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# Mézières Method vs. Isostretching Postures on Countermovement Jump Performance in Elite Rhythmic Gymnasts with Low Back Pain: A Randomized Controlled Trial

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**Abstract:** This study aims to investigate the influence of the Mézières method and Isostretching postures on countermovement jump (CMJ) performance in rhythmic gymnasts with low back pain (LBP) by examining changes in jump height, movement efficiency, and pain perception. A randomized controlled trial (RCT) with a parallel-group design was conducted. Participants were randomly allocated into one of two intervention groups: the Mézières or the Isostretching group. Both groups underwent a total of 24 sessions. The Baiobit sensor was used as the primary assessment tool for measuring CMJ performance in elite rhythmic gymnasts with low back pain. A total of 17 rhythmic gymnastics athletes with LBP participated in the study. No differences were observed between groups in age, weight, or height; nevertheless, the Isostretching group had greater variability in age (SD = 4.82 vs. 0.91), while the Mézières group showed higher variability in height. As per maximal speed and height, the overall treatment effect was significant ($p = 0.006$, $\eta^2 = 0.431$), indicating long-term benefits for Mezieres training, which also had a significant impact on CMJ Maximal Force, particularly at four sessions ($p = 0.036$), with improvements continuing over time ($p = 0.003$, $\eta^2 = 0.672$). The Mezieres group showed higher force values compared to the Isostretching group at all time points. The results indicate that Mezieres training significantly improved CMJ Flight Time over time ($p = 0.005$, $\eta^2 = 0.440$), with notable increases at all time points compared to the Isostretching group. Improvements were particularly evident in the 12th and 24th sessions, confirming its sustained effectiveness. CMJ Contact Time also showed a significant overall effect ($p = 0.027$, $\eta^2 = 0.521$), with Mezieres training leading to greater reductions in contact time, particularly at 24 sessions ($p = 0.003$), highlighting improved efficiency in jump execution. Lastly, CMJ VAS (perceived exertion or discomfort) showed a significant overall effect ($p < 0.001$, $\eta^2 = 0.896$), with Mezieres training leading to a progressive reduction in perceived exertion, particularly from eight sessions onwards, and the most pronounced effect at 24 sessions. The Mézières method and Isostretching postures offer substantial benefits for gymnasts with low back pain, though their mechanisms of improvement differ.

**Keywords:** postural treatment; elite athlete; low back pain; countermovement jump performance

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Received: 4 February 2025
Revised: 15 March 2025
Accepted: 17 March 2025
Published: 22 March 2025

**Citation:** Lena, O.; Qorri, E.; Martínez-Fuentes, J.; Todri, J. Mézières Method vs. Isostretching Postures on Countermovement Jump Performance in Elite Rhythmic Gymnasts with Low Back Pain: A Randomized Controlled Trial. *Appl. Sci.* **2025**, *15*, 3477. https://doi.org/10.3390/app15073477

## 1. Introduction

Rhythmic gymnastics is a discipline that demands a high level of flexibility, strength, and explosive power, particularly in jumping performance. Among the key assessments of lower limb power in gymnasts is the countermovement jump (CMJ) test, which evaluates the stretch-shortening cycle's efficiency and neuromuscular activation [1,2]. However, rhythmic gymnasts frequently experience low back pain (LBP) due to the extreme range of motion required in their sport, along with repetitive spinal hyperextension and postural imbalances, which might compromise jump performance [3]. Addressing LBP in gymnasts necessitates specialized postural correction methods.

Among the various postural rehabilitation techniques, the Mézières method and Isostretching have gained prominence in the treatment of LBP in elite athletes, including rhythmic gymnasts [4,5]. The Mézières method is based on the principle of global postural re-education, emphasizing the elongation of muscular chains to correct postural asymmetries and reduce musculoskeletal discomfort [6]. Recent studies have demonstrated its effectiveness in improving flexibility and reducing pain in athletes, contributing to enhanced motor performance and postural stability [3,4]. Similarly, Isostretching is a corrective exercise approach that integrates isometric muscle activation with controlled breathing, promoting spinal alignment and core stability [5,7]. This method has been shown to alleviate chronic low back pain while enhancing flexibility and neuromuscular coordination [8,9].

While extensive research has examined the effects of dynamic and static stretching on jump performance, the influence of long-term postural therapy techniques on explosive movements such as CMJ remains largely unexplored. Moreover, traditional acute interventions, such as post-activation potentiation (PAP) and dynamic stretching, have demonstrated short-term improvements in jumping ability, but their long-term benefits in athletes with postural dysfunctions or chronic pain remain uncertain [10–12]. In rhythmic gymnasts, previous studies have highlighted the effectiveness of Mézières and Isostretching methods in improving postural alignment, flexibility, and neuromuscular coordination [4,5], suggesting their potential role in optimizing movement patterns and motor control. However, to the best of our knowledge, no study has directly analyzed the impact of these methods on explosive strength performance in rhythmic gymnasts with LBP. Given that proper postural control influences force transmission and biomechanical efficiency during jump execution [13], understanding the role of postural rehabilitation techniques in CMJ performance could provide valuable insights into injury prevention and athletic performance enhancement.

Therefore, we aim to analyze the impact of the Mézières method and Isostretching on CMJ performance in rhythmic gymnasts with LBP, which might contribute to the development of evidence-based rehabilitation protocols that balance postural correction with athletic performance optimization. Specifically, it aims to investigate the influence of the Mézières method and Isostretching on CMJ performance in rhythmic gymnasts with LBP, evaluating changes in jump height, movement efficiency, and pain perception. The findings will contribute to the development of evidence-based rehabilitation protocols that balance postural correction with athletic performance optimization.

## 2. Materials and Methods

### *2.1. Trial Design*

This study is a randomized controlled trial (RCT) with a parallel-group design and an allocation ratio of 1:1. Participants were randomly allocated into one of two intervention groups: the Mézières method group or the Isostretching group. Both groups underwent a total of 24 sessions, with evaluations conducted at five time points: baseline and after

4 sessions, 8 sessions, 12 sessions, and 24 sessions. The study followed the CONSORT guidelines [14] for RCTs to ensure methodological rigor and transparency. The primary outcomes assessed included changes in countermovement jump (CMJ) performance, movement efficiency, and pain perception. The randomization process was conducted using a computer-generated sequence, and allocation concealment was ensured through an adaptive biased-coin design. Blinded assessors conducted the outcome evaluations to minimize bias. Ethical approval for the study was obtained from the Institutional Ethics Committee, and all procedures adhered to the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment in the study. The study protocol was registered in an international clinical trial registry to ensure adherence to ethical and methodological standards.

### *2.2. Participants*

Rhythmic gymnastics athletes between the ages of 10 and 30 who were experiencing low back pain were enrolled in the study. To be eligible, participants had to be actively engaged in competitive training and have a confirmed clinical diagnosis of low back pain. Athletes were excluded if they had systemic or neurological disorders, a history of recent spinal surgery, or musculoskeletal injuries that could affect their participation. Those who had received comparable physical therapy treatments within the past three months were also ineligible. Recruitment and data collection were conducted at the athletes' training camp. The sample size for this study was determined by considering the unique characteristics of the population, feasibility, and statistical factors relevant to the target group. Given that the study focused on 17 elite rhythmic gymnasts with low back pain, highly specialized cohort recruitment options were inherently limited. According to the power analysis, a priori calculations conducted using the G*Power program indicated that, assuming a medium-to-large effect size (Cohen's d = 0.8), a total of 16 participants (8 per group) would achieve 80% power with an alpha level of 0.05.

A total of 35 individuals were assessed for eligibility, with 15 being excluded due to failure to meet the inclusion criteria. The remaining 20 participants were randomly allocated to one of two groups: the Mézières group ($n$ = 10) or the Isostretching group ($n$ = 10). In the Mézières group, 2 participants did not undergo the assigned intervention, resulting in 8 participants completing the program. In the Isostretching group, 1 participant did not receive the assigned intervention, leaving 9 participants who completed the program. As a result, the final analysis included 8 participants from the Mézières group and 9 participants from the Isostretching group (Figure 1).

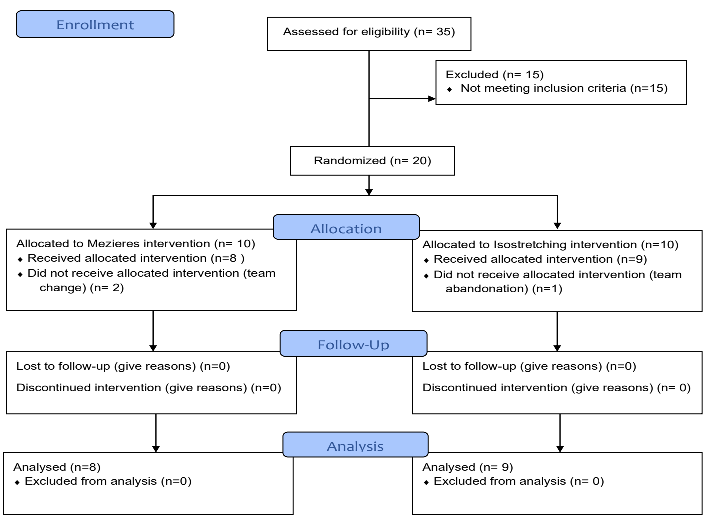


**Figure 1.** Participants' flowchart.

### 2.3. Interventions

Participants were randomly assigned to one of two intervention groups: Mezières method or Isostretching postures. Both interventions were administered over a 12-week period, with sessions held twice per week with a minimum of 30 min duration. The exercises were conducted in small groups under the supervision of a certified physiotherapist specializing in postural re-education.

#### 2.3.1. Mezières Method Group

The Mezières method aimed to restore postural balance through muscle chain stretching, respiratory control, and myofascial release. Sessions included postural assessment, targeted supine, seated, or standing positions, and techniques such as posterior muscle chain stretching, isometric contractions, myofascial release, and controlled breathing. Progression was individualized based on each athlete's postural adaptations. Concretely, each session began with an initial assessment, during which the athletes' posture was analyzed to identify compensatory patterns [4]. Participants were then guided into specific supine, seated, or standing positions designed to address muscular imbalances. The intervention incorporated various techniques, including global muscle chain stretching to elongate the posterior muscle chains, isometric contractions to engage deep stabilizing muscles, and manual myofascial techniques applied to areas of excessive tension [15]. Controlled breathing exercises were also integrated to enhance postural alignment and promote relaxation [16]. Throughout the program, adjustments were made based on each athlete's postural adaptations, ensuring individualized corrections and optimal progression [17] (Appendix A).

#### 2.3.2. Isostretching Method Group

The Isostretching intervention aimed to improve flexibility, postural alignment, and core stability through controlled, static, and dynamic movements emphasizing isometric engagement and spinal elongation [5,7–9]. The session began with a gentle warm-up consisting of mobility exercises aimed at spinal articulation. Athletes then performed exercises primarily in seated, standing, or quadruped positions, focusing on maintaining continuous postural control. The techniques included isometric contractions targeting deep postural muscles such as the transversus abdominis and multifidus, along with progressive spinal elongation through controlled axial stretching [8,9]. Breathing coordination was emphasized to promote diaphragmatic engagement and core activation [5]. Symmetric and asymmetric exercises were incorporated to address muscular imbalances. As the program progressed, the difficulty of postures and the duration of isometric holds were gradually increased based on each athlete's individual endurance (Appendix A).

Both intervention protocols were designed to minimize compensatory movement patterns and reinforce postural control, with compliance monitored through attendance logs and periodic reassessments.

### 2.4. Outcomes

The Baiobit sensor was used as the primary assessment tool for measuring countermovement jump (CMJ) performance in elite rhythmic gymnasts with low back pain [18–20]. This advanced sensor provides highly accurate and detailed data on several key performance metrics, making it an ideal tool for evaluating lower body power, strength, and jump mechanics.

The Baiobit sensor is a portable device designed to measure and record the biomechanics of vertical jumps, such as the countermovement jump (CMJ), which is often used to assess explosive power in athletes [18–20]. The sensor is placed on the lower back or attached to the athlete's body to capture movement in three dimensions, providing real-time data on several key performance indicators analyzed in this trial as

1. Maximal speed: the sensor measures the peak velocity achieved during the jump, giving insight into the athlete's explosive strength and ability to generate power quickly.
2. Maximal height: Baiobit accurately measures the highest point of the jump, which is indicative of the athlete's overall vertical leap and the efficiency of force production.
3. Maximal Force: the sensor records the maximum force exerted by the athlete during the push-off phase of the jump, which is a measure of lower limb strength and muscular power.
4. Concentric-Eccentric Exercise Performance: Baiobit distinguishes between the concentric (upward) and eccentric (downward) phases of the jump, assessing muscle function during both phases. This is important for understanding the balance between strength and flexibility in jump performance, which can impact recovery and injury prevention.
5. Flight time: the sensor records the time the athlete spends in the air during the jump, which reflects the efficiency of force application and how well the athlete can utilize stored elastic energy during the jump.
6. Contact time: the Baiobit sensor also measures the time the athlete spends in contact with the ground during the landing phase of the jump, providing insight into lower limb control and reaction time.
7. The Visual Analog Scale (VAS): it is used for countermovement jump (CMJ) performance measured with the Baiobit sensor, and it is employed to assess subjective perceptions related to jump execution, such as effort, fatigue, or pain during the movement. VAS consisted of a 10 cm horizontal line, where 0 represents "no discomfort or effort", and 10 indicates "maximum discomfort or effort." [21,22].

For each participant, the Baiobit sensor was used to assess three repetitions of each jump, ensuring the collection of reliable and consistent data. The mean of the three jumps was recorded for each parameter, providing a clear measure of each athlete's maximal performance. These measurements were taken pre-intervention, post-intervention, and during a follow-up assessment to track changes in performance over the course of the study. These assessments were conducted consistently at the same time of day to control for potential diurnal variations in performance.

### 2.5. Statistics

The statistical analysis included descriptive statistics, with continuous variables presented as mean ± Standard Deviation (SD). Group comparisons were conducted using independent t-tests for between-group differences. ANCOVA statistics with baseline data as covariance served for comparing the between groups treatments effects. Statistical significance was set at $\alpha = 0.05$, with effect sizes reported and multiple comparison corrections as Bonferroni applied when necessary. Partial Eta Squared ($\eta^2$) values were interpreted according to Cohen's (1988) guidelines, which suggest that an effect size is considered small when $\eta^2$ is 0.01, medium at 0.06, and large at 0.14 or higher [23]. These thresholds offer a practical framework for assessing the magnitude of observed effects in statistical analyses, particularly within the context of behavioral and social sciences research [24]. A 95% confidence interval was also reported for the statistical analysis.

## 3. Results

No differences were observed between groups in age, weight, or height; nevertheless, the Isostretching group had greater variability in age (SD = 4.82 vs. 0.91), while the Mézières group showed higher variability in height (SD = 12.85 vs. 6.64) (Table 1).

**Table 1.** Sample characteristics.

| Groups | | Age | Height | Weight | Training Hours Per Day | Training Days Per Week |
|---|---|---|---|---|---|---|
| Mezieres | N | 8 | 8 | 8 | 8 | 8 |
| | Mean | 13.375 | 157.250 | 42.000 | 14.875 | 4.380 |
| | SD | 0.916 | 12.848 | 7.171 | 2.474 | 0.518 |
| Isostretching | N | 9 | 9 | 9 | 9 | 9 |
| | Mean | 14.333 | 155.111 | 45.055 | 15.777 | 4.440 |
| | SD | 4.821 | 6.641 | 8.966 | 3.889 | 0.527 |
| Total | N | 17 | 17 | 17 | 17 | 17 |
| | Mean | 13.882 | 156.117 | 43.617 | 15.352 | 4.410 |
| | SD | 3.497 | 9.771 | 8.072 | 3.234 | 0.507 |
| | Sig. | 0.589 | 0.667 | 0.454 | 0.582 | 0.788 |

N = participant's number; SD: Standard Deviation, Sig.: significance.

### *3.1. CMJ Maximal Speed and Maximal Height Outcomes*

Tables 2–4 display the outcomes of the study groups measured with the Baiobit sensor. The results show that the Mezieres training method was more effective than Isostretching in improving CMJ maximal speed and height, especially in the early sessions. Significant differences in speed emerged after four sessions ($p$ = 0.048), with the Mezieres group performing better, though later sessions showed no significant differences. However, the overall treatment effect was significant ($p$ = 0.006, $\eta^2$ = 0.431), indicating long-term benefits. Similarly, for CMJ Maximal Height, the Mezieres group showed significant improvements at four ($p$ = 0.006) and eight sessions ($p$ = 0.048). Though later differences were not significant, the overall effect remained strong ($p$ = 0.006, $\eta^2$ = 0.422) (Table 2).

**Table 2.** CJM Maximal Speed and Height outcomes, measured with baiobit sensor.

| Outcomes Measured with Baiobit Sensor | Evaluation Period | Group | N | Mean | SD | *t* Test | | Between Groups Differences | | | | Between Groups Treatments Effects | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Sig | *t* | Sig. (2-Tailed) | Mean Difference | 95% Confidence Interval of the Difference | | F | Sig. | $\eta^2$ |
| CMJ Maximal Speed | Baseline | Mezieres | 8 | 1.974 | 0.261 | 0.086 | 0.799 | 0.437 | 0.087 | −0.145 | 0.320 | 10.603 | 0.006 | 0.431 |
| | | Isostretching | 9 | 1.887 | 0.187 | | | | | | | | | |
| | 4 sessions | Mezieres | 8 | 1.965 | 0.267 | 0.476 | 2.153 | 0.048 | 0.335 | 0.003 | 0.667 | | | |
| | | Isostretching | 9 | 1.630 | 0.360 | | | | | | | | | |
| | 8 sessions | Mezieres | 8 | 1.908 | 0.326 | 0.151 | 1.443 | 0.170 | 0.293 | −0.140 | 0.726 | | | |
| | | Isostretching | 9 | 1.614 | 0.484 | | | | | | | | | |
| | 12 sessions | Mezieres | 8 | 2.099 | 0.265 | 0.450 | 1.039 | 0.315 | 0.165 | −0.174 | 0.505 | | | |
| | | Isostretching | 9 | 1.933 | 0.374 | | | | | | | | | |
| | 24 sessions | Mezieres | 8 | 2.344 | 0.559 | 0.384 | 1.402 | 0.181 | 0.306 | −0.159 | 0.771 | | | |
| | | Isostretching | 9 | 2.038 | 0.324 | | | | | | | | | |
| CMJ Maximal Hight | Baseline | Mezieres | 8 | 16.125 | 3.227 | 0.378 | 0.552 | 0.589 | 0.792 | −2.268 | 3.851 | 10.212 | 0.006 | 0.422 |
| | | Isostretching | 9 | 15.333 | 2.693 | | | | | | | | | |
| | 4 sessions | Mezieres | 8 | 18.125 | 2.588 | 0.272 | 3.205 | 0.006 | 4.569 | 1.531 | 7.608 | | | |
| | | Isostretching | 9 | 13.556 | 3.206 | | | | | | | | | |
| | 8 sessions | Mezieres | 8 | 18.125 | 2.588 | 0.341 | 2.154 | 0.048 | 3.792 | 0.039 | 7.544 | | | |
| | | Isostretching | 9 | 14.333 | 4.330 | | | | | | | | | |
| | 12 sessions | Mezieres | 8 | 18.875 | 3.758 | 0.563 | 0.442 | 0.665 | 0.764 | −2.920 | 4.448 | | | |
| | | Isostretching | 9 | 18.111 | 3.371 | | | | | | | | | |
| | 24 sessions | Mezieres | 8 | 21.000 | 3.117 | 0.947 | 1.957 | 0.069 | 2.667 | −0.238 | 5.572 | | | |
| | | Isostretching | 9 | 18.333 | 2.500 | | | | | | | | | |

Legend: CMJ = countermovement jump test; N = participant's number; SD = Standard Deviation, Sig. = significance; *t* = *t* test; $\eta^2$ = partial eta squared.

**Table 3.** CMJ Maximal Force, Concentric and Eccentric outcomes measured with Baiobit sensor.

| Outcomes Measured with Baiobit Sensor | Evaluation Period | Group | N | Mean | Std. Deviation | t Test | | Between Groups Differences | | | | Between Groups Treatments Effects | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Sig | t | Sig. (2-Tailed) | Mean Difference | 95% Confidence Interval of the Difference | | F | Sig. | $\eta^2$ |
| CMJ Maximal Force | Baseline | Mezieres | 8 | 0.748 | 0.248 | 0.203 | 0.689 | 0.501 | 0.067 | −0.141 | 0.276 | 8.194 | 0.003 | 0.672 |
| | | Isostretching | 9 | 0.680 | 0.150 | | | | | | | | | |
| | 4 sessions | Mezieres | 8 | 0.700 | 0.124 | 0.426 | 2.309 | 0.036 | 0.134 | 0.010 | 0.259 | | | |
| | | Isostretching | 9 | 0.566 | 0.116 | | | | | | | | | |
| | 8 sessions | Mezieres | 8 | 0.693 | 0.156 | 0.452 | 0.998 | 0.334 | 0.063 | −0.071 | 0.196 | | | |
| | | Isostretching | 9 | 0.630 | 0.099 | | | | | | | | | |
| | 12 sessions | Mezieres | 8 | 0.866 | 0.210 | 0.928 | 1.779 | 0.095 | 0.171 | −0.034 | 0.375 | | | |
| | | Isostretching | 9 | 0.696 | 0.185 | | | | | | | | | |
| | 24 sessions | Mezieres | 8 | 0.956 | 0.211 | 0.063 | 0.180 | 0.860 | 0.025 | −0.273 | 0.323 | | | |
| | | Isostretching | 9 | 0.931 | 0.341 | | | | | | | | | |
| CMJ Concentric | Baseline | Mezieres | 8 | 0.230 | 0.146 | 0.228 | −0.802 | 0.435 | −0.073 | −0.268 | 0.122 | 2.865 | 0.048 | 0.170 |
| | | Isostretching | 9 | 0.303 | 0.219 | | | | | | | | | |
| | 4 sessions | Mezieres | 8 | 0.501 | 0.208 | 0.259 | 2.024 | 0.061 | 0.175 | −0.009 | 0.358 | | | |
| | | Isostretching | 9 | 0.327 | 0.146 | | | | | | | | | |
| | 8 sessions | Mezieres | 8 | 0.296 | 0.145 | 0.064 | −1.567 | 0.138 | −0.087 | −0.206 | 0.031 | | | |
| | | Isostretching | 9 | 0.383 | 0.079 | | | | | | | | | |
| | 12 sessions | Mezieres | 8 | 0.426 | 0.228 | 0.081 | 1.457 | 0.166 | 0.133 | −0.062 | 0.327 | | | |
| | | Isostretching | 9 | 0.293 | 0.144 | | | | | | | | | |
| | 24 sessions | Mezieres | 8 | 0.358 | 0.114 | 0.560 | 1.974 | 0.067 | 0.091 | −0.007 | 0.189 | | | |
| | | Isostretching | 9 | 0.267 | 0.074 | | | | | | | | | |
| CMJ Eccentric | Baseline | Mezieres | 8 | 0.430 | 0.150 | 0.337 | 0.407 | 0.690 | 0.028 | −0.118 | 0.173 | 2.396 | 0.119 | 0.375 |
| | | Isostretching | 9 | 0.402 | 0.131 | | | | | | | | | |
| | 4 sessions | Mezieres | 8 | 0.431 | 0.200 | 0.646 | −0.254 | 0.803 | −0.022 | −0.208 | 0.164 | | | |
| | | Isostretching | 9 | 0.453 | 0.159 | | | | | | | | | |
| | 8 sessions | Mezieres | 8 | 0.403 | 0.136 | 0.142 | 0.400 | 0.695 | 0.044 | −0.189 | 0.276 | | | |
| | | Isostretching | 9 | 0.359 | 0.280 | | | | | | | | | |
| | 12 sessions | Mezieres | 8 | 0.329 | 0.194 | 0.423 | −0.473 | 0.643 | −0.055 | −0.301 | 0.191 | | | |
| | | Isostretching | 9 | 0.383 | 0.270 | | | | | | | | | |
| | 24 sessions | Mezieres | 8 | 0.350 | 0.290 | 0.039 | 1.825 | 0.088 | 0.177 | −0.030 | 0.383 | | | |
| | | Isostretching | 9 | 0.173 | 0.028 | | | | | | | | | |

Legend: CMJ = countermovement jump test; N = participant's number; SD = Standard Deviation, Sig. = significance; *t* = *t* test; $\eta^2$ = partial eta squared.

**Table 4.** CMJ Flight and Contact Time outcomes measured with Baiobit sensor.

| Outcomes Measured with Baiobit Sensor | Evaluation Period | Group | N | Mean | Std. Deviation | *t* Test | | Between Groups Differences | | | | Between Groups Treatments Effects | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Sig | *t* | Sig. (2-Tailed) | Mean Difference | 95% Confidence Interval of the Difference | | F | Sig. | $\eta^2$ |
| CMJ Flight Time | Baseline | Mezieres<br>Isostretching | 8<br>9 | 0.356<br>0.346 | 0.032<br>0.026 | 0.548 | 0.753 | 0.463 | 0.011 | −0.020 | 0.041 | 10.987 | 0.005 | 0.440 |
| | 4 sessions | Mezieres<br>Isostretching | 8<br>9 | 0.371<br>0.324 | 0.033<br>0.046 | 0.237 | 2.373 | 0.031 | 0.047 | 0.005 | 0.089 | | | |
| | 8 sessions | Mezieres<br>Isostretching | 8<br>9 | 0.375<br>0.312 | 0.029<br>0.080 | 0.052 | 2.100 | 0.053 | 0.063 | −0.001 | 0.126 | | | |
| | 12 sessions | Mezieres<br>Isostretching | 8<br>9 | 0.390<br>0.377 | 0.033<br>0.041 | 0.901 | 0.730 | 0.477 | 0.013 | −0.026 | 0.052 | | | |
| | 24 sessions | Mezieres<br>Isostretching | 8<br>9 | 0.405<br>0.381 | 0.030<br>0.026 | 0.916 | 1.761 | 0.099 | 0.024 | −0.005 | 0.053 | | | |
| CJM Contact Time | Baseline | Mezieres<br>Isostretching | 8<br>9 | 0.661<br>0.710 | 0.164<br>0.342 | 0.114 | −0.366 | 0.719 | −0.049 | −0.332 | 0.235 | 4.352 | 0.027 | 0.521 |
| | 4 sessions | Mezieres<br>Isostretching | 8<br>9 | 0.935<br>0.781 | 0.288<br>0.213 | 0.812 | 1.262 | 0.226 | 0.154 | −0.106 | 0.414 | | | |
| | 8 sessions | Mezieres<br>Isostretching | 8<br>9 | 0.700<br>0.730 | 0.239<br>0.344 | 0.493 | −0.206 | 0.839 | −0.030 | −0.340 | 0.280 | | | |
| | 12 sessions | Mezieres<br>Isostretching | 8<br>9 | 0.665<br>0.677 | 0.281<br>0.294 | 0.916 | −0.083 | 0.935 | −0.012 | −0.310 | 0.287 | | | |
| | 24 sessions | Mezieres<br>Isostretching | 8<br>9 | 0.709<br>0.440 | 0.203<br>0.094 | 0.349 | 3.567 | 0.003 | 0.269 | 0.108 | 0.429 | | | |
| CJM VAS | Baseline | Mezieres<br>Isostretching | 8<br>9 | 5.750<br>5.778 | 0.886<br>0.833 | 0.785 | −0.067 | 0.948 | −0.028 | −0.917 | 0.861 | 34.392 | 0.000 | 0.896 |
| | 4 sessions | Mezieres<br>Isostretching | 8<br>9 | 4.125<br>4.333 | 1.458<br>1.000 | 0.292 | −0.347 | 0.733 | −0.208 | −1.487 | 1.071 | | | |
| | 8 sessions | Mezieres<br>Isostretching | 8<br>9 | 3.375<br>2.889 | 1.061<br>1.364 | 0.753 | 0.812 | 0.429 | 0.486 | −0.790 | 1.762 | | | |
| | 12 sessions | Mezieres<br>Isostretching | 8<br>9 | 2.750<br>2.333 | 0.886<br>0.707 | 0.269 | 1.077 | 0.298 | 0.417 | −0.408 | 1.241 | | | |
| | 24 sessions | Mezieres<br>Isostretching | 8<br>9 | 1.625<br>0.889 | 0.744<br>0.928 | 0.369 | 1.788 | 0.094 | 0.736 | −0.141 | 1.613 | | | |

Legend: CMJ = countermovement jump test; N = participant's number; SD = Standard Deviation, Sig. = significance; *t* = *t* test; $\eta^2$ = partial eta squared.

### *3.2. CMJ Maximal Force, Concentric, and Eccentric Exercise Outcomes*

Mezieres training had a significant impact on CMJ Maximal Force, particularly at four sessions ($p = 0.036$), with improvements continuing over time ($p = 0.003$, $\eta^2 = 0.672$). The Mezieres group showed higher force values compared to the Isostretching group at all time points. For CMJ Concentric, a significant difference was observed overall ($p = 0.048$), with Mezieres training showing notable improvements at 4 and 24 sessions. However, performance fluctuated, particularly at eight sessions, where no clear advantage was seen. The overall effect size ($\eta^2 = 0.170$) suggests a moderate impact. CMJ eccentric did not show statistically significant improvements between groups over time ($p = 0.119$), though Mezieres training appeared to maintain slightly higher values. The effect size (Partial Eta Squared = 0.375) suggests a moderate but non-significant impact (Table 3).

### *3.3. CMJ Flight, Contact, and VAS Outcomes*

The results indicate that Mezieres training significantly improved CMJ Flight Time over time ($p = 0.005$, Partial Eta Squared = 0.440), with notable increases at all time points compared to the Isostretching group. Improvements were particularly evident at 12 and 24 sessions, confirming its sustained effectiveness. CMJ Contact Time also showed a significant overall effect ($p = 0.027$, Partial Eta Squared = 0.521), with Mezieres training leading to greater reductions in contact time, particularly at 24 sessions ($p = 0.003$), highlighting improved efficiency in jump execution. Lastly, CMJ VAS (perceived exertion or discomfort) demonstrated the most substantial effect ($p < 0.001$, Partial Eta Squared = 0.896), with Mezieres training leading to a marked decrease in perceived exertion over time. The reduction was evident from eight sessions onwards, with the most significant difference at 24 sessions (Table 4).

## 4. Discussion

The present study aims to analyze the role of the Mézières method and Isostretching on CMJ performance in rhythmic gymnasts with LBP. All variables exhibit large or very large effect sizes, indicating that the Mézières training had a substantial impact on jump performance and efficiency over time. Specifically, CMJ Maximal Force ($\eta^2 = 0.672$) showed a large effect, suggesting significant strength improvements. CMJ Concentric ($\eta^2 = 0.170$) and CMJ Excentric ($\eta^2 = 0.375$) variables also displayed large effects, highlighting enhanced force production in both phases of the jump. Additionally, CMJ Flight Time ($\eta^2 = 0.440$) and CMJ Contact Time ($\eta^2 = 0.521$) demonstrated notable changes, pointing to improved jump mechanics and power application. The most pronounced effect was observed in CMJ VAS ($\eta^2 = 0.896$), indicating a very large reduction in pain perception, reinforcing the method's effectiveness in addressing low back pain while enhancing gymnastic performance. The analysis demonstrated that both interventions significantly reduced low back pain intensity, as measured by the Visual Analogue Scale (VAS). However, gymnasts in the Mézières group showed a slightly greater reduction in pain scores compared to those in the Isostretching group. These findings align with previous research emphasizing the benefits of postural re-education and myofascial elongation techniques [11]. Given that the Mézières method primarily focuses on global postural correction and muscle chain stretching, it may offer superior relief by addressing underlying musculoskeletal imbalances contributing to chronic pain. Although both groups exhibited improved core stability and strength, the Isostretching group showed a more pronounced increase in core endurance. Since core engagement plays a critical role in jump mechanics, force transfer, and eccentric control, the observed improvements in maximal speed, maximal height, Maximal Force, and Concentric-Eccentric Exercise Performance parameters could be explained due to neuromuscular efficiency and stabilizing muscle activation improvement. The observed improvements suggest that postural interventions, particularly Isostretching, may enhance neuromuscular efficiency by promoting better activation of stabilizing muscles. These results correspond with findings from Cabrejas et al. (2023), which highlight the importance of core stability in enhancing gymnastic performance. The Isostretching technique, which emphasizes controlled breathing and muscle activation, may have facilitated more efficient neuromuscular engagement, leading to better stabilization of the lumbar region [25].

While the Mézières method showed substantial effects on CMJ metrics, including Maximal Force ($\eta^2$ = 0.672) and flight time ($\eta^2$ = 0.440), the improvements were more focused on flexibility and pain reduction rather than explosive power. Feng et al. (2024) reported that cluster-based plyometrics specifically optimized neuromuscular coordination and rapid force development, which might offer superior benefits for gymnasts requiring quick, explosive movements [26]. However, the Mézières method's advantage in reducing CMJ VAS ($\eta^2$ = 0.896) suggests that it provides better pain management, which is critical for long-term athletic performance and injury prevention. A combined approach integrating both methodologies could maximize performance gains while ensuring injury resilience.

Functional movement improvements were assessed through standardized gymnastic performance tests, including vertical jump and dynamic flexibility assessments. Athletes undergoing the Mézières method displayed an enhanced range of motion, particularly in spinal mobility and hamstring flexibility. These findings are consistent with those reported by Souza et al. (2020), who indicated that flexibility gains contribute to better biomechanical efficiency during jumps and landings [27]. Conversely, the Isostretching group showed slight advantages in explosive strength, potentially due to the emphasis on isometric control and muscle activation, which can be beneficial for short-duration, high-intensity movements [28]. This supports the notion that myofascial stretching can play a crucial role in restoring movement patterns and reducing compensatory mechanisms. Similarly, findings by Petrigna et al. (2019) suggest that structured flexibility training can enhance movement economy and reduce injury risk, which aligns with our observed outcomes [29].

This study represents a novel approach as it is the first to examine the effects of the Mézières and Isostretching methods on athletic performance, specifically in the context of CMJ in rhythmic gymnasts with LBP. Previous research has investigated the influence of various training methods on vertical jump performance, including posterior chain and core strengthening programs [30], isokinetic training [31], kettlebell-based interventions [32], and alternative neuromuscular re-education strategies such as virtual reality training [31]. While these studies reported improvements in jump height, power, or neuromuscular efficiency, none have specifically targeted global postural therapy techniques like Mézières and Isostretching, which are designed to enhance muscular balance, reduce postural asymmetries, and promote long-term biomechanical efficiency. Our findings suggest that postural training may serve as a possible strategy not only for injury prevention and rehabilitation but also for performance optimization in rhythmic gymnasts, complementing existing strength and conditioning methodologies.

Based on previous research on postural therapy, this study extends current knowledge by demonstrating that Mézières and Isostretching techniques can influence not only postural alignment and pain management but also explosive movement performance, specifically CMJ outcomes in rhythmic gymnasts with LBP. While prior studies have highlighted the benefits of Mézières and Isostretching for flexibility improvements, postural stability, and neuromuscular coordination [3,4,6], these investigations primarily focused on rehabilitation markers rather than performance-based outcomes. Moreover, Isostretching has been reported to enhance core endurance and spinal alignment, which are key factors in optimizing motor control and injury prevention [5]. However, none of these studies have explored how postural therapies may directly contribute to power production, force efficiency, and movement execution in sports requiring explosive capabilities. Previous research has examined the role of global postural re-education (GPR) and other corrective strategies in musculoskeletal rehabilitation [7], but their potential implications for high-intensity athletic performance remain largely unexplored. By integrating postural therapies with jump performance assessments, this study provides novel insights that bridge the gap between rehabilitation-based postural training and sports performance optimization, contributing to a more comprehensive understanding of postural interventions in elite gymnastics training. Future research should further explore the long-term impact of postural correction techniques on explosive performance and their potential integration into athletic training programs, helping to refine evidence-based approaches for performance enhancement and injury prevention.

Reflecting on this trial's participants, an age range of 10 to 30 years can be considered for elite rhythmic gymnasts with low back pain (LBP) due to early specialization, peak performance demands, and physiological factors. Rhythmic gymnasts begin intensive training as early as 8–10 years old, predisposing them to overuse injuries, including LBP [33]. Elite gymnasts often compete at high levels into their late 20s or early 30s, with sustained training loads contributing to persistent LBP [34,35]. LBP is common in rhythmic gymnasts due to extreme spinal hyperextension and repetitive loading, often developing in adolescence (10–18 years) and persisting into adulthood (20–30 years) due to chronic stress [36,37]. Physiologically, younger gymnasts (10–18 years) are vulnerable to growth-related injuries such as apophyseal injuries and stress fractures [38], while older gymnasts (20–30 years) may suffer from degenerative changes and cumulative musculoskeletal stress [39].

A key limitation of this study is the wide age range (10 to 30 years) among elite rhythmic gymnasts, which introduces variability in maturation, height, and technique, potentially influencing jump performance outcomes. However, in our study, the mean age of both groups was 13.8 years old, with no significant differences between them, and only one participant was 27 years old. Despite the broad inclusion criteria, the sample was predominantly composed of adolescent gymnasts, which helps reduce the impact of extreme age-related differences. Nevertheless, younger gymnasts (10–18 years) are still undergoing growth and neuromuscular development, which can affect their ability to generate Maximal Force and optimize jump biomechanics [38]. In contrast, older gymnasts (20–30 years) typically have greater muscle strength, coordination, and refined technique, which may enhance jump performance [39]. Differences in limb length, muscle mass, and motor control strategies between younger and older gymnasts could influence jump variables such as maximal speed, height, and force production. Although only one participant was significantly older, her results may have slightly skewed overall performance trends. Future studies should consider narrower age groups or statistical adjustments for maturational differences to ensure more homogeneous comparisons.

Moreover, great variability of height was observed between Mézières and Isostretching groups, suggesting different anthropometric profiles among participants. Although this difference was not statistically significant, height differences could influence jump performance, namely due to limb length, segmental leverage, and force application, which, in turn, influence neuromuscular efficiency and movement biomechanics. Given that height can impact countermovement jump (CMJ) performance by altering the stretch-shortening cycle and force production mechanics, this variability should be considered a potential limitation of the study [40,41]. Future research should consider whether controlling for height variability in postural therapy interventions could help further refine the understanding of neuromuscular adaptations in rhythmic gymnasts with low back pain.

Another limitation of this study is also the relatively small sample size ($n$ = 17), which may restrict the generalizability of the findings. Additionally, the limited sample size in this study may have impacted the statistical power, reducing the ability to detect small but meaningful differences in performance outcomes. A small sample size increases the risk of Type II errors, making it difficult to generalize findings to the broader population of elite rhythmic gymnasts.

A larger sample should be selected in future studies to improve statistical power and ensure more reliable comparisons between groups. A larger, more diverse cohort would allow for subgroup analyses based on maturational status, helping to better understand the effects of age-related differences on jump performance. Additionally, longitudinal studies tracking gymnasts over time could provide further insights into how maturation, training adaptations, and injury history influence performance metrics.

Moreover, the study duration (24 weeks) might not be sufficient to capture long-term adaptations in pain management and athletic performance. Future research should consider larger cohorts and extended intervention periods to validate these results. Furthermore, integrating biomechanical assessments, such as electromyographic (EMG) analysis, could provide deeper insights into the neuromuscular adaptations elicited by each method.

Another limitation of the study is the absence of controls for potential confounding factors, including athletes' daily training intensity, dietary habits, and psychological states. Although the sample was relatively homogeneous in terms of competitive level, training regimens, and strict standardization, future research should also incorporate the control of other potential confounding factors, such as athletes' daily training intensity, dietary habits, and psychological states.

Future studies should consider more objective pain evaluation methods, such as quantitative sensory testing or other physiological measures, to complement the VAS and provide a more comprehensive assessment of pain outcomes. The follow-up assessments are recommended to determine how pain reduction influences training load management, injury prevention, and overall athletic career longevity.

## 5. Conclusions

In summary, both the Mézières method and Isostretching postures offer substantial benefits for gymnasts with low back pain, though their mechanisms of improvement differ. The Mézières approach excels in enhancing postural alignment and flexibility, while Isostretching appears more effective in developing core endurance and strength. Given the sport-specific demands of gymnastics, a combined approach incorporating elements of both methods may yield optimal outcomes for pain reduction and performance enhancement.

**Author Contributions:** Conceptualization, O.L., J.M.-F. and J.T.; Methodology, O.L. and J.T.; Software, O.L. and J.T.; Validation, O.L., J.M.-F. and J.T.; Formal analysis, O.L., J.M.-F. and J.T.; Investigation, O.L., J.M.-F. and J.T.; Resources, E.Q. and J.M.-F.; Data curation, O.L., E.Q., J.M.-F. and J.T.; Writing—original draft, O.L., E.Q., J.M.-F. and J.T.; Writing—review & editing, O.L., E.Q., J.M.-F. and J.T.; Visualization, O.L., J.M.-F. and J.T.; Supervision, O.L., E.Q., J.M.-F. and J.T.; Project administration, E.Q.; Funding acquisition, E.Q. All authors have read and agreed to the published version of the manuscript.

**Funding:** This study was supported by the Albanian University collaboration research project (Grant 305), Tirana, Albania.

**Institutional Review Board Statement:** This study was conducted in accordance with the principles outlined in the Declaration of Helsinki to ensure the ethical treatment and protection of all participants. Prior to the commencement of the study, the research protocol was reviewed and approved by the Catholic University San Antonio of Murcia, Spain, Ethics Committee approbation on 29 October 2021 with ID CE102105, ensuring compliance with ethical standards for human research. The trial was previously registered at ClinicalTrials.gov with ID NCT05149703.

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

**Data Availability Statement:** Data availability will be accessible upon request.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A

Detailed postural treatment protocol for both groups.

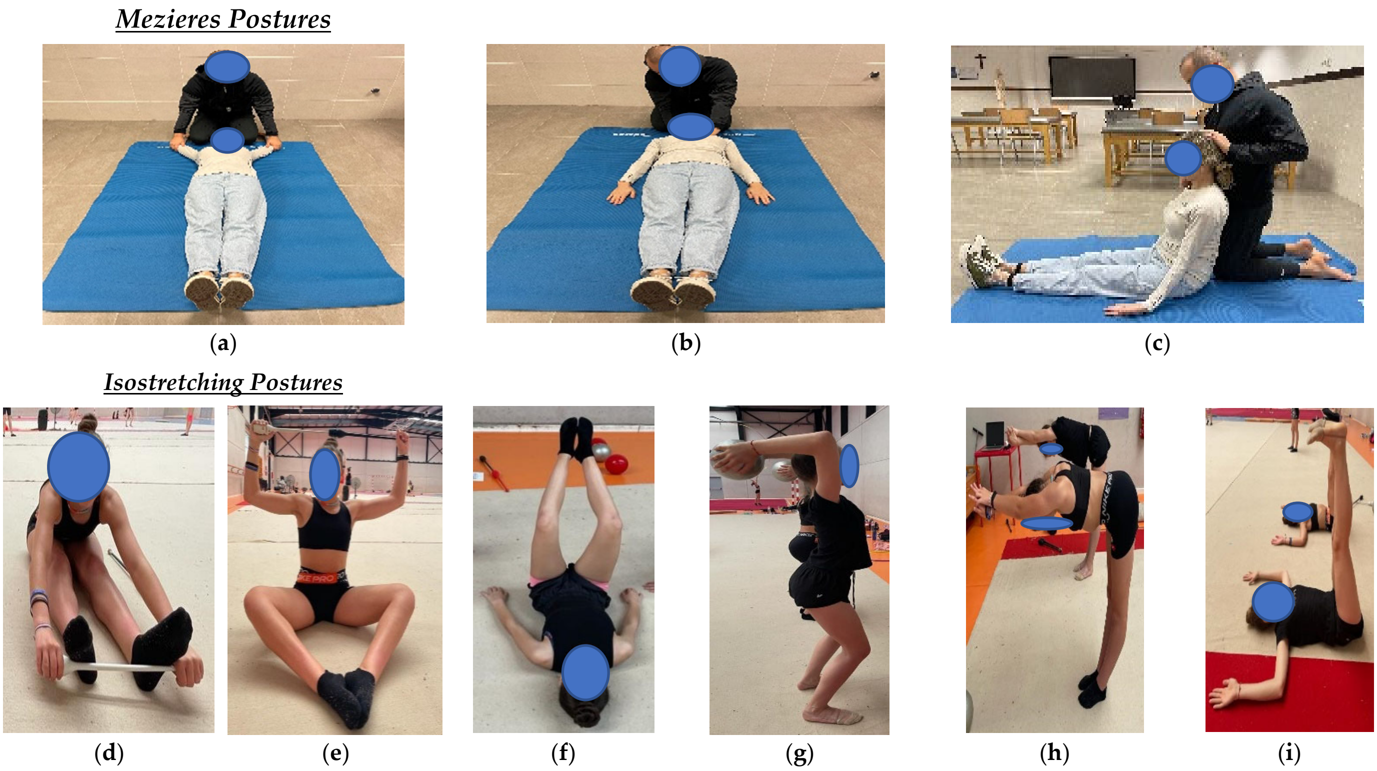


**Figure A1.** (**a**) Posture 1, (**b**) Posture 2, (**c**) Posture 3, (**d**) Posture 4, (**e**) Posture 5, (**f**) Posture 6, (**g**) Posture 7, (**h**) Posture 8, (**i**) Posture 9.

**Legend:**
**Mezieres Postures**

(a) Posture 1
- The patient is lying supine on a mat with arms relaxed by the sides.
- The therapist is stabilizing the head and neck, likely to ensure proper alignment and facilitate muscle elongation.
- This position helps assess tension in the posterior muscle chains and establish a starting point for postural correction.

(b) Posture 2
- The therapist is gently positioning the patient's arms above the head.
- This movement aims to stretch the upper body's muscle chains while keeping the spine aligned.
- It is essential to maintain even breathing to avoid compensatory muscle contractions.

(c) Posture 3
- The patient's legs are elevated, and the therapist is supporting them while keeping the back flat.
- This posture elongates the posterior chain, particularly the hamstrings and spinal muscles.

- ○ The therapist's control ensures that compensatory movements, such as excessive lumbar curvature, are minimized.

Isostretching Postures:

(d) Posture 4: Seated forward Fold with Baton
- ○ The patient sits on the floor with legs extended forward and feet flexed (toes pointing up). A rhythmic gymnastics baton is placed across the soles of the feet, and the person gently leans forward, holding the ends of the baton.

(e) Posture 5: Seated Cross-Leg Position with Arms Raised
- ○ The patient sits on the floor with legs crossed, arms bent at the elbows and raised in a gentle "flex" pose. The torso remains upright, indicating engagement of the upper body and core.

(f) Posture 6: Supine Leg Raise (Legs at 90 Degrees)
- ○ The patient lies on the back with arms by the sides and raises the legs together so they form a roughly 90-degree angle at the hips.

(g) Posture 7: Standing Overhead Ball Hold
- ○ The patient stands while holding a ball behind the head or upper back, with elbows bent. The arms and shoulders are lifted to engage the upper back and core.

(h) Posture 8: Forward Hinge with Arms Extended Overhead
- ○ Standing in a hip-width stance, the practitioner leans forward from the hips with arms extended overhead in line with the ears. The back remains relatively straight as the torso moves to a position roughly parallel to the floor.

(i) Posture 9: Legs-Up Angle
- ○ The patient lies on the back with arms extended out to the sides, forming a "T" shape. The legs are raised so that the hips and knees form about a 90-degree angle, or with the hips at 90 degrees and the knees extended upward.

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