glass into cold water, the bulbous head of the drop exhibits extraordinary strength (even being bulletproof) due to the unique distribution of compressive and tensile stresses within its structure, while its fragile tail can cause the entire system to shatter when compromised. This duality serves as a metaphor, or an analogy, for the adaptations observed in the human musculoskeletal system under specific types of training stress, especially what we shall examine here in the form of *YeokGeun* from the great tradition of the Korean *GiCheon*. *YeokGeun* is just one of the many ways or tools of *GiCheon*. The importance of the teachings of the great traditions of mankind for sports was already discussed in a previous article [1].

It is important to clarify that the use of the Prince Rupert's drop as a metaphor does not imply that after practicing *YeokGeun*, the human body develops weak

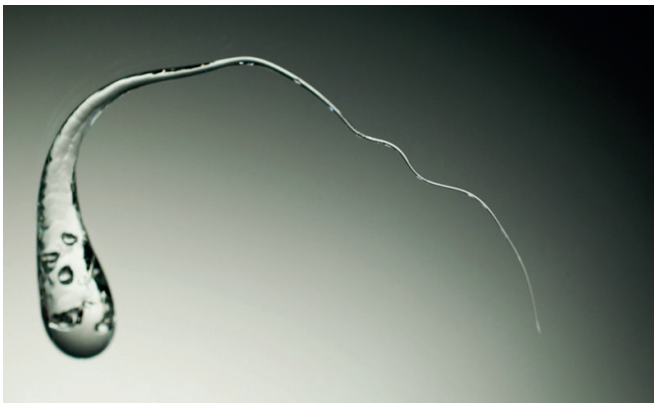

Figure 1. Prince Rupert's drop

or fragile parts. Rather, it illustrates the necessity of balance, refinement, and precision of human movement, especially when athletic performance and motor expertise are the desired outcomes. Just as the design of the drop demonstrates resilience through the interplay of forces, *YeokGeun* produces dynamic robustness by addressing areas of potential misalignment or inefficiency inside the various complex apparatuses that make up the musculoskeletal system. This ensures that the body develops strength, stability, and adaptability in a balanced manner. The very essence of the mechanism by which the Prince Rupert's drop itself withstands such enormous loads, is because it transfers and spreads them throughout its structure (especially to its weak tail). Therefore, the Prince Rupert's drop metaphor is an indirect reference to the tensegrity model and a direct reference to the body's extraordinary, save unrealized, capacities.

The practice of *YeokGeun*, which involves intense isometric locks at extreme joint positions, embodies this paradigm, fostering resilience while mitigating vulnerabilities. Through targeted training, *YeokGeun* induces structural, neurological, and functional adaptations that enhance the body's capacity to withstand external forces and recover from stress. This paradigm connects traditional practices with modern kinesiology, providing a framework for understanding the benefits of special isometric training across multiple levels of analysis. The following sections will explore these levels, starting with the historical and cultural context of *YeokGeun* and moving on to microscopic structural adaptations in muscle fibers and other important types of physiological and neurological transformations essential to understanding its holistic impact on human performance and well-being. As we shall see, such extreme locks may provide many benefits in terms of power, explosiveness, muscle architecture and injury prevention and rehabilitation − bold statements themselves, but this was the rationale behind the development of modern *GiCheon* itself both as a martial art and a spiritually oriented well-being system. Despite strong theoretical and interdisciplinary basis, current empirical support remains limited, largely due to the complexity of operationalizing holistic mind-body interventions in controlled studies. To advance scientific understanding, we recommend pilot studies using: controlled trials measuring musculoskeletal, metabolic, and neurological adaptation in athletes practicing *YeokGeun* or FlexLock vs. standard isometric training; biomechanical assessments (e.g., dynamometry, EMG, joint kinematics) to quantify stress distribution during extreme isometric locks; pre- and post-intervention physiological markers (e.g., lactate threshold, muscle fiber composition via noninvasive imaging or muscle biopsy, hormonal stress response). Such study designs can begin to provide empirical scaffolding without undermining the holistic principles of the practice.

The present paper (i) outlines the theoretical rationale of prolonged isometric *YeokGeun*, (ii) collates evidence for its structural, metabolic, and neurological adaptations, and (iii) proposes empirically testable study designs.

New perspective

The historical and cultural context of YeokGeun

GiCheon (기천), meaning "energy heaven," is a Korean discipline that emphasizes the harmonization of body and mind through the cultivation of *ki* (기, "life energy").[1] Popularized in the 1970s, it integrates elements of Korea's indigenous health traditions, Taoist inner alchemy (내단), and Buddhist meditative practices. *GiCheon* is structured around the interplay of physical rigor and meditative stillness, providing a holistic framework for self-cultivation aimed at achieving balance, resilience, and spiritual clarity. As a form of *ki suryŏn* (기수련), or "ki training," *GiCheon* focuses on transforming the body and mind-heart, aligning with practices characterized as internal alchemy (내단) and nourishing life (양생).

Within this broader discipline, *YeokGeun* (역근, "transforming muscles") is a central practice that encapsulates these principles through its focus on seemingly strenuous static joint-locking exercises − the *YeokGeun* principle. The foundational practice

[1] Due to the symbolic nature of the terms in the Korean language, there is no exact one-to-one correspondence between the terms and their definitions. Instead, their meaning encompasses a spectrum of interpretations and translations.

of *GiCheon* revolves around six archetypal postures: *Taedo*, essentially a long forward-stepping stance that trains reach and balance; *Pŏmdo*, a slightly shorter tiger position whose compact stride refines weight-shift control; *Kŭmgyedongnip*, literally "golden rooster stands on one leg," which challenges single-leg stability; *Hŏgong*, the empty sky pose that elongates the torso and opens the shoulders into spacious alignment; *Sodo*, a deliberately narrow small step stance that cultivates centred stillness; and *Tanbaegong*, a full-body deep bow in which knees, hips, elbows and wrists bend together to emphasise joint integrity and focus. Together these six positions furnish the scaffolding for all subsequent *YeokGeun* work, the foundation for more dynamic training later on, each highlighting a different corner of strength, flexibility and proprioceptive awareness. An example of a training session is depicted in Table 1.

The historical roots of *GiCheon* are intertwined with traditional Korean health practices, which sought to enhance physical strength and regulate the flow of *ki*. While it shares similarities with broader Eastern traditions such as *qigong* (氣功) and yoga, *YeokGeun* is uniquely Korean. The principles similar to *YeokGeun* itself also exist in other such systems, but nowhere as centrally placed as in *GiCheon* practice. Moreover, there are other differences as well: for example, in yoga, usually, the various locks are held in place with the help of the gravity or of other parts of the body; in *GiCheon*, *YeokGeun* is achieved only by using muscle force and the lock is isometric. For comparison, a very basic static exercise in *GiCheon*, which is used in many of its other forms, is what other traditions call the Buddha's palm. Here, the strenuous extension of the palm is kept for as long as possible without loosening the tension at all throughout the exercise (Figure 2). The same principle applies to the crane beak hand position (Figure 3), and of course to all other *GiCheon* hand and body positions (Figure 4).

Figure 2. A classic *GiCheon* hand position dynamically held in full extension, also known as Buddha's palm in certain martial art systems

Figure 3. A classic hand form in *GiCheon*, somewhat similar to the Prince Rupert's drop and reminiscent of the crane beak position found in certain martial art styles

The etymology of the term − *yeok* (역, "to change") and *geun* (근, "muscle") − highlights the focus of the practice on transformation, both corporeal and energetic. Practitioners hold prolonged, controlled positions at the boundaries of their physical range, cultivating resilience and adaptability. By prolonged, one means

Table 1. Example of practice program of traditional *GiCheon*

Phase / parameter	Beginner	Explanation
Warm-up	cyclic movements, joint static holds (such as Buddha's palm)	5 minutes of *GiCheon*-specific warm-up exercises
Static holds	3-6 positions × 2 sets × 1-9 minutes each	the number of positions and the duration of holds depends on the level of practitioners
Dynamic movements	*Tanbaegong*	*Tanbaegong* is central; many other movements are also practiced depending on the level
Static holds	*NaeGa ShinJang*	usually held for maximum amount of time as the final exercise/test
Weekly frequency	2-7 sessions	beginners do fewer sessions; advanced practitioners do the traditional daily practice

Figure 4. The most famous *GiCheon* form, *NaeGa ShinJang* (내가 신장, "inner divine palm" or "inner spirit expansion"), consisting of multiple and simultaneous locks in all areas of the body

from several minutes up to one Korean hour (which is actually 120 minutes). Standard holds last 1-3 minutes for novices, 3-10 minutes in intermediate practice, and close to an hour for advanced practitioners − two-hour holds or longer are for world-class, dedicated practitioners. Such volumes are dictated by *GiCheon* tradition; *GiCheon* itself was created based on the idea that these holds pose a significant stress to the meridians (the energy channels) and "force them to open". More modern approaches (and future studies) have already identified (and hopefully will continue to do so) other beneficial mechanisms, such as the ones proposed here. The approach *GiCheon* adopted also aligns with Korea's philosophical tradition, where the interplay of *eum* (음, "negative") and *yang* (양, "positive") energies fosters harmony and balance; by uniting opposites, it is comparable to yoga in this respect.

The transmission of *GiCheon* historically was grounded in oral traditions and close mentorship − like so many other traditions. This method of teaching emphasizes not only the technical aspects of the practice but also its deeper philosophical significance, developing trust and mutual growth between teacher and student. The preservation of this personal mode of transmission is crucial in that it reflects the holistic philosophy of *GiCheon*, where physical practice is inseparable from spiritual guidance. In adapting to modern contexts, *GiCheon* has successfully bridged its traditional roots with contemporary wellness practices, maintaining its essence while becoming accessible to a more global audience − a process still far from completed.

Mythologically, *GiCheon* draws upon Korea's rich spiritual heritage. One notable legend involves Bodhidharma acquiring *GiCheon* techniques from the sage CheonSeonYeo (천선여), a narrative symbolizing the synthesis of divine wisdom and human effort. Though not historically verified, these tales capture the essence of the practice, highlighting the quest for spiritual and corporeal transcendence through dedication and beauty.

Philosophically, *GiCheon* and its *YeokGeun* practice embody the principle of the Middle Path (중반지능), which promotes balance and neutrality as the foundation for physical and spiritual growth. By integrating *eum* and *yang* energies, the practice fosters mental clarity alongside physical resilience. The static joint-locking positions embody this balance, teaching practitioners to turn discomfort into resilience and resistance into adaptability. This approach highlights the idea that true growth comes from enduring challenges while maintaining balance.

In contemporary contexts, *GiCheon* has already started demonstrating its relevance through its alignment with modern wellness practices, finding applications in diverse fields such as rehabilitation, sports, and mental health − admittedly still at a rudimentary level. Its meditative and physical components can address modern challenges by promoting holistic wellness and resilience. As it continues to gain recognition internationally, *GiCheon* serves as both a cultural treasure and a living practice.

Next, we shall see the potential physiological, psychological and neurological adaptations to this kind of training mode, as well as potential benefits.

Structural and biomechanical adaptations in the musculoskeletal system

The human musculoskeletal system exhibits remarkable adaptability when subjected to specific types of stress, particularly through isometric training at the boundaries of the range of motion (ROM), as is customary in *GiCheon* practice. At the microscopic level, structural alignment of muscle fibers, hypertrophy, and changes in pennation angle underpin the adaptive benefits of *YeokGeun* training, particularly for extreme isometric locks at the limits of ROM [2]. These adaptations resonate with the balance of tensile and compressive forces observed in the Prince Rupert's drop, providing strength and resilience to the musculoskeletal system under high loads.

Muscle hypertrophy, primarily in type II fibers, facilitates rapid force generation, critical for sustaining high-intensity isometric holds at extreme ROM. Extreme isometric locks recruit high-threshold motor units, enhancing motor unit synchronization and increasing neural drive, which collectively boost force output and structural stability [3]. These adaptations also mirror the localized stress distributions and structural integrity of the Prince Rupert's drop. Simultaneously, type I fibers are engaged during prolonged holds, improving endurance and oxidative capacity, which are essential for maintaining stability in these challenging positions [4]. The dual activation of these fiber types promotes a versatile system capable of both explosive strength and sustained effort, a goal in many sports training programs.

Architectural changes such as increased fascicle length and optimized pennation angles are essential for maximizing force production during extreme isometric locks [5]. Chronic loading at extreme joint positions induces favorable shifts in the architectural gear ratio, enhancing the balance between force and velocity characteristics [6]. Proper alignment and orientation of muscle fibers enable efficient force transmission and minimize injury risks at the vulnerable boundaries of ROM [2, 5]. These structural adaptations echo the resilience of the Prince Rupert's drop, where precise internal alignment ensures integrity under high external loads.

Beyond muscle fibers, connective tissues such as tendons and fascia undergo significant remodeling under prolonged isometric stress. Increased collagen cross-linking and improved fiber alignment enhance tensile strength and elasticity, enabling efficient energy storage and release during extreme ROM movements; this is especially true for the Achilles tendon which is systematically and strenuously locked in many, if not all, *GiCheon* basic positions [7, 8]. These changes contribute to the viscoelastic properties of the musculoskeletal system, allowing it to respond effectively to dynamic external forces.

The tensegrity model is a biomechanical framework where stability arises from the balanced interplay of tensile (pulling) and compressive (pushing) forces. This framework offers a suitable context to understand complex biological systems such as the human body, especially the human body in action. This model conceptualizes the musculoskeletal system as an interconnected network, where continuous tension in muscles, fascia, and connective tissues supports and stabilizes discontinuous compression elements, such as bones and joints [9]. Applied to *YeokGeun* training, where extreme isometric locks place high stress at the limits of ROM, tensegrity ensures that forces are distributed efficiently throughout the system, minimizing localized strain and reducing injury risk [10]. Furthermore, tensegrity enhances dynamic stability by allowing the musculoskeletal system to adapt to varying mechanical loads, a process exemplified in natural systems and modeled by cellular and tissue-level structures [11]. This integrated stability mechanism supports the biomechanical transformations observed during *YeokGeun*, enabling greater resilience and efficiency under high loads.

Biochemical adaptations

YeokGeun training has the potential to induce profound biochemical transformations, driven by the unique metabolic demands of prolonged isometric holds at extreme ROMs. These sustained contractions activate glycolytic and oxidative pathways to maintain ATP resynthesis and energy balance. Key enzymes such as phosphofructokinase and succinate dehydrogenase are upregulated, optimizing both glycolysis and oxidative phosphorylation to ensure energy supply under continuous load [12]. Simultaneously, glucose uptake is enhanced through increased GLUT4 transporter activity, replenishing necessary substrates as muscle glycogen stores are gradually depleted [13]. Prolonged isometric holds, as practiced in *YeokGeun,* amplify these enzymatic adaptations, enabling practitioners to demonstrate remarkable metabolic efficiency during extended sessions lasting up to two hours.

A hallmark of *YeokGeun* training is the efficient clearance and utilization of lactate, a by-product of anaerobic metabolism. Elevated lactate dehydrogenase activity facilitates the conversion of lactate into pyruvate, which feeds into the oxidative pathway while preventing accumulation that could impair muscle performance. This process mitigates fatigue, accelerates recovery, and acts as a metabolic signal, triggering mitochondrial biogenesis and enhancing oxidative capacity. Lactate's broader role as a signaling molecule influences energy substrate partitioning and key enzymes regulation, as well as the promotion of endurance and recovery. Additionally, repeated isometric training drives structural adaptations in muscle fibers, including a shift in myosin heavy chain (MHC) expression from type IIb (fast-twitch glycolytic) to type IIx (fast-twitch oxidative), as observed by Haddad et al. [12]. These transitions enhance fatigue resistance and align with the demands of prolonged force generation at extreme ROM. Collectively, these adaptations

integrate metabolic efficiency, fiber plasticity, and recovery dynamics, reflecting the unique physiological and structural resilience cultivated through *YeokGeun* practice.

Neurological and cognitive transformations

Prolonged isometric holds of *YeokGeun* offer a unique platform for refining neuromuscular pathways by optimizing the balance between agonist and antagonist muscle activation. This balance enhances motor unit recruitment, enabling precise muscle engagement and promoting stability during dynamic movements. Such prolonged isometric activity promotes neuroplasticity by repeatedly engaging neural circuits involved in motor control, proprioception, and adaptation. Over time, this practice supports proprioceptive accuracy and adaptability − qualities crucial for athletic performance and functional movement [14, 15]. Enhanced rate coding and motor unit synchronization further refine these pathways, equipping practitioners with the ability to dynamically adjust their positioning, thereby reducing injury risk and maintaining equilibrium under unexpected perturbations [14, 16]. The consistent practice of engaging muscles in extreme joint positions strengthens neural connections, bolstering the stability and control required for maintaining prolonged isometric locks [16].

On the cognitive front, *YeokGeun* practitioners cultivate exceptional focus and pain tolerance through sustained effort under challenging conditions. These efforts align with the compressive forces fortifying the Prince Rupert's drop, where resilience is achieved under continuous stress without structural failure. Such sustained engagement is expected to enhance tolerance for exercise intensity and amplify cognitive resilience, as the emphasis of *GiCheon* on internal mental imagery mirrors evidence showing that visualization can improve stamina, power, and neuromuscular efficiency, all the more so when combined with deep breathing techniques [17, 18]. By maintaining composure under discomfort, practitioners develop mental endurance and adaptability, aligning with principles of traditional Korean self-cultivation, such as *GiCheon*, which emphasizes the intertwined development of body and *ki* [18]. Simultaneously, this training mirrors Western frameworks of decision-making under stress, highlighting how prolonged isometric holds foster both mental and physical integration [19]. The extraordinary commitment of *YeokGeun* to prolonged holds not only strengthens mental focus and endurance but also equips practitioners with transferable traits of concentration and composure, applicable to broader life challenges.

Neurological, biochemical and neuromascular adaptations are summarized in Table 2.

The culmination: bahn tan as internal plyometrics

A unique element of *YeokGeun* is the principle of *bahn tan*, or elastic reflex (*bahn*: "the other way," *tan*: "reflex"), which represents the culmination of the *YeokGeun* static practice, without itself referring to any specific positions. *Bahn tan* involves utilizing the capacity for internal tension developed after prolonged static holds to dynamically control ballistic movements. It may be characterized as internal plyometrics, where

Table 2. Proposed specific adaptations and benefits of *YeokGeun*

Training component	Key biochemical pathway	Neuromuscular adaptation	Sport-performance benefit
Prolonged isometric hold >3 minute at ROM limit	↑ AMPK and LDH activity → enhanced glucose uptake and lactate recycling	MHC shift toward oxidative IIx fibers; improved fatigue resistance	sustained force output during long rallies/endurance sets
Continuous high-tension fascia and tendon loading	collagen cross-linking + realignment → ↑ tendon stiffness	faster stretch-shorten rebound, higher RFD	quicker acceleration, sharper landing stability
Extreme-angle joint compression with diaphragmatic breathing	local hypoxia → VEGF up-regulation and capillarization	greater oxidative supply to working muscle; refined proprioceptive feedback	better micro-recovery between points; finer joint position sense
Bahn tan internal plyometric rebound	rapid elastic recoil through musculotendinous stiffness	synchronized motor-unit firing, heightened efferent drive	explosive whip-like strokes, improved serve velocity
Integrated mental imagery during static effort	cortical-spinal co-activation; dopaminergic modulation	enhanced motor-unit recruitment efficiency; pain tolerance	maintained technique under stress; reduced perceived exertion

Note: AMPK – adenosine monophosphate–activated protein kinase, LDH – lactate dehydrogenase, VEGF – vascular endothelial growth factor, MHC – myosin heavy chain, ROM – range of motion, RFD – rate of force development
Empirical basis for each pathway is documented in refs 3, 5-8, 12-16, 20-21; see corresponding sections for detail.

the stop and reversal of movement during rapid direction changes are achieved internally, rather than relying on external obstacles such as a wall or the ground, as is the case with classic plyometrics. This mechanism aligns with the biomechanical principle of stretch–shortening cycles (SSC), which describes how muscles and tendons store and release elastic energy during movement, a concept central to high-force and high-power activities [20]. This emphasis shifts the focus inward, requiring practitioners to develop not only physical strength and appropriate adaptations in soft tissue to withstand such forces, but also precise neuromuscular coordination to achieve a seamless transition between deceleration and acceleration.

The ability to generate and manage this internal tension is closely tied to the concept of the series elastic component (SEC). Although SEC was traditionally attributed solely to tendinous tissues, more recent perspectives suggest that it also resides within the muscle fibers themselves, thereby extending the potential for elastic energy storage beyond the tendons; a higher level of stiffness within this musculotendinous system has been associated with improved performance markers such as greater force output, faster contraction velocity, and enhanced running economy [20]. For instance, individuals exhibiting higher musculotendinous stiffness can achieve a higher rate of force development under both concentric and isometric conditions, as well as produce greater overall force in isometric tasks [20]. Moreover, stiffness appears to increase in parallel with rising movement velocity, as shown for knee joint stiffness during faster running speeds [20]. These observations underscore how the efficient storage and release of elastic energy, supported by both tendon and muscle fiber elasticity, play a pivotal role in dynamic, high-power actions.

In the context of *bahn tan*, the mechanism is also critical in the final segment of the kinetic chain, where the deceleration of one segment allows the subsequent segment to accelerate in a whip-like motion, as seen in sports such as tennis and javelin throw. Similar to the SSC, *bahn tan* relies on the efficient storage and release of elastic energy, but with a significant difference. While the SSC typically uses the soft tissue passively to create a rebound effect during dynamic movements, *bahn tan* demands an active rebound on musculature that has "hardened" after prolonged *YeokGeun* training in a fashion that resembles Prince Rupert's drop, and therefore is suitable as a rebound board. Here, the energy storage and release are managed through highly controlled muscular engagement, emphasizing peaks of internal tension over passive elasticity [21]. The secret lies in the combination of *bahn tan* and static *YeokGeun* training, which develops a musculature capable of alternating between shorter, more intense contractions and longer, more relaxed phases.[2] The result is a more deliberate and precise application of energy, refined through static isometric holds that prepare the body for ballistic outputs.

The principle of *bahn tan* bridges the static and dynamic aspects of *YeokGeun* by developing the internal strength and control necessary to optimize energy transfer across the kinetic chain. Prolonged static holds train muscles to increase, store, and manage elastic energy effectively, contributing to precise and explosive *bahn tan* movements. These movements are particularly advantageous in sports such as martial arts, gymnastics, and tennis, where rapid direction changes and explosive power are essential for peak performance [20, 22]. By simulating external obstacles through internally generated resistance, *bahn tan* represents a biomechanical innovation that enhances performance while reducing reliance on environmental aids.

Bahn tan therefore demonstrates the ability of *YeokGeun* to connect static isometric conditioning with dynamic athletic needs. It applies principles like tensegrity and kinetic chain efficiency to improve energy transfer, joint stability, and injury prevention. By balancing tensile and compressive forces, this practice enhances musculoskeletal resilience, benefiting both sports performance and rehabilitation. The principles of *YeokGeun* enable the body to translate the advantages of static holds into precise, real-world athletic movements, situating its training philosophy firmly in line with modern understandings of musculotendinous stiffness and elastic energy utilization [20]. The combination of *YeokGeun*, *bahn tahn* and *tah tong* (*tah*: "beat," *tong*: "flow" – hitting stiff muscles with bamboo sticks in a specific way to unblock the flow) is unique to *GiCheon*.

Holistic impact and lifelong benefits

The integration of structural, neurological, and cognitive adaptations typical of *YeokGeun* reaches beyond the boundaries of athletic performance. Prolonged

[2] More holistically, however, we should say that in *GiCheon* the secret always has three components: static training, dynamic training and proper visualizations and controlled breath during the practice. Regarding static *YeokGeun*, one should understand that through practice, one also develops the skill to maintain the *YeokGeun* principle even while moving − a more advanced concept.

isometric training addresses age-related physiologicaldeclines by preserving and enhancing critical muscle fiber types. Type II fibers, which are particularly prone to atrophy with aging, are maintained and fortified through consistent mechanical loading that stimulates hypertrophy and neuromuscular activation, while type I fibers gain endurance, ensuring a balance between explosive power and sustained effort. These adaptations are further supported by increased protein synthesis and mitochondrial efficiency, which enhance metabolic resilience during aging [23]. The remodeling of connective tissues, involves increased tendon stiffness and collagen realignment. These changes improve tendon elasticity and energy storage capacity, bolstering joint stability and reducing the risk of degenerative conditions such as osteoarthritis [23]. Neural adaptations associated with isometric training further refine motor unit recruitment and enhance movement control, reinforcing the neuromuscular foundation required for functional independence in later life [16].

Proprioceptive enhancements, integral to *YeokGeun* practice, play a pivotal role in mitigating age-related vulnerabilities. By refining the body's capacity for spatial awareness and movement coordination, practitioners experience reduced fall risks and improved postural control − critical factors in maintaining independence and quality of life in later years [15]. Balance-related training, such as *YeokGeun's* static holds, facilitates spinal and supraspinal adaptations that improve stability and mitigate risks of injury, particularly in older populations [15]. Additionally, *YeokGeun's* integration of mental imagery and deep breathing with isometric training is particularly beneficial for older populations, as cognitive visualization techniques have been shown to enhance neuromuscular efficiency and strength, compensating for physical limitations in this demographic [17]. The cumulative impact of these adaptations illustrates how *YeokGeun* could aid the development of resilience and longevity across diverse populations. The combined effects of muscle-tendon remodeling and proprioceptive refinement highlight the role of prolonged isometric training in preserving musculoskeletal function as part of a holistic approach to aging, for athletes and non-athletes alike. Table 3 summarizes the most important findings for all categories of practitioners.

Based on such integration, future applications in sports science may produce better methodologies. Tools like FlexLock emerge naturally from this framework, translating the focus of *YeokGeun* on structural and neurological refinement into targeted, sport-specific applications. As the next section will explore, these innovations exemplify the dynamic interplay between

Table 3. Summary of the most important hypothesized benefits along with their possible mechanisms and some relevant literature findings

Hypothesized physiological benefit	Key mechanism(s) proposed in text	Preliminary / case-based evidence cited
↑ Type II fiber hypertrophy and force output	high-threshold motor-unit recruitment during prolonged, maximal isometrics at ROM limits	Seynnes et al. 2007 [3]
↑ Fascicle length and optimized pennation angle (better force – velocity)	chronic loading at extreme joint angles shifts architectural gear ratio	Van Hooren 2024 et al. [5]; Azizi and Roberts 2010 [6]
↑ Tendon stiffness and collagen alignment (energy storage/injury resilience)	long duration isometrics remodeling ECM; Achilles tendon heavily loaded in *YeokGeun* stances	Magnusson and Kjaer 2003 [7]; Kjaer 2004 [8]
Efficient lactate clearance and metabolic flexibility	up-regulation of lactate dehydrogenase; lactate as signaling molecule for mitochondrial biogenesis	Brooks 2018 [13]
Shift toward oxidative MHC IIx profile (fatigue resistance)	repeated isometric endurance stress triggers fiber-type plasticity	Haddad et al. 1998 [12]
Improved proprioception and balance	continuous joint-angle monitoring + supraspinal adaptations from static holds	Taube et al. 2008 [15]
Enhanced neural drive and rate coding	agonist/antagonist co-activation refinement during extreme locks	Enoka and Duchateau 2017 [14]; Carroll et al. 2001 [16]
Higher musculotendinous stiffness → greater RFD / ballistic power (*bahn tan*)	internal plyometric rebound after static "hardening"	Wilson and Flanagan 2008 [20]; Bosco et al. 1981 [21]
Cognitive resilience and pain tolerance	sustained isometric discomfort + mental imagery protocols	Slimani et al. 2016 [17]; Brown and Bray 2015 [19]
Attenuation of age-related muscle/tendon decline	persistent mechanical loading preserves type II fibers and tendon elasticity	Reeves and Narici 2006 [23]

Note: ECM – extracellular matrix, MHC – myosin heavy chain, RFD – rate of force development, ROM – range of motion

tradition and modernity, redefining the possibilities for athletic performance and sustainable physical health.

FlexLock: YeokGeun for sports use

Building upon the foundational principles of *YeokGeun*, the Distal Method offers a paradigm-shifting framework for understanding motor expertise. The Distal Method is a framework to develop world-class motor and cognitive expertise. Unlike conventional sports training paradigms, which focus on short-term, measurable outcomes, the Distal Method prioritizes long-term, holistic adaptations. It integrates a range of tools and methodologies − including biomechanical models, synthetic paradigms like SBLM and SFSB, and advanced techniques such as motowords and performance spirals − to foster motor expertise, focusing on sustainable skill acquisition [24]. Other works have elaborated on the role of the Distal Method in tennis and coach development, further reinforcing its relevance to contemporary sports science [25].

The role of FlexLock in the Distal Method

Redefined as FlexLock, *YeokGeun* serves as a core tool within the Distal Method. FlexLock involves the six foundational positions of *GiCheon*, always focusing on extreme isometric holds at joint boundaries (supplemented by visualizations and deep breathing). This practice strengthens posture, enhances reflexes, and integrates the principles of the *bahn tan* elastic rebound to dynamically control ballistic movements [26]. These elements are particularly valuable in sport such as tennis, where energy transfer and precision are critical.

Whip-like tennis movements that utilize the serial kinetic chain could be further optimized through the *bahn tan* approach derived from *GiCheon* [27]. Programs and tools integrating this rebounding methodology are expected to significantly enhance the explosive power critical to the SSCs involved in tennis strokes.

A paradigm beyond conventional models

The Distal Method represents a significant departure from traditional training paradigms by emphasizing epistemological depth, holistic integration, and a connection to the enduring traditions of human development [1, 26, 28]. Rooted in the recognition that the body is not merely a mechanical apparatus but an integrated system of perception, action, and cognition, the Distal Method challenges reductionist frameworks (e.g., the talent hypothesis – i.e., the claim that ability is innate; motor program theory; reflex theory) that isolate physical movement from its broader contexts.

At its core, the Distal Method draws upon the premises that align with the philosophies of great traditions, such as the embodied practices found in *GiCheon* and other systems of self-cultivation, all passed through the filters of classic epistemology. These traditions underscore the interdependence of internal focus, mental discipline, and physical execution − principles that resonate with contemporary understandings of motor learning and neuromuscular adaptation. By leveraging this wisdom in a sound methodological way, the Distal Method provides a framework that transcends conventional biomechanical analysis, integrating elements of visualization practices, proprioceptive training, and complex movement patterns. This approach is particularly relevant in an era where calls for truly holistic tools are increasingly urgent. Modern athletic training, in practice, often prioritizes performance metrics at the expense of adaptability, resilience, and sustainability. The Distal Method counters this trend by stressing adaptations that extend beyond immediate gains, aiming for long-term (i.e., distal) physical and cognitive development.

Thomas Kuhn's analysis of paradigm shifts underscores the challenges inherent in adopting such transformative approaches. As Kuhn observed, "Conversions will occur a few at a time until, after the last holdouts have died, the whole profession will again be practicing under a single, but now a different, paradigm" [29]. The Distal Method faces similar obstacles as it seeks to shift perspectives from isolated, linear models of training to integrated, systemic approaches that embrace complexity and diversity. However, it is precisely this complexity that makes the method indispensable for athletes seeking to achieve both peak performance and long-term physical harmony.

In the context of tennis, the relevance of Distal Method becomes evident in its focus on distal adaptations, that is, long term adaptations that may only be developed following a method designed to achieve exactly that: world class expertise in the long term, not just better performance *now* (these two goals are inherently contradictory, *cf.* learning vs. performance). These principles not only refine the biomechanical execution of strokes but also cultivate the mental clarity and proprioceptive awareness required for consistent, high-level play; expert characteristics are not a matter of talent but are meticulously developed and refined through the approach of K.A. Ericsson's deliberate and well-structured practice, as is refined and specialized via the Distal Method [30, 31, 32].

Ultimately, the Distal Method bridges the wisdom from various philosophical and spiritual traditions with

modern *epistēmē*, providing athletes with tools and principles that align with the complexities of human movement and cognition. This approach fosters a holistic training framework that integrates mind and body (*cf*. perceptuomotor continuum), emphasizing practical strategies while respecting theoretical foundations.

Experimental directions for the Distal Method

While paradigms cannot be conclusively proven, specific aspects of the Distal Method and FlexLock can be empirically evaluated. Potential studies include: (1) neuromuscular adaptations: examining motor unit recruitment improvements during for example tennis-specific drills; (2) biomechanical benefits: evaluating energy transfer efficiency through the kinetic chain; (3) rehabilitation applications: comparing injury recovery rates in FlexLock-trained and control groups.

Another interesting phenomenon to be studied in relation to *YeokGeun* is the ischemic preconditioning (cardiology) where brief, controlled restriction of blood flow makes tissues more resilient to later stress. If this is demonstrated to be the case in the long, isometric, extreme holds of *YeokGeun*, it would have significant implications for both sports conditioning and therapeutical interventions.

These experiments should respect the holistic ontology of Distal Method, emphasizing long-term adaptations rather than immediate performance metrics. As a brief reminder, apart from the Distal Method, other similar approaches defy the classic (save problematic) notion of experimental proof (otherwise forbidden by logic) such as the Montessori or Waldorf systems, where individual elements are tested within a broader framework.

The holistic and multidisciplinary nature of *YeokGeun*, while intellectually and culturally valuable, also complicates conventional validation routes. Future research should therefore adopt innovative mixed-method frameworks − single-subject designs, qualitative experiential analysis, and objective physiological markers − implemented through cross-disciplinary collaboration among sports scientists, medical practitioners, and experts in traditional Korean practice. However, a note of epistemological caution: while such designs may elucidate underlying mechanisms or help fine-tune specific aspects of the practice, the practice itself neither can, should, nor needs to be empirically verified.

Limitations

A robust set of limitations constrains the development and broader adoption of FlexLock. These challenges are both practical and epistemological.

1. Teacher availability and expertise: The scarcity of qualified instructors represents a significant barrier. *GiCheon* teachers − while themselves adept in the traditional forms − are not automatically suitable for adapting *GiCheon* principles to specific sports. Nor can intermediate or advanced practitioners, whether from yoga, chi kung, or any similar discipline, effectively apply their own methods directly without specialized knowledge of sports biomechanics and motor learning. The intersection of these fields requires individuals with dual expertise, which is rare. Institutions such as federations or academic bodies must invest in training these experts to bridge the gap between traditional practices and modern sports applications. Which is also a problem in itself since the various institutions lack the knowledge and have no valid criteria to meaningfully choose among the various traditional practices, given that due to our human nature, it is quite common that practitioners and teachers from different traditions will promote their approach as optimal. A good example of it is the otherwise precious Anuttara Tantra-like meditative practices which, to an outsider, seem relevant and useful to athletes (seemingly similar to mindfulness or visualization techniques, which are beneficial), but they are not at all helpful being somewhat detrimental to performance; maybe another article should focus on such misunderstanding.

Consequently, the chief impediments to both wider dissemination and rigorous investigation are the scarcity of dual-trained instructors and the methodological difficulty of translating a holistic practice into reductionist research protocols − without implying that complete reductionism of such practices is either the goal or even desirable. However, many of the physiological effects discussed here are inferred from studies on cognate isometric or relevant modalities rather than from randomized controlled trials on *YeokGeun* itself. Future work should pursue controlled yet ecologically sensitive designs − single-case time series, mixed-methods cohorts, and longitudinal field studies − that can quantify adaptations while preserving the contextual integrity of the practice.

2. Conceptual paradigm shifts: Resistance from entrenched methodologies poses another limitation. As Thomas Kuhn famously noted, paradigms often shift not through rational persuasion but as the "old guard" gradually… "dies off" [29]. This resistance − particularly from practitioners and educators accustomed to linear and reductionist frameworks − hinders the integration of complex, holistic paradigms like the Distal Method.

3. Terminological precision and cultural contexts: The term *bahn tan*, deeply rooted in *GiCheon* tradition,

carries cultural and practical significance. Its use requires mastery within the *GiCheon* system to avoid misrepresentation. The redefining as FlexLock addresses this challenge by offering a sports-specific terminology that resonates more broadly. However, this linguistic adaptation may dilute the traditional depth of the concept, posing challenges for practitioners seeking authenticity.

4. Empirical validation challenges: Holistic methodologies, by their nature, resist reductionist empirical testing. The interconnectedness of the principles of FlexLock means isolating variables for study is inherently complex. While educational paradigms like Montessori have found ways to evaluate holistic frameworks, developing similarly robust methods for FlexLock will require considerable innovation in research design, especially when considering expertise attainment [30].

Expanding on Prince Rupert's drop analogy

The innovations and challenges of FlexLock are illuminated by the Prince Rupert's drop analogy. Just as the drop's resilience depends on the equilibrium of tensile and compressive forces, FlexLock balances the development of explosive strength and proprioceptive control with the minimization of vulnerabilities. This interplay − between robustness and fragility − offers a conceptual lens for addressing the limitations and potential expansions of the method.

Conclusions

The exploration of *GiCheon's YeokGeun* practice through the lens of the Prince Rupert's drop metaphor shows the benefits of exploring and integrating into modern training insights from great traditions of the past. This Korean discipline embodies a unique synthesis of physical rigor, meditative stillness, and philosophical depth, offering a holistic framework for developing resilience, strength, and adaptability. By addressing structural, neurological, and cognitive adaptations, *YeokGeun* bridges past wisdom with contemporary sports science, revealing its potential to enhance athletic performance, prevent injuries, and support healthy aging.

The emphasis on prolonged isometric holds at extreme joint positions, combined with mental visualization and breathing techniques, highlights the capacity of *YeokGeun* to foster neuromuscular precision and metabolic efficiency. These principles resonate across a wide spectrum of applications, from optimizing sports performance to addressing age-related vulnerabilities. Moreover, the integration of *bahn tan*, or internal plyometrics, into *YeokGeun* training expands its scope, illustrating how static practices can prepare the body for dynamic, high-intensity movements as long as the correct tools are applied to bridge that gap.

As *GiCheon* continues to adapt to modern contexts, even through this article, researchers ought to also shift their focus from classic training to more integrated models, maybe taking a small break from overemphasizing proving training systems in sports science (which is utterly utopic − statistics is *not* a proving field). Future research and practical applications can further elucidate its potential, paving the way for innovative approaches to physical and cognitive performance and well-being. By proactively addressing some methodological challenges, future work can further substantiate the potential of *YeokGeun* for both sports science innovation and holistic wellness, thereby integrating traditional wisdom with modern empirical rigor.

In an era that often prioritizes immediate performance metrics over long-term adaptability, *GiCheon* provides a counterbalance, reminding us that true growth arises from discipline, balance, and the harmonious integration of opposites.

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