Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 32s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Comparison of the effectiveness and general synthesis of EMS, heat, and air massage combined with EMG single application

Jaewon Lee[1], Kyoung-Rok Roh[2], Jaeho Yu[2]*

[1,2,]Dept. of Physical Therapy, Sunmoon Univ, 70, Sunmoon-ro 221beon-gil Tangjeong-myeon Asan-si Chungcheongnam-do Republic of Korea, 31460
Email Id : naresa@sunmoon.ac.kr
Correspondence Author:
Jae-Ho Yu

.Cite this paper as: Jaewon Lee, Kyoung-Rok Roh, Jaeho Yu (2025) Comparison of the effectiveness and general synthesis of EMS, heat, and air massage combined with EMG single application. *Journal of Neonatal Surgery*, 14 (32s), 6111-6118.

1. INTRODUCTION

Due to the rapid transition to an aging society and the increase in digital work environments, **musculoskeletal disorders (MSDs)** are reported to be the occupational disease with the highest prevalence and socioeconomic burden worldwide (Punnett & Wegman, 2004; WHO, 2021). In particular, tendonitis of the upper limbs, tennis elbow (lateral epicondylitis), and golfer's elbow (medial epicondylitis) caused by repetitive VDT (Visual Display Terminal) work environments account for a significant portion of all musculoskeletal pain. If these conditions become chronic, they can lead to a decline in work performance and quality of life (Walker-Bone et al., 2003; van Tulder et al., 2007).

Traditionally, drug therapy, physical therapy, and local injection therapy are used to treat these upper limb musculoskeletal disorders, and symptoms are improved through repeated physical therapy(Coombes et al., 2015). However, due to the time and cost burdens associated with repeated visits and limited access to hospitals, many patients miss the appropriate treatment period or neglect their symptoms, leading to chronic conditions(Rohde et al., 2004; Walker-Bone et al., 2012).

As a result, there has been growing interest in personal wearable rehabilitation devices (EMS, heat therapy devices, massage devices, etc.) that can be easily used at home(Giggins et al., 2013; Hu et al., 2018). Low-frequency electrical muscle stimulation (EMS) is widely used as a physical therapy method to induce muscle contraction, strengthen weakened muscles, promote blood circulation, and relieve pain(Maffiuletti, 2010; Laufer & Elboim-Gabyzon, 2011). However, existing EMS devices are mainly limited to single stimulation functions, and there have been criticisms that they have limitations in terms of multifaceted management, such as tissue relaxation and pain relief(Petrofsky et al., 2013; Draper et al., 1995).

Accordingly, recent studies have focused on the potential of composite stimulation devices that combine EMS with functions such as heat and air pressure massage to improve blood flow and recover muscle fatigue simultaneously(Lee et al., 2014; Bove et al., 2020). The application of complex EMS is being proposed as an alternative that can increase practicality in the home care market by not only maintaining upper limb strength and increasing joint mobility, but also increasing patient satisfaction and compliance (Yu et al., 2022).

Based on this background, this study aims to evaluate the differences between composite EMS devices and single EMS devices in terms of muscle strength, joint range of motion (ROM), hand function performance, pain relief, and user satisfaction in the prevention and management of upper limb tendonitis. The results of this study will serve as basic data for the development of personalized home care wearable devices in the future

2. METHOD

2.1 Study Design

This study is a repeated cross-sectional study conducted at S University in south korea

2.2 Participants

The subjects of this study were five healthy men and women in their 20s, and the sample size was calculated using the GPOWER 3.1.9.7 program. The inclusion criteria for the subjects in this experiment were as follows: (a) those in good overall health, (b) those who had not experienced severe wrist or elbow pain within the past three months, and (c) those who did not have trauma such as arthritis or fractures.

The exclusion criteria were as follows: (a) those who had experienced wrist or elbow pain within the past month, (b) those with systemic diseases such as arthritis or gout, or a history of trauma such as a previous wrist fracture, (c) those with a history of elbow surgery, and (d) those with unstable wrists.

The study participants were given a thorough explanation of the purpose and methods of the experimental study, and the researcher informed them that any physical or personal information obtained during the study would not be disclosed for purposes other than the experiment. Subsequently, the participants voluntarily signed a written consent form and participated in the study. All participants had their height measured using an autonomic BMI measuring instrument (BSM 370, Korea) and their weight measured using a body composition analyzer (Inbody 6570, Biospace, Korea) prior to the experiment.

2.3 Sample Size Calculation

The sample size was calculated using computer software G-power version 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany) with the following settings: The test method was "repeated measurements within factors," the significance level was 0.5, the confidence level was 80%, and the effect size was 0.3. When using a single group, the minimum number of participants was four, and considering the possibility of dropouts, one more participant was added, resulting in a total of five participants in this study. [Figure 1] shows the research flowchart.

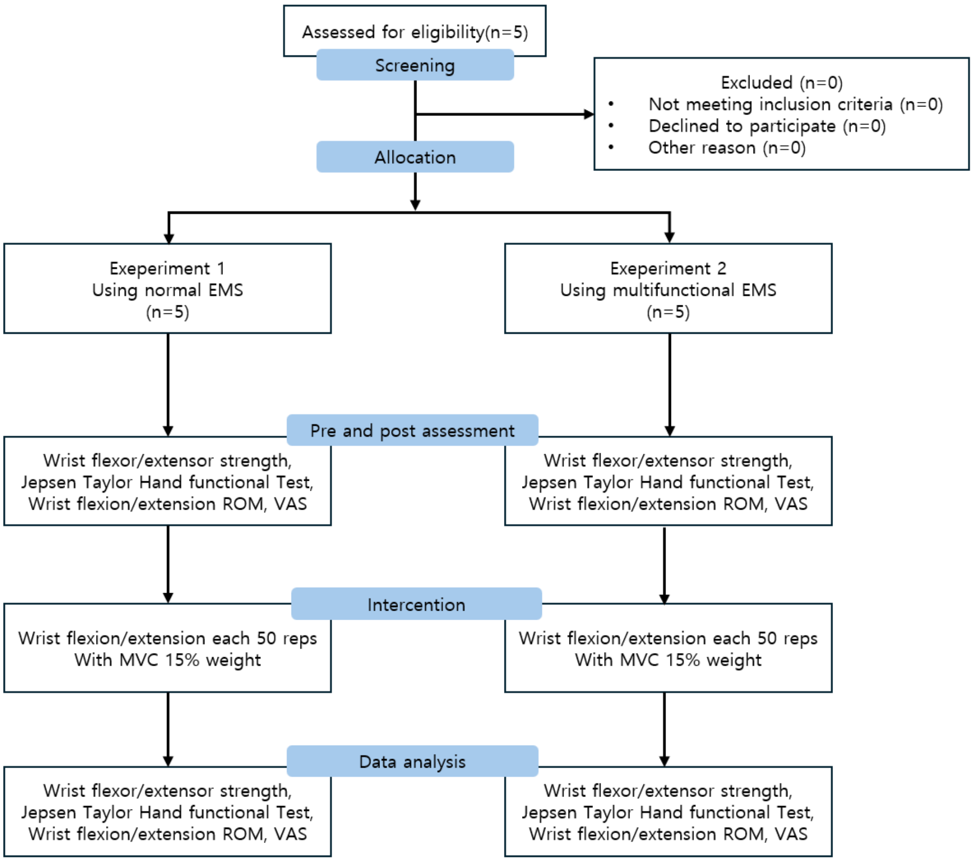


Figure 1. CONSORT flow chart

2.4 Experimental Procedure

The participants in this study had their height and weight measured once before the experiment, and all subjects underwent preliminary measurements first. The measurement items included wrist flexor/extensor strength, wrist flexion/extension ROM, and two items from the Jebsen Taylor Hand Functional Test: writing and small common object. Following this, to induce DOMS, wrist flexion and extension were performed 50 times each at 15% MVC intensity.

Then, in the first condition, the EMS device was applied once around the left elbow, and post-measurements were conducted using the same method (experiment 1).

Next, the same participants were subjected to a 20-minute application of a composite EMS device with added air massage and heat functions to the same area under the same conditions, followed by re-measurement of the same items (experiment 2).

Figure 2. Application of composite EMS device

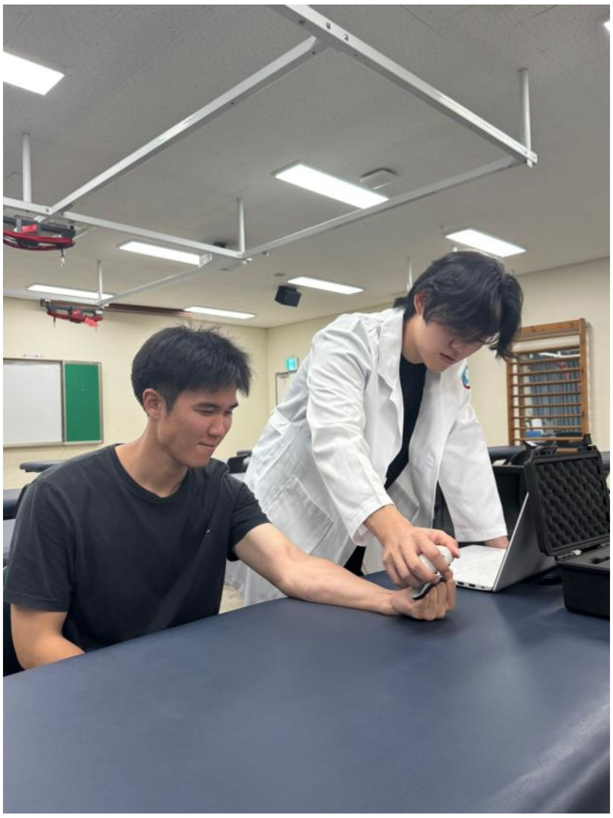


Figure 3. Muscle strength measurement (dynamometer)

2.4 Measurement equipment and methods

2.4.1 Wrist Strength Measurement

The strength of the flexor and extensor muscles of the left wrist was measured using a dynamometer. Before measurement, participants sat in a standardized position with their elbows bent at 90 degrees and fixed in place, and were instructed to apply maximum force using only their hands without moving their wrists. Each direction (flexion/extension) was measured twice, and the average value was used for analysis.

2.4.2 Wrist Joint Range of Motion Measurement

The range of motion of the wrist joint during flexion and extension movements was measured using a **goniometer**. Participants were instructed to sit in a comfortable position with their arms fixed and move only their wrists. The examiner aligned the reference point and axis to maximize the range of motion, and two measurements were taken in each direction, with the average value used.

2.4.3 Hand Function Test

Hand function was evaluated using the writing and small common objects items from the Jebsen-Taylor Hand Function Test (JTHFT).

Writing item: Participants were asked to write the given sentence on paper as quickly and accurately as possible.

Small common objects item: The movement of picking up small objects of various sizes with one hand and transferring them to another container was measured.

All items were measured in seconds to evaluate functional performance speed.

2.4.4 Application of Intervention Device

The intervention device used was an air massage-heat-combined EMS elbow management device (CELLION, Korea 2025).

General electrical stimulation device (EMS): A device with only basic electrical stimulation functions to induce muscle contraction was applied once around the elbow. The application time was approximately 20 minutes, and the intensity was set to a level where voluntary contraction was observed.

Combined electrical stimulation device: A combined device that included massage and heat functions in addition to electrical stimulation was applied to the same area under the same conditions (time/intensity).

Post-measurements were conducted immediately after stimulation for both interventions.

2.4.5 Visual Analogue Scale (VAS)

After each measurement, the subjective pain scale was administered by asking participants to rate their pain level on a scale from 0 (no pain) to 10 (extreme pain).

2.4.6 Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST)

To assess satisfaction with the devices, participants were asked to evaluate their experience with each device intervention, including usability, comfort, and effectiveness, on a 5-point scale. Other questions not related to satisfaction with the devices were excluded.

3. Results

3.1 General Characteristics

The general characteristics of the study participants are presented in Table 1. The mean age, height, weight, and body mass index were 24.60 ± 1.14 years, 167.94 ± 9.64 cm, 68.48 ± 14.64 kg, and 24.15 ± 4.84 kg/m², respectively. There were 2 male participants and 3 female participants, with all participants participating in both Experiment 1 and Experiment 2.

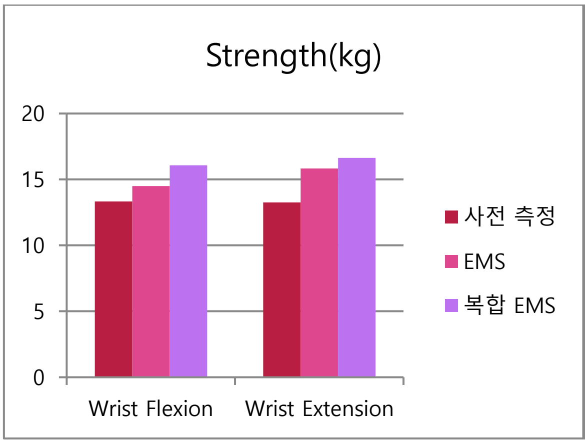
Table 1. General Characteristics of Participants

General Characteristics	mean	standard deviation	rande
Sex (male/female)	2/3	-	-
age	24.6	1.14	23~26
height(cm)	167.94	9.64	158~178
weight (kg)	68.48	14.64	53.1~82.4
BMI (kg/m^2)	24.15	4.83	19.58~31.75

When complex EMS was applied, there was a tendency for wrist strength to improve more than with general EMS. Left wrist flexion strength increased by approximately 11.8% more than with general EMS, and extension strength increased by approximately 6.0% more.

The results of joint range of motion measurements also showed that combined EMS had a more positive effect. The range of motion for wrist flexion improved by approximately 10.7% more than with general EMS, and the range of motion for wrist extension increased by approximately 1.4% more.

Table 4. Strength **Table 5. ROM**



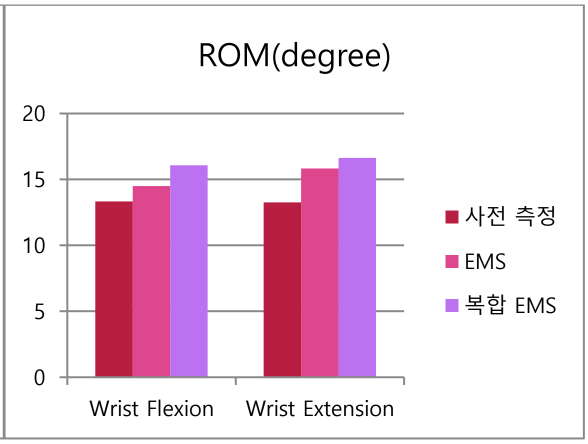
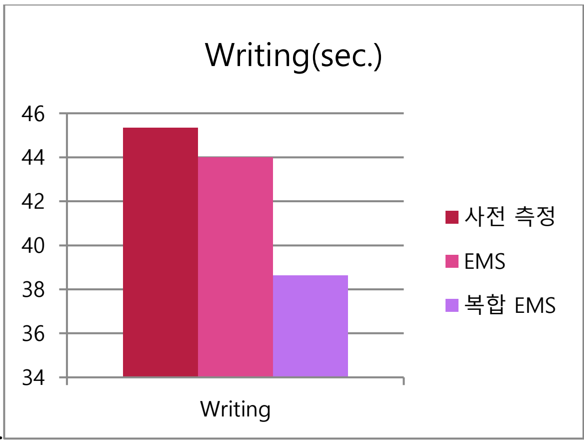


Table 2. strength and ROM

variable	EMS	Combined EMS	t	*P*
Wrist flexion Strength	14.5±3.99	16.08±3.77	-0.643	0.966
Wrist extension Strength	15.84±4.91	16.64±5.29	-0.298	0.782
Wrist flexion ROM	59.00±10.84	65.00±9.34	-0.937	0.454
Wrist extension ROM	73.00±5.70	74.00±4.18	-0.316	0.478

In the hand function test, the writing item of the Jebsen-Taylor hand functional test showed that the performance time of the left hand decreased by approximately 17.5% when complex EMS was applied, demonstrating faster performance than general EMS. In addition, in the small object transfer item, the time required for the left hand decreased by approximately 7.4% when complex EMS was applied.

Table 6. Writing **Table 7. small common object**



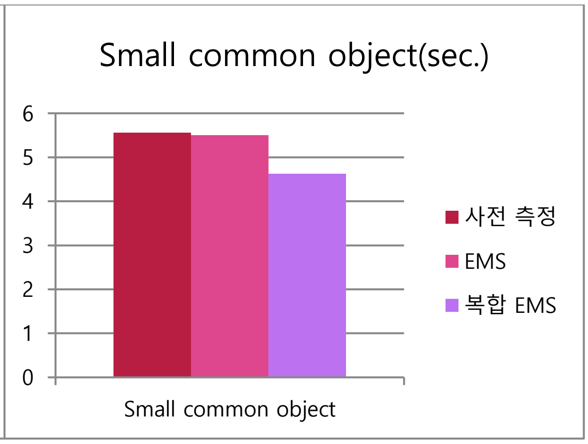


Table 3. Jebsen Taylor Hand Functional Test

Variable	EMS	Combined EMS	t	*P*

Writing	44.00±7.48	38.63±8.08	1.092	0.307
Small common object	5.03±0.76	4.63±0.53	0.988	0.352

These results suggest that complex EMS may be more effective than general EMS in improving wrist strength, flexibility, and functional task performance.

In terms of pain scale, the application of complex EMS reduced pain levels by approximately 29% compared to general EMS, and satisfaction increased by 14.2% in terms of usability, 5% in terms of effectiveness, and 6% on average.

Table 4. Analysis of pain, usability, comfort, and effectiveness

Variable	EMS	Combined EMS	t	*P*
VAS	1±1.0	0.6±0.89	0.667	0.524
QUEST usability	4.2±0.447	4.8±0.447	-2.121	0.67
QUEST comfort	4.0±0.70	4.0±0.70	0.000	1.0
QUEST effectiveness	4.0±0.70	4.2±0.83	-0.408	0.694
QUEST average	4.06±0.28	4.26±0.43	-0.866	0.412

These results suggest that complex EMS may be more effective than general EMS in improving wrist strength, flexibility, and functional task performance.

IV. Discussion

This study compared the effectiveness of a **combined EMS device with added heat and air massage functions**, developed to improve the efficiency of prevention and management of upper limb musculoskeletal disorders, with that of a conventional single EMS device. The primary outcomes included wrist flexion and extension strength, joint range of motion (ROM), hand functional performance (Jebsen-Taylor Hand Functional Test), subjective pain scale (VAS), and user satisfaction (QUEST).

The results showed that the combined EMS device demonstrated positive differences in improving wrist strength and ROM compared to the conventional EMS device. Specifically, flexor strength improved by 11.8%, and extensor strength improved by 6.0%. Additionally, flexion ROM increased by 10.7%, and extension ROM increased by 1.4%. This aligns with previous studies reporting that the combined application of electrical stimulation, heat, and mechanical massage increases muscle blood flow and promotes muscle fatigue recovery more effectively than single modalities (Lee et al., 2014; Petrofsky et al., 2013).

Heat stimulation can contribute to reducing inflammatory responses by promoting oxygen supply within tissues and facilitating the removal of metabolic waste products (Draper et al., 1995). Additionally, the pressure stimulation from air pressure massage promotes lymphatic circulation, reducing swelling and inducing muscle relaxation and a relaxation response (Choi & Park, 2016). This may also be related to the fact that the VAS scores in the combined EMS group were approximately 29% lower than those in the general EMS group in this study.

The Jebsen-Taylor Hand Functional Test results showed that complex EMS reduced writing performance time by 17.5% and small object transfer performance time by 7.4%. This suggests that complex EMS may be more effective than simple electrical stimulation in improving neuromuscular control and muscle endurance (Magnusson et al., 2007; Laufer & Elboim-Gabyzon, 2011). This suggests the clinical utility of combined stimulation technology in upper limb rehabilitation programs for the recovery of activities of daily living (ADL) (Portney & Watkins, 2015).

Among the user satisfaction (QUEST) items, the usability and effectiveness scores also increased by 14.2% and 5%, respectively, for the combined EMS. These are important factors in determining user compliance and the possibility of continuous use in wearable devices (Giggins et al., 2013). This study experimentally confirmed that multifunctional devices can provide a higher user experience (UX) than single EMS devices.

However, this study has several limitations. First, the study sample was limited to a small number of healthy individuals in their 20s (5 participants), making it difficult to generalize the results to actual patients with upper limb tendinitis or chronic musculoskeletal conditions. Second, the analysis focused solely on short-term effects from single application, without evaluating cumulative effects from repeated applications (2–3 times per week) or the duration of functional maintenance. Third, subjective pain scales (VAS) and satisfaction are self-report measures with significant individual variability, so they should be considered alongside bio-signal-based pain indicators or long-term tracking data (Kumar et al., 2016).

In subsequent studies, the therapeutic efficacy of complex EMS should be verified through long-term randomized controlled trials (RCTs) targeting patients with chronic tennis elbow and golfer's elbow. Additionally, combining ultrasound imaging, electromyography (EMG) signal analysis, and other methods will help elucidate more objective physiological mechanisms, and real-world studies including cost-effectiveness evaluations will be necessary (Schuermans et al., 2017).

The wearable rehabilitation device market is currently evolving toward providing user-specific customized stimulation patterns by combining IoT and AI-based smart modules (Yu et al., 2022). Therefore, it is necessary to expand composite EMS devices into smart healthcare solutions, such as user feedback-based automatic adjustment of stimulation intensity and device usage history monitoring based on big data.

V. Conclusion

This study suggests that composite EMS devices have greater potential than conventional single EMS devices in terms of improving muscle strength and ROM, improving hand function, reducing pain, and increasing user satisfaction. This can be used as experimental evidence to support the need for the development of composite stimulation-based wearable devices in the areas of upper limb musculoskeletal disorder prevention and home-based care

REFERENCES

[1] Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J Electromyogr Kinesiol. 2004;14(1):13–23.

[2] WHO. Musculoskeletal conditions. World Health Organization. 2021. https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions

[3] Walker-Bone K, Palmer KT, Reading I, et al. Prevalence and impact of musculoskeletal disorders of the upper limb in the general population. Arthritis Rheum. 2003;48(4):1027–1033.

[4] van Tulder M, Malmivaara A, Koes B. Repetitive strain injury. Lancet. 2007;369(9575):1815–1822.

[5] Coombes BK, Bisset L, Vicenzino B. Management of lateral elbow tendinopathy: one size does not fit all. J Orthop Sports Phys Ther. 2015;45(11):938–949.

[6] Rohde RS, Wolfe SW. Tennis elbow. Curr Opin Rheumatol. 2004;16(2):138–143.

[7] Walker-Bone K, Palmer KT. Musculoskeletal disorders in manual workers: occupational burden and the role of primary care. Br J Gen Pract. 2012;62(605):e434–e436.

[8] Giggins OM, Persson UM, Caulfield B. Biofeedback in rehabilitation. J Neuroeng Rehabil. 2013;10:60.

[9] Hu G, Pang Z, Xu Y. A Wearable Rehabilitation System for Wrist Joint: Design and Pilot Study. IEEE Access. 2018;6:44691–44702.

[10] Maffiuletti NA. Physiological and methodological considerations for the use of neuromuscular electrical stimulation. Eur J Appl Physiol. 2010;110(2):223–234.

[11] Laufer Y, Elboim-Gabyzon M. Does low-frequency electrical stimulation improve motor recovery after stroke? Neurorehabil Neural Repair. 2011;25(4):339–347.

[12] Petrofsky JS, Laymon M, Alshammari F. Heat, Cold, and Stretching: The Effect on Muscle Strength and Length. J Appl Res. 2013;13(1):1–9.

[13] Draper DO, Ricard MD, Reynolds J, et al. Infrared heat and stretching in the treatment of muscle tightness. Med Sci Sports Exerc. 1995;27(10):1315–1319.

[14] Lee JH, Choi JH, Kang YJ. Effects of heat and massage on muscle fatigue recovery. J Phys Ther Sci. 2014;26(5):681–683.

[15] Bove M, Carvalhais VO, Baroni BM, et al. Effects of different frequencies of neuromuscular electrical stimulation on muscle strength and fatigue. Phys Ther Sport. 2020;44:26–33

[16] Yu JH, Park K, Lee S. Smart wearable devices in rehabilitation: Current status and future prospects. Sensors. 2022;22(4):1274.

[17] Knight KL, Draper DO. *Therapeutic Modalities: The Art and Science.* Lippincott Williams & Wilkins, 2001.

[18] Petrofsky JS, Laymon M, Alshammari F. Heat, Cold, and Stretching: The Effect on Muscle Strength and Length. *J Appl Res*. 2013;13(1):1–9.

[19] Draper DO, Ricard MD, Reynolds J, et al. Infrared heat and stretching in the treatment of muscle tightness. *Med Sci Sports Exerc.* 1995;27(10):1315–1319.

[20] Lee JH, Choi JH, Kang YJ. Effects of heat and massage on muscle fatigue recovery. *J Phys Ther Sci.* 2014;26(5):681–683.

[21] Choi Y, Park S. Effect of pneumatic compression on muscle soreness and blood flow. *J Sports Sci Med.* 2016;15(1):12–18.

[22] Laufer Y, Elboim-Gabyzon M. Does low-frequency electrical stimulation improve motor recovery after stroke? *Neurorehabil Neural Repair.* 2011;25(4):339–347.

[23] Magnusson SP, Aagaard P, Larsson B, et al. Passive energy absorption by human muscle–tendon unit during stretch. *Scand J Med Sci Sports.* 2007;17(1):2–9.

[24] Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. 3rd ed. F.A. Davis, 2015.

[25] Hu G, Pang Z, Xu Y. A Wearable Rehabilitation System for Wrist Joint: Design and Pilot Study. *IEEE Access.* 2018;6:44691–44702.

[26] Kumar S, Rathi R, Arya S. Subjective and objective assessment of pain. *Indian J Pain.* 2016;30(1):19–25.

[27] Schuermans J, Van Tiggelen D, Danneels L, Witvrouw E. Biceps femoris injury risk is associated with eccentric strength and flexibility. *Br J Sports Med.* 2017;51(4):310–315.

[28] Giggins OM, Persson UM, Caulfield B. Biofeedback in rehabilitation. *J Neuroeng Rehabil.* 2013;10:60.

[29] Bove M, Carvalhais VO, Baroni BM, et al. Effects of different frequencies of neuromuscular electrical stimulation on muscle strength and fatigue. *Phys Ther Sport.* 2020;44:26–33.

[30] Balthazard P, de Oliveira LF, Rahal A. Efficacy of combined therapies for tendinopathies: A systematic review. *Phys Ther Rev.* 2020;25(2):125–138