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PULL-OVER: THE APPLICATION OF PHYSIOTHERAPY TREATMENTS FOR SPORT CLIMBERS WITH PULLEY INJURY

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Summary: The objective of this research is to assess the condition of sport climbers with pulley injuries, to apply a complex physiotherapy programme and to evaluate the effectiveness of the treatment.

Our study was carried out at the Kézklinika in Budapest between June and October 2024. Ten active sport climbers with injuries sustained at least five days prior to the assessment were investigated. For the assessment we used pain scores (VAS), mobility, muscle strength, flexibility and special tests. The physiotherapy intervention consisted of passive and active elements, comprising 10 sessions of 40 min each. Descriptive statistics were calculated using MS Excel, with results expressed as mean ± standard deviation (SD), as well as median (Me) and interquartile range (IQR). To assess changes, the Wilcoxon signed-rank test was applied, with a significance level set at $p \leq 0.05$.

The study involved 10 participants (6 men), with a mean age of 293 ±10.9 years. The main complaint was pain, which was eliminated after treatment. The distal interphalangeal joint (DIP) flexion motion showed a strong significant change on both sides. Muscle strength on the affected side of the EDC showed a 16,3% increase. Finger flexors on the affected side with a half-closed grip at 25mm edge and 20 mm edge showed a strong significant improvement ($p = 0.008$, $p = 0.007$).

All assessed modalities showed positive changes, allowing a return to climbing. Properly structured rehabilitation and prevention programmes can help prevent further injuries.

Keywords: *sport climbing, pulley injury, hand function, physiotherapy*

1. INTRODUCTION

Until the second half of the 20th century, sport climbing served as a training tool for mountaineering. Today, it has become a sport – in its own right –, and made its first appearance at the 2020 Olympics in Tokyo. Sport climbing is a full-body sport. With an increasing focus on vertical or overhanging walls, greater strain is placed on the hands and fingers. Since its inclusion in the Olympics, the popularity of the sport has continued to grow. [1] There are more than 44.5 million climbers worldwide, and half of them started their climbing career after the Olympic Games. [2] In Hungary,

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the number of climbers registered in 2023 was 2,256 and in 2024, a total of 66 associations were listed in the Hungarian Mountaineering and Sport Climbing Federation. [3] The importance of this topic is also highlighted by the number of injuries: around 75% of elite and recreational sport climbers report upper limb injuries, and roughly 30% have specific signs of pulley tears, which are associated with a reduction in muscle strength and a loss of full range of motion (ROM) in the fingers. [4] On the long fingers there are 5 annular pulleys (A1-A5), 3 cruciate pulleys (C1-C3). The A2, A4 pulleys are wider, stronger and attach directly to the bone, while the others are less rigid and are attached to the palmar plates above the joints.[1, 5] Their function is to eliminate lateral movements, prevent bowstringing, convert linear forces into torque, increase flexor tendon strength and reduce friction through lubrication. [1, 5, 6] Different types of holds apply different forces to the flexor tendons and annular ligaments. The full crimp increases the forces placed on the A4 pulley by 3.9 times compared to the open grip, while the A2 pulley experiences an increase of 31,5 times. Therefore, the A2 pulley is more likely to be damaged. [7]

Although this type of injury is becoming more common, it is often underestimated and given little attention, which can lead to progression of the injury. In the early (mild) stage, finger injuries are easily overlooked and neglected by enthusiastic climbers. However, the truth is that climbing with an injured finger can exacerbate the injury and significantly extend recovery time, potentially doubling or tripling it. [8] This is also why it is necessary to design a well-constructed rehabilitation and prevention programme that can be used with confidence by both those who are affected and those medical professionals who are not familiar with sport climbing.

The objective of this research is to assess the condition of athletes with pulley injuries, to apply a complex physiotherapy programme and to evaluate the effectiveness of the treatment.

2. Material and Methods

Participants

The measurements were carried out between June and October in 2024. The testing and treatments took place at the Kézklinika in Budapest. The study includes active sport climbers who have suffered a traumatic pulley injury while sport climbing. Eligibility criteria required that the participants had a history of at least 5 days since the injury.

Examination

The selection was based on a questionnaire and patient examination. In the anamnesis we recorded the age of the climber, the number and length of training sessions, the time spent in sport climbing, the form and the level of training. We also inquired about the circumstances of the injury, included the type of movement or hold involved. We recorded the symptoms experienced at the time of injury, location, pain, swelling, bruising, loss of mobility, popping sound at the time of injury. Particular attention was paid to the type and intensity of current pain at rest and during movement, recorded on the Visual Analogue Scale (VAS). Pain intensity was categorised as mild (VAS 1–3), moderate (VAS 4–6), or severe (VAS 7–10). Previous treatments and previous and/or co-injuries were noted. Following this, a visual and palpation examination was performed from the elbow to the distal part of the limb according to the rules of physiotherapy, supplemented by a modified trigger finger examination. For the mobility test, we assessed the active range of motion (AROM). We measured quick finger testing and sagittal movements of the wrist and finger joints using a traditional and finger goniometer. The values are given were expressed in degrees (°). The muscle strength was measured manually and graded on a scale of 0–5. The muscle strength of the wrist flexors and extensors, mm. lumbricales, mm. interosseous volares and dorsales, and the m. extensor digitorum communis (EDC), m. flexor digitorum superfitialis (FDS) and m. flexor digitorum profundus (FDP) of the affected finger were measured on both sides. In addition to muscle strength, the maximum flexibility of the muscles was also tested. The specific tests we used were the Bunnel-Littler-, Retinaculum tests (which was considered positive in the case of pain or if there was no full passive ROM) Proximal Interphalangeal joint (PIP) hyperextension test (positive if there was pain in passive hyperextension), Paper sheet test and the Froment sign (the test is positive, if the sheet of paper could be pulled out). Pressure sensitivity was assessed at the level of the pulleys on the affected finger (positive if pain occurs). In the next step, the strength of the grip was measured with a digital hand dynamometer, followed by the Chuck pinch and Key pinch were measured with Baseline's mechanical pinch gauge, with results recorded in Newton (N) A fingerboard and a dynamometer were used to measure climbing-specific finger strength, which was adapted from Cheung, W. 2023 guideline.[1] The test was performed in the standing position. On the fingerboard, participants performed maximum pulls on 25-, 20-, and 15-mm crimps with half-closed, closed, and open grips. The results, were recorded, are given in N. The intact side was compared individually to the values of the injured side. As a final step in the patient assessment, we performed functional tests and asked about limitations in everyday activities and sport climbing.

Therapy

Individual therapies were provided twice a week for 40 minutes per session. Each participant received a total of 10 sessions, which was combined with home exercise and patient education. The treatment had a threefold structure. The warm-up lasted 10 minutes and was designed to increase blood flow. We used passive and active techniques such as massage on the forearms and fingers (also with tools such as mini SMR roller, finger rollators, massage ring), Floss band exercises and PNF dynamic translation technique. The main training session lasted 20 minutes. Elements included respiratory-circulation exercises, climber-specific isometrics, exercises for neighbouring joints-, followed by all-joint movements, working in ischaemia, antagonist strengthening, mini rubber band exercises, and extension improvement with pencil curl exercises. Darabosné Tim et al., 2020 and Egyedi, B. 1983 [9, 10] elastic bandage exercise modified with balloon was applied. PNF isotonic combination techniques were performed on wrist and finger extensors.

Strengthening of the flexors was initially done with eccentric rolling of a 2 kg barbell, followed by a combination of Floss band and hangboard. Later, depending on the treatment week, we gave specific training tools: in week 1 a wooden ball, in weeks 1-2 a 25 mm crimp, in week 3, a 20 mm crimp, and in week 4, a 15mm crimp, all pulled with a fixed amount of force. Finally, the fingers were strengthened in function. A rubber band was applied to the fingerboard. Participants first held the hangboard from above, then held it from below and finally pulled it towards them with a Gaston grip. The physiotherapy treatment was completed with a 10-minute cool-down session. It consisted of stretching PIR, PNF hold relax and contract relax techniques, soft tissue mobilisation and massage on the forearm. In chronic phases, it was complemented by a paraffin pack. In cases of severe flexion contracture, a “Chrisofix” orthesis was applied.

Statistical analysis

Descriptive statistics were calculated using Microsoft Office Excel, with results expressed as mean ± standard deviation (SD), and median (Me) and interquartile range (IQR) calculated using SPSS 30.0. To assess changes, the Wilcoxon signed-rank test was applied, with a significance level set at $p \leq 0.05$. Values marked with * indicate $p \leq 0.05$, while values marked with ** indicate $p \leq 0.01$.

3. RESULTS

The study involved 10 participants (6 men) with a mean age of 29.3 ± 10.9 years and a mean sport climbing experience of 9.4 ± 8.16 years. Two participants had completed a UIAA grade X route. The most common training frequency was 3 sessions per week, and each training session lasted 2.7 ± 0.82 hours. Three athletes presented with acute pulley injuries. The ring finger was affected in 6 cases, the middle finger in 3 cases, and the little finger in 1 case. Regarding the injured structures, the A2 pulley was involved in 7 cases, the A4 in 2 cases, and the A3 in 1 case. Baseline characteristics of the sport climbers are shown in *Table 1*.

Table 1

Basic data of the participants before intervention (N = 10)

	Code	Sex	Climbing years	Climbing grade achieved (UIAA)	Training sessions per week	Duration of one session (hours)	Time since injury	Affected finger	Pulley
1.	N1T6	W	6	9	3	3	1 year	3	4
2.	4LA8	M	17	8	1	1	2 weeks	5	3
3.	H31A	W	8	8	3	3	3 years	3	4
4.	H2Á3	M	5	8	3	3	3 weeks	4	2
5.	S19R	W	3	8	2	3	1 year	4	2

	Code	Sex	Climbing years	Climbing grade achieved (UIAA)	Training sessions per week	Duration of one session (hours)	Time since injury	Affected finger	Pulley
6.	G37P	M	25	10	5	3	2 years	3	2
7.	3C4G	M	2	7	2	4	1 year	4	2
8.	HS41	M	4	7	3	2	3 months	4	2
9.	D2A8	M	20	10	5	3	2 years	4	2
10.	S16Z	W	4	8	3	2	5 days	4	2
mean			9.4	8.3	3	2,7		3.8	2.5
SD			8.17	1.06	1.25	0.82		0.63	0.85

SD= Standard Deviation

The main complaint was pain, assessed using VAS. Before the intervention, pain at rest was minimal in one case (VAS = 2), while pain during climbing averaged 4.3 ±2.54. Five climbers reported severe pain (VAS 5-7), two reported moderate pain (VAS= 4-6) and one reported mild pain (VAS 1-3). In the quick range of motion test, the common PIP – Distal Interphalangeal joint (DIP) flexion test showed that half of the participants on the intact side and four participants on the affected side had a range of motion below physiological. The other two tests each showed one case of deficiency on the affected side. The parameters are categorised as hypomobile and hypermobile. The detailed initial AROM averages and the number of participants with hyper- or hypomobility per joint are presented in *Table 2*. The greatest deficits in AROM were observed in the joints of the digits, which may increase the risk of injury. Specifically, wrist extension and DIP flexion were generally hypomobile while PIP extension was hypermobile in the participants. These altered joint mobility patterns may predispose climbers to finger injuries due to abnormal movement mechanics. Furthermore, the flexion range of motion of the affected PIP joint was severly reduced, representing a functional deficit, that couls increase the likelihood of re-injury in sport climbing.

Table 2

AROM mean results by joints before intervention (N = 10)

AROM	Before intervention							
	Intact side (◦)		Affected side (◦)		Hypomobile (n)		Hypermobile (n)	
	Mean	SD	Mean	SD	Intact	Affected	Intact	Affected
Wrist flexion	89.0	11.623	86.5	9.868	2	1	1	0
Wrist extension	59.2	15.193	60.7	8.512	7	9	0	0
MCP flexion together	85.8	7.480	85.6	8.821	5	4	2	2
MCP extension together	31.2	14.085	28.5	6.964	1	1	0	0
PIP flexion	106.9	6,436	95.5	12.429	1	6	4	2

AROM	Before intervention							
	Intact side (◦)		Affected side (◦)		Hypomobile (n)		Hypermobile (n)	
	Mean	SD	Mean	SD	Intact	Affected	Intact	Affected
PIP extension	–10.1	7.202	–2.9	8.748	0	3	10	7
DIP flexion	55.0	15.355	52.0	19.223	9	8	0	0
DIP extension	–2.7	5.716	–1.6	5.872	1	3	3	3

SD = Standard Deviation

Based on the study, the greatest deficit on the affected side was observed in the EDC and in the dorsalis interosseus muscles of both hands, which may lead to muscle imbalance. The average muscle strength of the EDC was 4+ on the affected side, with 20% of participants having a muscle strength of 3 and a further 30% having a muscle strength of 4. On average, the dorsal muscle strength of the interosseous mm was 4+ for both sides. The lowest value was muscle strength of 3, which was measured in 30% of the participants on the intact side and 20% on the affected side. In addition, muscle strength 4+ was recorded in 20% of the affected side and above average muscle strength 5+ in the remaining 60%, which was 70% on the intact side. When testing maximum flexibility, both the intact and affected sides of the EDC were shortened in 4-4 participants, indicating a reduction in both muscle strength and flexibility of the EDC were reduced. In addition, I found 1 case of shortening at the FDP on both sides and 2 cases of shortening at the wrist extensors on the affected side. From the findings of the positive specific tests, it can be said that the tests most sensitive for detecting injury were the pressure sensitivity (8+), retinaculum (6+) and PIP hyperextension test (6+) on the affected side. Among the specific tests, we quantified the grip strength, chuck pinch and key pinch *(Table 5)* Except for the key pinch, the other parameters were found to be lacking compared to the intact side. These grips are the most adaptable for sport climbing. The median (Me) and interquartile range (IQR) parameters of the specific finger strength measured with the fingerboard are presented in *Tables 6., 7.* and *8*. The results show that the climbing specific test demonstrated a remarkable lag of the affected side compared to the intact side for all crimp sizes and grip types. This manifests as a functional deficit during climbing, meaning that muscle strength is decreased on the injured side, making it difficult to use the holds and crimps effectively.

At retesting, we found that physiotherapy had completely eliminated pain at rest and during exercise for all participants. In the case of the quick range of motion test, all tests, i.e. fist lock, palm touch and common PIP- DIP flexion tests, are now all possible for sport climbers. The output values for joint active range of motion and the changes in the hypomobile and hypermobile groups are shown in *Table 3*. The intervention resulted in a major reduction of hypomobility, but increased hypermobility in the sagittal movements of the PIP joint. Apart from this, most of the parameters were successfully within the normal range of motion when tested back.

Table 3
Output values for joint AROM and changes in the hypomobile and hypermobile groups (N = 10)

AROM	After intervention							
	Intact side (◦)		Affected side (◦)		Hypomobile (n)		Hypermobile (n)	
	Mean	SD	Mean	SD	Intact	Affected	Intact	Affected
Wrist flex.	95.00	9.37	92.10	6.76	0	0	0	0
Wrist ext.	67.00	4.40	71.10	9.41	5	5	0	0
MCP flex.	93.80	3.52	95.80	6.73	0	0	0	0
MCP ext.	40.80	9.86	40.10	9.01	0	0	1	1
PIP flex.	110.90	4.33	111.40	3.53	0	0	7	6
PIP ext.	–11.10	5.09	–8.20	4.52	0	0	10	10
DIP flex.	78.90	7.59	81.10	4.70	2	0	0	0
DIP ext.	–3.40	6.36	–2.00	4.89	1	1	4	2

SD= Standard Deviation

The sagittal movements of the PIP and DIP joints were statistically tested, summarised in *Table 4*. A strong significant change was found in the PIP flexion range of motion on the affected side and in the DIP joint flexion range of motion on both sides. There is also a significant change on the PIP extension on the affected side.

Table 4
Statistical results of the sagittal plane movements of the PIP and DIP joints (N = 10)

Finger AROM	Intact before (°)	Intact after (°)	Affected before (°)	Affected after (°)
PIP flexion	Me = 106.5 [IQR = 10.5]	Me = 111.5 [IQR = 5.5] p = 0.057	Me = 93.0 [IQR = 20.75]	**Me = 113.0 [IQR = 6.5] p = 0.008
PIP extension	Me = –9.5 [IQR = 8]	Me = –10.0 [IQR = 7.75] p = 0.857	Me = –5.5 [IQR = 14.25]	*Me = –7.5 [IQR = 4.25] p = 0.046
DIP flexion	Me = 56.5 [IQR = 19.25]	**Me = 80.5 [IQR = 12.75]	Me = 50.5 [IQR = 28]	**Me = 82.0 [IQR = 4.75]
DIP extension	Me = –2.0 [IQR = 5]	Me = –1.5 [IQR = 6.25]	Me = –2.5 [IQR = 8]	Me = –1.0 [IQR = 5]

Me = Median; IQR = interquartile range; Values with * indicate p ≤ 0,05. Results with ** represent results with p ≤ 0,01.

When measuring muscle strength retested on the Oxford scale for wrist extensors, all participants finished with a muscle strength of 5, as did FDS, FDP, EDC and mm. lumbricales. Only one case of mm. interossei showed a muscle strength of 4. For the volar interosseus muscles, the mean score was 4.9 ±0.31 on the intact side, while the same result was observed for the dorsal side (4.9 ±0.31). When maximum flexibility was measured back, we found that muscle elasticity was regained in all modalities by the end of the treatments. Of the specific tests, pressure sensitivity was eliminated in all cases, as it was for the Bunnel-Littler test. The Paper Sheet and Retinaculum test was positive in one case on the affected side on remeasurement. The data after treatment for grip strength, peak grip and key grip are given in *Table 5*.

Table 5

Mean values of opening and closing data for grip strength, chuck pinch and key pinch (N = 10)

Special test	Before intervention(N)				After intervention (N)				Changes (%)			
	intact		affected		intact		affected		intact		affected	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Grip strength	429.6	103.57	424.9	100.57	457	105.16	480.6	116.23	6.96	7.1	13.74	14.75
Chuck pinch	102.5	23.83	96	29.88	102.5	19.03	107	23.35	1.36	11.35	16.17	23
Key pinch	102	26.68	107.5	22.26	112	19.17	112	17.82	12.61	12.82	5.34	7.26

SD = Standard Deviation

For special holds used in sport climbing, it can be seen that the affected side has improved on all edge sizes and has improved to nearly match or keep up with the unaffected side. It can be said that by the end of the treatments, the finger strength on both sides became almost symmetrical.

The statistical summary of finger strength is given in *Tables 6., 7.*, and *8*. A strong significant improvement was found at 25 mm with a half-closed grip on the affected side, at 20 mm with a half-closed grip on both side, and at 15 mm with an open grip on the unaffected side. Furthermore, we found a significant change in the 25mm crimp for all hold types on the intact side, at the 15mm crimp with closed grip on the intact side and with open hold on the affected side.

Table 6

Finger strength statistical summary results for 25mm crimp (N = 10)

25mm	Intact before (N)	Intact after(N)	Affected before (N)	Affected after (N)
Half-closed grip	Me = 361.5 [IQR = 154.5]	*Me = 463.5 [IQR = 124.5] p = 0.013	Me = 347.0 [IQR = 109.75]	**Me = 425.0 [IQR = 135.75] p = 0.008

25mm	Intact before (N)	Intact after(N)	Affected before (N)	Affected after (N)
Closed grip	Me = 377.0 [IQR = 165.25]	*Me = 471.5 [IQR = 115] p = 0.022	Me = 382.5 [IQR = 165]	Me = 441.0 [IQR = 135.75] p = 0.093
Open grip	Me = 290.0 [IQR = 163]	*Me = 359.5 [IQR = 166.25] p = 0.022	Me = 325.0 [IQR = 167.5]	Me = 341.0 [IQR = 141] p = 0.074

Me = Median; IQR = interquartile range; Values with * indicate p ≤ 0,05. Results with ** represent results with p ≤ 0,01.

Table 7
Finger strength statistical summary results for 20mm crimp (N = 10)

20mm	Intact before (N)	Intact after(N)	Affected before (N)	Affected after (N)
Half-closed grip	Me = 345.0 [IQR = 71.5]	**Me = 395.5 [IQR = 95] p = 0.005	Me = 302.0 [IQR = 122]	**Me = 410.0 [IQR = 92.75] p = 0.007
Closed grip	Me = 365.0 [IQR = 129]	Me = 446.0 [IQR = 131.75] p = 0.092	Me = 353.5 [IQR = 116.75]	Me = 390.0 [IQR = 110] p = 0.059
Open grip	Me = 335.0 [IQR = 102.25]	Me = 336.5 [IQR = 97.5] p = 0.114	Me = 321.0 [IQR = 125]	Me = 342.0 [IQR = 77.25] p = 0.083

Me = Median; IQR = interquartile range; Values with * indicate p ≤ 0,05. Results with ** represent results with p ≤0,01.

Table 8
Finger strength statistical summary results for 15mm crimp (N = 10)

15mm	Intact before (N)	Intact after(N)	Affected before (N)	Affected after (N)
Half-closed grip	Me = 297.5 [IQR = 76]	Me = 332.0 [IQR = 126.75] p = 0.114	Me = 271.5 [IQR = 124.5]	Me = 325.5 [IQR = 105.25] p = 0.083

15mm	Intact before (N)	Intact after(N)	Affected before (N)	Affected after (N)
Closed grip	Me = 306.0 [IQR = 105]	*Me = 340.0 [IQR = 143.75] p = 0.028	Me = 277.5 [IQR = 81.25]	Me = 352.5 [IQR = 112.25] p = 0.059
Open grip	Me = 252.0 [IQR = 121.5]	**Me = 319.0 [IQR = 91] p = 0.007	Me = 236.0 [IQR = 77.75]	*Me = 308.5 [IQR = 93] p = 0.047

Me = Median; IQR = interquartile range; Values with * indicate $p \leq 0,05$. Results with ** represent results with $p \leq 0,01$.

4. DISCUSSION

The most important finding of our research is that structured physiotherapy completely eliminated pain and resulted in significant improvement in joint mobility and muscle strength in climbers suffering from pulley injuries. It is important to address DIP joint stability, as instability clearly plays a role in pulley injuries, particularly during crimp grips, when hyperextension significantly increases the load on the pulley. [11] Both the interosseous and extensor digitorum communis muscles contribute to finger stability and fine motor control [12], and in our study, these muscles showed measurable improvement. Furthermore, controlled strengthening of the finger flexor muscles is essential, as this not only restores function but also promotes gradual adaptation of the pulley system to mechanical load. [13] In addition, proprioceptive training should also be incorporated, as mechanoreceptors have been identified in the annular ligaments. [14]

In contrast to the Isele, K. 2016 [15] pilot study, that looked at the effect of a single treatment with limited measurements, our study used repeated, structured therapy and assessed a wider range of functional and objective parameters. While Cheung, W. 2023 [1] guide provides a comprehensive overview of the management of pulley injuries, it is missing objective measurements. Thus, our study contributes quantitative, objective data to the physiotherapeutic management of pulley injuries in sport climbers.

Some limitations must be acknowledged. The sample size was small, and all participants were recruited from a single centre. We also lacked a control group, so spontaneous recovery cannot be fully excluded. Furthermore, long-term follow-up was not performed, making it unclear whether improvements were maintained over time. Future studies should include larger, more diverse populations, a control group, and long-term outcome measures.

5. CONCLUSION

The results of the research suggest that pulley injuries can be very manageable, and significant improvement can be achieved with progressive structured rehabilitation and physiotherapy treatments. This opens up the possibility for athletes to return to climbing pain-free, with improved range of motion and muscle strength. The therapies we have used have been most effective in reducing pain and pressure sensitivity as well as in rebalancing joint mobility and antagonistic muscles. The symmetry of sport-specific finger strength was also influenced by our therapy, however, maximizing finger strength and reducing hypermobility would require further therapy. It is essential to continue integrating regular physiotherapy into everyday life and to adopt a preventive approach, such as thorough warm-up and stretching, to avoid future injuries.

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