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ORIGINAL RESEARCH

Effects of Hip Joint Motion-Style Acupuncture Treatment in Patients with Acute Radiating Leg Symptoms After Traffic Accidents: A Pilot Pragmatic Randomized Controlled Trial

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Purpose: We aimed to evaluate the short-term efficacy and safety of early MSAT intervention in patients with acute radiating leg pain following traffic accidents.

Patients and Methods: This single-center, pragmatic, randomized controlled trial was conducted at a Korean medicine hospital and included 40 patients with radiating leg pain following traffic accidents hospitalized between November 2023 and October 2024. The patients received integrative Korean medicine treatment (IKMT, control) or IKMT combined with MSAT on hospitalization Days 2, 3, and 4. Primary and secondary outcomes, including the numeric rating scale(NRS) for radiating leg pain and low back pain, Oswestry disability index(ODI), and EuroQol-5-Dimension-5-Level(Q-5D-5L), were assessed daily form Day2 to Day5 during hospitalization and at a 14-day follow-up. Analyses included intention-to-treat and Cox regression for time-to-event outcomes.

Results: The MSAT group experienced a significantly greater reduction in radiating leg pain than the IKMT group on hospitalization Day5 (difference: 2.28, 95% confidence interval [CI]: 1.54–3.01; $p < 0.001$). Significant between-group differences were observed for the NRS scores of low-back pain (difference: 1.81; $p < 0.001$), ODI (difference: 11.23; $p = 0.002$), EQ-5D-5L (difference: –0.09; $p = 0.006$), etc. Kaplan–Meier analysis revealed a faster recovery (≥50% pain reduction) in the MSAT (median, 3.5 vs. 13 days; log-rank $p < 0.001$) than IKMT group with a 4.473 hazard ratio (95% CI: 1.658–12.067; $p = 0.005$). One mild adverse event occurred, which was unrelated to the intervention.

Conclusion: This pilot study suggests that early MSAT combined with IKMT may provide more rapid pain relief, improved functional outcomes, and higher patient satisfaction compared with IKMT alone during the acute phase.

Registration: ClinicalTrials.gov (NCT06179901).

Keywords: MSAT, movement therapy, traffic accident, back pain, radiating leg pain, acupuncture

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Introduction

Traffic accidents have several outcomes, ranging from minor injuries to severe physical damage and death, depending on the severity. The number of deaths caused by traffic accidents has decreased; however, the proportion of survivors with minor injuries has increased. Accordingly, medical expenses related to traffic accidents have increased in Korea.[1]

Lumbar and cervical sprains, usually accompanied by radiating leg pain, constitute the largest proportion of medical expenses related to traffic accident insurance.[1–3] Patients with radiating leg and low-back pain exhibit greater pain intensity and functional disability than those who experience low-back pain alone.[4] As symptoms worsen, these patients usually require substantial healthcare services and become vulnerable to an increased risk of unemployment. Unresolved radiating leg pain adversely affects patients' economic conditions, creating a vicious cycle.[5,6] Thus, providing prompt and effective therapeutic intervention for patients who develop radiating leg pain after a traffic accident is crucial to prevent chronic progression.

The treatment plan for low-back or radiating leg pain after a minor traffic accident varies according to the underlying cause and pain severity.[7] Radiological examination is usually recommended when neurological symptoms such as radiating leg pain accompany low-back pain, and various conservative treatments such as pharmacotherapy, physical therapy, or exercise therapy are considered.[8] Analgesics, nonsteroidal anti-inflammatory drugs, or muscle relaxants are commonly prescribed, and physical or exercise therapy is applied to facilitate rehabilitation and return to daily activities.[9]

The Korean medical system comprises Western and Korean medicines, whereas many patients of traffic accidents receive Korean medicine treatments.[1,10] The Korean Medicine Clinical Practice Guideline for Traffic Accident Injury Syndrome recommends acupuncture, electroacupuncture, pharmacopuncture, motion-style acupuncture treatment (MSAT), and Chuna manual therapy as standalone or combination treatments for traffic injuries.[11]

Among these treatments, MSAT is a recently introduced technique that induces the active or passive movement of acupuncture sites after conventional acupuncture to maximize therapeutic effects.[12] MSAT combines acupuncture's physiological analgesic effects, such as endorphin release via diffuse noxious inhibitory control, with the cognitive reconfiguration of pain. By safely mobilizing the affected area during needle stimulation, MSAT is hypothesized to reduce fear-avoidance behaviors and correct negative pain perceptions, which are often heightened in patients with acute radiating leg pain.[12] Considering the increasing utilization of Korean medicine among traffic accident patients—many of whom experience significant low back and radiating leg pain—MSAT is an appropriate and promising intervention for rapid pain relief and functional recovery in this population through these specific mechanisms.[13]

Randomized controlled trials have shown that early MSAT intervention in patients with acute low-back pain owing to traffic accidents significantly improves pain relief and range of motion.[14,15] Another trial regarding the comparison of MSAT with diclofenac injection for severe acute low-back pain revealed that MSAT resulted in greater reduction in Numeric Rating Scale (NRS) scores for low-back and radiating leg pain within 30 min; these benefits were maintained for 4 weeks.[16] In addition, there are observational studies on the effects of MSAT in patients with lumbar disc herniation presenting with concurrent low-back and radiating leg pain;[17,18] however, no study exists regarding the efficacy and safety of MSAT. Notably, there have been no clinical trials specifically evaluating "Hip joint MSAT" for radiating leg pain or hip-related discomfort. Hip joint MSAT is a specialized intervention that combines acupuncture with motion, specifically targeting the hip joint and its constitutive musculature—including the piriformis, gluteus medius, and quadratus lumborum—to facilitate rapid functional recovery.

To address this knowledge gap, we aimed to conduct a preliminary randomized controlled trial to assess the efficacy and safety of early MSAT in patients who developed acute radiating leg pain and paraesthesia within 3 days post-traffic accident and evaluate the feasibility of conducting a larger main trial.

We hypothesized that the early integration of MSAT into integrative Korean medicine treatment would lead to more rapid pain relief and functional improvement compared with integrative Korean medicine treatment alone.

Materials and Methods

Study Design and Setting

This parallel, single-center, pragmatic, randomized controlled trial included 40 patients who were hospitalized owing to traffic accidents at a hospital of Korean medicine in the Republic of Korea between November 2023 and October 2024.

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Jaseng Hospital of Korean Medicine (JASENG 2023–09-035-002) and registered at ClinicalTrials.gov (NCT06179901) before participant recruitment. All participants signed an informed consent form after receiving a comprehensive explanation of the study procedures and precautions from the investigator before enrolment.

Participants

Inclusion Criteria

Participants were recruited if they met all the following inclusion criteria: no difficulty in verbal communication; male or female aged 19–69 years; hospitalized for treatment after a traffic accident; radiating leg pain or paraesthesia reported within 3 days of the accident; NRS score ≥5 for radiating leg pain or paraesthesia; and voluntary participation in the clinical trial, as evidenced by signing the informed consent form.

Exclusion Criteria

Participants were excluded if they met any of the following criteria: diagnosis of critical conditions that could cause radiating leg pain, such as malignant tumors, vertebral fractures, spinal infections, or inflammatory spondylitis; presence of progressive neurological deficits or severe neurological symptoms such as cauda equina syndrome; history of lumbar or lower limb surgery or procedures in the preceding 3 weeks or scheduled surgery during the study; presence of chronic diseases that could interfere with treatment outcomes or the interpretation of results, such as cardiovascular disease, renal disease, active hepatitis, diabetic neuropathy, dementia, severe psychiatric disorders, or epilepsy; conditions where acupuncture may be contraindicated or unsafe, including bleeding disorders, current anticoagulant therapy, severe cardiovascular disease, pregnancy, severe diabetes with infection risk, or seizure disorders; current use of steroids, immunosuppressants, psychiatric medications, or other drugs that could affect the study results; participation in another clinical trial involving therapeutic intervention (participation in observational studies without intervention was allowed); inability to provide written informed consent; or being deemed unsuitable for participation by the principal investigator.

Participants were withdrawn from the study if they met any of the following conditions: violation of the inclusion or exclusion criteria during the study; discharge from the hospital on Day 1 or 2 of admission; occurrence of a serious adverse event; withdrawal of informed consent; difficulty in receiving the intervention; the use of medications or receipt of other treatments that could influence outcome assessment during the study without the investigator's approval; or principal investigator perceiving that continued participation as inappropriate to ensure study integrity.

Sample Size

There were no previous studies appropriate for estimating the sample size for this trial, and this pilot study was conducted to assess the feasibility and practicality of a future main clinical trial. Therefore, we did not perform a formal sample size calculation; we adopted the accepted minimum requirement for pilot studies of approximately 15 participants per group.[19,20] Considering an anticipated dropout rate of approximately 20% and the need for subgroup analyses, we enrolled 20 participants in each group, yielding a total sample size of 40.

Randomization and Allocation Concealment

Screening, participant recruitment, and randomization were conducted simultaneously on the first day of hospitalization. Simple randomization was performed by a researcher who was not involved in the recruitment using 2021 Microsoft Excel for Windows software (Microsoft Corporation, Redmond, WA, USA). A uniformly distributed random number was generated in Excel, and the "IF" function was used to assign participants to Group B or A when the value was >0.5 or <0.5, respectively.[21]

The clinical investigator was blinded to the randomization list, which was sealed in sequentially numbered opaque envelopes and stored in a locked cabinet by a third party. Randomization was performed for participants who signed the informed consent form and met all inclusion criteria. After enrolment, the opaque envelope was opened to reveal the group assignment. Accordingly, each participant was assigned a randomization number, and a third party maintained the data security until after intervention.

Blinding

The blinding of the practitioner and participants was infeasible owing to the nature of the intervention. An independent third party was the outcome assessor and evaluated the treatment results while remaining blinded to group allocation. The assessor did not participate in the intervention; they collected the outcome measurements at separate locations after the treatment sessions.

Study Intervention

Control Group

The control group received integrative Korean medicine treatment (IKMT), including acupuncture, pharmacopuncture, moxibustion, cupping, and Chuna manual therapy, based on the clinical practice guidelines for traffic injury syndrome.[11] Acupuncture treatment was performed using disposable sterile stainless steel needles (0.25 × 30 or 0.30×40 mm; Dongbang Acupuncture, Korea). To reflect real-world clinical practice in this pragmatic trial, the selection of acupoints was not strictly fixed but was left to the practitioner's clinical judgment based on the patient's symptoms and palpation. Commonly used points included Ashi points and those located along the bladder meridian (eg, BL23, BL24, BL25) and Huatuo jiaji points of the affected lumbar segment. Six to ten acupoints were selected, and manual stimulation was used to elicit a de-qi sensation. Each treatment session lasted approximately 15–20 min, including the needle retention time.

Pharmacopuncture, a combination of acupuncture with pharmacotherapy, involves injecting an appropriate volume of refined herbal extracts into therapeutic acupoints or tender points on the body surface using a syringe. This technique has demonstrated anti-inflammatory, analgesic, and anti-swelling effects. Moxibustion and cupping therapies were performed concurrently during needle retention. Based on the clinical judgment, one moxibustion (indirect moxa) and two cupping treatments were applied to the appropriate acupoints in the lumbar region per treatment session.

Chuna manual therapy is a traditional Korean manual technique where a Korean medicine physician uses the hands or body parts to correct structural imbalances in the musculoskeletal system, alleviating structural and functional disorders. Techniques such as myofascial release, joint traction, and high-velocity, low-amplitude manipulation were used once daily for approximately 10–15 min per session. Herbal medicine, comprising medicinal constituents that promote blood circulation, resolve blood stasis, and provide analgesic effects, was administered twice daily. The medication was administered once each morning and evening, 30 min after meals; however, this pattern may be adjusted.

Experimental Group

Participants in the experimental group received IKMT and underwent MSAT once daily for approximately 10 min on hospitalization Days 2, 3, and 4. MSAT was performed on the symptomatic side where radiating leg pain or paraesthesia occurred. The target muscle for MSAT (eg., piriformis, gluteus medius, or quadratus lumborum) was determined through a predefined clinical assessment algorithm, including palpation, manual muscle strength testing (MMT), and tenderness evaluation. This ensured that the intervention was tailored to the specific anatomical source of the radiating symptoms in each patient. The specific MSAT procedures applied to each muscle, as described previously,[18] are discussed subsequently.

For the piriformis and gluteus medius MSAT, the patient lay on the treatment table in the lateral decubitus position; the affected side faced upward, and the practitioner stood behind the patient. The unaffected leg was slightly flexed and stabilized, and the affected hip and knee joints were flexed to approximately 90°. The practitioner palpated the gluteal region to locate three to four myofascial trigger or tender points and inserted 0.30×60 mm disposable sterile stainless steel acupuncture needles (Dongbang Acupuncture Co., Republic of Korea). The insertion depth was ≥2 cm, reaching the superficial gluteal muscles and deep piriformis trigger points; adjustments were made based on the patient's anatomical characteristics. After needling, the affected hip was gently abducted to create a space between the legs, with the practitioner supporting the patient's affected ankle. Subsequently, the affected hip was flexed and extended 5–10 times to mobilize the gluteal musculature. During this motion, the affected knee was maintained at 90° flexion. After performing MSAT, the needles were removed, and the practitioner assessed the alleviation of trigger points and tenderness.

For quadratus lumborum MSAT, the patient lay on the treatment table in the lateral decubitus position; the affected side faced upward, and the practitioner stood behind the patient. The patient raised their arm above the head to allow sufficient stretching of the quadratus lumborum. Furthermore, the practitioner palpated the quadratus lumborum lateral to the erector spinae to identify three to four myofascial trigger or tender points and inserted 0.30×40 mm disposable sterile stainless steel acupuncture needles (Dongbang Acupuncture Co., Republic of Korea). The insertion depth was approximately 2–4 cm, adjusted according to the patient's anatomical characteristics. After needling, the practitioner supported the patient's upper arm, moving it upward and downward to perform shoulder abduction and adduction 5–10 times, mobilizing the quadratus lumborum muscle. After completing MSAT, the needles were removed, and the practitioner assessed the alleviation of trigger points and tenderness.

Co-Intervention

Participants were not restricted from receiving other treatments during intervention or follow-up if they experienced severe pain or other physical complications. The participants were instructed to report any additional treatments to the investigators, who verified and documented the reports.

Outcome Measurement

Primary Outcome

The primary and secondary outcomes and measurements are presented in Supplementary Table 1. The overall severity of radiating leg pain, including pain and associated paraesthesia, was assessed using the NRS.[22] On this scale, 0 represents no pain, whereas 10 indicates unbearable, maximal pain. Baseline was defined as the NRS score measured before the treatment intervention on hospitalization Day 2, and the primary outcome was the NRS score of radiating leg pain assessed immediately before treatment on hospitalization Day 5 (primary endpoint) and post-intervention.

Secondary Outcome

The following outcomes were assessed on Days 1–5 (with hospital admission defined as Day 1) and at the follow-up visit on Day 14:

NRS of Low-Back Pain (NRS of LBP)

In addition to radiating leg pain and paraesthesia, the degree of accompanying low-back pain was assessed using the NRS.

Oswestry Disability Index (ODI)

The ODI was used to measure the degree of disability experienced by patients in daily activities owing to low-back pain, radiating leg pain, and paraesthesia. This functional assessment tool was used to evaluate the level of difficulty in 10 daily activities, such as sitting, standing, walking, lifting objects, and social activities, with each item scored from 0 to 5. The total score ranges from 0 to 50, with high scores indicating great functional disabilities.[23,24]

European Quality of Life-5 Dimensions-5-Level (EQ-5D-5L)

The EQ-5D-5L, a common tool for measuring health-related quality of life, was used to assess patients' quality of life. This questionnaire is used to evaluate current health-related quality of life across five dimensions, namely mobility, self-care, usual activity, pain/discomfort, and anxiety/depression. Each dimension is rated on a five-point scale as follows: Level 1 (no problems), Level 2 (slight problems), Level 3 (moderate problems), Level 4 (severe problems), and Level 5 (extreme problems).[25,26]

The EuroQol Visual Analog Scale (EQ-VAS) is a 20-cm vertical scale accompanying the five dimensions of the EQ-5D-5L. The top of the scale represents "the best imaginable health state," whereas the bottom denotes "the worst imaginable health state." Respondents indicate their current health status by marking a point between these two extremes.

Patient Global Impression of Change (PGIC)

The PGIC was used to subjectively evaluate patient satisfaction with treatment and perceived improvement. Because the subjective criteria for improvement or worsening are ambiguous in the PGIC, the tool is used to assess treatment satisfaction rather than precise symptom changes. Among patients who report treatment satisfaction, changes in pain and functional disability indices can be analyzed concurrently to clarify the clinical relevance of improvement.[27]

Straight Leg Raise Test (SLRT)

SLRT was performed to determine the angle at which the patient experienced discomfort from low-back or radiating leg pain. This physical examination was conducted in patients presenting with concurrent low-back and radiating leg pain. Through patient interviews, we identified whether radiating leg pain occurred in the left, right, or both lower limbs. The test was performed on the unaffected and affected sides while the patient was in the supine position. The examiner held the patient's heel with one hand and stabilized the knee with the other hand to prevent flexion. Subsequently, the leg was raised to flex the hip and identify the symptom onset angle. The test was conducted to reproduce the patient's pain; thus, the unaffected side was tested before the affected side.[28]

Lumbar-Spine Magnetic Resonance Imaging (MRI)

Data regarding patients who underwent lumbar-spine MRI were retrospectively collected from the electronic medical records. MRI was performed by a radiologist with over 20 years of clinical experience. Researchers recorded the degree of disc herniation on MRI as mild (subtle), moderate, or severe. Disc herniation was classified as bulging, protrusion, extrusion, or sequestration/migration, and its direction was categorized as central, subarticular, foraminal, lateral, or anterior.[29,30]

If a patient was discharged on Day 3 or 4, the data for those periods were not collected. Alternatively, data were collected at the primary endpoint (Day 5) and on Day 14 of follow-up. SLRT data were not collected on follow-up Day 14.

Adverse Effects

Adverse effects refer to undesirable and unintended objective signs, subjective symptoms, or diseases occurring after the intervention during the clinical trial and do not necessarily have a causal relationship with the intervention. During the study, adverse events were determined through patient self-reports and investigator observations. Additionally, the type of adverse event and its causal relationship with the intervention were recorded in the electronic medical records. When an adverse event occurred, follow-up monitoring was conducted, and serious adverse events were immediately reported.

Causality was evaluated according to the World Health Organization–Uppsala Monitoring Centre (WHO-UMC) causality categories at six levels, namely certain, probable/likely, possible, unlikely, unassessable/unclassifiable, and unclassifiable.[31] Adverse event severity was assessed using the Spilker classification as follows: mild (requires no treatment and does not significantly interfere with normal daily function); moderate (significantly interferes with normal daily function and may require treatment, which results in recovery); and severe (requires intensive treatment owing to a serious adverse event and may result in sequelae).

We identified and analyzed the incidence of adverse events in the IKMT and MSAT groups when a potential association with the treatment intervention was suspected. Serious adverse events were descriptively recorded, and the collected data were summarized and organized.

Statistical Analysis

Statistical analyses were performed following an intention-to-treat approach. Missing data were handled using Mixed Models for Repeated Measures. For sensitivity analysis, missing data were handled using multiple imputation and the last observation carried forward method.

Participant demographics in each group were evaluated. Continuous variables were presented as mean (standard deviation) or median (interquartile range). Furthermore, between-group differences were analyzed using independent *t*-tests (continuous variables) and chi-square tests (categorical variables). For the primary and secondary outcomes,

a linear mixed model was used for the main analysis, with the baseline value (measured on Day 2 before the intervention) included as a covariate, the group denoted a fixed effect, and the patient was included as a random factor. To compare differences between the groups during the entire study, the area under the curve was calculated for each outcome across all time points, and group differences were analyzed using a *t*-test.

Furthermore, a survival analysis was performed, with a ≥50% reduction in the NRS score from baseline defined as the event. Differences between the two groups were compared using a Kaplan–Meier survival curve, and hazard ratios (HRs) were calculated using a Cox regression model. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) and R software version 4.5.1 (R Foundation for Statistical Computing, Vienna, Austria), and statistical significance was set at $p < 0.05$.

Results

Participants

Forty inpatients with low-back and radiating leg pain following traffic accidents were recruited between November 2023 and October 2024 at a Korean medicine hospital. After screening, eligible patients were enrolled and randomly assigned to the MSAT or IKMT group. Among 20 patients in the MSAT group, 17 received the 3-day treatment, and three had 2 days of treatment. In the IKMT group, 19 patients completed the 3-day treatment, and one received 2 days of treatment. All patients completed the 5 and 14 days of follow-up assessments and were subjected to an intention-to-treat analysis (Figure 1).

Baseline Characteristics

The baseline characteristics of the patients in the two groups are summarized in Table 1. The mean age of the participants was 39.88 ± 12.97 years, and 47.5% were women, indicating an even sex distribution. The mean length of hospital stay was 7.85 ± 5.04 days. No significant differences were observed between the two groups regarding age, sex, height, weight, alcohol consumption, smoking status, or length of hospital stay. Additionally, the groups exhibited no significant differences regarding the NRS score of radiating leg pain, NRS score of LBP, ODI score, EQ-5D-5L index, EQ-VAS score, SLRT result, or pain during SLRT. Among the 16 patients who underwent lumbar-spine MRI (5 and 11 in the MSAT and IKMT groups, respectively), disc herniation of protrusion grade or higher was observed in three and eight in the MSAT and IKMT groups, respectively.

Outcome Comparisons Between the IKMT and MSAT Groups

The changes from baseline at each time point were compared between the IKMT and MSAT groups (Table 2 and Figure 2). For the primary outcome, the NRS score of radiating leg pain showed a significantly greater reduction in the MSAT group than in the IKMT group at the primary endpoint (Day 5) (difference: 2.28, 95% confidence interval [CI]: 1.54–3.01; $p < 0.001$). In addition, the MSAT group demonstrated a significantly greater pain reduction than did the IKMT group on Days 3, 4, and 14.

For the secondary outcomes, significant between-group differences were observed on Day 5 for the NRS scores of LBP (difference 1.81, 95% CI: 1.14–2.49; $p < 0.001$), ODI scores (difference 11.23, 95% CI: 4.15–18.30; $p = 0.002$), and EQ-5D-5L indices (difference −0.09, 95% CI: −0.15 to −0.03; $p = 0.006$). These differences persisted until Day 14. In addition, statistically significant improvements were observed in the MSAT group for PGIC and SLRT.

Per-protocol analysis was performed on patients who completed the 3-day treatment, and the results are summarized in Supplementary Table 2. Consistent with the intention-to-treat analysis, the MSAT group showed significantly greater improvements in the NRS score of radiating leg pain, NRS score of LBP, EQ-VAS, and PGIC on Day 5 ($p < 0.001$). Additionally, statistically significant differences were observed in ODI scores ($p = 0.008$), EQ-5D-5L indices ($p = 0.012$), and SLRT results ($p = 0.008$).

Missing data were handled using multiple imputation, and the results are presented in Supplementary Table 3. On Day 5, the two groups exhibited significant differences regarding the NRS score of radiating leg pain, the NRS score of LBP, the EQ-VAS score, the PGIC score, and SLRT results ($p < 0.001$). In addition, statistically significant differences were

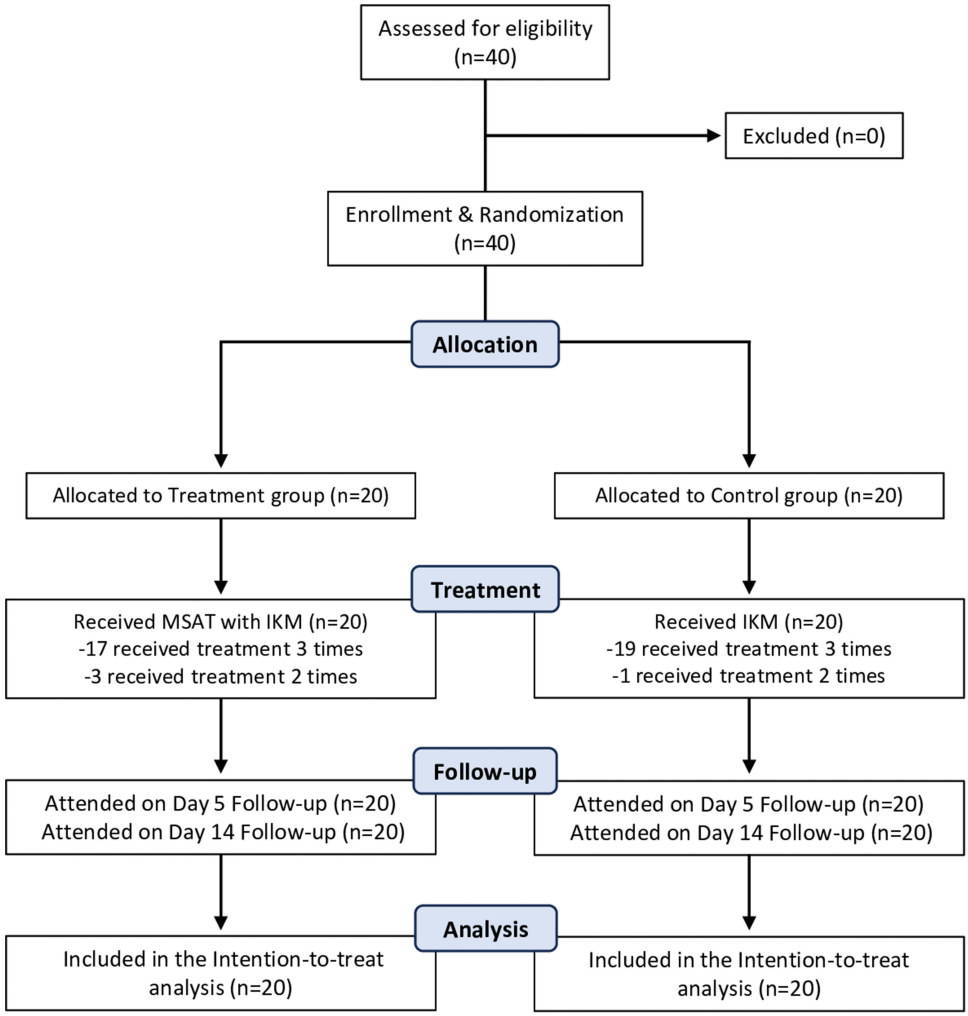

Figure 1 Flowchart of the participants.

observed in the ODI score ($p = 0.001$) and EQ-5D-5L index ($p = 0.002$). Furthermore, we used the last observation carried forward method to handle missing data, and the results are summarized in Supplementary Table 4. On Day 5, the two groups demonstrated significant differences in the NRS score of radiating leg pain, the NRS score of LBP, the EQ-VAS score, and the PGIC score ($p < 0.001$). However, no significant differences were observed in the ODI score ($p = 0.003$), EQ-5D-5L index ($p = 0.003$), or SLRT result ($p = 0.001$).

Additionally, the area under the curve analyses were used to compare the NRS score of radiating leg pain, the NRS score of LBP, the ODI score, the EQ-5D-5L index, and the EQ-VAS score between the MSAT and IKMT groups throughout the study period. All outcomes showed statistically significant differences (Table 3).

Survival Analysis

A Kaplan–Meier survival analysis was performed, with recovery defined as a ≥50% reduction in the NRS score of radiating leg pain compared with that at baseline (Figure 3). The Log rank test indicated a statistically significant difference between the two groups ($p < 0.001$). Additionally, the median survival duration was 3.5 and 13 days in the MSAT and IKMT groups, respectively. Cox proportional hazards regression analysis (Table 4) revealed that the recovery HR was significantly higher in the MSAT group (HR = 4.473, 95% CI: 1.658–12.067; $p = 0.005$). After adjusting for baseline NRS score of radiating leg pain, the effect of MSAT remained statistically significant (HR = 4.002, 95% CI 1.434–11.163, $p = 0.011$).

Table 1 Baseline Characteristics of Participants According to Treatment Group

Variable	Treatment (n=20)	Control (n=20)	Total (N=40)	p-value
Age (years)	39.80 ± 13.41	39.95 ± 12.86	39.88 ± 12.97	0.971
Sex				1
Male	10 (50.00%)	11 (55.00%)	21 (52.50%)	
Female	10 (50.00%)	9 (45.00%)	19 (47.50%)	
Height (cm)	166.55 ± 7.95	169.75 ± 9.87	168.15 ± 8.99	0.266
Weight (kg)	67.90 ± 11.91	70.65 ± 15.43	69.28 ± 13.68	0.532
BMI (kg/m^2)	24.33 ± 2.62	24.43 ± 4.21	24.38 ± 3.46	0.929
Alcohol consumption				0.506
None	10 (50.00%)	9 (45.00%)	19 (47.50%)	
Past	5 (25.00%)	3 (15.00%)	8 (20.00%)	
Now	5 (25.00%)	8 (40.00%)	13 (32.50%)	
Smoking				0.751
None	12 (60.00%)	10 (50.00%)	22 (55.00%)	
Past	–	–	–	
Now	8 (40.00%)	10 (50.00%)	18 (45.00%)	
Length of stay (days)				
Mean ± SD	7.85 ± 5.25	7.85 ± 4.94	7.85 ± 5.04	1
Median (Q_1,Q_3)	6.50 (4.50, 9.00)	6.50 (4.50, 8.00)	6.50 (4.50, 8.50)	0.989
Stage of disc herniation (n=16)				
Bulging	2 (40%)	3 (27.27%)	5 (31.25%)	
Protrusion	2 (40%)	5 (45.45%)	7 (43.75%)	
Extrusion	1 (20%)	1 (9.09%)	2 (12.50%)	
Sequestration or migration	0 (0%)	2 (18.18%)	2 (12.50%)	
Baseline				
NRS of radiating leg pain	6.15 ± 0.67	6.45 ± 0.69	6.30 ± 0.69	0.17
NRS of LBP	6.35 ± 0.59	6.45 ± 0.69	6.40 ± 0.63	0.623
ODI	44.88 ± 12.40	41.54 ± 12.65	43.21 ± 12.48	0.405
EQ-5D-5L	0.63 ± 0.15	0.63 ± 0.15	0.63 ± 0.15	0.863
EQ-VAS	36.31 ± 16.41	41.89 ± 18.48	39.10 ± 17.48	0.319
SLRT	64.75 ± 12.51	69.25 ± 10.79	67.00 ± 11.76	0.231
Pain during SLRT				0.301
<80	16 (80.00%)	12 (60.00%)	28 (70.00%)	
≥80	4 (20.00%)	8 (40.00%)	12 (30.00%)	

Abbreviations: BMI, body mass index; NRS, Numeric Rating Scale; LBP, low-back pain; ODI, Oswestry Disability Index; EQ-5D-5L, European Quality of Life-5 Dimensions-5-Level; VAS, Visual Analog Scale; SLRT, straight leg raise test.

Adverse Effects

During the study, one patient in the MSAT group reported a mild adverse event. The patient developed an acute upper respiratory infection on Day 6, after the intervention. The symptoms showed no evident association with the intervention and resolved after 3 days of medication.

Discussion

In this pragmatic clinical trial, we compared the therapeutic effects of IKMT alone and IKMT combined with MSAT in hospitalized patients who developed radiating leg pain within 3 days after a traffic accident. The group that received combined MSAT and IKMT demonstrated significantly greater improvements in early pain reduction, functional recovery, and quality of life than did the control (IKMT only) group. At the primary assessment time point (Day 5), MSAT showed the greatest and statistically significant reduction in NRS scores for radiating leg and low-back pain ($p < 0.001$). Similarly, significant between-group differences were observed on Days 3, 4, and 14 ($p < 0.001$). Kaplan–Meier

Table 2 Primary and Secondary Outcomes According to Treatment and Time Point Relative to Baseline

Outcome	Value	Baseline (Day 2)	Day 3	Day 4	Day 5	Day 14
NRS of radiating leg pain	Treatment	6.30 (6.09 to 6.51)	4.94 (4.42–5.45)	4.12 (3.57–4.67)	3.24 (2.72–3.75)	1.89 (1.37–2.40)
	Control		5.86 (5.35–6.38)	5.72 (5.19–6.24)	5.51 (5.00–6.03)	4.06 (3.55–4.58)
	Difference	–	0.93 (0.19–1.66)	1.60 (0.83–2.36)	2.28 (1.54–3.01)	2.18 (1.44–2.91)
	P-value	–	0.014*	<0.001***	<0.001***	<0.001***
NRS of low back pain	Treatment	6.40 (6.20 to 6.60)	5.34 (4.86–5.82)	4.61 (4.11–5.12)	3.79 (3.31–4.27)	2.44 (1.96–2.92)
	Control		6.11 (5.63–6.58)	5.92 (5.44–6.41)	5.61 (5.13–6.08)	4.21 (3.73–4.68)
	Difference	–	0.76 (0.09–1.44)	1.31 (0.61–2.01)	1.81 (1.14–2.49)	1.76 (1.09–2.44)
	P-value	–	0.027*	<0.001***	<0.001***	<0.001***
ODI	Treatment	43.21 (39.34 to 47.08)	36.27 (31.29–41.26)	30.48 (25.25–35.71)	23.86 (18.88–28.85)	16.33 (11.34–21.31)
	Control		39.58 (34.59–44.57)	37.58 (32.52–42.64)	35.09 (30.10–40.08)	28.20 (23.21–33.19)
	Difference	–	3.30 (−3.77–10.38)	7.10 (−0.21–14.40)	11.23 (4.15–18.30)	11.87 (4.80–18.95)
	P-value	–	0.355	0.057	0.002**	0.001**
EQ-5D-5L	Treatment	0.63 (0.58 to 0.67)	0.69 (0.65–0.73)	0.75 (0.70–0.79)	0.78 (0.74–0.83)	0.84 (0.79–0.88)
	Control		0.65 (0.61–0.70)	0.69 (0.65–0.74)	0.70 (0.65–0.74)	0.72 (0.68–0.76)
	Difference	–	−0.03 (−0.10–0.03)	−0.05 (−0.12–0.01)	−0.09 (−0.15 to −0.03)	−0.11 (−0.18 to −0.05)
	P-value	–	0.26	0.098	0.006**	<0.001***
EQ-VAS	Treatment	39.10 (33.68 to 44.52)	50.35 (45.24–55.46)	59.54 (54.12–64.96)	70.17 (65.07–75.28)	75.76 (70.65–80.87)
	Control		42.58 (37.46–47.69)	44.66 (39.46–49.86)	47.30 (42.19–52.42)	58.03 (52.91–63.14)
	Difference	–	−7.77 (−15.03 to −0.52)	−14.88 (−22.42 to −7.34)	−22.87 (−30.13 to −15.62)	−17.73 (−24.99 to −10.48)
	P-value	–	0.036*	<0.001***	<0.001***	<0.001***
PGIC	Treatment	–	–	–	1.90 (1.60–2.20)	1.90 (1.60–2.20)
	Control	–	–	–	3.10 (2.80–3.40)	2.90 (2.60–3.20)
	Difference	–	–	–	1.20 (0.77–1.63)	1.00 (0.57–1.43)
	P-value	–	–	–	<0.001***	<0.001***
SLRT	Treatment	67.00 (63.36–70.64)	69.30 (67.39–71.21)	71.87 (69.89–73.86)	75.88 (73.92–77.85)	–
	Control		68.31 (66.39–70.22)	68.83 (66.90–70.77)	69.56 (67.64–71.47)	–
	Difference	–	−0.99 (−3.72–1.73)	−3.04 (−5.84 to −0.24)	−6.32 (−9.09 to −3.56)	–
	P-value	–	0.467	0.034*	<0.001***	–

Notes: * change from baseline. *, p<0.05; **, p<0.01; ***, p<0.001

Abbreviations: NRS, Numeric Rating Scale; ODI, Oswestry Disability Index; EQ-5D-5L, European Quality of Life-5 Dimensions-5-Level; VAS, Visual Analog Scale; PGIC, patient global impression of change; SLRT, straight leg raise test.

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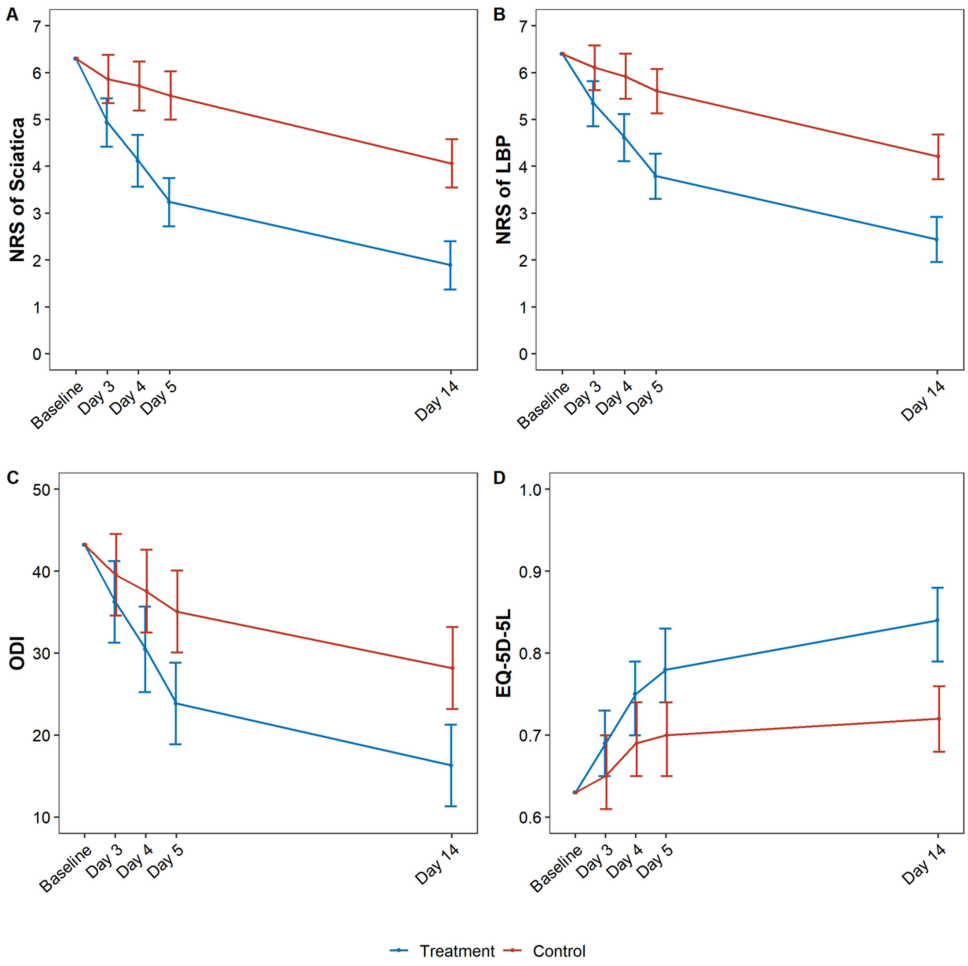

Figure 2 Changes in primary and secondary outcomes over time. (**A**) Numeric rating scale of sciatica, (**B**) Numeric rating scale of low back pain, (**C**) Oswestry disability index, (**D**) EuroQol-5 Dimension-5 Level.
Abbreviations: NRS, Numeric Rating Scale; LBP, low-back pain; ODI, Oswestry Disability Index; EQ-5D-5L, European Quality of Life-5 Dimensions-5-Level.

analysis revealed that the MSAT group achieved significantly faster recovery than the IKMT group, which was confirmed using the Cox proportional hazards regression analysis.

Our findings are consistent with those of previous studies, which revealed that MSAT provides faster pain relief than does IKMT alone or diclofenac injection in patients with acute low-back pain.[14–16,32] The rapid pain reduction effects of various MSAT techniques have been demonstrated for low-back pain following traffic accidents.[14,15,32] Consistent with the results of the present study, most previous reports showed that between-group differences gradually diminished at follow-up. In a randomized controlled trial for the effects of diclofenac and MSAT in patients with severe functional impairment, the MSAT group showed significantly greater improvement in pain and functional measures than did the

Table 3 Comparison of the Area Under the Curve for Outcomes During the Study Period

Outcome	Treatment	Control	Difference	p-value
NRS of radiating leg pain	36.69 (31.39–41.99)	60.75 (55.45–66.04)	−24.05 (−31.64 to −16.47)	<0.001
NRS of low back pain	43.18 (37.99–48.37)	62.18 (56.99–67.38)	−19.00 (−26.36 to −11.65)	<0.001
ODI	283.73 (231.53–335.93)	399.19 (347.00–451.38)	−115.46 (−189.61 to −41.30)	0.003
EQ-5D-5L	9.40 (9.01–9.78)	8.39 (8.00–8.77)	1.01 (0.46–1.56)	<0.001
EQ-VAS	817.03 (763.85–870.21)	606.82 (553.65–660.00)	210.21 (134.51–285.91)	<0.001

Abbreviations: NRS, Numeric Rating Scale; ODI, Oswestry Disability Index; EQ-5D-5L, European Quality of Life-5 Dimensions-5-Level; VAS, Visual Analog Scale.

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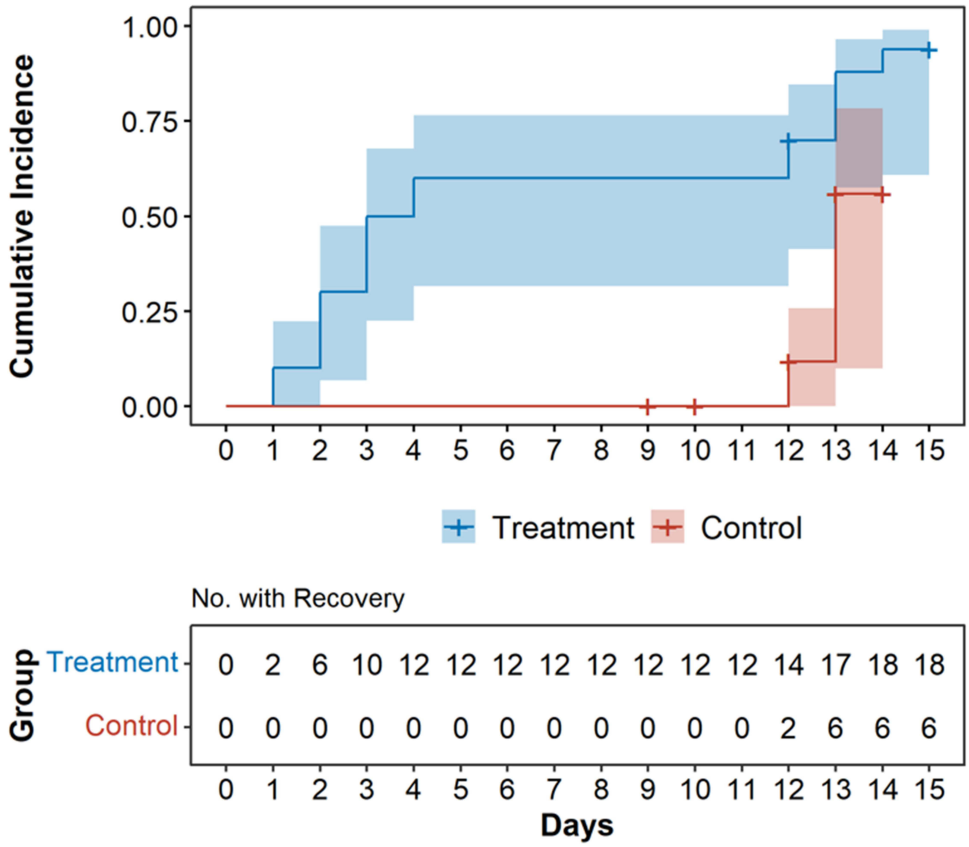

Figure 3 Cumulative incidence of recovery based on the NRS score of radiating leg pain.
Abbreviation: NRS, Numeric Rating Scale.

diclofenac group, and this difference remained significant up to the 4-week follow-up.[16] Prospective observational[18] and retrospective chart review[33] studies have reported the effectiveness of MSAT in patients hospitalized in Korean medicine hospitals for radiating leg pain caused by lumbar disc herniation. Although direct comparison is challenging because the study designs differ, both studies reported between-group NRS differences of approximately 1–2.5 points on hospitalization Day 7, comparable to the 2.28-point difference observed in the present study.

Our findings align with the growing emphasis on active interventions in rehabilitation. A recent Bayesian network meta-analysis indicated that active physiotherapy yields superior outcomes in pain and disability compared with

Table 4 Cox Regression Analysis for Time to 50% Reduction in the NRS Score of Radiating Leg Pain

	Crude Model		**Adjusted Model**	
	HR (95% CI)	**p-value**	**HR (95% CI)**	**p-value**
Group				
Control	Ref		Ref	
Treatment	4.473 (1.658–12.067)	0.005	4.002 (1.434–11.163)	0.011
Baseline				
NRS of radiating leg pain	-	-	0.679 (0.272–1.694)	0.388

Abbreviations: NRS, Numeric Rating Scale; CI, confidence interval; HR, hazard ratio.

predominantly passive approaches in low back pain.[34] MSAT, which functions as a hybrid of needling and active/passive movement, integrates these early active components even in acute post-traumatic settings. The rapid recovery observed in our study may, in part, reflect the advantages of incorporating active neurodynamic and motor-control elements over conventional passive care.

The minimal clinically important difference for NRS scores of low-back and radiating leg pain in lumbar disorders is approximately 1.5–2 points.[35,36] In this study, although the MSAT group showed significantly greater improvements in NRS scores for low-back and radiating leg pain than did the control group, the control group demonstrated improvements of >2 points on Day 14 of follow-up, exceeding the minimal clinically important difference threshold. Hence, the control group exhibited clinically meaningful improvements after IKMT. These findings suggest that although IKMT alone effectively improves post-traumatic low-back and radiating leg pain, adding early MSAT may enhance rapid pain relief. In addition, the findings from previous studies,[14,15,32] which indicated no significant differences between groups at follow-up, can be interpreted within the same context of meaningful improvement in the control group. A similar pattern may have emerged in this study, given its longer follow-up period.

A similar pattern was observed for changes in functional outcome measures. The improvement in ODI scores was statistically significant between the groups on Days 5 and 14. Consistent with our findings, previous studies have reported that combined MSAT treatment yielded significantly greater improvements in ODI than did IKMT alone or diclofenac injection treatment.[16,33] However, in contrast to our findings, some reports demonstrated no significant differences in ODI improvement between the MSAT and control groups.[15,32]

The quality-of-life measures, EQ-5D-5L index and EQ-VAS score, were significantly improved in the MSAT group compared with those in the control group on Days 5 and 14, with the EQ-VAS score showing a significant difference on Day 4. In contrast, several previous studies on patients with acute pain after traffic accidents did not report significant between-group differences in quality-of-life indices.[15,37] This discrepancy may be attributed to early intervention, as our study included patients with radiating leg pain within 3 days of a traffic accident. Patients with concurrent low-back and radiating leg pain experience greater pain intensity, functional disability, and a significantly lower quality of life than do those with low-back pain alone.[4] The average EQ-5D-5L index reported in typical Korean patients with low-back pain is approximately 0.83 ± 0.52; however, the mean score at admission among participants in this study was lower (0.63 ± 0.15).[38] Radiating leg pain appears within days to weeks after the onset of low-back pain, with earlier onset associated with greater pain burden and poorer quality of life.[39] Therefore, performing MSAT thrice consecutively during the acute phase may have induced early pain reduction, possibly contributing to the improvement in the EQ-5D-5L index. These findings are consistent with the significantly higher PGIC scores observed in the MSAT group on Days 5 and 14, reflecting greater subjective recovery and treatment satisfaction.

Lumbar disc herniation is the primary cause of radiating leg pain,[40] and MRI evaluation is recommended for patients who do not respond to conservative treatment.[2] However, there are a few cases where no structural cause was identified on lumbar spine MRI despite the presence of radiating leg pain.[41] Youn et al reported that lumbar disc herniation was confirmed using MRI in only 123 of 188 patients (65.4%) with radiating leg pain after a traffic accident.[42] Consistent with this, among the 16 patients who underwent MRI in this study, eight exhibited lumbar disc herniation of protrusion grade or greater, and the remaining eight showed only disc bulging. This suggests that the pathophysiology of acute radiating leg pain after a traffic accident is not radiologically homogeneous; however, the generalizability of our findings is limited, given the small size of the MRI subgroup in this study.

Furthermore, radiating leg pain occurs from peripheral nerve compression and irritation by muscles, such as in lumbar sprain or piriformis syndrome.[43] Vein compression by muscles causes nerve enema through a local blood flow effect (tourniquet effect), increasing mechanical sensitivity and amplifying pain.[44] In addition, when the sciatic nerve becomes hypersensitive owing to nerve root compression and inflammation associated with disc lesions, the passage of the nerve through the deep gluteal muscles may cause secondary entrapment, resulting in double crush syndrome.[45,46] Noh et al reported that pelvic MSAT may help break the vicious cycle of neuroinflammatory responses caused by lumbar disc herniation and tension pain resulting from muscle ischemia.[18] These findings suggest that the radiating leg pain observed in this study population was influenced by multiple mechanisms, such as radiculopathic mechanisms and musculoskeletal, soft tissue, and peripheral nerve entrapment factors, and that MSAT applied to the symptomatic region effectively

addressed these complex mechanisms. However, the causal mechanisms underlying these effects could not be conclusively determined because of the study design. Future studies should validate the efficacy of MSAT according to different etiological patterns of radiating leg pain through randomized controlled trials stratified according to MRI findings, peripheral nerve entrapment signs, and myofascial pain-related markers.

Although the therapeutic mechanism of MSAT remains unclear, the mechanistic evidence from previous studies can be summarized into two primary components, namely the physiological analgesic effect of acupuncture and the cognitive reconfiguration of pain perception. First, acupuncture stimulation produces a relatively mild nociceptive input that activates the central nervous system and induces analgesia by facilitating endorphin release through the diffuse noxious inhibitory control pathway.[47,48] Additionally, studies on sensory discrimination have revealed that the analgesic effect is enhanced when patients clearly recognize the needle insertion site compared with the stimulation provided during a simple relaxation state.[49] Strong acupuncture stimulation, such as MSAT, enhances the sensory awareness of the needle location while eliciting the "de-qi" sensation and promoting the release of cytokines, prostaglandins, and various neurotransmitters, amplifying the therapeutic effect of acupuncture.[50,51] Second, MSAT reduces avoidance behaviors associated with pain-related fear by allowing the combination of acupuncture stimulation with active or passive movements. In patients with severe pain, such as concurrent low-back and radiating leg pain, negative perceptions of pain are strengthened, triggering a fear-avoidance response where pain-provoking movements are avoided.[52,53] Such avoidance behaviors contribute to the chronicity of pain and functional disability.[54–56] MSAT corrects negative pain-related perceptions and reduces the fear of movement by safely and repeatedly mobilizing the pain-affected region during the treatment process.

The movements applied in MSAT are based on biomechanical principles similar to those of neural mobilization. Neural mobilization is categorized into two techniques: the slider method, which induces gliding movements relative to adjacent tissues, and the tensioner approach, which increases neural tissue tension; both techniques are used to alleviate neuropathic pain.[44] In patients with concurrent low-back and radiating leg pain, SLRT or slump test maneuvers are suitable neurodynamic treatments, and such approaches reportedly contribute to pain relief and functional improvement.[57,58] Therefore, MSAT may promote recovery from pain and functional impairment by reducing neural tissue tension and improving gliding in the surrounding soft tissues.

In this study, mild adverse events were reported in only one participant (assigned to the MSAT group) out of 40 participants. The patient developed an acute upper respiratory infection on Day 6 post-intervention, which resolved with medication. The causal relationship between adverse events and MSAT intervention was deemed low. Moreover, previous clinical studies related to MSAT have reported a significantly low incidence of adverse events, and the symptoms observed exhibited mild severity.[14,18,32] Therefore, our findings and those of previous studies indicate MSAT as a relatively safe therapeutic intervention.

This study has some limitations. First, owing to the nature of the MSAT intervention, the blinding of the patients and practitioners was infeasible, which introduced the risk of detection and performance bias. To mitigate this limitation and minimize potential bias, patient evaluations were conducted by medical personnel who were not involved in the intervention process and were blinded to the group allocation. Second, all participants received IKMT based on the clinician's judgment, with MSAT additionally administered only to the MSAT group. Therefore, the independent effects of MSAT alone could not be evaluated. However, in real-world clinical practice, clinicians usually administer combination therapy according to patient symptoms, and MSAT is frequently combined with other Korean medicine treatments. Thus, the pragmatic clinical trial design of this study accurately reflects real clinical practice. Third, the follow-up period was limited to 14 days, restricting the evaluation of the long-term therapeutic effects of MSAT. Previous findings suggest that the difference in treatment effects between the intervention and control groups gradually decreases after 14 days;[14,15,32] however, a further large-scale study with longer follow-up is required to confirm the long-term durability and its impact on chronicity. Finally, in this study, many patients did not undergo MRI owing to constraints such as patient circumstances and study-related costs. Consequently, the generalizability and precision of our findings might have been enhanced with a universal MRI assessment.

Despite these limitations, this study provides meaningful preliminary evidence as the first pragmatic clinical trial evaluating early MSAT for post-traffic accident radiating leg pain. While the results suggest significant clinical potential,

they remain exploratory and should be viewed as a foundation for future research. Subsequent large-scale, stratified randomized controlled trials with extended follow-up periods are necessary to confirm the durability of these effects and their impact on preventing chronicity.

Conclusion

This pilot pragmatic randomized controlled trial suggests that combined MSAT and IKMT has the potential to yield greater short-term improvements in pain, functional disability, quality of life, and patient satisfaction than IKMT alone in patients with acute post-traffic accident radiating leg pain. Our findings indicate that MSAT is a potentially safe and effective therapeutic option for acute post-traumatic radiating leg pain, providing a clinical basis for further large-scale, definitive trials.

Abbreviations

CIS, confidence interval; EQ-5D-5L, European Quality of Life-5 Dimensions-5-Level; HRs, hazard ratios; IKMT, integrative Korean medicine treatment; MRI, Magnetic Resonance Imaging; MSAT, motion-style acupuncture treatment; NRS of LBP, Numeric Rating Scale of low back pain; NRS, Numeric Rating Scale; ODI, Oswestry Disability Index; PGIC, Patient Global Impression of Change; SLRT, Straight Leg Raise Test.

Data Sharing Statement

The data presented in this study are available on request from the corresponding author (D.K, doori.k07@gmail.com). The data are not publicly available due to privacy/ethical restrictions.

Ethics Approval and Informed Consent

The study protocol was reviewed and approved by the Institutional Review Board of Jaseng Hospital of Korean Medicine (JASENG 2023-09-035-002) and registered at ClinicalTrials.gov (NCT06179901) before participant recruitment. All participants signed an informed consent form after receiving a comprehensive explanation of the study procedures and precautions from the investigator before enrollment.

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Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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