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Previous Knee Injury Alters Bilateral Supraspinal Excitability During Torque Control: An Exploratory Study

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ABSTRACT

Background: Knee ligament and meniscal injuries may cause persistent neuromuscular alterations despite successful return to sport (RTS). However, whether previous knee injury affects supraspinal excitability during torque control remains unclear. This observational study investigated the association between previous knee ligament or meniscal injury and supraspinal excitability in female university basketball players using long-latency reflexes (LLRs).

Methods: Nineteen athletes participated, including five with a history of knee injury who had completed rehabilitation and returned to sport. During a sustained knee extension task at 25% of maximal voluntary isometric contraction, LLR characteristics (appearance rate, latency, duration, LLR/Mmax ratio, and phase count) were recorded from the ipsilateral *opponens pollicis* muscle. Comparisons were made between injured and non-injured limbs, between dominant and non-dominant limbs, and between the injured limbs of previously injured athletes and the dominant limbs of healthy athletes.

Results: Healthy athletes demonstrated significantly shorter latency and greater LLR duration, LLR/Mmax ratio, and phase count in the dominant limb than in the non-dominant limb ($p < .05$). In contrast, no significant interlimb or dominance-related differences were observed in athletes with previous knee injury. Compared with the dominant limbs of healthy athletes, the injured limbs of previously injured athletes exhibited significantly prolonged LLR latency.

Conclusion: These findings suggest that previous knee ligament or meniscal injury is associated with bilateral alterations in supraspinal neuromuscular control and delayed supraspinal processing during torque control. LLR assessment may complement conventional RTS evaluations by providing objective neurophysiological information relevant to safer RTS decision-making.

Keywords: Long-latency reflex, neuromuscular control, knee injury, sports

1. INTRODUCTION

Knee ligament and meniscal injuries, particularly those involving the anterior cruciate ligament (ACL) and menisci, are among the most common sports-related injuries and frequently occur in activities involving cutting, pivoting, and jumping movements (Majewski et al., 2006; Waldén et al., 2016). These injuries often require prolonged rehabilitation, and the ultimate goal of treatment is a safe return to sport (RTS) at the preinjury level of performance (Paschos & Howell, 2017; van Melick et al., 2016).

Current RTS decision-making primarily relies on quantitative measures, including time since surgery, muscle strength, and hop performance (Gokeler et al., 2017; Xergia et al., 2013). However, reinjuries continue to occur even in athletes who satisfy

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these criteria (Kyritsis et al., 2016; Losciale et al., 2019). This suggests that conventional RTS assessments may not fully capture the qualitative aspects of neuromuscular control that are necessary for safe sports participation.

One potential factor underlying persistent functional deficits is impairment of proprioceptive input. Mechanoreceptors such as Ruffini endings, Pacinian corpuscles, and Golgi tendon organs are present in the ACL, collateral ligaments, and menisci and contribute to the detection of joint position, movement, and loading (Kennedy et al., 1982; Zimny et al., 1986; Zimny et al., 1988). Damage to these structures may reduce afferent sensory information to the central nervous system (CNS), potentially altering motor control and joint stability (Çabuk et al., 2022; Xu et al., 2022).

Previous studies have demonstrated a close relationship between proprioception and supraspinal excitability during torque control tasks (Daikuya et al., 2017; Daikuya & Okayama, 2018). Moreover, individuals with impaired knee joint integrity exhibit altered neuroplastic responses during torque maintenance, and proprioceptive errors are associated with changes in supraspinal excitability (Okayama & Daikuya, 2025; Strong et al., 2022). These findings suggest that reduced peripheral feedback following ligament or meniscal injury may alter supraspinal neural control during force regulation.

To evaluate such supraspinal involvement, long-latency reflexes (LLRs) recorded from the upper limb during lower-limb tasks have been used as an objective neurophysiological index of supraspinal excitability. Previous studies have demonstrated that sensory feedback conditions influence LLR responses during torque control (Okayama & Daikuya, 2025); however, it remains unclear whether a unilateral knee injury produces only localised changes in the injured limb or broader bilateral alterations in neuromuscular control.

Clarifying this issue requires comparisons not only between injured athletes and uninjured controls but also between the injured and non-injured sides within injured athletes and between dominant and non-dominant limbs. Such analyses may reveal whether previous knee trauma alters the normal inter-limb relationship and induces bilateral changes in supraspinal neuromuscular control.

Therefore, the present study aimed to assess the effects of previous knee ligament or meniscal injury on supraspinal excitability during torque control by comparing LLR responses between the injured and non-injured limbs and between the dominant and non-dominant limbs in athletes with and without an injury history. These findings may contribute to the development of neurophysiological assessment indicators to support safer RTS decision-making.

2. METHODS

Ethical considerations

The study protocol received formal approval from the Ethics Committee of Hokuriku University on 29 June 2023 (Approval No. 2023-16). Prior to enrolment, all eligible athletes were comprehensively briefed on the nature and scope of the research, and they voluntarily provided written informed consent.

Study population

This observation study enrolled female university basketball players. Participants were eligible for inclusion if they were actively training and competing at the time of the study and had no current musculoskeletal injuries that could affect basketball performance.

Exclusion criteria included a history of lower extremity injury within the previous six months, current pain or functional limitations during sports activities, and any neurological or systemic disorders affecting movement.

The cohort was divided into two distinct experimental groups based on musculoskeletal injury history. Group I (the injured group) comprised athletes with a documented history of knee ligament or meniscal injury who had completed standard phase-based rehabilitation (Drigny et al., 2025; van Melick et al., 2016) and had received official medical clearance for a full return to sport. Conversely, Group II (the control group) consisted of healthy control athletes with no prior history of knee trauma or related musculoskeletal impairments.

Sample size

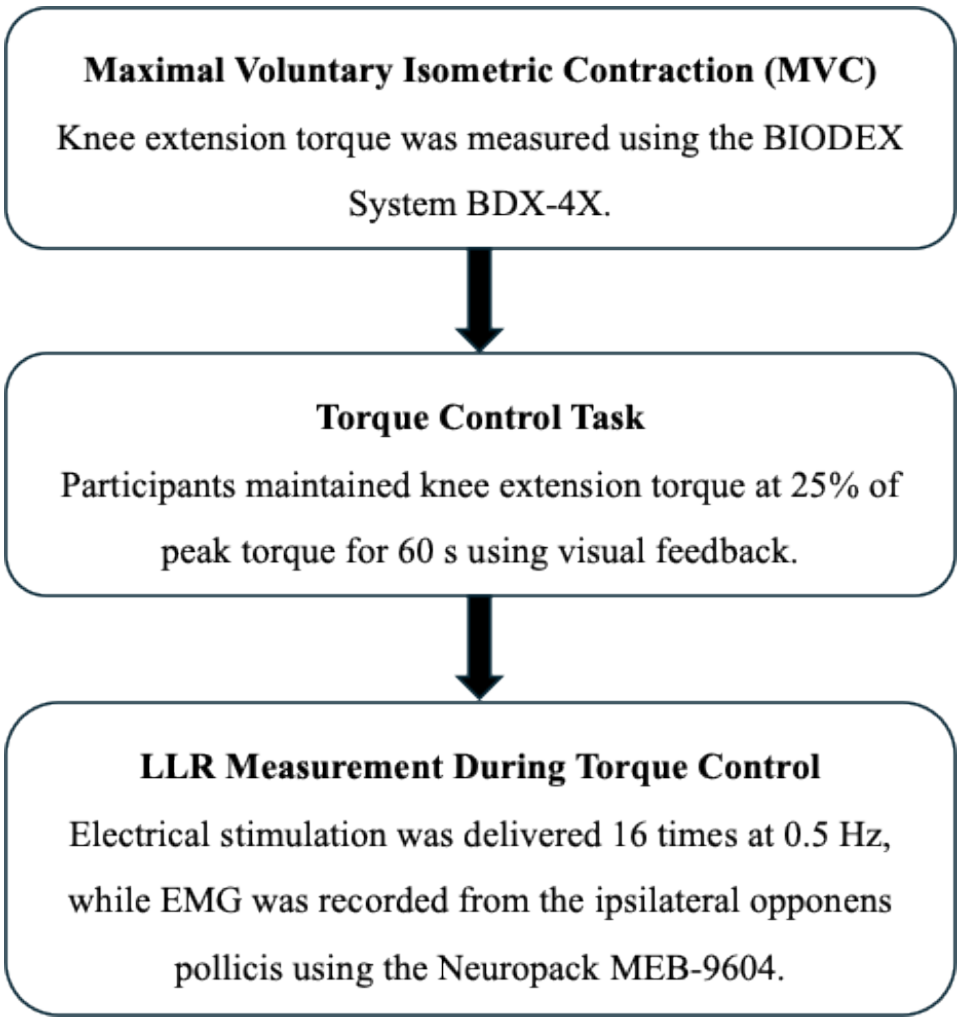
Participants were recruited using a convenience sampling method from a female university basketball team at a single university. The researcher explained the purpose and procedures of the study to all team members during a team meeting, and those who met the inclusion criteria and provided written informed consent were enrolled.

A priori power analysis was conducted for a Wilcoxon Signed-Rank Test (two-tailed, $\alpha = .05$, power $= .80$), which indicated that a minimum of five participants would be required.

Study procedures

An overview of the experimental organisation and data acquisition procedure is presented in Figure 1. To determine the maximal voluntary isometric contraction torque during knee extension, we utilised the BIODEX System BDX-4X (*Biodex Medical Systems Inc., Shirley, NY, USA*) with each participant positioned in a seated posture and the knee secured at a 60° flexion angle. Following this baseline assessment, participants were instructed to maintain a constant knee extension output corresponding to a visually displayed target line set at 25% of their peak torque for a continuous duration of 60 s while maintaining the same position. For the purpose of this investigation, limb dominance was operationalised as the preferred leg used to kick a ball, given that ball-kicking actions necessitate precise, goal-directed neuromuscular regulation (Okayama & Daikuya, 2023); this criterion was deemed highly appropriate for the current torque-matching paradigm. To ensure precise data alignment, the BIODEX system was electronically synchronised with the Ultium EMG EM-U880 system (*Noraxon USA Inc., Scottsdale, AZ, USA*), allowing the continuous torque data stream to be captured and stored on a personal computer.

Figure 1. **Schematic overview of the experimental organisation**



First, maximal voluntary isometric contraction torque during knee extension was measured using the BIODEX System BDX-4X. Participants then maintained knee extension torque at 25% of peak torque for 60 s using visual feedback. During the torque-control task, electrical stimulation was delivered to evoke long-latency reflexes (LLRs), and EMG signals were recorded from the ipsilateral *opponens pollicis* using the Neuropack MEB-9604. The torque signal was simultaneously acquired using the Ultium EMG EM-U880 system.

Concurrent with this motor control task, LLR characteristics were evoked and recorded from the ipsilateral upper extremity muscle (*opponens pollicis*)

via a Neuropack MEB-9604 clinical electromyography system (*Nihon Kohden Corporation, Japan*).

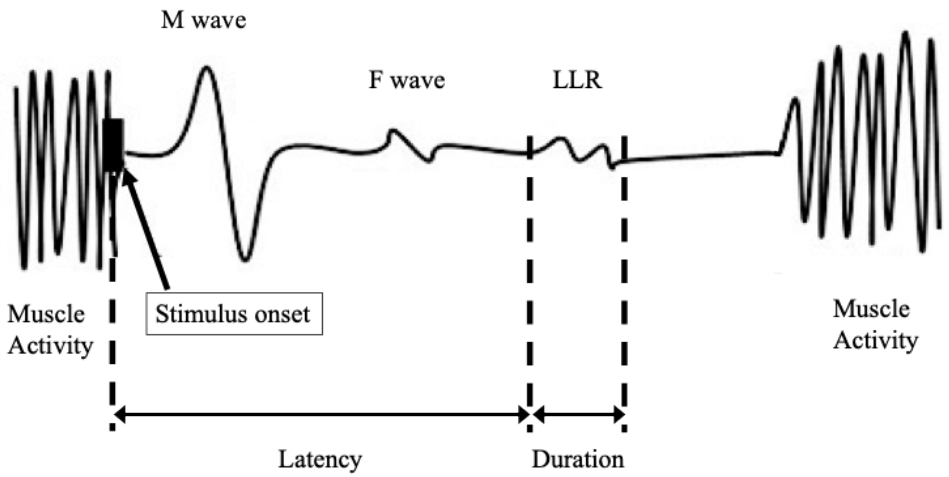
The LLR recorded from the upper limb muscles is elicited by peripheral nerve stimulation and mediated through supraspinal neural pathways (Marsden et al., 1973). It serves as an objective neurophysiological measure of supraspinal pathway excitability and conduction (Conrad & Aschoff, 1977; Zhou et al., 2008). The evaluated parameters included occurrence rate, latency, duration, LLR/Mmax, and phase count.

The participants were asked to gently grasp a rubber ball to elicit contraction of the *opponens pollicis* muscle to evoke a LLR. To capture LLR signals, we secured the active recording electrode onto the centre of the *opponens pollicis* muscle belly, while the reference electrode was placed over the thumb's dorsal interphalangeal joint. The electrical stimulation profile adhered to previously validated parameters (Daikuya et al., 2017; Daikuya & Okayama, 2018): the stimulus intensity was calibrated to 120% of the threshold required to elicit a peak M-wave response, delivered at a constant frequency of 0.5 Hz with a pulse width of 0.2 ms. For each experimental trial, a total of 16 individual pulses were applied.

Data collection

Participant age was documented through personal interviews, while anthropometric data including height and weight were recorded using standard clinical scales. Regarding neurophysiological evaluation, we quantified multiple LLR-related components based on established diagnostic protocols (Daikuya et al., 2017): the LLR appearance rate, latency from stimulus onset, LLR duration (operationalised as the chronological span between the initial deflection and its return to baseline), LLR/Mmax, and total phase count.

Figure 2. **Schematic of EMG signal and LLR measurements**



The percentage of trials when LLR was observed can be defined as the LLR occurrence rate. The delay between the start of the stimulus and the start of the LLR response may be called latency. The duration referred to the amount of time between the LLR EMG response's onset and offset. The peak amplitude ratio showed the maximum LLR response normalised to the peak M-wave amplitude. The phase count was the number of distinct EMG bursts observed during the LLR period.

Data analysis

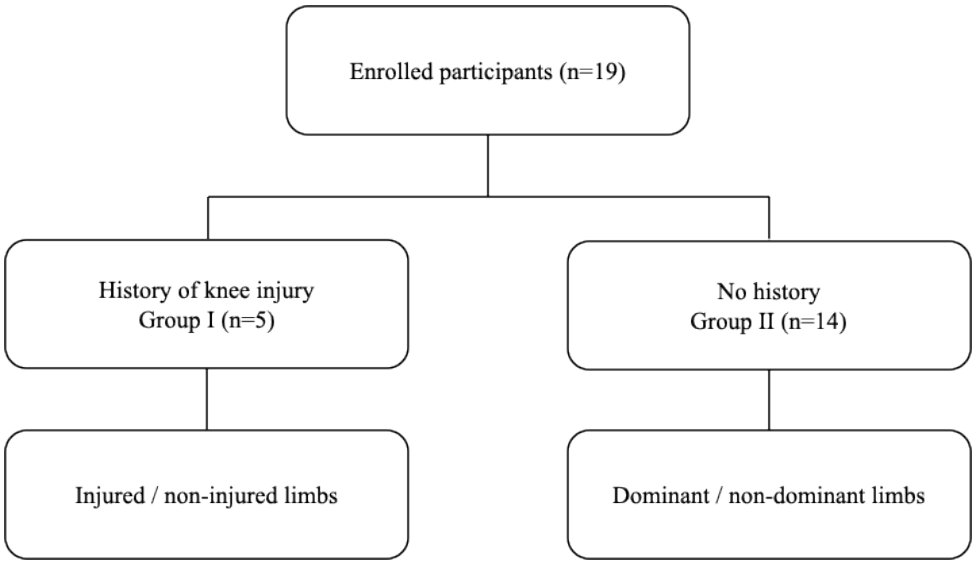
The distribution of the data was evaluated using the Shapiro–Wilk Test. Given that the variables exhibited a non-normal distribution, all continuous outcomes are reported as median values accompanied by their corresponding interquartile ranges (IQR). For baseline demographic features, differences in age, height, and weight between athletes with and without a history of knee injury were analysed using the non-parametric Mann–Whitney U Test. To assess neuromuscular variations within Group I (injured cohort), we compared LLR outcomes between the injured and non-injured extremities, as well as between the dominant and non-dominant sides. For Group II (uninjured cohort), side-to-side differences between the dominant and non-dominant limbs were examined using the Wilcoxon Signed-Rank Test. The significance level was set at 5%, and IBM SPSS 30.0 for Windows (*IBM Corp., Armonk, NY, USA*) was used for statistical analysis.

3. RESULTS

Demographic profiles

A total of 19 female collegiate basketball players volunteered for this investigation. Within this study population, five individuals presented with a documented history of sports-related knee trauma (Figure 3).

Figure 3. **Participant flowchart**



Baseline metrics and waveform characteristics

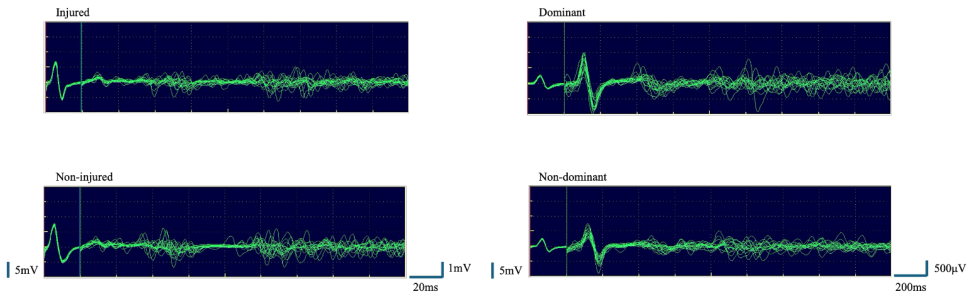
Statistical analysis revealed no significant differences in baseline anthropometric variables, including chronological age, standing height, or body mass, when comparing athletes with and without a history of knee trauma (Table 1). Representative electrophysiological tracings for both Group I and Group II are illustrated in Figure 4, with each waveform displaying the superimposed patterns of 16 consecutive stimulus sweeps. The captured LLR waveforms presented as stable, multi-phasic electromyographic deflections emerging after the short- and medium-latency intervals, demonstrating robust cross-trial reproducibility. Representative waveforms appeared to show shorter latencies and greater LLR duration, LLR/Mmax, and phase count in the dominant limb than in the non-dominant limb within the uninjured cohort.

Table 1. **Comparison of the demographic data between participants with and without a history of sports-related injury**

	With a history (n = 5)			Without a history (n = 14)			p
Age (years)	19.80	±	0.84	19.43	±	1.34	0.56
Height (cm)	166.00	±	5.00	163.50	±	5.27	0.34
Weight (kg)	62.78	±	5.74	61.16	±	3.48	0.26

Notes: Data are presented as mean ± SD. Items under different history (with a history and without a history) were compared using the Mann–Whitney U Test to identify significant differences.

Figure 4. **Typical waveforms**



Neuromuscular profiles in athletes with an injury history

When examining the subgroup of athletes with prior sports-related knee trauma, the non-parametric inter-limb analysis demonstrated no statistically significant differences in any of the investigated LLR metrics between the injured and contralateral non-injured extremities (Table 2). Furthermore, within this same injured cohort, no significant side-to-side differences were observed between the designated dominant and non-dominant limbs across all electrophysiological parameters (Table 3).

Table 2. **Comparison of LLR-related EMG outcomes between injured and non-injured legs in participants with a history of injury**

	Injured (n = 5)		Non-injured (n = 5)		Z	p
Frequency of LLR appearance (%)	100.00	(90.63–100.00)	93.75	(73.44–100.00)	−1.07	0.29
Latency (ms)	48.06	(47.63–63.27)	48.84	(45.81–51.22)	−1.10	0.27
Duration (ms)	37.40	(29.59–42.15)	40.80	(35.02–74.12)	−1.10	0.27
LLR/Mmax (%)	0.04	(0.03–0.08)	0.07	(0.05–0.18)	−0.73	0.47
Number of phases	7.47	(6.31–8.72)	7.92	(7.23–9.63)	−1.46	0.14

Notes: Data are presented as median (IQR). Items in legs with a history of injury under different injured sides (injured and non-injured) were compared using a Wilcoxon Signed-Rank Test to identify significant differences.

Table 3. **Comparison of LLR-related EMG outcomes between dominant and non-dominant legs in participants with a history of injury**

	Dominant (n = 5)		Non-dominant (n = 5)		Z	p
Frequency of LLR appearance (%)	100.00	(87.5–100.00)	96.88	(75.00–100.00)	−0.54	0.59
Latency (ms)	50.11	(47.43–52.89)	48.01	(45.91–66.28)	0.00	1.00
Duration (ms)	37.06	(32.31–40.97)	42.15	(32.13–73.60)	−0.37	0.72
LLR/Mmax (%)	0.04	(0.03–0.07)	0.08	(0.04–0.18)	−0.73	0.47
Number of phases	7.93	(6.68–9.22)	7.69	(6.56–8.87)	−0.37	0.72

Notes: Data are presented as median (IQR). Items in legs with a history of injury under different dominant sides (dominant and non-dominant) were compared using a Wilcoxon Signed-Rank Test to identify significant differences.

Limb dominance characteristics in healthy controls

Conversely, among the healthy counterpart athletes without any prior history of sports injuries, limb dominance exerted a clear influence on neuromuscular traits. Specifically, the dominant lower extremity exhibited a significantly shorter reflex latency combined with significantly higher values for LLR duration, LLR/Mmax, and total phase count compared with the non-dominant lower extremity ($p < 0.05$). In contrast, the spatial frequency of LLR appearance showed no significant side-to-side differences within this uninjured control group (Table 4). In contrast to healthy athletes, these dominance-related differences were absent in athletes with a previous knee injury (Tables 3 and 4).

Table 4. **Comparison of LLR-related EMG outcomes between dominant and non-dominant legs in participants without a history of injury**

	Dominant (n = 14)		Non-dominant (n = 14)		Z		p
Frequency of LLR appearance (%)	96.88	(68.75–100.00)	93.75	(59.38–100.00)	−0.95		0.34
Latency (ms)	46.99	(46.17–48.87)	48.94	(47.24–53.13)	−2.48	*	0.01
Duration (ms)	40.42	(34.82–43.15)	35.34	(31.86–37.75)	−2.83	*	0.01
LLR/Mmax (%)	0.04	(0.03–0.12)	0.02	(0.01–0.05)	−2.23	*	0.03
Number of phases	8.28	(7.09–9.66)	7.06	(6.00–8.01)	−2.90	*	0.00

Notes: Data are presented as median (IQR). Items in legs without a history of injury under different dominant sides (dominant and non-dominant) were compared using a Wilcoxon Signed-Rank Test to identify significant differences. *$p < 0.05$.

Limb comparison between healthy dominant legs and previously injured legs

Comparison between the dominant legs of athletes without a history of knee injury and the injured legs of athletes with a previous knee injury revealed a significantly longer LLR latency in the injured legs ($p = 0.04$). No significant between-group differences were observed in LLR appearance rate, LLR duration, LLR/Mmax ratio, or phase count (Table 5).

Table 5. **Comparison of LLR-related EMG outcomes between dominant legs in participants without a history of injury and injured legs in participants with a history of injury**

	Dominant (n = 14)		Injured (n = 5)		Z		p
Frequency of LLR appearance (%)	96.88	(68.75–100.00)	100.00	(90.63–100.00)	−0.90		0.44
Latency (ms)	46.99	(46.17–48.87)	48.06	(47.63–63.27)	−2.04	*	0.04
Duration (ms)	40.42	(34.82–43.15)	37.40	(29.59–42.15)	−0.74		0.50
LLR/Mmax (%)	0.04	(0.03–0.12)	0.04	(0.03–0.08)	−0.28		0.82
Number of phases	8.28	(7.09–9.66)	7.47	(6.31–8.72)	−1.02		0.34

Notes: Data are presented as median (IQR). LLR-related EMG outcomes were compared between the dominant legs of participants without a history of injury and the injured legs of participants with a history of injury using the Mann–Whitney U Test. *$p < 0.05$.

Sixteen superimposed waveforms recorded during the experiment. Left: Participant with a history of sports-related injury. Right: Participant without a history of sports-related injury.

4. DISCUSSION

The present study investigated whether previous knee ligament or meniscal injury is associated with alterations in supraspinal excitability during torque control by comparing LLR responses between injured and non-injured limbs, between dominant and non-dominant limbs in athletes with and without an injury history, and between the injured limbs of previously injured athletes and the dominant limbs of healthy athletes. The principal findings were twofold. First, the normal limb

dominance characteristics observed in healthy athletes were absent in athletes with previous knee injuries, suggesting bilateral alterations in supraspinal neuromuscular control following unilateral knee trauma. Second, compared with the dominant limbs of healthy athletes, the injured limbs of athletes with a previous knee injury exhibited significantly prolonged LLR latency, indicating delayed supraspinal processing during torque control.

Peripheral injuries can impair proprioception on the affected side, resulting in decreased proprioceptive function in the injured leg compared with the non-injured or healthy leg (Kim et al., 2017). Moreover, several studies have demonstrated that tissue damage may also reduce proprioception in the contralateral, non-injured limb (Laboute et al., 2019). Proprioceptive improvements following ACL reconstruction have also been documented (Furlanetto et al., 2016). However, proprioceptive recovery does not occur immediately post-ACL reconstruction. A recent systematic review has reported that recovery of proprioception after ACL reconstruction may take 6–24 months (Fleming et al., 2022). At the cellular level, receptor regeneration begins immediately after injury (Çabuk et al., 2022), and this recovery process is thought to depend largely on the compensatory mechanisms in soft tissues, such as the joint capsule and surrounding muscles (Xu et al., 2022). The prolonged LLR latency observed in the injured limbs compared with the dominant limbs of healthy athletes may reflect reduced efficiency of proprioceptive afferent transmission, resulting in greater reliance on cortical processing during visually guided torque control. Because the LLR is mediated through transcortical pathways, delayed latency may indicate that additional cortical processing is required to compensate for impaired peripheral sensory input following knee injury.

In the present study, no significant differences in LLR indices were observed between the injured and non-injured limbs. However, the absence of a significant side to side difference alone cannot establish the presence of bilateral neuroplastic adaptation. Previous studies have demonstrated alterations in brain activity and corticospinal excitability following unilateral knee injury, including changes involving the contralateral, non-injured limb, suggesting that neural adaptations following knee injury may not necessarily be restricted to the injured side (Neto et al., 2019). In the present study, LLR latency in the injured limbs was significantly prolonged compared with that in the dominant limbs of healthy athletes. Because electrically evoked LLRs are considered to reflect sensorimotor processing involving supraspinal, including transcortical, pathways (Palmer & Ashby, 1992), this finding may indicate altered supraspinal sensorimotor processing in athletes with a history of knee injury. Nevertheless, the neural structures responsible for the observed latency differences cannot be identified from the present methodology. Taken together, the lack of side-to-side differences within the injured group and the difference between the injured limbs and healthy athletes raise the possibility that neuromuscular alterations following unilateral knee injury may extend beyond the injured limb. From a clinical perspective, these findings suggest that assessment for return to sport should not rely exclusively on interlimb symmetry, because the non-injured limb may not necessarily represent an unaffected reference after unilateral knee injury.

Regarding limb dominance, the dominant leg in the present study was defined as the leg preferred for kicking a ball. However, leg dominance should be interpreted cautiously because limb preference is task-dependent. Velotta et al. (2011) demonstrated that leg preference differed between manipulative and postural-stability tasks, indicating that dominance defined by a kicking task does not necessarily represent superiority across all lower-limb functions. Nevertheless, previous studies have identified dominance-related differences in neuromuscular and postural control. Promsri et al. (2023), who similarly defined the dominant leg as the preferred kicking leg, reported more irregular postural acceleration fluctuations during unipedal standing on the dominant leg, which were interpreted as reflecting greater postural control efficiency or automaticity. In the present study, healthy athletes demonstrated distinct dominance-related differences in LLR characteristics, whereas no significant dominant–non-dominant differences were detected in participants with a history of knee injury. Although this finding does not directly demonstrate bilateral neuroplasticity, it may be consistent with previous evidence that unilateral knee injury can be accompanied by bilateral alterations in neural control (Neto et al., 2019; Rodriguez et al., 2021). Therefore, the reduced dominance-related asymmetry observed in the injured group may reflect alterations in sensorimotor organisation following knee injury; however, this interpretation requires confirmation in larger prospective studies.

In participants without a history of sports-related injury, the dominant limbs exhibited shorter

latency, longer duration, higher LLR/Mmax, and greater phase counts in the LLR than the non-dominant limbs. In participants without a history of sports-related injury, the dominant legs exhibited shorter LLR latency, longer duration, higher LLR/Mmax, and greater phase counts than the non-dominant legs. These findings indicate that LLR characteristics differed according to limb dominance in healthy athletes. Although leg dominance is known to be task-dependent (Velotta et al., 2011), previous studies have demonstrated interlimb differences in neuromuscular and postural control. In particular, Promsri et al. (2023) reported greater postural control efficiency or automaticity in the dominant leg during unipedal balance tasks. Thus, the present LLR findings may reflect limb-specific characteristics of supraspinal sensorimotor control in healthy athletes. However, the physiological significance of individual LLR parameters, particularly response duration, LLR/Mmax, and phase count, remains unclear, and these parameters should not be interpreted as direct measures of specific neural pathways or levels of neural processing. These findings suggest that the dominant leg utilises more complex and sustained motor control mechanisms, enabling precise and continuous torque maintenance. This pattern aligns with previous evidence indicating that the dominant leg exhibits superior neuromuscular control and postural stability (Velotta et al., 2011; Promsri et al., 2023). Conversely, the significantly prolonged LLR latency observed in the injured limbs relative to the dominant limbs of healthy athletes may therefore indicate altered supraspinal sensorimotor processing after knee injury. However, the present methodology does not allow identification of the specific neural structures or mechanisms responsible for this latency prolongation. Taken together, these findings suggest that limb dominance is associated with characteristic supraspinal control patterns in healthy athletes, whereas previous knee injury may diminish these physiological asymmetries through bilateral neuroplastic adaptations.

Overall, healthy athletes demonstrated characteristic limb dominance in supraspinal excitability, whereas athletes with a history of knee injury did not. Furthermore, previously injured limbs exhibited longer LLR latency than the dominant limbs of healthy athletes, suggesting delayed supraspinal processing that may reflect greater cortical involvement during torque control. These findings indicate that previous knee injury is associated with bilateral alterations in supraspinal neuromuscular control rather than persistent unilateral deficits. Such neurophysiological changes should be considered when evaluating readiness for RTS.

Limitations

The present study has some limitations. The sample size was limited, the participants' injury histories were heterogeneous, and the cross-sectional design precluded the assessment of temporal changes. Thus, future longitudinal studies with larger samples are warranted to clarify the interactions between leg dominance and injury history and to enhance the clinical applicability of LLR-based assessments.

5. CONCLUSIONS

The relationship between prior knee injuries and supraspinal neural excitability during knee extension torque control was examined. In healthy athletes, the dominant leg exhibited inherent neurophysiological advantages characterised by efficient LLR indices. However, this physiological asymmetry and the neural benefits of limb dominance appear to be disrupted following a sports-related knee injury. Furthermore, compared with healthy dominant limbs, previously injured limbs demonstrated significantly prolonged LLR latency, potentially reflecting delayed supraspinal processing and a greater reliance on compensatory cortical pathways due to impaired peripheral proprioception. These findings suggest that unilateral knee trauma may induce widespread, bilateral neuroplastic adaptations within the central nervous system rather than persistent localised deficits. Clinically, RTS protocols might benefit from transitioning from eliminating side-to-side asymmetries to implementing comprehensive bilateral training strategies to enhance overall neuromuscular control.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Ethical Approval: This study was approved by the Research Ethics Committee of Hokuriku University (Approval No. 2023-16, 29 June 2023).

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Conflicts of Interest: The authors declare no conflict of interest.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

AI Use Statement: No generative AI and AI-assisted technologies were used in the research or the drafting of the manuscript.

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