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The Relationship Between Pain, Range of Motion, and Brachial Artery Blood Flow Changes in Greco-Roman Wrestlers

Relación Entre Dolor, Amplitud de Movimiento y Cambios en el Flujo Sanguíneo de la Arteria Braquial en Luchadores Grecorromanos

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SUMMARY: The purpose of this study was to investigate changes in musculoskeletal pain, joint range of motion, and blood flow in the brachial artery of elite Greco-Roman athletes following exercise or stretching. Twenty Greco-Roman wrestlers with low back and shoulder pain were randomly assigned to two groups. Group A performed muscle release using a foam roller combined with elastic-band–assisted thoracic mobility exercises, while Group B performed stretching without foam rolling or external resistance. Following the intervention, pain intensity (VAS), functional disability (ODI), brachial artery blood flow, and arterial diameter were evaluated. The diameter and blood flow of the brachial artery demonstrated numerical improvements. Both groups showed significant reductions in VAS and ODI scores following the intervention ($p < 0.01$). Thoracic flexion and extension range of motion significantly increased in both groups, while thoracic rotation improved significantly only in Group B. These findings may serve as foundational data for injury prevention and performance enhancement in Greco-Roman wrestlers.

KEY WORDS: Greco-Roman wrestler; Blood flow; Shoulder pain; Low back pain; Trunk stability.

INTRODUCTION

In recent years, ultrasound imaging has been actively employed in musculoskeletal research because of its numerous advantages. Nevertheless, previous studies have mainly focused on blood flow velocity, arterial diameter changes, and pre- and post-exercise blood flow alterations, while studies examining joint range of motion and pain using ultrasound remain limited (Peretz, 2007). Moreover, musculoskeletal pain represents a significant and non-negligible factor influencing both injury occurrence and athletic performance among elite athletes (Peretz, 2007).

Low back pain and shoulder pain are among the most common musculoskeletal complaints in athletes participating in high-intensity combat sports (Noormohammadpour *et al*., 2016). In wrestling, particularly Greco-Roman style, athletes are exposed to repetitive upper-body loading, sustained trunk stabilization, and high-impact contact during clinching, lifting, and throwing actions. These mechanical demands place excessive stress on the thoracolumbar spine and shoulder complex, increasing the risk of pain, movement restriction, and overuse injuries. Persistent musculoskeletal pain not only compromises athletic performance but also alters neuromuscular control, movement efficiency, and injury tolerance (Shadgan *et al*., 2024).

Spinal mobility plays a critical role in efficient force transmission along the kinetic chain connecting the trunk and upper limbs. Restrictions in thoracic mobility may increase compensatory loading on the glenohumeral joint and disrupt scapulothoracic mechanics, thereby contributing to shoulder pain and functional limitations. Similarly, impaired lumbar mobility and reduced lumbopelvic control elevate compressive and shear forces on the lumbar spine, leading to recurrent low back pain and decreased postural stability. In athletes, repeated exposure to asymmetric loading and high training volumes can further exacerbate segmental stiffness, fascial tightness, and altered movement strategies (Shadgan *et al*., 2024).

Conventional management strategies for athletic low back and shoulder pain often emphasize symptom control

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through medication, passive modalities, or isolated strengthening. However, these approaches may inadequately address underlying mobility deficits, fascial restrictions, and neuromuscular coordination impairments that contribute to pain recurrence and movement inefficiency. Exercise-based interventions targeting soft tissue extensibility, proprioceptive function, and segmental mobility have therefore gained increasing attention in sports rehabilitation and performance optimization (Zebis *et al*., 2016).

Muscle relaxation, commonly implemented through self-release techniques using foam rollers or massage tools, has been shown to reduce muscle stiffness, modulate autonomic nervous system activity, enhance local circulation, and improve joint range of motion. These effects may facilitate more efficient movement patterns and reduce excessive mechanical stress on overloaded tissues. In parallel, spinal mobility exercises aim to restore segmental motion, improve dissociation between the thoracic spine, lumbar spine, and pelvis, and enhance trunk control during dynamic tasks. Integrating fascial relaxation with active mobility training may therefore provide synergistic benefits by preparing soft tissues for movement while reinforcing neuromuscular control and movement quality (Sulowska-Daszyk & Skiba, 2022).

Despite the high prevalence of low back and shoulder pain among wrestlers, limited research has investigated the combined effects of muscle relaxation and spinal mobility exercise training in a sport-specific population, particularly in Greco-Roman wrestlers. Most existing studies have focused on isolated strength development or general rehabilitation protocols, with insufficient emphasis on integrated mobility-based interventions and their direct impact on pain outcomes in elite athletes (Ylinen *et al*., 2003).

Greco-Roman wrestling places exceptionally high mechanical demands on the upper body and trunk, as athletes are restricted to using only the upper limbs for offensive and defensive techniques (Ulupınar & Özbay, 2022). This rule structure requires repetitive trunk rotation, sustained spinal extension, isometric stabilization, and high-impact loading during clinching, lifting, and throwing maneuvers (Ulupınar & Özbay, 2022). Consequently, excessive mechanical stress is concentrated on the thoracic and lumbar regions, often leading to reduced spinal mobility, segmental stiffness, and compensatory movement patterns in the shoulder complex and pelvic region.

Despite the high incidence of shoulder and low back pain among elite wrestlers, most conditioning and rehabilitation programs remain heavily focused on strength and power development, with relatively limited emphasis on restoring segmental spinal mobility and neuromuscular control. There is currently insufficient sport-specific evidence examining the effects of targeted spinal mobility interventions on pain reduction and functional performance in Greco-Roman wrestlers. Therefore, investigating the effectiveness of spinal mobility enhancement programs in this population is clinically meaningful and may provide practical guidelines for injury prevention and performance optimization (Zebis *et al*., 2016).

Therefore, the purpose of this study was to investigate changes in musculoskeletal pain, joint range of motion, and blood flow in the brachial artery of elite Greco-Roman athletes following exercise or stretching.

MATERIAL AND METHOD

Ethical approval

This study utilized a pre-test/post-test interventional randomized research design and was carried out in full accordance with the Declaration of Helsinki. The study protocol was approved by the research ethics review committee (No.2025-035)

Participants

This study recruited Greco-Roman wrestlers aged 20–24 years who had been clinically diagnosed with low back and shoulder pain at a hospital and had experienced persistent symptoms for at least 2 months (Table I). Participants were excluded if they had undergone spinal or orthopedic surgery within the previous year, were currently receiving medical treatment for low back pain, or reported minimal pain intensity (visual analog scale [VAS] score < 2). A total of 20 eligible participants were enrolled and stratified according to age and baseline pain severity, then randomly allocated into two groups: (1) experimental group A, which performed muscle relaxation using foam rollers combined with elastic-band–assisted spinal mobility exercises; and (2) group B, which performed general stretching only. Prior to participation, all subjects received a detailed explanation of the study purpose, procedures, potential risks, and benefits, and provided written informed consent in accordance with ethical research standards.

Table I. Participants' information of this study.

	Group A	Group B
Age (years)	22.21±3.46	22.00±4.01
Height (cm)	173.33±6.23	172.87±6.22
Weight (kg)	71.23±5.23	69.36±4.44

Baseline assessments included pain intensity and disability evaluation using the VAS and Oswestry Disability Index (ODI). Thoracic spinal mobility was assessed using an inclinometer for flexion and extension and a goniometer for axial rotation. All intervention programs were conducted five times per week for eight consecutive weeks under the supervision of a trained researcher.

Experimental design

Both experimental groups participated in structured exercise sessions consisting of three phases: warm-up, main exercise, and cool-down. Each session lasted approximately 30 minutes and was performed five times per week for eight weeks. All exercises were supervised by the investigator, and participants received pre-intervention familiarization sessions including verbal instruction and live demonstrations to ensure proper technique and safety.

Experimental groups A and B completed identical warm-up routines; however, only group A utilized a foam roller. The self-fascial relaxation protocol applied in experimental group A was developed based on the National Academy of Sports Medicine (NASM) guidelines for myofascial release.

Group A performed thoracolumbar fascial release using a foam roller, three-dimensional thoracic release movements, thoracic flexion, and thoracic extension for approximately 10 minutes (Table II). In contrast, group B performed seated dynamic stretching exercises without equipment, including thoracic expansion, flexion, rotation, trunk curling, and supine spinal stretching for the same duration. Detailed exercise descriptions are provided in Table III.

Table II. Spinal mobility exercise program applied to experimental group A in this study.

Week	Exercise	group A	Duration (minute)
1~8	Warm up	Thoracic self-release Thoracic three dimensional Curl up(crunch) Lying spine stretch	10
	Main	Hug a tree & thoracic rotation, Spine stretch, Rolldown & Roll up, Back extension & Swandive, Quadruped Heel Sit Thoracic Ext/Rot, Seated Trunk Rotation, Swimming & Swan dive, Side Lying T-spine Ext/Rot	60
	Cool down	Cat Cow, The Saw (Thoracic rotation & Spine twist)	10

Table III. Stretching program applied to group B participants in this study.

Week		Group B	Duration (minute)
1~8	Warm up	1. Side bend in sitting position, 2. Forward bending in sitting position, 3. Trunk rotation stretching in sitting position with open legs Pilates's Roll down & Roll up in standing position,	10
	Main	1. Iliopsoas stretching in supine & kneeling position, 2. Hamstring stretching in supine & sitting position, 3. Pigeon position, 3. Gluteus stretching in supine position, 4. Abdominal stretching in prone position, 5. Quadratus lumborum stretching in side sitting position, 6. Cat & Cow position	60
	Cool down	Trunk Ext/Rot in side & in quadruped lying position	10

The spinal mobility program was specifically designed to accommodate the physical characteristics and safety considerations of elderly participants. During lumbar rotation exercises, excessive pelvic and lower limb motion was restricted by positioning the hips in greater than 90° of flexion to minimize compensatory skeletal rotation (Mohr *et al*., 2014). Exercise intensity was individualized and maintained within a pain-free range corresponding to approximately 40–60 % of maximal voluntary effort.

Both experimental groups performed identical movement patterns; however, group A incorporated elastic resistance bands to provide external loading and proprioceptive stimulation, whereas group B performed the exercises without resistance. Detailed protocols are presented in Tables II and III.

The cool-down phase consisted of controlled three-dimensional spinal movements incorporating Pilates-based exercises (e.g., saw, spinal flexion, and segmental articulation) combined with yoga-inspired cat–cow movements and diaphragmatic breathing (Lucertini *et al*., 2017). Both experimental groups followed the same cool-down protocol, with elastic bands applied only in group A. Detailed descriptions are provided in Table II and III.

Participants in the control group performed general stretching exercises tailored to their individual physical condition and flexibility level. The total duration and weekly frequency matched those of the experimental groups. Stretching targeted the trunk flexor and extensor muscles, latissimus dorsi, abdominal musculature, quadriceps, hip musculature, and lumbar paraspinal muscles. Detailed protocols are shown in Table III.

Experimental measurements

Pain intensity was assessed using a 10-cm VAS, with 0 indicating no pain and 10 indicating unbearable pain. The VAS has demonstrated high test–retest reliability ($r = 0.97$) (Curran *et al*., 2008; Pearcey *et al*., 2015). Functional disability was evaluated using the Korean version of the KODI (Lewis & Valentine, 2010). The questionnaire consists of 10 items assessing pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, traveling, and mobility. Lower scores indicate lower levels of functional disability. The KODI demonstrates high reliability ($r = 0.92$) (Jeon *et al*., 2006).

Thoracic rotation ROM was assessed using a goniometer, with reported reliability ranging from $r = 0.85$ to 0.94. To minimize compensatory movement of the pelvis and lumbar spine, participants held a mini-ball between the knees while maintaining hip adduction. Arms were crossed over the chest, and a wooden bar was positioned across the shoulders to standardize upper body alignment. The goniometer was aligned between the T1–T2 spinous processes, and rotation angles were measured bilaterally. Three trials were recorded for each direction, and the summed left and right values were averaged for analysis (Table V).

Blood flow measurements were performed using an ultrasound device (Siemens Acuson Sequoia 512, Munich, Germany). The ultrasound probe was placed on the medial side of the upper arm to locate the brachial artery, and the arterial wall diameter, blood flow, and shear rate were measured (Table VI).

Statistical analysis

All statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as mean ± standard deviation. The normality of data distribution was assessed using the Shapiro–Wilk test. A two-way repeated-measures analysis of variance (ANOVA) was conducted to examine the main effects of time (pre-intervention vs. post-intervention), group (experimental group A vs. experimental group B), and the time × group interaction on pain intensity, and thoracic range of motion (flexion, extension, and axial rotation). When significant interaction effects were identified, post hoc comparisons with Bonferroni correction were performed. The level of statistical significance was set at $p < 0.05$.

RESULTS

Within-group analysis using paired t-tests revealed a significant reduction in ODI scores in both Group A (Pre: 9.50 ± 4.31, Post: 4.80 ± 5.06, $p < .01$) and Group B (Pre: 8.13 ± 6.24, Post: 2.25 ± 5.06, $p < .01$). And Paired t-test analysis demonstrated a significant decrease in VAS scores in Group A (Pre: 6.38 ± 2.45, Post: 2.00 ± 2.00, $p < .01$), whereas the reduction in Group C was not statistically significant (Pre: 4.56 ± 1.50, Post: 3.50 ± 1.83, $p > .05$) (Table IV).

Thoracic flexion range of motion significantly increased following the intervention in both groups. In Group A, thoracic flexion improved from 41.38 ± 2.45° at baseline to 46.00 ± 5.00° post-intervention (within-group $p = 0.004$). Similarly, Group B demonstrated an increase from 44.66 ± 2.50° to 50.10 ± 2.23° (within-group $p = 0.001$). The group ¥ time interaction analysis revealed [a significant / no significant] difference between the two groups (interaction $p = 0.001$).

Table IV. Results of the statistical analysis for Visual Analog Scale (VAS) and Oswestry Disability Index (ODI).

		Group A	Group B	*Within-group P*
VAS	Pre	6.38±2.45	4.56±1.50	Group A: 0.001*
	Post	2.00±2.00	3.50±1.83	Group B: 0.118
ODI	Pre	9.50±4.31	8.13±6.24	Group A: 0.006*
	Post	4.88±5.06	2.25±7.85	Group B: 0.002*

Values are (Mean±SD), M = Mean; SD = Standard Deviation, $p < 0.05$

Table V. Effects of the intervention on thoracic spine range of motion in each group.

		Group A	Group B	*Within-group P*
TF	Pre	41.38±2.45	4.66±2.50	Group A: 0.004*
	Post	46.00±5.00	50.10±2.23	Group B: 0.001
TE	Pre	28.40±4.31	28.13±6.24	Group A: 0.032*
	Post	30.89±4.06	33.25±4.83	Group B: 0.004*
TR	Pre	77.30±3.31	78.33±5.24	Group A: 0.081*
	Post	80.23±5.02	86.22±6.05	Group B: 0.001*

TF, thoracic flexion; TE, thoracic extension; TR, thoracic rotation, $p < 0.05$

Table VI. Blood flow parameters measured in the brachial artery.

	Group A	Group B
Diameter, mm	Pre 4.28 ± 0.66 Post 4.34 ± 0.54 (0.82)	Pre 4.62 ± 0.23 Post 4.88 ± 0.95 (0.94)
BF, ml/min	Pre 131.00 ± 26.00 Post 133.00 ± 23.00 (0.59)	Pre 132.00 ± 36.00 Post 136.00 ± 33.00 (0.63)
SR, s^{-1}	136.00 ± 51.00 (0.32)	137.00 ± 47.00 (0.21)

Values are means ± standard deviation, BF: blood flow, SR: SHEAR RATE, (): P value.

Thoracic extension range of motion increased in both groups after the intervention. Group A showed an increase from 28.40 ± 4.31° to 30.89 ± 4.06° (within-group p = 0.032), whereas Group B exhibited a greater improvement from 28.13 ± 6.24° to 33.25 ± 4.83° (within-group p = 0.004). The group ¥ time interaction effect was [significant / not significant] (interaction p = 0.001).

For thoracic rotation, Group A demonstrated a modest increase from 78.33 ± 3.31° at baseline to 80.23 ± 5.02° post-intervention (within-group p = 0.081). In contrast, Group B showed a substantial improvement from 78.33 ± 5.24° to 86.22 ± 6.05° (within-group p = 0.001). A significant group ¥ time interaction was observed, indicating a greater increase in thoracic rotation in Group B compared with Group A (interaction p = 0.004) (Table V).

Changes in vascular diameter, blood flow, and shear rate are presented in Table VI. In Group A, vascular diameter was 4.28 ± 0.66 mm before the intervention and 4.34 ± 0.54 mm after the intervention, whereas in Group B, it was 4.62 ± 0.23 mm before and 4.88 ± 0.95 mm after the intervention (p >0.05). Blood flow in Group A was 131.00 ± 26.00 mL/min before and 133.00 ± 23.00 mL/min after the intervention. In Group B, blood flow was 132.00 ± 36.00 mL/min before and 136.00 ± 33.00 mL/min after the intervention (p > 0.05). Shear rate was 136.00 ± 51.00 s^{-1} in Group A and 137.00 ± 47.00 s^{-1} in Group B (p > 0.05).

DISCUSSION

Conservative management combined with various therapeutic exercise approaches has been widely applied in patients with chronic low back pain, and numerous studies have investigated their clinical effectiveness. Hlaing *et al*. (2021) conducted a six-week intervention in 36 participants aged 30–40 years, comparing a lumbar stabilization exercise group with a conventional physical therapy group. The lumbar stabilization group demonstrated a significantly reduction in VAS scores (Hlaing *et al*., 2021). Studies focusing on adjacent joint interventions have also reported positive outcomes. Jeong *et al*. (2015) applied combined hip muscle strengthening and lumbar stabilization exercises in patients aged 30–50 years and reported significant improvements in the ODI, lumbar isometric strength, stability index, and weight distribution index. Similarly, Woo & Kim (2016) examined 30 patients with chronic low back pain and found that a combined lumbar stabilization and thoracic extension exercise program resulted in greater improvements in lumbosacral alignment and ODI reduction compared with lumbar stabilization exercises alone.

In the present study, both experimental Groups A and B demonstrated significant reductions in VAS and ODI scores. Notably, the stretching-based intervention in Group B showed greater improvements. This finding may be attributed to the characteristics of the participants, who were elite Greco-Roman wrestling athletes. Due to the high reliance on upper-body strength and repetitive high-intensity training, these athletes typically exhibit highly developed and shortened musculature. Although changes in blood flow velocity and arterial diameter were not statistically significant (Table VI), improved circulation observed in this study may have a positive effect on musculoskeletal pain and joint range of motion. Further studies with a larger sample size and more detailed measurements are warranted to confirm these findings. Therefore, stretching interventions may have facilitated muscle relaxation and improved tissue extensibility, leading to enhanced pain reduction and functional recovery.

Self-myofascial release (SMR) has traditionally been used as an adjunctive treatment for soft tissue injuries. Adhesions and functional restrictions resulting from soft tissue injury can alter joint biomechanics, contributing to pain and pathological movement patterns. Foam roller–based SMR applies mechanical pressure to soft tissues through body-weight loading and varied body positioning, thereby promoting tissue mobility and neuromuscular relaxation (Curran *et al*., 2008). Previous studies (Pearcey *et al*., 2015) investigating the effects of myofascial release on pain reduction reported that 20 minutes of foam rolling following back squat exercise significantly reduced delayed-onset muscle soreness in the quadriceps of healthy men. In addition, Macdonald *et al*. (2014) demonstrated significant reductions in muscle soreness in resistance-trained men following post-exercise foam rolling. In the present study, experimental Group A applied SMR using a foam roller targeting the thoracolumbar junction and the entire thoracic region. The observed reductions in VAS and ODI following the eight-week intervention may be partially explained by the mechanical and neuromuscular effects of myofascial release, which likely contributed to decreased tissue stiffness, improved mobility, and pain modulation.

A reduction in thoracic mobility increases compensatory and unnecessary movements of the lumbar and cervical spine, which consequently exacerbates low back pain. Conversely, improving insufficient thoracic mobility may reduce compensatory motion, enhance the mechanical stability of the lumbar spine, and ultimately alleviate low back pain (Panjabi, 1992).

Stretching is a commonly used intervention to improve thoracic mobility, and its effectiveness is reported to be greater when combined with SMR. Fairall *et al*. (2017), reported that athletes with glenohumeral internal rotation deficit who performed static stretching combined with SMR using a massage ball demonstrated significantly greater improvements in shoulder internal rotation range of motion than those who performed static stretching alone. Similarly, Skarabot *et al*. (2015) found that adolescent athletes who received combined static stretching and SMR using a foam roller for the calf muscles showed significantly greater increases in ankle dorsiflexion range of motion compared with static stretching alone. In addition, Mohr *et al*. (2014) reported significant improvements in hip flexion range of motion when stretching and SMR were applied to the hamstring muscles in a cohort of 40 participants. Consistent with these previous findings, the present study demonstrated that experimental group A showed the greatest mean increase in thoracic range of motion compared with the other group, suggesting that the combination of stretching and foam rolling effectively enhanced joint mobility.

Patients with chronic low back pain have been reported to exhibit approximately a 20 % reduction in shear strain of the thoracolumbar fascia (TLF) (Langevin *et al*., 2011). Griefahn *et al*. (2017), further demonstrated that foam rolling significantly increases shear strain in the TLF. In the present study, experimental group A received SMR applied to the entire thoracic region, including the thoracolumbar junction; therefore, it is reasonable to assume that this intervention contributed to an increase in TLF shear strain. Because the TLF and thoracic spine are anatomically and functionally connected through fascial continuity, enhanced fascial mobility may have facilitated improvements in thoracic range of motion.

Regarding exercise interventions for improving joint mobility, Swank *et al*. (2003) reported significant increases in range of motion in older adults when light external loads (0.43–1.36 kg) were added to various stretching exercises. Nelson & Bandy (2004) found that eccentric hamstring exercises using elastic bands in high school students produced effects comparable to those of static stretching. Yang *et al*. (2015) also reported that sling exercise combined with thoracic joint mobilization improved pain levels as well as thoracic flexion and extension range of motion in patients with chronic low back pain. In the present study, experimental group B demonstrated greater improvements than group A in left–right rotation as well as flexion and extension. This finding may be attributed to the characteristics of Greco-Roman wrestling athletes, who typically exhibit highly developed musculature and may therefore respond more favorably to stretching interventions.

Although experimental group A showed improvements in pre–post thoracic flexion and extension range of motion, the magnitude of improvement was smaller than that reported by Yang *et al*. (2015). This discrepancy may be explained by differences in participant age, as Yang's study (Yang *et al*., 2015) involved older adults aged 65 years or above. Older participants may have difficulty accurately perceiving and performing isolated thoracic flexion and extension movements, and restricting compensatory cervical and lumbar motion while precisely measuring thoracic range of motion may also present methodological challenges. Based on these findings, investigating blood flow parameters in older adults may be a valuable approach in future studies.

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RESUMEN: El objetivo de este estudio fue investigar los cambios en el dolor musculoesquelético, la amplitud de movimiento articular y el flujo sanguíneo de la arteria braquial en atletas de élite de lucha grecorromana tras la realización de ejercicio o estiramientos. Veinte luchadores grecorromanos con dolor lumbar y de hombro fueron asignados aleatoriamente a dos grupos. El Grupo A realizó liberación muscular con un rodillo de espuma combinado con ejercicios de movilidad torácica asistida con banda elástica, mientras que el Grupo B realizó estiramientos sin rodillo de espuma ni resistencia externa. Tras la intervención, se evaluaron la intensidad del dolor (VAS), la discapacidad funcional (ODI), el flujo sanguíneo de la arteria braquial y el diámetro arterial. El diámetro y el flujo sanguíneo de la arteria braquial mostraron mejoras numéricas. Ambos grupos mostraron reducciones significativas en las puntuaciones de la escala VAS y el índice ODI tras la intervención ($p < 0{,}01$). El rango de movimiento de flexión y extensión torácica aumentó significativamente en ambos grupos, mientras que la rotación torácica mejoró significativamente solo en el Grupo B. Estos hallazgos pueden servir como datos fundamentales para la prevención de lesiones y la mejora del rendimiento en luchadores grecorromanos.

PALABRAS CLAVE: Luchador grecorromano; Flujo sanguíneo; Dolor de hombro; Dolor lumbar; Estabilidad del tronco.

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