Original Article

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Short-term effectiveness of a physiotherapy programme in young athletes with Osgood-Schlatter syndrome

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Abstract: Osgood-Schlatter syndrome (OSS) is a prevalent overuse injury of the patellar ligament that has recently exhibited a marked increase among young athletes. The syndrome predominantly afflicts male athletes between the ages of 10 and 15 years and female athletes between the ages of 8 and 13 years. Potential risk factors for the development of OSS include excessive sporting loads, specific types of loads, the characteristics of the sporting terrain, and the athletes' physical growth. The objective of this study was to ascertain the short-term effects of a physiotherapy-kinesiology rehabilitation program in young athletes with OSS.Twenty participants (aged 13–16 years) completed an intensive 6-week program consisting of strength training, focused extracorporeal shockwave therapy (fESWT), and magnetotransduction therapy (EMMT) (18 sessions). At the commencement and conclusion of the program, a comprehensive array of data was collected, encompassing body composition, contractile properties of the anterior (rectus femoris (RF), vastus medialis (VM), vastus lateralis (VL)) and posterior (biceps femoris (BF)) thigh muscles, and VAS pain levels. The findings of the study substantiate the salutary impacts of the rehabilitation program on young athletes afflicted with OSS. The rehabilitation program led to an increase in overall muscle mass, as well as in the dominant and non-dominant leg muscles. Additionally, it resulted in a reduction in the percentage of fat mass. Statistical analysis revealed that the dominant and non-dominant leg exhibited shorter contraction times (Tc), increased muscle tone, and decreased radial displacements of the muscle belly (Dm) in the RF, VM, VL, and BF muscles. Furthermore, the relaxation time (Tr) of the BF muscle was significantly reduced in both legs. The program also led to a substantial reduction in VAS pain levels, from 83.0±5.9.0 to 10.0±2.9, suggesting a positive impact on pain management. These findings indicate that a multimodal approach, integrating strength training, focused extracorporeal shockwave therapy (fESWT), and magnetotransduction therapy (EMMT), can offer effective short-term relief and promote functional improvements for young athletes affected by OSS.

Keywords: physiotherapy, exercise, Osgood-Schlater syndrome, rehabilitation, youth sport

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INTRODUCTION

Osgood-Schlatter syndrome (OSS), first described in 1903 [1,2], is an injury to the patellar ligament (osteochondrosis of the knee). OSS occurs between the ages of 10 and 15 years in boys and between the ages of 8 and 13 years in girls [3]. At least 10% of adolescents worldwide have OSS, with a recent increase in adolescent athletes [4]. Typical symptoms include a severely swollen knee and severe pain when walking downstairs, sitting for long periods at school, squatting, running on hard surfaces [5], and limited participation in sports. Only the dominant knee is affected in the majority of cases due to the greater stress during sports activities, although it can be bilateral in 20-30% of cases [6].

Most studies describe conservative physiotherapy treatment of the injury with exercise intervention [1,6]. In OSS, we do not know the specific cause of the injury, but it is thought that micro-injuries occur at the patellar ligament outgrowth due to athletic stress. The higher the load and the greater the traction on the RCL, the earlier the young athlete is at risk for injury [5]. OSS can also occur in adolescents who grow rapidly in a short period of time (10 cm or more in a year) [4,5]. The tightness or increased muscle tone resulting from rapid growth of the long bones (femoral condyles) can cause a strong pull of the rectus femoris on the patellar ligament (tibial tubercle) [8].

Excessive training loads in young athletes cause irritation of the quadriceps process and swelling, which later results from inflammation of the soft structures around the patellar tendon process. During the same period, physical development is also an important factor influencing the occurrence of OSS with overuse (rapid increase in height and thus body mass) [9]. A common hypothesis on the etiology of OSS suggests that the asynchronous development of bone (femoral condyle) and soft tissues (quadriceps femoris muscle), especially the rectus femoris muscle, during puberty is a possible cause [8]. The traction force of the muscle causes irritation and, in severe cases, partial avulsion of the apophysis of the tibial tubercle. The traction force increases with intense athletic activity and especially after periods of rapid growth during puberty [9].

Muscular factors are critical in the development of OSS. Enomoto et al [10] point out that a rectus femoris muscle, characterized by high muscle tone due to rapid growth and intensive training, significantly influences the growth of the patellar ligament. This stiffness reduces knee joint mobility and increases ligament traction, increasing the risk of OSS [11].

Onset of OSS typically lasts from 6 to 18 months [12]. In 20 to 30% of cases, OSS occurs in both knees (bilateral), but in the majority of cases, the onset is in one knee (usually the dominant limb, which is more stressed during sports activities) [6].

Over the last 10 years, it has been observed that young athletes in Slovenia are taller and heavier at a certain age, and have a higher fat mass on average [15]. A similar trend of increasing body size and percentage of fat mass can be observed in other countries around the world [16,17]. Higher body mass and low muscle strength are also factors that can lead to OSS [18]. In most cases, the muscle strength of young athletes is at a low level and they are not capable of high loads in the training process [4,13,14]. One of the important factors in the occurrence of OSS is the dominance of the limb (dominant leg) [4], which can be heavily loaded unilaterally in certain sports disciplines. Asymmetric sports such as soccer, tennis, basketball, dance, figure skating, and handball place a greater load on the dominant limb - the leg (left limb in right-handed athletes, right limb in left-handed athletes) [19].

The main morphological risk factors for OSS are: 1) tall height, 2) increased body mass or body mass index (BMI), 3) decreased mobility of the thigh muscles (anterior and posterior thigh muscles), 4) height of the inner longitudinal arch of the foot (risk increases with higher arch), 5) previous diagnosis of Sever's pathology [20], 6) limited dorsal ankle flexion to 10° or less [21], 7) tibial rotation (increase in condylo-maleolar angle and external rotation of the tibia) [22], and 8) co-occurrence of valgus knee and foot pronation [23].

According to the authors, a long-standing problem in sports is the unsystematic approach to physical training, which is necessary for the prevention of knee joint injuries, as it is known from studies and clinical practice that most sports techniques and loads cause or require a high level of exertion/loading of the leg/knee joint musculature [24–27].

The main question we wanted to address in the study was the effectiveness of a selected physiotherapy-kinesiology rehabilitation program in young athletes with Osgood-Schlatter disease (OSS). Therefore, we tried to evaluate some short-term effects of the program on individual body components: 1) lean body mass and dominant and non-dominant leg muscle mass, 2) neuromuscular components such as muscle contraction time (Tc), muscle relaxation time (Tr), and dominant and non-dominant limb muscle contraction displacement (Dm), and 3) reduction of VAS pain score in young athletes with Osgood-Schlatter syndrome (OSS).

MATERIAL AND METHODS

Participants

The sample consisted of a total of 20 elite young male athletes aged 13 to 16 years diagnosed with Osgood-Schlatter syndrome (13 years - N4, 14 years - N2, 15 years - N2 and 16 years - N12). They were all categorized by the National Olympic Committee of Slovenia and were mainly members of national teams. The participants were examined at the beginning and at the end of the physiotherapy program. During the measurement period, subjects were required to be relatively rested, not to have performed high-intensity training immediately or the day before the measurements, and to ensure adequate nutrition and hydration. They did not exercise at school or in a club during the rehabilitation sessions.

Ethical approval

The study protocol was approved by the National Committee for Medical Ethics of the Republic of Slovenia (No. 0120-239/2023/7). The study was conducted in accordance with the tenets of the Declaration of Helsinki.

Measurement methods

Measurements and diagnostics were performed in the laboratory of the Global Treatment Clinic in Ljubljana. There we also carried out a physiotherapy and kinesiology treatment program for young athletes with Osgood-Schlatter syndrome.

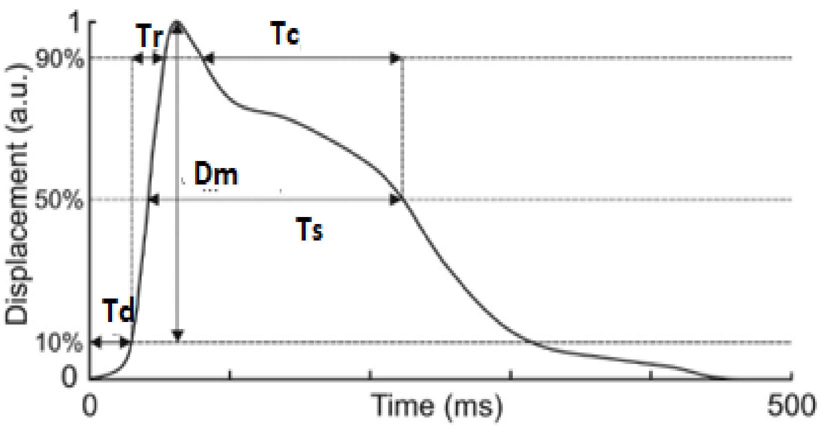

Figure 1. TMG muscle parameters [28].

Measurement instruments

Body composition analysis (Tanita 780 MA system, Bia Technology, Japan: body height (BH), body mass (BM), % fat mass, % total muscle mass, % muscle mass of the dominant and non-dominant leg, body mass index (BMI)).

We performed a manual examination of both knees (assessment of knee joint mobility with a goniometer (ROM: flexion and extension of the knee joint).

All subjects underwent TMG measurement - tensiomyography (TMG - TMG-BMC, Slovenia), a diagnostic method for detection and evaluation of mechanical and contractile properties of thigh muscles. It is a non-invasive detection of contractile properties of skeletal muscles using a technique that selectively measures the time courses of radial displacements of the muscle belly [28]. We analyzed the rectus femoris (RF), vastus medialis (VM), vastus lateralis (VL) and biceps femoris (BF) muscles of the dominant and non-dominant leg. Parameters measured: 1. Tc - muscle contraction time (the time from 10% Dm to 90% Dm), 2. Dm - maximum amplitude or radial displacements of the muscle belly and 3. Tr - muscle relaxation time (time between 90% contraction (Dm) and 50% relaxation (Dm)) (Figure 1).

The calculation of the patellar functional symmetry coefficient (FSp) involves the assessment of the balance between the vastus medialis (VM) and vastus lateralis (VL) muscles. As described by Stella et al [29], this metric is commonly used to assess the functional coordination of these muscles, which is critical for knee stability and proper patellar tracking. FSp is typically derived from measurements such as muscle contraction time (Tc) or displacement (Dm) using TMG (tensiomyography). To calculate FSp, the values of VM and VL are compared, often expressed as a ratio or percentage that indicates their functional balance. Significant asymmetry in FSp could indicate potential risk for knee instability or predisposition to injury.

Subjects completed the Visual Analogue Scale (VAS) Pain Severity Questionnaire. The Visual Analogue Scale (VAS) is a psychometric instrument that measures the intensity of pain in the presence of a specific injury, as it cannot be measured directly in clinical trials [30]. In our case, we measured the degree of pain felt by the patient on a scale from 0 - no pain to 100 - severe pain [31]. Operationally, the VAS is a horizontal line 100 mm long with verbal descriptors at each end [32].

The first (initial) measurement of each subject was taken 1 day before the start of the rehabilitation program and the second (final) measurement was taken 1 day after the end of the rehabilitation program (after 6 weeks - 18 treatments).

Physiotherapy program: Sequence of procedures of a multi-component OSS rehabilitation program, including exercises, for young athletes with OSS based on evidence-based physiotherapy and applied kinesiology. Subjects received 3 treatments per week for 6 weeks (18 treatments in total) - followed by control measurements at time 2. The study lasted 24 weeks, with 5 subjects receiving the treatment program simultaneously over a 6-week period. Musculoskeletal activation was improved by exercise (strength training) followed by physiotherapy methods such as Focused Extracorporeal Shockwave Therapy (fESWT) (Storz Medical) and Extracorporeal Magnetotransduction Therapy EMMT (Storz Medical).

Exercise program OSS: 1) Warm up: bike 10 min - pedaling frequency 60 watts (indoor bike), 2) Exercise according to a designed exercise protocol for each subject according to ability: each exercise was performed in 3 sets of 10 repetitions; 1 min rest between sets, 2 min between exercises; at the beginning of the program (treatment 1), the maximum strength of 10RM was measured in each subject and then the cut-off weights were determined:

- Squeeze ball with knees and hold for 2 seconds
- One leg toe raises (left and right leg - no rest between leg changes)
- One leg hip extension with cable (left and right leg - no rest between leg changes)
- Single leg knee curl (left and right leg - no rest between leg changes)

- Single leg eccentric lowering (double leg knee extension) - hold for 3 seconds and slowly lower to starting position (left and right leg - no rest between leg changes)

Focused extracorporeal shockwave therapy (fESWT) for patellar tendon (3rd, 6th, 9th, 12th, 15th therapy) (Masterpuls MP 50, Storz, Switzerland). Pneumatically generated acoustic pulses were delivered throughout the painful area using a mobile applicator. The subject was seated on a physiotherapy table with the knee flexed at 90°. Shock waves were applied to the patellar tendon with a power of 1.5 bar and a duration of 2000 Hz [33]. After shock wave application, EMMT was followed by analgesic therapy.

Extracorporeal magnetotransduction therapy (EMMT) (analgesic therapy after focused shock wave therapy and strength training) 3000 pulses (6 Hz level) - analgesic therapy [34].

Data processing and analysis

Data were entered into Microsoft Office Excel and then analyzed using IBM SPSS Statistics 23. Before comparing results and assessing progress, the Shapiro-Wilk test was used to assess the normality of the distributions of numerical variables. For variables that deviated from a normal distribution, nonparametric tests (Mann-Whitney U test, chi-square test, Wilcoxon signed-rank test) were used to assess differences between baseline and follow-up measurements. Comparative statistical analysis was used to examine and compare the participants' physical characteristics, physical and neuromuscular components, and pain levels (measured using the VAS scale) at two measurement points: pre-treatment (1st measurement - initial) and post-treatment (2nd measurement - final).

The Shapiro-Wilk test indicated that anthropometric variables and symmetry measures followed a normal distribution ($p > 0.05$), while some muscle and flexibility related variables deviated from normality ($p \leq 0.05$). VAS results also indicated possible deviations from normality, although not statistically significant (before treatments: W=0.915; p=0.078 / after treatments: W=0.912; p=0.069). Since the analyses were performed on a small sample (n=20) and certain deviations from normality were observed in the visual representation of the data as well as in the examination of the skewness and kurtosis coefficients, we decided to present the results using the median and IQR, and non-parametric tests (Mann-Whitney U test, chi-square test, Wilcoxon signed-rank test) were used to assess the differences between the initial and final measurements.

RESULTS

Table 1 shows the results of the initial and final measurements of height, body mass, body mass index (BMI), fat mass, bone mass, muscle mass, muscle mass of the dominant and non-dominant leg, and the differences between the two measurements. The results show a statistically significant increase in body mass (BMI) between the initial and final measurements ($Z = -2.451$, $p = 0.014$), whereas no differences were found for body height (BH) ($p = 1.000$) and body mass index (BMI) ($p > 0.05$). Body weight increased from a mean of 62.7 kg (SD = 16.0) to a mean of 63.1 kg (SD = 15.9) ($p = 0.001$). The experimental group achieved a mean increase in muscle mass of 2.1 kg ($p < 0.001$). The increase in muscle mass in the dominant leg was 0.5 kg in the experimental group and 0.8 kg in the non-dominant leg ($p = 0.001$), which also supports a clinically significant improvement.

However, we also found a statistically significant decrease in fat mass in the experimental group, which averaged 11.2% (SD = 4.6) at baseline and 10.3% (SD = 3.9) at baseline ($p = 0.001$), indicating a positive effect of the rehabilitation program on body composition by reducing fat mass while increasing muscle mass (Table 1).

Table 1. Body height, body mass and BMI, Fat mass, bone mass, muscle mass, dominant and non-dominant leg muscle mass - comparison between initial and final measurements (before and after physiotherapy program).

Indicator	Before treatments			After treatments			Z	p
	Q1	median	Q3	Q1	median	Q3		
Body height (cm)*	166.0	177.0	181.8	166.0	177.0	181.8	0.000	1.000
Body mass (kg)	50.9	67.5	75.3	67.6	50.8	67.6	2.451	0.014
BMI (kg/m^2)	18.3	20.8	22.8	18.2	21.0	22.7	1.281	0.200
Fat mass (%)*	7.9	10.8	15.1	7.1	9.9	13.8	3.361	0.001
Bone mass (kg)	2.3	2.8	3.4	2.3	2.8	3.4	0.000	1.000
Muscle mass (kg)*	42.0	54.4	64.2	44.0	56.6	66.4	3.926	<0.001
Muscle mass dominant leg (kg)*	7.8	9.6	11.1	8.2	10.3	11.6	3.927	<0.001
Muscle mass non-dominant leg (kg)*	7.4	9.3	10.7	8.2	10.1	11.5	3.932	<0.001

* the difference between the initial and final measurements is statistically significant (p < 0.05).

Table 2. Mobility of the injured knee (ROM knee flexors, extensors) - comparison between initial and final measurements (before and after physiotherapy program).

Indicator	Before treatments			After treatments			Z	p
	Q1	median	Q3	Q1	median	Q3		
ROM knee flex (°)*	137.0	140.5	143.0	148.0	149.0	150.0	12.500	<0.001
ROM knee ext (°)*	0.0	1.0	2.0	0.0	0.0	0.0	80.000	0.001

* the difference between the initial and final measurements is statistically significant (p < 0.05).

Table 2 shows the results of the initial and final measurements of knee ROM (flexion, extension of the knee). The results showed clinically significant improvements in knee flexion and extension. Mean knee flexion improved by 8.5° ($p < 0.001$), and knee extension also improved significantly by a mean of 1.5° ($p < 0.05$).

Figure 2A shows the results of the initial and final measurements of the contractile properties of the rectus femoris (RF) muscle in both the dominant and non-dominant legs as assessed by the TMG method. In the experimental group, RF muscle contraction time decreased on average by 4.2 ms ($p < 0.001$) in the dominant leg and by 4.4 ms ($p < 0.001$) in the non-dominant leg (Figure 2A). RF muscle tone (Dm) decreased on average by 2.2 mm ($p < 0.001$) in the dominant leg and by 2.6 mm ($p < 0.001$) in the non-dominant leg (Figure 2C). Although muscle relaxation time (Tr) showed a mean decrease in both legs, the changes did not reach statistical significance at the 5% error threshold (Figure 2B).

The results of the Wilcoxon test indicate statistically significant differences in the contractile properties of the biceps femoris muscle between the baseline and final measurements for most parameters. In the experimental group, the contraction time (Tc) of the BF muscle decreased on average by 8.5 ms ($p < 0.001$) in the dominant leg and by 2.7 ms ($p < 0.001$) in the non-dominant leg (Figure 2A). Relaxation time (Tr) of the BF muscle decreased on average by 14.8 ms ($p < 0.001$) in the dominant leg and by 25.2 ms ($p < 0.001$) in the non-dominant leg (Figure 2B), whereas muscle displacement (Dm) showed a decrease that did not reach statistical significance in the non-dominant leg ($p = 0.057$) (Figure 2C).

The subjects included in our study reported a significant reduction in subjective pain perception according to the VAS scale. This is indicated by the large differences in median and mean scores between baseline and final scores, and is confirmed by the Wilcoxon test ($p < 0.001$). In the experimental group, pain decreased significantly from 83.1 ± 5.9 at baseline to 10.1 ± 2.3 at follow-up ($p < 0.001$) (Figure 3A).

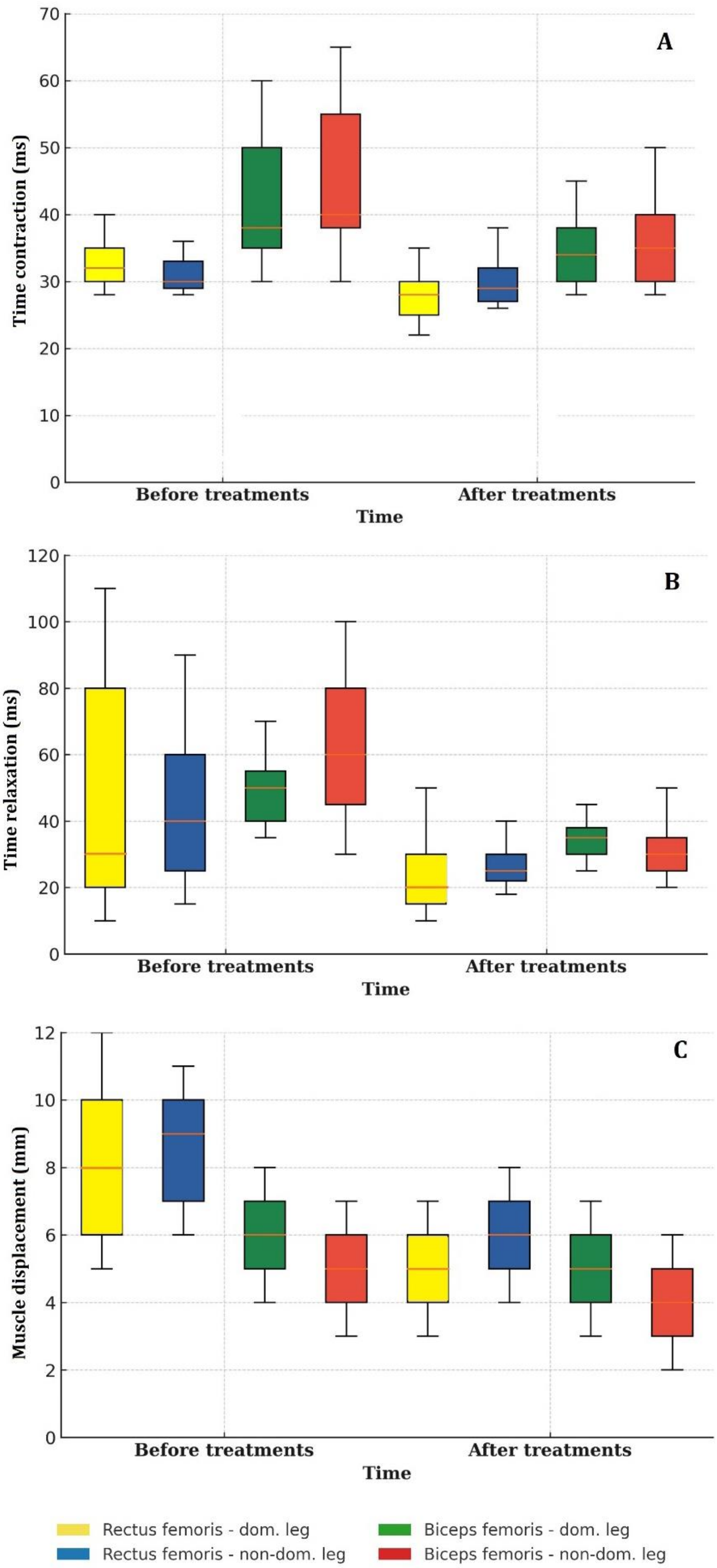

Figure 2. TMG of the rectus femoris and biceps femoris muscles on the dominant and non-dominant leg, comparing initial and final measurements (before and after physiotherapy program).

Figure 3B summarizes the differences in muscle symmetry between the vastus medialis (VM) and vastus lateralis (VL) muscles for both the dominant and non-dominant legs before and after the 6-week physiotherapy program. The results show a statistically significant improvement in functional symmetry scores for both the dominant and non-dominant legs ($p < 0.001$). In the dominant leg, symmetry scores increased from a median of 85.5% before treatment to 90.5% after treatment, with the mean score increasing from 85.6 ± 4.1% to 90.9 ± 1.7%. Similarly, in the non-dominant leg, median functional symmetry improved from 85.0% to 91.0%, and the mean score increased from 85.5 ± 6.1% to 91.5 ± 2.5% (Figure 3B).

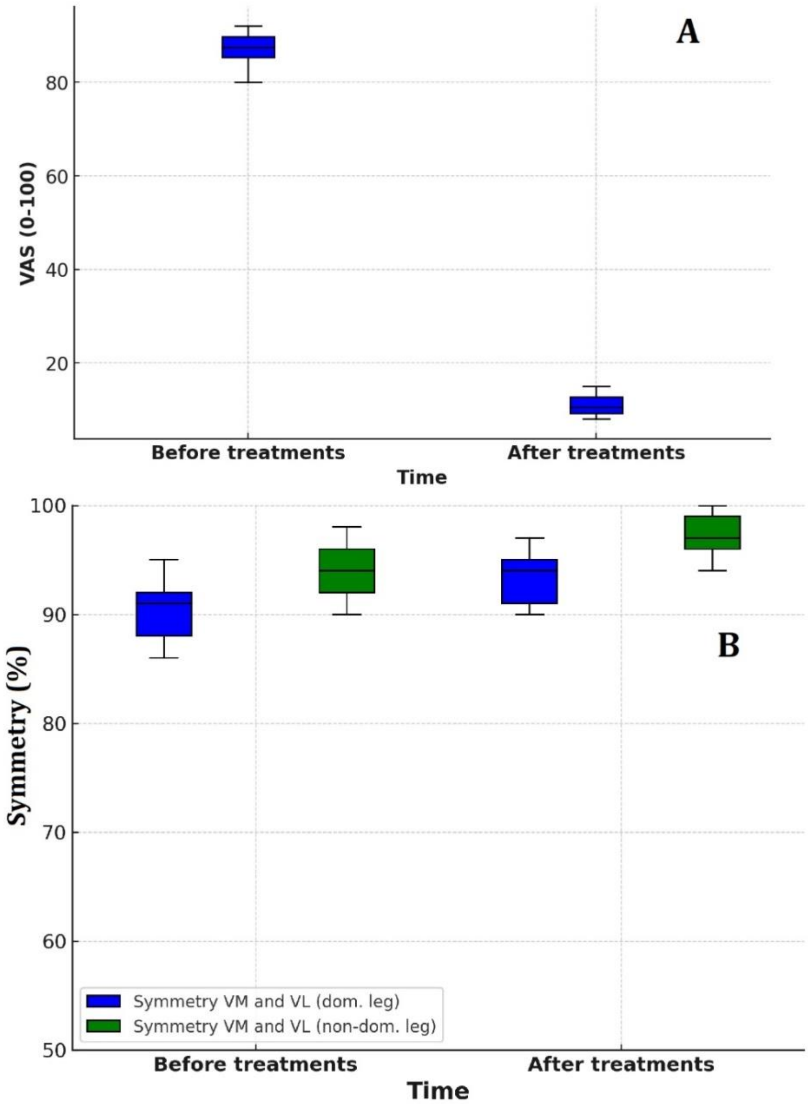

Figure 3. Pain on the VAS scale - comparison between initial and final measurements (before and after physiotherapy program) (Figure A), and testing differences over time in muscle functional symmetry VM and VL (dominant and non-dominant leg) - comparison between initial and final measurements (before and after physiotherapy program) (Figure B).

DISCUSSION

The results of the study confirm the positive effects of a multi-component rehabilitation program, including exercise, for young athletes affected by OSS. Based on the results, we can conclude that our program increased the total muscle mass, the muscle mass of the dominant and non-dominant leg, and reduced the percentage of fat mass. By measuring the contractile properties of the rectus femoris, vastus medialis, vastus lateralis and biceps femoris muscles, we found a shorter contraction time (Tc) in the dominant and non-dominant leg, as well as an increase in muscle tone and a decrease in muscle belly displacement (Dm). Muscle relaxation time (Tr) was statistically significantly reduced only in the biceps femoris muscle, both in the dominant and non-dominant leg. These adaptations contribute to improved knee joint stability, reduced patellar ligament tension, and improved functional performance of the knee. The rehabilitation program significantly reduced the subjective level of pain sensation on the VAS scale or significantly exceeded the criterion (10 out of 100), which is considered by researchers to be a clinically significant change in adolescents [31]. The reduction in pain, as indicated by the very large reduction in VAS scores, underscores the effectiveness of the program in alleviating the primary symptom of OSS. The incorporation of focused extracorporeal shockwave therapy (fESWT) and magnetotransduction therapy (EMMT) likely played a critical role in achieving these results, as previous studies have highlighted their efficacy in reducing musculoskeletal pain and promoting tissue healing [33,34].

Of particular note are the observed improvements in muscle functional symmetry between the vastus medialis (VM) and vastus lateralis (VL). Functional symmetry is critical for maintaining proper patellar tracking and preventing excessive stress on the knee joint during dynamic movements in sports. The success of the rehabilitation program in addressing this aspect reinforces the importance of designing interventions that target both the anterior and posterior thigh muscle groups.

Most authors believe that the main cause of OSS is the prolonged traction of the patellar tendon and the repetitive stress caused by strong and forceful traction of the quadriceps (rectus femoris, vastus lateralis, vastus medialis) and the patellar ligament, which is located on the apophyseal cartilage of the anterior tibial tubercle, combined with changes that occur during rapid body growth (rapid growth of the femoral bones) [35]. The changes during puberty are of particular interest in the context of youth sport, when the process of accelerated adolescent growth occurs around 8 to 10 years of age in girls and 10 to 12 years of age in boys [36].

The exercise protocol, designed for each subject according to ability, showed short-term effects on body weight gain, total muscle mass, and dominant and non-dominant leg muscle mass. As expected, the exercise also resulted in a reduction in fat mass in the young athletes. The selection of exercises and loads was aimed at strengthening the anterior and posterior thigh muscles (quadriceps femoris and biceps femoris), hip adductors, hip extensors (gluteal muscles) and ankle extensors (calf muscles). After 18 training sessions, the expected positive effects were achieved, which were also reflected in the improvement of the contraction time (Tc) and relaxation time (Tr) and the increase of the muscle tone (Dm) of the rectus femoris and biceps femoris muscles of the dominant and non-dominant leg.

A multi-component OSS rehabilitation program, including exercise, demonstrated a significant effect on the neuromuscular components of the vastus medialis, vastus lateralis, rectus femoris (knee extensors), and biceps femoris (knee flexors) muscles. The results indicate that exercise improves muscle contraction time (Tc), whereas inactivity worsens it. Improved contraction time reflects more efficient muscle function, which improves knee stability and reduces the risk of injury. In contrast, inactivity or lack of specific strength training can lead to a decrease in muscle contraction time, increasing the risk of knee injury.

The reduced muscle relaxation time (Tr) after the OSS rehabilitation program indicates an improved ability of the biceps femoris muscles to relax quickly after activation, which improves coordination, stability, and force control in the knee joint. The results suggest that shortening the relaxation time with exercise may: 1) contribute to greater safety of the knee joint during loading (running, jumping), 2) reduce the risk of injury due to excessive muscle tension, and 3) improve knee functionality and movement quality (intermuscular coordination). However, during periods of inactivity, the relaxation time is prolonged, which can lead to less than optimal muscle function and an increased risk of knee joint injury.

Muscle symmetry is a critical parameter for maintaining knee stability, proper joint function, and injury prevention. In the dominant leg, symmetry scores increased from a median of 85.5% before treatment to 90.5% after treatment, with the mean score increasing from 85.6 ± 4.1% to 90.9 ± 1.7%. Similarly, in the non-dominant leg, median functional symmetry improved from 85.0% to 91.0% and the mean score increased from 85.5 ± 6.1% to 91.5 ± 2.5%. These improvements highlight the effectiveness of the program in addressing muscle imbalances. By reducing asymmetry, the intervention likely contributed to improved patellar tracking and reduced the risk of knee joint overload. Importantly, the observed increase in symmetry of 5.3% in the dominant leg and 6.0% in the non-dominant leg underscores the potential of the program to restore balanced muscle function, which is essential for optimizing joint health and athletic performance.

An imbalance in the strength of the quadriceps femoris and the posterior thigh muscles (biceps femoris) affects their agonist-antagonist relationship with the two-jointed thigh muscles (rectus femoris & biceps femoris) [37]. A number of other important movement patterns have a major influence on the occurrence of OSS (jumping, sprinting, leg kicks and changes in running direction), the increase in muscle mass and strength that occurs at puberty (especially in boys), the decrease in quadriceps flexibility and stiffness [38]. From our results, we can conclude that regular and systematic strength training of the leg muscles is crucial to establish symmetry between the anterior (QF) and posterior (BF) thigh muscles and to maintain adequate muscle tone, as this reduces complications and long-term absence from training when OSS occurs.

One of the main goals of physical therapy is to reduce pain. The combination of exercise intervention, fESWT, and EMMT showed positive results in measuring the level of pain according to the VAS scale. After the exercise program, focused shock wave therapy (fESWT) and EMMT significantly reduced the pain level in all subjects. Before the rehabilitation program, the pain level was high (83.1 ± 5.9) and after the rehabilitation program, the pain level was very low (10.1 ± 2.3). The results of the study show that the chosen rehabilitation program can increase the muscle mass of the leg muscles, as well as the functional capacity of these muscles (contraction time (Tc) and relaxation time (Tr)) and muscle tone (Dm). This, in turn, has an impact on the reduction of knee pain in young athletes with OSS, which is essential both for normal life (walking to school, climbing stairs, participating in sports training) and for reintegration into the athletic training and competition process.

The study is consistent with previous research highlighting the role of exercise (strength training) and physical therapy in the management of OSS. However, the inclusion of innovative modalities such as fESWT and EMMT differentiates this program and provides a more comprehensive approach to the rehabilitation of OSS. While the existing literature often emphasizes rest as the primary treatment for OSS [1], this study demonstrates that an active, multi-component rehabilitation program, including exercise, can achieve better results in a shorter period of time.

LIMITATION

It is important to recognize that the results of the study are limited to short-term effects; the long-term outcomes of the rehabilitation program and the potential recurrence of symptoms remain uncertain, highlighting the need for further research. To extend the current research and deepen the understanding of rehabilitation programs for OSS, future studies could include additional methodologies: 1) periodic follow-up of the same group of athletes (maintenance of results after the end of therapy), with repeated measurements at different time points (e.g, 3, 6, and 12 months post-rehabilitation), 2) the use of surface electromyography (EMG) during stability, strength, and proprioception exercises to identify which muscles are under greater stress and how they adapt after OSS injury, 3) the inclusion of surveys or interviews in addition to pain scales such as the VAS to capture athletes' perspectives on functional improvement, motivation, and confidence in returning to sport, 4) addressing the sample limitations of this study by including a larger and more diverse population, thereby increasing the validity and generalizability of the findings, 5) addressing some other important factors such as dynamic stability of the knee joint, and 6) adding a control group of participants who received conservative physiotherapy treatment for OSS with exercise intervention or even complete rest.

CONCLUSION

The exercises in the OSS rehabilitation protocol improved functional symmetry (FS) between the vastus medialis (VM) and vastus lateralis (VL) muscles, which is critical for injury prevention and long-term knee joint stability. Addressing the observed imbalance highlights the importance of targeted strengthening to minimise asymmetry, ensure even force distribution across the knee joint and reduce the risk of patellar ligament injury.

This study confirms the short-term effectiveness of a combination of exercise intervention, ESWT and EMMT in the treatment of young athletes with Osgood-Schlatter syndrome (OSS). Improvements in muscle function, body composition and pain reduction underline the value of the programme in accelerating recovery and allowing a faster return to training and competition.

Understanding the physical changes that adolescents undergo during growth spurts is critical for youth sports professionals. Greater awareness of injury risks and tailored interventions can help young athletes maintain participation and reach their full potential. This research makes a valuable contribution to physiotherapy and kinesiology, providing evidence-based evidence to improve clinical practice and support the development of safer, more effective rehabilitation protocols for young athletes.

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