Eurasian Research in Sport Science • Avrasya Spor Bilimleri Araştırmaları • ERISS • Volume/Cilt 10 • Issue/Sayı 1 • June/Haziran 2025, ISSN 2636-8269, ss. 1-17 • DOI: 10.29228/ERISS.52

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

Acute Effects of Concentric and Eccentric Exercise on Knee Extensor Flexibility: A Comparative Trial

Konsantrik ve Eksantrik Egzersizin Diz Ekstansör Esnekliği Üzerindeki Akut Etkileri: Karşılaştırmalı Bir Çalışma

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Öz

Çeşitli kas kasılma modalitelerinin eklem esnekliği üzerindeki etkilerini anlamak, egzersiz protokollerini geliştirmek için büyük önem taşır. Egzersiz programlamasının ana değişkenlerinden olan kontraksiyon tipinin esneklik üzerindeki akut etkileri henüz kapsamlı bir şekilde anlaşılmamıştır. Bu çalışma, sağlıklı genç erkeklerde tek seans izokinetik konsantrik ve eksantrik diz ekstansiyon egzersizinin aktif ve pasif diz ekstansör kaslarının esnekliği üzerindeki akut etkilerini karşılaştırmayı amaçlamıştır. Yirmi altı katılımcı (yaş: 23±1.4 yıl) rastgele olarak Eksantrik (n=13) veya Konsantrik (n=13) egzersiz grubuna atanmıştır. Aktif ve pasif diz fleksiyon eklem hareket açıklığı (EHA), bir dinamometre üzerinde gerçekleştirilen izokinetik egzersiz protokolünden (60 derece/saniye hızda 3 set 12 tekrar) önce ve hemen sonra bir akıllı telefon inklinometresi kullanılarak değerlendirilmiştir. Aktif diz fleksiyon EHA, her iki grupta da ön testten (Ort. = 130.10^0) son teste (Ort. = 128.07^0) istatistiksel olarak anlamlı bir oranda azalmıştır ($p = 0.044$). Bu azalma eksantrik ve konsantrik gruplar arasında benzer bulunmuş olup, anlamlı bir grup farkı veya etkileşim etkisi gözlenmemiştir. Pasif diz fleksiyon EHA için, her iki grupta da ön testten son teste istatistiksel olarak anlamlı bir değişiklik saptanmamış ve gruplar arasında da anlamlı bir fark bulunamamıştır; ancak eksantrik grupta daha büyük bir azalma eğilimi kaydedilmiştir. Sonuç olarak, tek seans maksimal izokinetik diz ekstansiyon egzersizi akut seviyede, aktif diz ekstansör esnekliğinde anlamlı bir azalmaya yol açmakta olup, bu etki konsantrik ve eksantrik kasılmalar arasında benzerlik göstermektedir. Bu sonuçlar konsantrik ve eksantrik egzersize verilen akut esneklik tepkilerinin karmaşık doğasını vurgulamaktadır.

Anahtar Kelimeler: Quadriceps esnekliği, Eklem hareket açıklığı, İzokinetik egzersiz, Fasya

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How to cite this article/Atıf için: Danlı, G., Tatar, Y., Uzun, S., Ramazanoğlu, N. (2025). Acute Effects of concentric and eccentric exercise on knee extensor flexibility: A Comparative Trial.. *Eurasian Research in Sport Science, 10*(1), 1-17. DOI: 10.29228/ERISS.52

Makale Gönderim Tarihi: 06.03.2025 **Yayına Kabul Tarihi:** 15.05.2025

Abstract

Understanding the effects of various muscle contraction modalities on joint flexibility is essential for refining exercise protocols. The acute effects of contraction type on flexibility, which is one of the main variables in exercise programming, are not yet comprehensively understood. This study aimed to compare the acute effects of a single session of isokinetic concentric and eccentric knee extension exercise on the active and passive flexibility of the knee extensor muscles in healthy young men. Twenty-six participants (age: 23±1.4 years) were randomly assigned to an eccentric (n=13) or concentric (n=13) exercise group. Active and passive knee flexion range of motion (ROM) were assessed using a smartphone inclinometer before and immediately after an isokinetic exercise protocol (3 sets of 12 repetitions at 60 degrees/second). Active knee flexion ROM significantly decreased from pre-test (Mean = 130.10^0) to post-test (Mean = 128.07^0) across both groups ($p = 0.044$). This decrease was similar between the Eccentric and Concentric groups, with no significant group differences or interaction effects observed. For passive knee flexion ROM, no statistically significant changes from pre-to post-test were detected for either group, and the changes did not differ significantly between the groups, although a trend towards a greater reduction was noted in the eccentric group. In conclusion, a single acute session of maximal isokinetic knee extension exercise resulted in a significant decrease in active knee extensor flexibility, comparably between concentric and eccentric contractions. These results highlight the complex nature of the acute flexibility responses to maximal exertion.

Keywords: Quadriceps flexibility, Range of motion, Isokinetic exercise, Fascia

INTRODUCTION

Flexibility, defined as the available range of motion (ROM) at a joint or a series of joints, is broadly acknowledged as a critical component of musculoskeletal health and integral to overall physical function (Wilmore & Costill, 1994). Adequate flexibility underpins the efficient execution of activities of daily living, contributes to the preservation of physical function across the lifespan, and is frequently implicated in the optimization of athletic performance and the potential mitigation of musculoskeletal injury risk (Stathokostas et al., 2012). The ability of a joint to achieve its full range of motion is a complex trait influenced by multiple factors, including the mechanical properties of various biological tissues. These tissues encompass articular structures, muscles, tendons, and the connective tissue network, all of which contribute to joint mobility (Favro et al., 2022).

Among these influential structures, the fascial system has garnered increasing recognition for its pivotal role. Fascia, conceptualized as a pervasive, three-dimensional viscoelastic continuum composed of collagen-rich connective tissue, meticulously envelops, interconnects, and supports all muscles, organs, and other internal structures, forming an integrated body-wide tensional network (Bordoni et al., 2022). It forms an integrated, body-wide network of tension, actively contributing to physiological processes such as force transmission within muscles, shear strain between tissues, and regulation of movement coordination. The mechanical properties of fascial tissues, including their stiffness, elasticity, and ability to glide, significantly impact overall tissue compliance and may influence limitations in joint range of motion (Slater et al., 2024; Colonna et al., 2024a).

The specific properties of fascial tissues directly affect flexibility. Elevated fascial stiffness or densification, potentially resulting from changes in extracellular matrix composition or hydration levels, can hinder relative movement between neighboring fascial layers and reduce overall tissue extensibility (Colonna et al., 2024b). Crucially, the capacity for inter-fascial sliding, the ability of distinct fascial layers to glide smoothly over one another, is essential for accommodating changes in muscle length, shape, and position during movement. The ability of fascial layers to glide smoothly over one another, known as inter-fascial sliding, is vital for accommodating variations in muscle length, shape, and position during movement. This sliding process is primarily facilitated by hyaluronan, a significant glycosaminoglycan present at loose connective tissue interfaces, which functions as a biological lubricant (Cowman et al., 2015; Langevin & Huijing, 2009). Impairments in inter-fascial sliding, caused by increased hyaluronan viscosity or fascial adhesions, can substantially diminish range of motion and heighten the perception of movement resistance.

Physical exercise serves as a potent mechanical stimulus capable of inducing a spectrum of acute and chronic adaptations within both muscular and fascial tissues, thereby significantly influencing flexibility (Favro et al., 2022; Colonna et al., 2024a; Warneke et al., 2024). The nature of muscle contraction during exercise, primarily categorized as concentric (muscle shortening under load) and eccentric (muscle lengthening under load), plays a pivotal role in determining the type and magnitude of mechanical stresses imparted to the musculoskeletal system, including its fascial components (Douglas et al., 2017). Eccentric contractions, which can generate higher forces and produce greater mechanical strain than concentric contractions, are believed to induce unique adaptive responses in the muscle-fascia complex (Hody et al., 2019; Reeves et al., 2009).

Chronic eccentric training has been consistently associated with significant improvements in joint flexibility, often exceeding those observed with concentric training or static stretching (Diong et al., 2022; Vetter et al., 2022; Kay et al., 2023; Liang et al., 2024). Conversely, the immediate and acute effects of a single exercise session on joint range of motion (ROM) may involve complex physiological mechanisms that are potentially affected by transient factors such as neuromuscular fatigue, changes in muscle spindle sensitivity, or rapid modifications in fascial tissue compliance. These immediate responses are distinct from the delayed consequences of exercise-induced muscle damage (EIMD) (Gandevia, 2001; Proske & Gandevia, 2012). Therefore, understanding short-term post-exercise flexibility changes is essential for isolating the primary effects of the mechanical stimulus itself.

The knee extensors, particularly the quadriceps femoris, are fundamental for numerous daily and athletic movements, and their flexibility significantly influences knee joint biomechanics and health. Although chronic eccentric training is recognized for enhancing knee extensor flexibility, there is limited understanding of the immediate effects of a single session of maximal isokinetic concentric versus eccentric exercise on the flexibility of this muscle group (Katsura et al., 2019; Behm et al., 2006; Chaabene et al., 2019). Eccentric muscle actions can generate higher forces and mechanical stress than concentric actions. In individuals unaccustomed to such activities, this often results in acute muscle damage, which manifests as strength reduction, soreness, swelling, and temporary restriction of range of motion (ROM) (Ochi et al., 2016; Tsuchiya et al., 2015). Conversely, not all eccentric exercises induce muscle stiffness; a single session involving eccentrically biased movements across the full ROM has been shown to acutely enhance hamstring flexibility more effectively than static stretching (Nelson, 2006). These seemingly conflicting findings highlight a gap in the literature, as few studies have directly compared the acute flexibility outcomes of concentric versus eccentric contractions, particularly in young, healthy populations. Addressing this gap is important for refining exercise prescriptions, as acute ROM alterations can influence performance or injury risk in the short term.

Therefore, the aim of this study was to compare the acute effects of a single session of isokinetic concentric versus isokinetic eccentric knee extension exercises on active and passive knee extensor flexibility in healthy young males. Considering the greater mechanical stress involved in eccentric contractions and their potential to induce immediate neuromuscular or tissue resistance changes, it was hypothesized that the two contraction modalities would produce differential effects on knee extensor flexibility.

METHODS

Study Design

This study utilized a between-subjects experimental design, with measurements of knee extensor flexibility conducted before and immediately after the intervention. Participants were assigned to either an eccentric or concentric exercise group, and assessments were carried out to examine the immediate effects of the respective exercise protocols.

Study Group

Twenty-six healthy young male individuals (mean ± SD; age: 23 ± 1.4 years, height: 178.9 ± 6.2 cm, weight: 82.0 ± 11.6 kg) volunteered to participate in this investigation. Post-hoc power analyses using G*Power (Version 3.1.9.6) were conducted to determine the achieved power for the main effects of time with this sample size (N=26) and an alpha of 0.05. The analyses indicated that the achieved power for detecting the observed main effect of time on active knee flexion ROM was 0.99 (partial $\eta^2 = 0.159$), and for passive knee flexion ROM, it was 0.82 (partial $\eta^2 = 0.079$). The participants had a consistent background in athletic activities, with all reporting at least three years of regular engagement in various sports, and several were currently involved in competitive sports. None of the participants were engaged in systematic flexibility training programs at the time of the study. Participants were randomly allocated into two experimental groups: an Eccentric exercise group (n=13) and a Concentric exercise group (n=13). Inclusion criteria required participants to be free from lower extremity musculoskeletal or neurological disorders within the previous 12 months that could influence their performance or participation. Exclusion criteria encompassed any known cardiovascular conditions, recent significant lower limb injuries or surgeries within the past five years, and current pain or discomfort in the lower extremities.

Ethics Approval

The study protocol was approved by the Marmara University Faculty of Medicine Clinical Research Ethics Committee (Approval Date: 25.12.2021; Approval Number: 09.2021.1271), in accordance with the Declaration of Helsinki. All participants provided written informed consent prior to their participation in the study.

Procedures

Participants attended a single experimental session conducted at the Marmara University Sports Sciences and Athlete Health Research and Application Center (SBSAM) laboratory. The overall procedural sequence involved an initial familiarization with the testing protocols, followed by baseline (pre-intervention) flexibility assessments. Subsequently, participants performed a standardized warm-up protocol, after which they engaged in the designated isokinetic exercise intervention (either eccentric or concentric) specific to their group assignment. Post-intervention flexibility assessments were conducted immediately after completing the exercise protocol.

Warm-up Protocol

Prior to the exercise intervention, all participants performed a standardized warm-up protocol. This consisted of 5 min of cycling on a stationary bicycle ergometer at a constant workload of 50 watts and a cadence between 50-60 rpm.

Flexibility Assessment

Knee extensor flexibility was evaluated by measuring the active and passive knee flexion range of motion (ROM). These assessments were conducted by an experienced practitioner using an inclinometer application (Clinometer – Plaincode, Germany) on a smartphone device (iPhone, Apple Inc., USA), which has demonstrated acceptable reliability and validity for lower extremity joint ROM evaluation (Mohammad et al., 2021; Pantouveris et al., 2024). All measurements were performed with the participant in a prone position on a standard examination stretcher. The pelvis was manually stabilized by the examiner to prevent compensatory anterior pelvic tilt or lumbar extension, thereby ensuring an isolated assessment of knee flexion (Peeler & Anderson, 2008; Olivencia et al., 2020). The testing sequence was standardized such that active knee flexion was measured prior to passive knee flexion in all participants.

- **Active Knee Flexion (AKF) Test:** Participants were instructed to actively flex their knee maximally, bringing their heel as close as possible towards the ipsilateral buttock, without lifting the hip from the stretcher. The maximum angle of knee flexion achieved voluntarily was recorded by placing the smartphone along the longitudinal axis of the tibia (Gajdosik, 1985).

- **Passive Knee Flexion (PKF) Test (Modified Ely's Test):** Following the active test, the examiner passively flexed the participant's knee. The practitioner gently moved the heel towards the ipsilateral buttock until firm resistance was encountered at the end range of motion or until any compensatory movement of the pelvis or hip was observed. The maximum angle of passive knee flexion was then recorded using a smartphone inclinometer (Peeler & Anderson, 2008; Olivencia et al., 2020).

For each participant, flexibility assessments were performed on their designated support limb (stance leg), which was also the limb subjected to the exercise intervention. The support limb was standardized for all participants as their dominant leg, determined by asking which leg they would use to kick a ball for maximal distance (Neto et al., 2018; van Melick et al., 2017). The maximum knee flexion angle achieved was recorded in degrees (^{0}).

Exercise Intervention

Following the warm-up and baseline flexibility assessments, participants performed the assigned isokinetic exercise protocol using a Biodex System 4 Pro isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA). Participants were positioned supine on the dynamometer chair, with the hip joint of the exercising limb (support limb) maintained at approximately 180 degrees of extension (full extension) to ensure optimal length and engagement of the rectus femoris muscle. The trunk and pelvis were stabilized using straps to minimize compensatory movements. The axis of rotation of the dynamometer was aligned with the lateral epicondyle of the femur of the exercised limb.

Participants performed either concentric or eccentric knee extension exercises based on their group allocation. The exercise protocol for both groups consisted of 3 sets of 12 repetitions. A rest period of 90 seconds was provided between each set.

- **Concentric Group:** Participants initiated movement from a position of 110 degrees of knee flexion and were instructed to actively extend their knee against the dynamometer lever arm to 0° (full extension) at 60°/s.
- **Eccentric Group:** Participants initiated movement from a position of 0° knee extension. They were instructed to maximally resist the dynamometer lever arm as it moved their knee into flexion from 0° to 110° at 60°/s.

For both groups, the dynamometer passively returned the limb to the starting position after each repetition at a slower speed of 45°/s. This deliberate methodological choice aimed to enhance safety and ensure consistency across the repetitions. A passive return creates a brief unloading period during which the muscles are not actively contracting, establishing an approximate work-to-rest ratio within each cycle. The literature indicates that such contract–relax paradigms can allow partial neuromuscular recovery during the set; the built-in rest from the passive return may help offset fatigue accumulation to some extent (Duffett, 2020). This controlled passive return provided the quadriceps with temporary respite after each contraction, reducing stretch reflex activation and minimizing additional muscle shortening or stretching under load. This approach was designed to isolate the specific contraction mode (concentric or eccentric) during the active phase and to standardize the total duration of tension per repetition across groups.

Data Analysis

For both active and passive flexibility tests, the maximum knee flexion angle achieved, recorded in degrees (°), was used for subsequent statistical analysis.

Statistical Analysis

Prior to the statistical analysis, the assumptions for parametric testing were evaluated. Normality of the pre-intervention, post-intervention, and change scores for both active and passive flexibility measures was confirmed via Shapiro–Wilk tests (all $p > 0.05$) and visual inspection of Q–Q plots. Homogeneity of variance between the groups for baseline measures and change scores was supported by Levene's tests (all $p > 0.05$), with only minor tail deviations observed upon visual inspection of data distributions. Accordingly, given these assumption checks and the well-documented robustness of parametric procedures, particularly in designs with balanced group sizes, the collected data were analyzed to determine the acute effects of the different contraction types on knee extensor flexibility using a 2 (Group: Eccentric, Concentric) × 2 (Time: Pre-test, Post-test) repeated measures Analysis of Variance (ANOVA). The 'Group' factor served as the between-subjects variable, and the 'Time' factor served as the within-subjects variable. The level of significance was set at $p < 0.05$. All statistical analyses were performed using JASP (Version 0.19.3, JASP Team, University of Amsterdam, The Netherlands).

RESULTS

The descriptive statistics for active and passive knee flexion ROM at pre – and post-test for both the Eccentric and Concentric exercise groups are presented in Table 1.

Table 1. Pre-test and Post-test Mean (±S) Values for Active and Passive Knee Flexion Range of Motion (ROM) by Exercise Group

			Pre-test		Post-test		
Parameter	**Contraction Type**	**N**	**Mean**	**S**	**Mean**	**S**	**p**
Active Knee Flexion ROM (^{0}) ^{T}	Eccentric	13	129.9	7.1	127.8	9.8	0.883
	Concentric	13	130.2	7.3	128.4	7.8	
Passive Knee Flexion ROM (^{0}) ^{NS}	Eccentric	13	137.2	7.5	135.0	9.7	0.961
	Concentric	13	136.4	6.1	136.0	8.2	

^{NS} No significant main effect and interaction, ^{T} Significant main effects of time

Active Knee Flexion ROM

A significant main effect was found between the pre – and post-tests for active knee flexion ROM ($p = 0.044$). This indicates that, irrespective of the exercise group, there was a significant change in active knee flexion ROM from pre-test ($130.10^0 \pm 7.15^0$) to post-test ($128.07^0 \pm 8.74^0$). Specifically, the active knee flexion ROM decreased significantly after the exercise intervention.

However, the main effect of group was not statistically significant ($p = 0.883$), suggesting no significant overall difference in active knee flexion ROM between the Eccentric and Concentric groups. Furthermore, the group × time interaction effect was not statistically significant ($p = 0.876$). This indicates that the change in active knee flexion ROM from pre-test to post-test did not significantly differ between the Eccentric (Pre: $129.9^0 \pm 7.1^0$; Post: $127.8^0 \pm 9.8^0$) and Concentric groups (Pre: $130.2^0 \pm 7.3^0$; Post: $128.4^0 \pm 7.8^0$). The changes in active knee flexion ROM in both groups are illustrated in Figure 1.

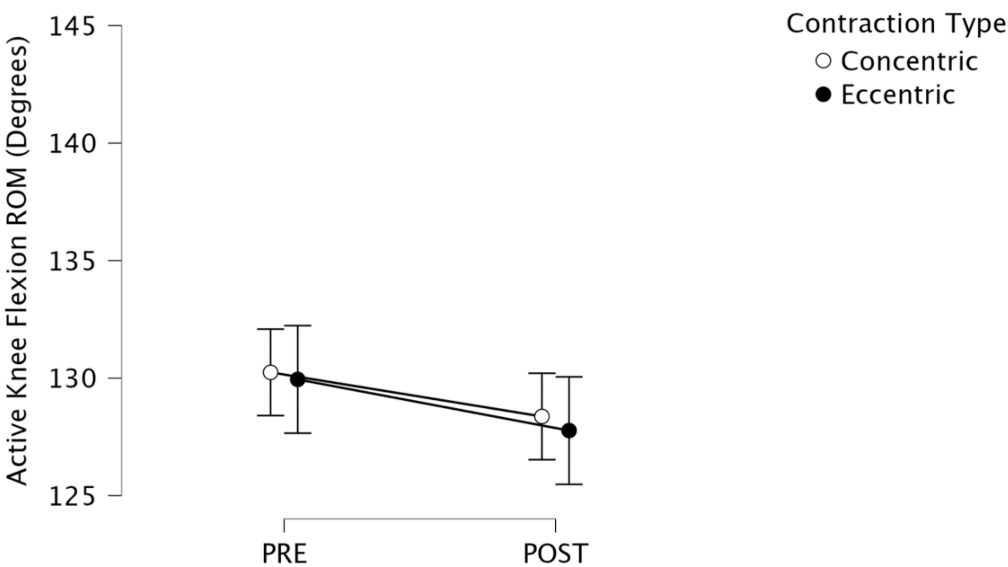

Figure 1. Changes in Active Knee Flexion ROM from Pre-test to Post-test for Concentric and Eccentric Exercise Groups

Passive Knee Flexion ROM

No statistically significant main effect was found between the pre – and post-test results for Passive Knee Flexion ROM ($p=0.165$). This suggests that the exercise intervention did not lead to a significant overall change in passive knee flexion ROM from pre-test ($136.83^0 \pm 6.79^0$) to post-test ($135.51^0 \pm 8.87^0$).

Similarly, the main effect of group was not statistically significant ($p = 0.961$), indicating no significant overall difference in passive knee flexion ROM between the two exercise groups. The group × time interaction effect was not statistically significant ($p = 0.332$). This implies that the change in passive knee flexion ROM from pre – to post-test did not significantly differ between the Eccentric (Pre:

137.2^0 ± 7.5^0; Post: 135.0^0 ± 9.7^0) and Concentric groups (Pre: 136.4^0 ± 6.1^0; Post: 136.0^0 ± 8.2^0). The changes in passive knee flexion ROM in both groups are depicted in Figure 2.

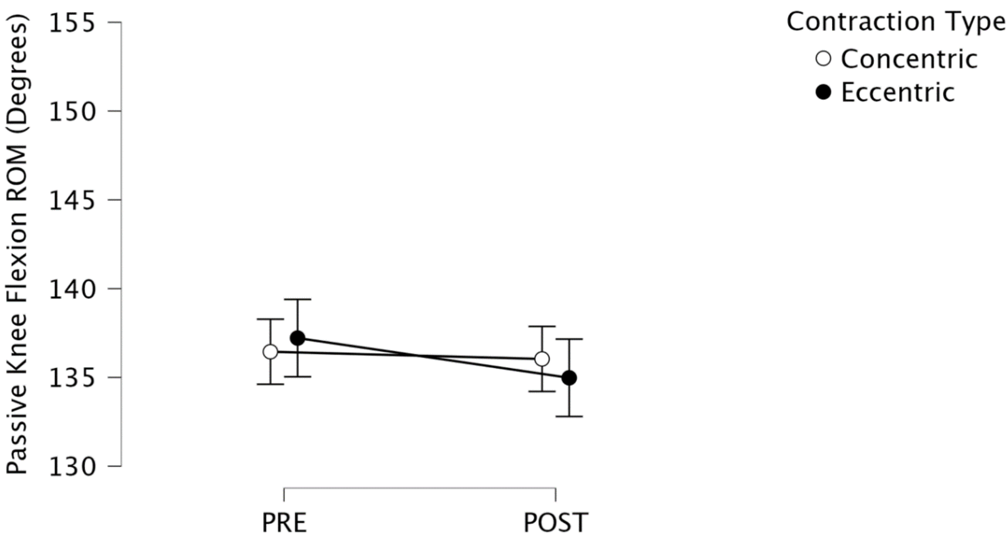

Figure 2. Changes in Passive Knee Flexion ROM from Pre-test to Post-test for Concentric and Eccentric Exercise Groups

DISCUSSION AND CONCLUSION

The primary aim of this study was to compare the immediate effects of a single session of isokinetic concentric and eccentric knee extension exercises on both active and passive knee extensor flexibility in healthy young male participants. Both contraction modalities resulted in a comparable minor reduction in active knee flexion range of motion (ROM) from pre – to post-intervention. Neither exercise type produced a statistically significant alteration in passive ROM. Specifically, active ROM decreased by approximately 2° immediately following exercise in both groups, representing a significant reduction, whereas passive ROM remained largely unchanged. There was no significant interaction between the group and time, suggesting that eccentric and concentric muscle actions did not differentially influence the immediate flexibility response.

The observed acute decrease in active range of motion (PRE: 130.10 ± 7.15^0; POST: 128.07 ± 8.74^0, $p = 0.044$), irrespective of contraction type (Concentric PRE: 130.25 ± 7.35^0, POST: 128.37 ± 7.78^0; Eccentric PRE: 129.95 ± 7.09^0, POST: 127.77 ± 9.83^0; interaction $p=0.876$), can be attributed to several physiological responses. Maximal exertion can induce temporary muscle fatigue, characterized by increased effort perception and neuromuscular inhibition, which limits voluntary joint movement

(Gandevia, 2001). Additionally, the accumulation of metabolic byproducts and temporary changes in intramuscular fluid balance may lead to increased muscle stiffness, further restricting the movement capacity (MacIntosh et al., 2006). Alterations in proprioceptive feedback or heightened sensitivity of muscle sensory receptors following maximal contractions could also reflexively restrict movement (Proske & Gandevia, 2012).

In contrast to the findings related to active flexibility, the analytical assessment of passive knee extensor flexibility did not reveal a statistically significant main effect for the time variable or a significant interaction between time and contraction type. The lack of statistically significant acute modifications, despite the numerical trend towards greater reduction following eccentric exercise, implies that a single session of maximal isokinetic exercise may not be sufficient to elicit immediate, substantial changes in the passive viscoelastic properties of the muscle-tendon complex and surrounding fascial tissues, which predominantly influence passive range of motion. Fascial tissues, including their collagenous matrix and hyaluronan content, exhibit viscoelastic properties that can be influenced by mechanical loading (Pratt, 2021). However, measurable structural or material changes within these structures may require repeated stimuli over a longer period (i.e., chronic training) rather than a single acute bout. The half-life of hyaluronan and the turnover rates of collagen suggest that immediate, substantial changes in these components affecting passive ROM are unlikely (Cowman et al., 2015).

The anticipation of more significant acute alterations in passive flexibility after eccentric contractions is based on their inherently higher mechanical stresses and the well-established connection to muscle damage responses, particularly in untrained populations (Konrad et al., 2022). Eccentric exercise is traditionally associated with more pronounced immediate neuromuscular impairments compared to concentric exercise, including larger reductions in maximal force output and an increased likelihood of inducing exercise-induced muscle damage (EIMD) and subsequent stiffness (Miller et al., 2020; Ochi et al., 2016; Tsuchiya et al., 2015). Contrary to this traditional view, our results revealed no significant difference between the contraction modalities in terms of their immediate effects on passive flexibility. This suggests that for young, physically active men performing a controlled volume of maximal knee extensions, an eccentric bout does not acutely compromise or improve passive flexibility to a greater extent than a concentric bout. The findings are likely heavily influenced by the participants' recreationally active status, which plays a critical role in shaping exercise responses. Higher habitual activity levels may contribute to greater baseline flexibility and enhanced tolerance to muscle stretch and damage, thereby buffering against acute flexibility deficits (Neto et al., 2018). Furthermore, individuals with prior eccentric training experience often develop repeated-bout adaptations that provide a protective effect against reductions in the range of motion and soreness in subsequent sessions (Hody et al., 2018; Clarkson & Hubal, 2002).

The novelty of the specific isokinetic task may have contributed to the observed trends, such as the non-significant tendency for a greater reduction in passive ROM within the eccentric group. It is also plausible that the immediate post-exercise assessments captured an early phase before the full development of EIMD-related stiffness, which typically develops over subsequent hours and days

(Wilke et al., 2022; Paschalis et al., 2023). Alternatively, the mechanical effects of a single exercise bout may not have been sufficiently intense to overcome the passive resistance of the tissues within the statistical power of this study.

The mechanical properties of fascial tissues are modulated by physical activity, and their viscoelastic nature enables dynamic adaptation to applied loads (Favro et al., 2022; Colonna et al., 2024a; Bordoni et al., 2022). The higher mechanical stress characteristic of eccentric contractions may impose a greater acute challenge to these structures (Hody et al., 2019; Douglas et al., 2017). While some studies have suggested that certain acute eccentric loading protocols may transiently reduce passive stiffness (Zhi et al., 2022), the trend towards a greater reduction in passive flexibility with eccentric exercise in our study may reflect an initial, subtle increase in tissue resistance due to high tensile forces. Such a response could serve as an immediate protective mechanism or reflect the early stages of processes that may contribute to stiffness associated with exercise-induced muscle damage.

The discrepancy between the established chronic flexibility enhancements from eccentric training and the acute decremental trend for passive flexibility observed here underscores the differing physiological timescales and dominant mechanisms. Chronic adaptations involve structural remodeling (Franchi et al., 2017; Bizet et al., 2025; Morgan, 1990) and potentially long-term changes in fascial viscoelasticity (Colonna et al., 2024b), which require repeated stimuli. A single exercise bout, as employed in this study, is unlikely to induce such structural changes. Any immediate passive flexibility alterations are more likely due to transient shifts in tissue material properties or acute neural responses. High tensile forces during eccentric work, rather than immediately enhancing extensibility, may cause a subtle rise in tissue resistance or micro-disruption within the fascial matrix. This aligns with the understanding that unaccustomed eccentric exercise triggers EIMD and inflammation, leading to increased stiffness post-exercise (Wilke et al., 2022; Tenberg et al., 2022; Paschalis et al., 2023), although the timing of our measurement aimed to precede significant EIMD manifestation.

The observation that active flexibility significantly decreased in both groups, whereas passive flexibility did not significantly change, is noteworthy. Active ROM is a complex, multifactorial parameter influenced by factors beyond tissue extensibility, including muscular strength, neuromuscular control, coordination, pain perception, and psychological components, such as the participant's willingness to exert maximal effort (Gandevia, 2001). The maximal effort involved in the isokinetic exercise likely resulted in acute muscle fatigue and increased neuromuscular inhibition, which may have contributed to a temporary reduction in active movement capacity immediately post-exercise. Passive ROM, which primarily depends on the mechanical properties of inert tissues when external forces are applied, would be less affected by these acute neuromuscular factors.

The minimal and statistically non-significant change in passive flexibility observed after the concentric exercise protocol is consistent with existing research. Concentric training is generally considered less effective in modifying flexibility parameters than eccentric training (Vetter et al., 2022; Katsura et al., 2019). Concentric contractions, characterized by muscle shortening against resistance, do not produce the same tensile mechanical stretch on muscle fibers and fascial structures as eccentric contractions (Douglas et al., 2017). Additionally, the associated greater fascicle shortening and radial deformation within the muscle may generate complex strains in the surrounding fascial matrix. Considering that key ECM components, such as collagen and fibrin, are known to stiffen significantly and develop anisotropy even under moderate deformations of approximately 10%, it is plausible that radial strains during concentric exercise contribute to acute ECM stiffening. This may particularly influence tissues rich in hyaluronan (Goren et al., 2024). Therefore, the mechanical stimulus necessary to induce immediate changes in passive fascial compliance or provoke significant thixotropic responses in the ground substance may be diminished following a single bout of concentric exercise. This observation is supported by studies on long-term adaptations, which consistently report minimal flexibility improvements following concentric-only training (Vetter et al., 2022).

The methodological strengths of this study include the employment of isokinetic dynamometry, which allows for precise control and standardization of exercise protocols (Wu et al., 1997; Higbie et al., 1996), and the dual assessment of active and passive flexibility. Despite these strengths, certain limitations intrinsic to the study design and implementation must be recognized. The utilization of a between-subjects design, in which different individuals were allocated to the concentric and eccentric exercise groups, introduces the possibility that inter-subject variability in baseline characteristics and exercise responses could have influenced the results. Additionally, the dual assessment of both active and passive flexibility enhances the comprehensiveness of the evaluation. However, certain limitations inherent to the study design and execution must be acknowledged. The use of a between-subjects design, assigning different individuals to concentric and eccentric exercise groups, may introduce variability due to differences in baseline characteristics and individual responses. Furthermore, the relatively small sample size of 13 participants per group may have constrained the statistical power necessary to detect subtle yet physiologically relevant differences in immediate passive flexibility changes. This limitation could be especially significant concerning the interaction between contraction type and time, as the non-significant trend observed could potentially attain significance with a larger sample size.

The current study demonstrated that a single acute session of isokinetic knee extension exercise resulted in a statistically significant decrease in active knee extensor flexibility among healthy young males. No significant difference was observed in the magnitude of this effect between the concentric and eccentric contraction modalities. Regarding passive knee extensor flexibility, neither contraction type produced statistically significant immediate changes; however, a non-significant trend towards a greater reduction in passive flexibility following eccentric exercise was observed. These findings suggest that both exercise modalities can acutely reduce the active range of motion, possibly due to neuromuscular fatigue, increased muscle resistance, or protective inhibitory responses. The stimulus provided by a single exercise session appears to be insufficient to produce statistically significant changes in passive tissue extensibility, as measured in this study. These results highlight the complexity of acute flexibility adaptations to maximal exertion and emphasize the need for further research with larger sample sizes and direct tissue assessments.

In conclusion, this study provides evidence that a single session of maximal concentric or eccentric quadriceps exercise induces a small, transient reduction in active flexibility, while passive flexibility remains largely unaffected in the immediate term. Both eccentric and concentric modalities produced comparable acute outcomes, suggesting that the immediate flexibility response is primarily driven by overall fatigue rather than the specific type of muscle contraction. These findings contribute to the nuanced understanding of how different resistance exercise modalities acutely affect joint ROM, emphasizing the role of neuromuscular factors in post-exercise flexibility assessment. Further research is warranted to examine the longer-term and delayed effects, such as those occurring 24 to 48 h after exercise, and to include other muscle groups and populations, including less-trained individuals and females. Such investigations will contribute to a more comprehensive understanding of the differential impacts of concentric versus eccentric exercises on flexibility, aiding in the development of optimized training and rehabilitation protocols.

Practical Implications

- Both maximal isokinetic concentric and eccentric knee extension exercises can lead to an immediate, albeit temporary, decrease in active knee extensor flexibility. Practitioners should anticipate this reduction when planning subsequent activities or performance tasks that require optimal active ROM.
- Athletes whose performance relies on explosive movements or extensive active joint excursion should be mindful of this potential temporary impairment if maximal concentric or eccentric contractions are performed shortly before a competition or critical training drills.
- A brief recovery period or specific cool-down interventions aimed at restoring movement capacity may be beneficial before engaging in activities that demand full active joint excursion, especially after maximal exertion.
- A single session of maximal eccentric exercise, unlike chronic eccentric training, may not immediately enhance passive flexibility and may even show a trend towards a temporary decrease in well-trained individuals. If the immediate goal is to maintain or improve passive ROM, alternative or supplementary strategies, such as self-myofascial release might be considered alongside acute maximal eccentric work.

Acknowledgements: We would like to thank Marmara University Sports Sciences and Athlete Health Research and Application Center (SBSAM) laboratory for providing the facilities and resources that made this research possible.

Conflicts of Interest: There is no personal or financial conflict of interest within the scope of the study.

Authors' contributions: Design of the study: GŞ % 60, YT % 20, SU %20 contributed. Methodology: GŞ % 40, YT %20, NR % 20, SU %20 contributed. Statistical analysis: GŞ % 40, SU % 30, YT: %15, NR %15 contributed. Manuscript writing: GŞ % 40, YT %20, NR % 20, SU %20 contributed. Review and editing: GŞ % 40, YT %20, NR % 20, SU %20 contributed.

Ethics Committee: Marmara University Faculty of Medicine Clinical Research Ethics Committee (Approval Date: 25.12.2021; Approval Number: 09.2021.1271).

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