

Efficacy of high-power laser therapy combined with exercise on wrist pain, function and joint position sense in female gymnasts with non-specific chronic wrist pain

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ABSTRACT

Background: Wrist pain is common and debilitating among gymnasts, presenting a tricky diagnostic and therapeutic challenge resulting in falling down in training sessions and during performance.

Objective: To find out the effect of high-power laser treatment, either alone or in combination with exercise, on wrist pain, function and joint position sense in female gymnasts with non-specific chronic wrist pain. **Methods:** Thirty-six female gymnasts (aged 10 to 16 years) who were diagnosed with non-specific wrist pain were recruited as the participants for the study, and were randomly allocated into three groups. The participants of the laser therapy group received only high power laser therapy, the exercise program group participants received exercises only, and the participants of the

combined therapy group received both laser and exercises. Pain, function, and joint position sense were the outcomes measures in the study. **Results:** In all treatment groups, all measured results improved after therapy. The laser therapy group had the least significant impact, whereas the combined therapy group had the most significant impact. **Conclusion:** It might be early to say whether solely high-power laser therapy is an effective non-invasive modality for treating female gymnasts with non-specific chronic wrist pain. The addition of associated co-interventions to high power laser treatment can improve the beneficial effects of laser therapy.

KEYWORDS

High-power laser; Exercise; Wrist pain; Function; Joint position sense.

1. INTRODUCTION

Wrist pain can be induced during weight-bearing activities in gymnasts due to musculoskeletal abnormalities, incorrect motion patterns, or improper training methods. Insufficient proximal control could have a negative effect on loading mechanics across the upper extremities, resulting in wrist pain in gymnasts (Boucher & Smith-Young, 2017). One of the most common sports in youth is competitive gymnastics in which most of the players fall in the age group between 6 to 14 years.

The disparity in the wrist injuries between women and men gymnasts may be related to variances in the biomechanical requirements of the athletic event. Upper body injuries are common in both male and female gymnasts (Westermann et al, 2015; Benjamin et al, 2017). In physically demanding activities, the pain in the wrist joint is the commonest one (Ferguson et al., 2019). In the general population, nonspecific hand and wrist pain affect about 10% of people (Walker Bone, 2004). Physicians find it difficult to diagnose and manage chronic wrist pain (Van Vugt, 1999). Physicians must first exclude an anatomic lesion before determining a non-organic cause of pain in their patients. However, the underlying non-medical aspects complicate the picture and make a definitive diagnosis even more difficult (Kasdan & Millender, 1996). In a retrospective study of three hand surgeons, the wrist joint was the most popular place of perplexing pain. More than half of the patients obtained no specific diagnosis for the same (Cooney, 1993; Johnstone et al., 1997; Earp et al., 2006; Wagner et al., 2014; Mohamadi et al., 2017).

Adolescents frequently experience generalized chronic wrist pain, which is characterized by vague, chronic, and activity-related wrist pain without any history of trauma, while there may be a

history of heavy engagement in grip strenuous sports. Regular physical strain may cause ligament laxity which does not lead to any significant finding in radiographs or MRI.

Treatment entails the appropriate use of conservative measures with a keen focus on the grip strength. Isokinetic exercises and wrist range of motion exercises have been successfully found in lowering pain in a variety of patients (Cornwall, 2010).

Laser is an acronym for light amplification by stimulated emission of radiation. Lasers can be classified as high power or low-level lasers therapy (LLLT) and High power lasers therapy (HILT). When compared to low-intensity laser therapy, high-intensity laser therapy (HILT) is considered a novel form of application in the field of physical therapy, as it has various mechanisms of action (Burley & Müller, 1997; Moskvina & Buylin, 2008; Niemz, 2007; Angelova & Ilieva, 2016). HILT has more depth of penetration, short emission time, and long rest periods preventing heat accumulation in addition to its safest and painless application in comparison to LLLT (Moskvina & Buylin, 2008; Zati & Valent, 2006; Santamato et al., 2009; Ordahan et al., 2018).

Proprioception retraining is a well-accepted and evidence-based rehabilitation technique for improving the dynamic stability of the ankle, knee, and shoulder joint (McKeon & McKeon, 2012; Postle et al., 2012; Smith et al., 2012; Fhyr et al., 2015; Schifano et al., 2015). Nevertheless, there is a paucity of research on the evaluation and proprioceptive training in ligament injury to the wrist joint (Hincapie et al., 2016)

In a scoping review conducted by Valdes et al. (2014), the authors concluded that sensorimotor training had an additive effect on people with particular upper limb problems. However, there is a dearth of evidence on the effectiveness of sensorimotor training on chronic wrist pain with no known cause.

To the best of the researcher's knowledge, no previous literature has been found on the impact of different types of treatment on wrist pain in gymnast players. Hence, the primary aim of the study was to find out the impact of high power laser treatment, either alone or in combination with exercise, on wrist pain, function, and joint position sense in girls' gymnasts having non-specific chronic wrist pain.

2. METHODS

2.1. Design

The present study was a single blinded randomized clinical trial. The study was conducted in the outpatient clinic of Badr University's Faculty of Physical Therapy in Cairo and the outpatient

clinic of Cairo University's Faculty of Physical Therapy. The ethical approval was obtained from the local institutional Ethics committee (P.T. REC/012/003114). The study was also registered in clinical trial registry at <https://clinicaltrials.gov> with registration number NCT04984187.

2.2. Participants

Participants for the present study were recruited via communicating with physicians at different sports clubs. A total of 36 participants were diagnosed and referred with non-specific wrist pain. Inclusion criteria for the present study was female gymnast falling within the age group of 10-16 years, diagnosed with chronic unilateral wrist pain for more than 3 months but less than 2 years with normal X-ray findings, capable of comprehending the English language, with no existing diseases, had not undergone physical therapy intervention in the last 6 months, with no neurological problems or traumatic or post-surgical disorders impacting upper extremities. The players with pain in the wrist due to hand fractures or bone diseases such as bone tumors, other neuromuscular or systematic diseases were excluded from the study. All the enrolled participants were directed to avoid taking analgesics and/or NSAIDs during the course of study.

2.3. Randomization

A total of 46 individuals were screened for eligibility based on the selection criteria for the present study. Out of which, 6 individuals did not fulfill the selection criteria. Guardians of four females refused to give consent to participate in the study. A total of 36 participants were recruited in the study as shown in figure 1. A random number generator was used to perform the randomization (www.randomization.com). The randomized list was prepared by a research assistant who was not involved in the research processes. The assignment to one of the three treatment options was revealed to the participants at the time of confirmation of their enrollment. The study has three intervention groups. Laser therapy group, exercises program group and, the combined therapy group. Participants of the Laser group received intervention using high-power laser. Participants of the exercise group received intervention including exercises program and the participants of the combined group received intervention including laser and exercise program. An evaluator who was blind to the therapy allocation group performed all the assessment procedures at baseline and after the intervention. Prior to the enrolment, all the participants were given a thorough description regarding the objective and procedure of the study. Each parent was given a consent form to sign indicating their agreement to participate.

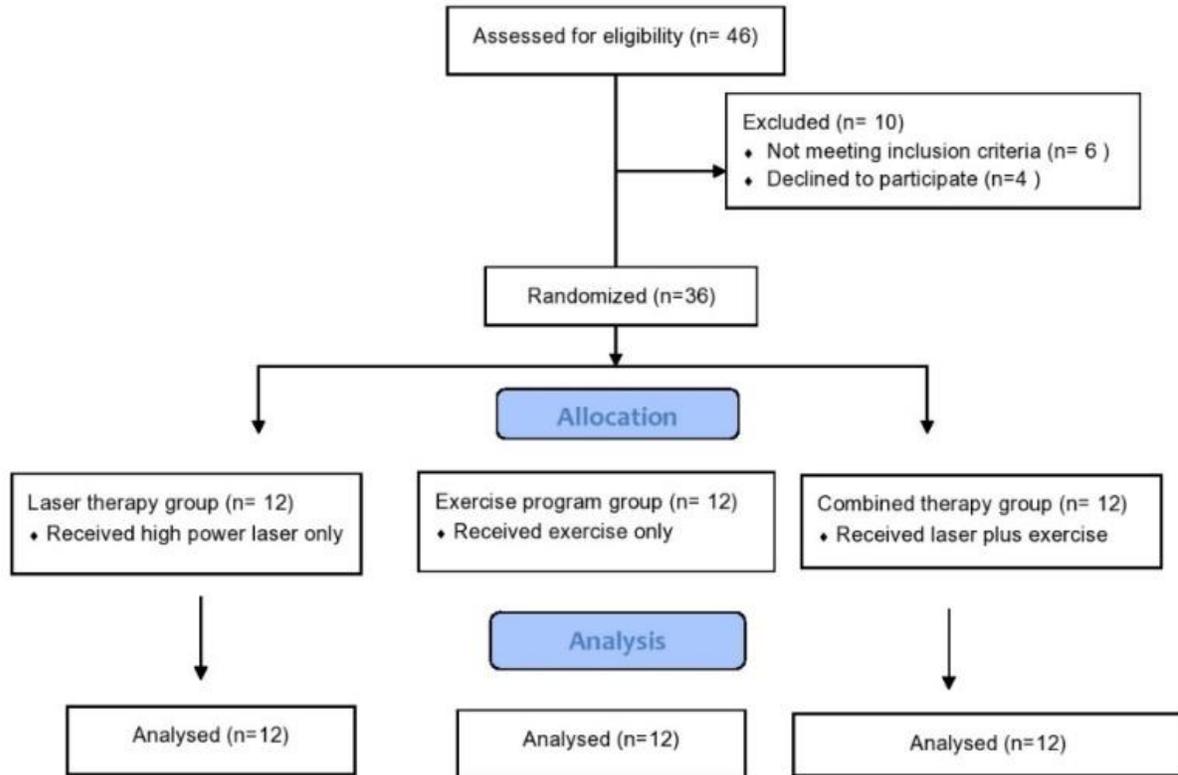


Figure 1. Participants consort flow diagram

2.4. Outcome measures and assessment procedures

2.4.1. Pain, wrist-specific disability, and usual disability

The pain subscale of the patient-rated wrist evaluation (PRWE) was used to assess the severity of pain. The PRWE included a 15-item survey that uses an 11-point (0-10) scale to assess the function of the wrist joint based on patient pain and function. Across a wide range of wrist disorders, the PRWE provides an accurate and sensitive evaluation of wrist-related pain and dysfunction. Moreover, the individual subscales are stable enough to be utilized as independent measurements of pain, wrist-specific disability, as well as usual activity disability (MacDermid, 2015).

The pain subscale was used to evaluate pain at rest, during repeated movements, and while carrying a heavy object, along with the intensity and frequency of pain (5 items). It is an eleven-point scale (0-10) with 0 indicating no pain and 10 indicating the worst pain imaginable or incapacity

to conduct the activity due to pain. The cumulative score was calculated as the total of the five pain items (MacDermid, 2015; Hincapie et al., 2016). PRWE has been evidenced as a valid and responsive wrist function questionnaire (MacDermid et al., 2000; Changulani, 2008; Mehta et al., 2015).

2.4.2. Joint position sense

In healthy volunteers, the goniometry-based active wrist joint position sense test showed poor to fair test–retest reliability and acceptable measuring error. The most reliable wrist joint position sense angle was 20° flexion (Pilbeam & Hood-Moore, 2018). The accuracy or precision with which a joint is repositioned at a particular target angle is evaluated by testing joint position sense (Roijezon et al., 2015). The contralateral matching test (Goble, 2010; Elangovan et al., 2014) or relative reproduction test was used to test joint position sense (Co et al., 1993). The test was conducted by keeping the participant blindfolded. The participant was instructed to return to or match a position of reference. The precision of matching was determined by using a clinical goniometer (Hincapie et al., 2016).

Each participant was made to sit comfortably in blindfolded position with the elbows resting on the table. The researcher attained a random angle on the unaffected wrist. Followed by this, the participants were instructed to take the affected wrist joint to the same position, attained by the therapist on the unaffected wrist joint. The absolute error was found after performing two tests (30 and 45 ° of extension) (Hincapie et al., 2016). The absolute error is the difference in degrees between the references and matched joint angles (Co et al., 1993). One attempt was made for each angle.

2.5. Interventions procedures

2.5.1. Treatment procedure for laser therapy group

A Zimmer Opton pro, integrated high-power class IV laser device (serial N: 15200013306 & REF: 4682, made in Germany, manufactured by Zimmer Medizin Systeme), was used for intervention in the present study. The participant was asked to sit comfortably with the arm supported on the table. Prior to the application of the Laser, the underlying skin surface was cleaned. To protect the eyes from the radiation effects, the researcher and participants were instructed to wear goggles during the period of Laser application. A single laser probe was utilized to provide laser radiation at dual wavelengths of 810 nm and 980 nm simultaneously, and a power density of 1 W/cm² duty cycle 1:1 to the dorsal and palmer aspect of the wrist 8 minutes. The apparatus was set manually to the

analgesic mode 40 J/cm² energy, 80 sec for each point. The overall energy applied to patients during a session was 240 J.

2.5.2. Treatment procedure for exercises program group

Exercise program in form of proprioceptive awareness and joint position sense retraining was given to the participants. The exercises were performed by the participants to strengthen the muscles of wrist joint to improve the wrist joint stability, based on the work of Hagert (2011) and Hincapie et al. (2016) with some modifications.

The first week of rehabilitation started with proprioception awareness using mirror therapy. In mirror therapy, the participant was made to watch the reflection of various movements of the wrist joint of his/her unaffected hand and imitate these movements with the affected hand which was kept hidden behind the mirror. A total of 2 sets were performed by the participant including 10 repetitions each, with a 5-second hold in between each set.

In this study initially, JPS deficiency was managed. Each participant was blindfolded. His/her unaffected side was kept at various angles of wrist extension and flexion. Followed by this, they were directed to replicate the angles with the affected wrist using the same procedure employed for the assessment (contralateral matching). A total of 2 sets were performed by the participant including 10 repetitions each, with a 5-second hold in between each set.

In the second week of rehabilitation, isometric exercises were added to the previous set of exercises. Manual resistance was applied by the researcher in all directions. A total of 2 sets were performed by the participant including 10 repetitions each, with a 5-second hold in between each set. The patient was instructed to avoid performing those activities which caused wrist pain throughout the first and second weeks of rehabilitation.

In the third week of rehabilitation, the researcher increased the weight. This progression started using a weight of 1-pound medicine ball and increased based on the patient's tolerance. A total of 2 sets were performed by the participant including 10 repetitions each, with a 5-second hold in between each set.

In the fourth week of rehabilitation, eccentric exercises of the extensor carpi radialis longus were added by the researcher in the exercise program. The co-activation pattern of the wrist flexors (Flexor Carpi Ulnaris) is influenced by the eccentric contraction of extensor carpi radialis longus, which promotes wrist stability. During the session, the patient executed two sets of 10 repetitions each. Furthermore, when standing and pressing on a softball versus the wall, a controlled weight-bearing exercise was started.

2.5.3. Treatment procedure for combined therapy group

The participants of the combined group received intervention with Laser therapy and exercise program. A total of three sessions per week for four successive weeks were given to the participants.

2.6. Statistical analysis

In the present study, one way ANOVA was done to analyze subject properties between groups. The normal distribution was established using the Shapiro-Wilk test, and the homogeneity between groups was tested using Levene's test. Impact of high-power laser and exercises within and between groups was investigated by mixed MANOVA. In the present study, the significance level was set at $p < 0.05$. All statistical tests were conducted using SPSS version 25 (IBM SPSS, Chicago, IL, USA).

2.7. Sample size

G*POWER statistical software (version 3.1.9.2; Franz Faul, University of Kiel, Germany) was used to calculate the sample size for the present study [F tests- MANOVA: repeated interaction measures, $\alpha=0.05$, $\beta=0.2$, and large effect size=0.48]. The sample size calculated for the study was 36.

3. RESULTS

Table 1 displays baseline demographic characteristics for each treatment group. Non-significant difference was found in the baseline characteristics between all the intervention groups with $p>0.05$.

Table 1. Girls' demographic characteristics at baseline

	Laser Therapy group	Exercises Program group	Combined therapy group	p-value
	$\bar{x}\pm SD$	$\bar{x}\pm SD$	$\bar{x}\pm SD$	
Age (years)	12.7 \pm 1.96	12.83 \pm 2.04	13.17 \pm 1.59	0.84
Height (cm)	152.33 \pm 9.99	152.42 \pm 9.75	155.09 \pm 8.38	0.71
Weight (kg)	45.84 \pm 10.86	47.40 \pm 12.50	47.53 \pm 8.55	0.91
BMI (kg/m²)	19.44 \pm 2.44	20.06 \pm 3.11	19.61 \pm 2.16	0.83

SD, Standard deviation; P-value, level of significance

Treatment and time had a significant interaction (Wilks' Lambda = 0.110; F =15.16, p = 0.000, $\eta^2 = 0.66$). Time had a significant main impact (Wilks' Lambda = 0.00; F =3837.21, p = 0.000, $\eta^2 =0.99$). Treatment had a significant main impact (Wilks' Lambda = 0.25; F = 7.41, p = 0.000, $\eta^2 = 0.49$).

3.1. Effect of treatment on patient rated wrist and joint position sense

The results of three groups on the scales used to measure pain, functioning, and joint position sense are shown in Table 2.

3.2. Within group comparison

In the present study, within group comparison revealed significant improvement (p < 0.001) in all the measured variables.

3.3. Between group comparison

In the present study, non-significant difference was found in all the parameters between all the groups with p > 0.05. Post-treatment comparison of the groups demonstrated a significant improvement in the measured parameters in the combined therapy group compared to the laser and exercises group (p < 0.001). No significant difference was found in any of the measured variables (P > 0.05) on comparison between the laser and exercise groups.

A post-treatment comparison of the groups demonstrated a significant improvement in the measured parameters in the combined therapy group compared to the laser and exercises group (p < 0.001). No significant difference was found in any of the measured variables (P > 0.05) on comparison between the laser and exercise groups.

Table 2. Mean of PRWE and JBS pre and post treatment of all groups

	Laser therapy (I)	Exercises program (II)	Combined therapy (III)	P value		
	Mean \pm SD	Mean \pm SD	Mean \pm SD	I vs II	I vs III	II vs III
PRWE						
Pain						
Pretreatment	41.33 \pm 1.32	41.91 \pm 1.01	42.45 \pm 1.21	0.71	0.08	0.82

Post -treatment	24.41±0.51	23.50±1.78	18.83±0.83	0.19	0.001	0.001
P value	<i>P=0.001</i>	<i>P=0.001</i>	<i>P=0.001</i>			
Functions						
Pretreatment	42.04±1.61	42.87±1.53	41.37±1.46	0.58	0.89	0.06
Post- treatment	24.04±0.96	23.16±1.80	19.16±0.96	0.32	0.001	0.001
P value	<i>P=0.001</i>	<i>P=0.001</i>	<i>P=0.001</i>			
Total score						
Pretreatment	83.37±2.41	84.79±1.77	83.83±2.27	0.36	1.00	0.86
Post- treatment	48.45±1.15	46.66±3.04	38.00±0.70	0.08	0.001	0.001
P value	<i>P=0.001</i>	<i>P=0.001</i>	<i>P=0.001</i>			
JPS						
AT 45°						
pretreatment	9.29±1.11	9.70±0.83	10.12±0.64	0.77	0.08	0.77
Post- treatment	4.16±0.57	4.58±0.90	3.33±0.77	0.57	0.03	0.001
P value	<i>P=0.001</i>	<i>P=0.001</i>	<i>P=0.001</i>			
AT 30°						
pretreatment	9.33±0.74	8.75±0.86	8.25±1.60	0.65	0.07	0.86
Post- treatment	4.83±1.33	4.25±1.65	2.66±0.77	0.84	0.001	0.17
P value	<i>P=0.001</i>	<i>P=0.001</i>	<i>P=0.001</i>			

SD Standard deviation; *MD*, Mean difference; *P-value*, Level of significance.

4. DISCUSSION

To the best of the researcher's knowledge, very few studies were found stating the benefits of high power laser therapy and/or proprioceptive training in patients who have chronic wrist pain. The statistical analysis of the present study revealed significant improvement in the symptoms of non-specific chronic wrist pain in female gymnasts with the additive effect of high power laser therapy to the standard physiotherapy rehabilitation than the standard physiotherapy rehabilitation alone. Significant results were obtained on within-group comparison in all the groups but more significant improvement was found in the combined therapy group.

The results of the present study were found to be consistent with the findings of the study conducted by Ezzati et al. Authors of the present study stated that it is too early to judge whether HILT is a useful non-invasive treatment for musculoskeletal pain because only a few research have proved its clinical usefulness. The addition of associated co-interventions to HILT may improve the laser therapy's beneficial impacts (Ezzati et al., 2020).

The significant reduction in the symptoms of pain with the application of HILT may be attributed to both central and peripheral mechanisms of pain reduction. Laser treatment increases the

secretion of endogenous opioids like β -endorphins in the central nervous system, which centrally suppressed the symptoms of pain (Hagiwara et al., 2008).

Substance P sensitizes pain-transmitting neurons in the peripheral nervous system, resulting in hyperalgesia. Nevertheless, laser treatment was found to reduce the level of substance P secretion via peripheral receptors (Hsieh et al., 2015; Alaya et al., 2016). By suppressing A α - and C-fiber transmission, laser treatment may prolong the latency and lower the conduction velocity of sensory nerves, reducing the transmission of pain signals (Chow et al., 2011).

The laser treatment reduces the release of bradykinin and histamine in the wounded tissues due to which the pain threshold gets increased (Maeda, 1989; King et al., 1990). These numerous effects of laser treatment could indicate the fundamental mechanisms implicated in pain control in different musculoskeletal disorders. Furthermore, in patients with MSD, a reduction in pain sensation has a major impact on increasing quality of life and functional abilities (Pekyavas & Baltaci, 2016).

The results of the present study came in agreement with the work of many investigators who stated that HILT was more successful in treating pain in patients with different musculoskeletal disorders (Fiore et al, 2011; Alayat et al., 2017; Chen et al., 2018; El-Shamy & Abdelaal, 2018; El-Shamy et al., 2018; Ordahan et al., 2018).

In accordance top the results of the present study, HILT was found to be beneficial in lowering pain, enhancing functional ability, and boosting locomotor efficiency in children with hemophilic arthropathy. It must be used in conjunction with an exercise program to improve the quality of life of the affected individuals (El-Shamy& Abdelaal, 2018).

The results of the study were consistent with a study conducted by El-Shamy et al., (2018) on children with JRA. The authors of the study stated that HILT was found to be more beneficial when paired with an exercise program than a placebo laser technique with exercises

Similarly, the results of the current study were in accordance to a study conducted by song et al. They reported that HILT treatment for different musculoskeletal disorders considerably enhanced pain and disability scores when compared to controls (Song et al., 2018).

Besides the beneficial effect of laser alone and/or combined with exercises, our results also demonstrated that the exercises alone have significant effect and this is in line with the findings of Hincapie et al. (2016), who stated that sensorimotor approaches such as proprioceptive retraining can help individuals with chronic wrist pain enhance their pain, neuromuscular control, and functional results.

The present study had several limitations. The study included female gymnasts with non-specific chronic wrist pain as the participants. Secondly, in the present study, the immediate effect of

the HILT was observed. No follow-up was included. On the other hand, when it comes to evaluate JPS, researchers agreed that the manual goniometers might not be as accurate and repeatable as more sophisticated equipment (Gay et al., 2010; Clark et al., 2015). Nevertheless, the procedure adopted in this study is simply replicable for a hand therapist with a goniometer who could evaluate and retrain JPS. Because controlling the speed and degree of joint movement manually is challenging, this study concentrated on assessing JPS rather than kinesthesia (movement detection threshold). In the future, researchers may focus on conducting comparison studies between laser and other electrotherapy modalities.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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