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RESEARCH ARTICLE

The Effect of Knee Stretching Exercise with Knee Strengthening Exercise on Pain, Rom, and Motion Function Post Knee Injury in Climbing Athletes

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ABSTRACT

The main purpose of the study was to determine the effect of providing knee stretching exercises combined with knee strengthening exercises on reducing pain, increasing ROM, and increasing motor function in rock climbing athletes who have knee injuries. This research design uses quasi-experimental pretest and posttest design. The number of participants were 110 selected by using purposive sampling technique, inclusion/exclusion criteria was also employed, 55 participants each were in the intervention group and control group. The experiment was conducted in different phases, namely the preparatory phase, implementation phase and termination phase. The instruments used in this research include a questionnaire for demographic data, a pain scale using NRS, flexion and extension ROM using a goniometer, and movement function using KOS (knee injury outcome survey). Knee stretching exercise intervention combined with knee strengthening exercise was found effective in reducing the pain scale, increasing flexion and extension ROM, and improving motor function in athletes after knee injury. The advantages of knee stretching exercise, a combination of knee strengthening exercise, can increase blood flow, which can reduce the level of pain, increase muscle and joint flexibility so that ROM increases, and reduce or eliminate pain in the joints, which can improve the function of knee movement for daily activities. Thus, intervention in the form of knee stretching exercise combined with knee strengthening exercise can be used as a treatment to improve the quality of life and performance of athletes after injury.

INTRODUCTION

Sports-related injuries can manifest during training sessions, competitive events, or in the aftermath of a match. While minor ailments like muscle stiffness and fatigue typically resolve independently without necessitating medical intervention, more severe conditions such as muscle tears, tendon and ligament ruptures, or fractures represent significant trauma to bodily tissues and demand specialized medical care (Wang, 2021). Among these, the incidence of ankle, muscle, and knee dislocations, along with sprains and strains, is notably prevalent, posing a substantial concern for athletes' health and performance (Emery and Pasanen, 2019; Giwanatara and Hendrawan, 2021).

The knee, one of the largest and most complex joints in the human body, plays a pivotal role in bearing and distributing enormous forces during physical activities. Its mechanical and practical complication makes it vulnerable to injuries, particularly when the applied weight surpasses the tissues' capacity for adaptation. Knee injuries can affect both the skeletal constituents—such as the tibia, femur, and patella—and the soft tissues, including cartilage, ligaments, tendons, and muscles integral to the joint's integrity and function (Truong et al., 2020).

In sports, the occurrence of knee injuries, predominantly those involving the Anterior Cruciate Ligament (ACL), is very high, between 100,000 and 200,000 ACL ruptures occur per annum in the United States (Leguizamo et al., 2023). The ACL plays a vital role in calming the knee by preventing the anterior displacement of the tibia and facilitating proper joint rotation. Particularly, ACL injuries are predominantly observed in sports that require vibrant movements such as jumping, pivoting, and sudden directional changes, with a substantial majority of these injuries happening in non-contact circumstances (Arundale et al., 2022; Chen et al., 2018; Mehl et al., 2018).

Moreover, football, basketball, volleyball, etc., are characterized by hasty variations in direction and speed and are often associated with ACL injuries. This menace is also extended to climbing sports, like mountaineering and bouldering, which, regardless of their diverse physical and protective requirements, have not been exempted from the occurrence of knee injuries. Injuries in such sports often stem from high-impact manoeuvres and uncontrollable falls, leading to conditions such as medial meniscus tears and iliotibial band sprains, alongside ACL ruptures (Boden and Sheehan, 2022; Jam et al., 2014; Lutter et al., 2021).

The outcome of these injuries includes not only instant bodily impairments but also long-term psychosomatic and performance hurdles, with the distress of re-injury and a substantial decrease in muscular strength during periods of rest. Particularly, retrieval rates are found to lag behind the swift loss of muscular strength, underlining the significance of rapid and efficacious restoration approaches (Hor, 2016; Lum and Park, 2019; Lee et al., 2021).

Previous research by Shamsi et al. (2020) emphasized the efficiency of static stretching over muscle-strengthening exercises in improving dynamic balance among individuals with low back pain and shortened hamstrings. Stretching exercises, particularly static stretching, are known to recover muscle and joint flexibility, thus easing pain and improving blood flow and bone strength. There are no adverse effects of therapies observed during the treatment (Behm et al., 2015; Harøy et al., 2019; Sayari, 2020).

The study by McQuade and De Oliveira (2011) demonstrated marked improvement in pain, symptoms, daily activities, quality of life, stiffness, and function scores after strength training. However, both moments increased in knee internal valgus and hip internal rotation after the training period, but these changes did not exceed statistical significance.

According to Nejati et al. (2015), exercises targeting the muscles around the knee considerably increase the effect size of all other interventions in knee osteoarthritis, including medication, acupuncture, and many other therapeutic approaches.

Ceballos-Laita et al. (2024) concluded that for pain relief and improvements in physical function in knee Osteoarthritis (OA), Strength Training (ST) and Aerobic Training (AT) may show clinical benefits among individuals, and similar evidential findings, as other strong systematic reviews and meta-analyses.

Wang et al. (2023) in his research concluded that using a motorized device for Neuromuscular Electrical Stimulation (NME) along with conventional physical therapy, including joint mobilization, stretching, and Active Range of Motion (AROM) exercises at Frozen Shoulder (FS), has proven to be more effective for alleviating pain and enhancing AROM than standard physical therapy combined with strengthening exercises.

According to Wen et al. (2022), functional exercise hastens joint recovery, as evidenced by enhancing muscle strength surrounding the joints and accelerating local nutrient metabolism. The impact of muscle and joint training on postoperative meniscus injuries deserves acknowledgement. According to this study, rehabilitation approaches integrating proprioceptive exercises are more effective than neuromuscular ones alone. Fokmare et al. (2023) in their research found that contrast bath therapy, whether in its traditional form using water or through modifications like compression methods and knee pad devices, effectively reduces pain, which is an initial complaint leading to difficulty in bending the knee and disruptions in daily activities.

Contemporary research offers valuable insight into treating knee injuries and conditions using strength training, Neuromuscular Electrical Stimulation (NME), contrast bath therapy, and various exercise programs. There is a research gap in the exact combination and comparison effect of knee-stretching and knee-strengthening exercises toward pain, Range of Motion (ROM), and motion function in climbing athletes with knee injuries.

The research by McQuade and De Oliveira (2011), Nejati et al. (2015), Ceballos-Laita et al. (2024), Wang et al. (2023), and Fokmare et al. (2023) have exposed the benefits of strength training, NME, and contrast bath therapy on general populations or individuals with specific conditions like osteoarthritis and frozen shoulder, they do not overtly report the combination of knee stretching and strengthening exercises in climbing athletes. Climbing athletes present a unique case due to the specific demands their sport places on their knees, requiring a balance of flexibility, strength, and functional mobility that may differ from the general population or athletes in other sports. Wen et al. (2022) highlight the importance of functional exercises and proprioceptive training for recovery from joint injuries, which aligns with the potential benefits of a combined stretching and strengthening exercise regimen.

A direct comparison of the efficacy of these combined approaches in post-injury recovery among climbing athletes was not presented. This very purpose of the study, entitled "Effect of knee stretching exercise with knee strengthening exercise on pain, ROM, and motion function post knee injury in climbing athletes," thus intends to fill this very gap by comparing the outcome of this unique particular population of athletes. From this perspective, such studies may offer specific indications to optimize rehabilitation strategies for climbing athletes with the final scope of implementing more efficient recovery protocols that better target the specific needs of such a population.

In this regard, the study focused on the particular needs and challenges that climbing athletes may respond to in such a way as to result in positive sport-specific performance outcomes and injury recovery processes. A more comprehensive approach to the rehabilitation process would be a protocol that integrates knee stretching with strengthening exercises. It would also offer yet another strategy toward mechanical knee function, contributing to pain management and improving the overall range of motion. This holistic approach may surpass the results of applying these in isolation. It contributes to the evidence base since the results of combined stretching and strengthening exercises on knee injury recovery were systematically researched. This provides empirical data about rehabilitation protocols that could impact clinical practice and athletic training regimes. The research aims to validate an intervention that can lead towards better recovery outcomes related to pain reduction, increased range of motion, and improved motion function. It may impair an athlete's ability to return to sport with improved performance, then decrease the risk of re-injury. A vast body of literature about knee rehabilitation is available. However, there is still a need to focus more on the combined effect of knee stretching and strengthening exercises in climbing athletes. In this background, this study tries to plug this gap and provides valuable insights into efficacious rehabilitation strategies for this group. Identifying the most effective treatment strategies for knee injuries in climbing athletes will study the recovery target of the athletes' immediate recovery and sustainability for the health and performance of the climber in the long run. It can guide preventative measures and inform training practices to mitigate the risk of future injuries. Given the outlined challenges, this research aims to explore the combined effects of knee stretching and strengthening exercises on mitigating pain, enhancing the Range of Motion (ROM), and improving movement functionality in athletes recovering from knee injuries, with a particular focus on those involved in climbing sports.

Objectives

The following were the main objectives of the study:

- To find out the effect of knee stretching combined with strengthening exercises in decreasing pain in rock climbing athletes with knee injuries.
- To determine the variations in ROM, specifically flexion and extension, as an aftermath of intervention.
- To examine the effect of intervention in the improvement of motor function of the injured knee.

LITERATURE REVIEW

This literature review emphasizes the multidimensional nature of ACL injury, from the biomechanical underpinning to the pivotal place of prevention, cutting-edge approaches to rehabilitation, and psychological support integration. Such insights add to the need for an all-encompassing approach to knee injuries among athletes, underlining the dynamism characterizing research and practice in sports medicine. According to evidence, therapeutic stretching and strengthening exercises, with biomechanically guided training programs and individually designed rehabilitation protocols, facilitate recovery and prevent recurrence.

Biomechanics and risk factors of ACL injuries

Understanding the biomechanics of the knee and specific mechanisms that result in an ACL injury are essential aspects of developing strategies for preventing and effectively rehabilitating the injury. Maestroni (2024) further postulate in their research that specific athletic movements, whereby the athlete lands from a jump in poor knee alignment and where sudden deceleration occurs, pose a risk of an ACL rupture. This is also supported by findings from Boden and Sheehan (2022), stating that sports with rapid direction changes at high speed predispose players to get ACL injuries. From a biomechanical point of view, the call is for suitable training programs that may evade such risks.

Prevention strategies in sports

The measures towards injury prevention to the knee, particularly the ACL, should be proactive. This would translate into training-specific or specialized training programs for further neuromuscular control, perfecting landing techniques, and improving knee-supporting musculature. Focusing on the study of Pfile and Curioz (2017), it is affirmed that their efficacy was close, in a very significant percentage, to reducing the incidence of this type of injury related to athletes, especially in high-risk sports. These findings invite the integrated practice of habitual training with exercises focused on prevention.

Advances in rehabilitation protocols

Contemporary developments in rehabilitation procedures highlight the significance of a modified step-by-step method for recovery from knee injuries. According to Hazbun (2020), primary post-injury interventions that endorse placid movement and steady loading of the injured knee can speed up the remedial process and expand outcomes. Moreover, the combination of proprioceptive exercises and Neuromuscular Electrical Stimulation (NMES) has increased the reclamation of knee function post-ACL reconstruction (Ogrodzka-Ciechanowicz et al., 2021).

Psychological aspects of recovery

The emotional effect of knee injuries, mainly the fear of re-injury, plays a vital role in rehabilitation and athletes' return to sport. Research by Bird et al. (2024) highlights the efficacy of emotional support interventions in addressing these apprehensions with goal-setting, self-concept, and confidence-building exercises. Incorporating psychological support into rehabilitation programs is vital for a rounded recovery and a fruitful return to competition.

The role of stretching and strengthening exercises

Regarding the importance of stretching and strengthening exercises, further research by Perez-Huerta et al. (2020) advocates the combined application of these exercises in improving knee stability and function post-injury. Their study specifically points to the benefits of dynamic stretching and eccentric strengthening exercises in restoring muscle balance and preventing re-injury, aligning with earlier findings by Behm et al. (2015) and Harøy et al. (2019).

METHODOLOGY

It is an experimental study which uses a quasi-experimental design with a pretest-posttest control group design.

Participants

The study employed purposive sampling to select participants based on specific inclusion and exclusion criteria. The inclusion criteria targeted individuals who had sustained non-specific post-knee injuries characterized by mild to moderate pain, slight swelling, and stiffness in the muscles and joints. Participants were required to express a willingness to participate in the study, be between the ages of 17 and 40, and exhibit decreased motor function and range of motion. The study focused on those in the sub-acute (5 days to 4 weeks) and chronic (more than 4 weeks) stages of injury recovery. Exclusion criteria include, but are not limited to, moderate and severe swelling, fractured bone, and an open wound in the injured area; the subject is in the acute phase (1-3 days post-injury); grades 2 and 3 strain or sprain. The valid population participants of rock climbing and bouldering athletes were members of Koni at Surabaya, East Java, Indonesia, aged between 15 and 30 years old. The research sample included 110 athletes, evenly divided into two groups: 55 participants in the intervention group and 55 in the control group. The choice of using this approach in selecting the participants was structured in a manner that assured focus on proper examination of the effects of the proposed interventions on a given athletic population with consideration given to their stages of recovery from injury and conditions of their physical fitness. The average age of the selected participants was 25 years.

Instrumentation

The research utilized a four-part measurement instrument to collect comprehensive data. The first part concerns the assessment of their demographic data, such as age, gender, education, and marital status, which is identified as first-round data, and further, the data is identified later in a manner to have context for the analysis of results in terms of groups of participants. The second part involved the use of the Numeric Rating Scale (NRS) to measure pain and was expressed as 0 = no pain, 1-3 = mild pain, 4-6 = moderate pain, 7-9 = severe pain, 10 = very severe pain (derived from Haefeli and Elfering, (2006). This scale allowed for a quantifiable assessment of participants' pain experiences. The third section, ROM, is measured by a goniometer (between 10° and 140° of flexion and between 5° and 10° of extension), according to the parameters provided by (Santos et al., 2017). It further explained that the knee flexion and extension were further elaborated, which means testing ROM was further done. The fourth part measured the knee joint function or movement function, having 42 questions in six categories: 1) pain, 2) symptoms, 3) Daily Activities (ADL), 4) sports/recreation, and 5) Quality Of Life (QOL) using the Knee Injury Outcome Survey (KOS). The responses vary from "never" to "extreme" on a five-point scale. A high KOS score indicates good knee functioning, while a low score indicates poor knee functioning (Phatama et al., 2021). The instrument reliability presented a cronbach alpha value of 0.84. The item's internal consistency during the test-retest exercise was confirmed. This structured approach guaranteed a detailed and reliable assessment of the impact of the intervention on recovery from knee injury.

Intervention

The experimental group had well-administered intervention programs of knee-stretching and -strengthening exercises over eight weeks. The process was initiated right from the preliminary stage, whereby participants were instilled with an idea of the forthcoming procedures so that the essence of privacy and comfort during sessions could be ensured and prepare a supporting and informed environment. The implementation phase includes only those subjects who will carry out the research, for which they were first provided with training modules to learn the proper techniques. Joint-stretch and joint-strengthening exercises were also done. The stretching module contained nine specific stretches that were done in a static (passive) manner to attain maximum flexibility and stiffness reduction in the muscle. The strengthening component constituted twelve specific movements designed to enhance muscle strength around the knee joint, aimed at joint stability and function. After every session, it proceeded to the termination or evaluation stage. In this case, the part presented was essential for collecting participant responses and examining the immediate effects of the exercise. The post-training experiences and effects resulting from interventions observed by the participants may have provided some critical insights into the impact of the intervention.

The control group, on the other side, did not have this structured exercise regimen. Instead, they continued their activities like before, but with a tendency not to have knee exercises as targeted sessions. Such a comparative analytical approach was pursued to make a case for the specific benefits and results of the intervention within the experimental group, using a baseline set based on the experiences of the control group. This ensured a detailed assessment of the exercises focusing on knee stretching and strengthening. It underscored the essence of personal feedback and modifications so that the benefits patients would derive from rehabilitation following knee injury through the intervention would be enriching. No adverse effects were observed in the experiment as it was conducted under controlled conditions.

Data collection

Data collection was planned and conducted to facilitate face-to-face contact between the researchers and participants. Prior to the beginning of the research, all participants were thoroughly briefed by the researchers about the objectives, methodology, and possible implications. This was very important in building transparency and trusting rapport. Further, the participants were given an informed consent form, including their rights, voluntary involvement in the study, and confidentiality. The data collection proceeded only after participants fully understood the consent form and willingly signed it.

First of all, the participants must fill in a demographic questionnaire; this forms part one of the data collection and helps gather information on basic details such as age, gender, education level, and marital status of the subject. This formed an important aspect that was put in context with the different demographic factors that would influence the outcomes of the study. After the demographic data, the participants from the intervention and control groups were requested to fill out pretest questionnaires that sought to capture baseline measures information on three primary dimensions:

Pain scale: Participants' intensity of pain was rated on a defined numeric rating scale ranging from 0 (no pain) to 10 (very severe pain) on entry. This, therefore, could give a clear assessment of the users' pain level prior to the intervention. The scale's reliability was confirmed by a cronbach's alpha value of 0.81.

Range of Motion (ROM): A goniometer measured knee ROM, including flexion and extension degrees. Participants' ROM measurements were taken to establish baseline mobility and flexibility levels.

Movement function: The Knee Outcome Survey (KOS) was applied to research the functional ability of the knee joint. The items in this survey refer to pain, symptoms, sports/recreation, daily activities, and quality of life; that is, it is targeted at measuring the level of overall function in a subject at the initial stage. A cronbach's alpha value of 0.81 confirmed the reliability of the instrument.

RESULTS

Specifically, this included data on frequency and percentage distributions of gender, education level, marital status of the participants, Body Mass Index (BMI), and initial pain levels. This step illustrated the heterogeneity and homogeneity of the sample in the study. For example, knowing the distribution of participants' education level would enable establishing relationships with health outcomes or adherence to intervention protocols, given the level of education. Subsequently, age, Range of Motion (ROM), and motor function data were reported through the mean, median, and *standard deviation* values. All the above gave a dimension of central tendency and variation in the data with a great sense of accuracy in order to examine the participant's characteristics at baseline. The test for the outcome between the start and the end in each group was carried out through the Wilcoxon rank-sum test. This test is worth noting, using non-parametric tests, and is best applied when comparing paired datasets, such as pretest and posttest results, especially when the data do not tend to follow a normal distribution. It quantifies the effectiveness of intervention for pain, ROM, and motor function over time by effectively identifying whether the median values of two related samples differ significantly. This test choice emphasizes an approach for the nuanced effects of the intervention since the improvement or change in outcome is only sometimes linearly distributed.

Then, the Mann-Whitney U test was computed to establish the differences between the intervention group's and control group's outcomes after the intervention. This is a test of the mean ranks from two independent samples to determine if the control group and the intervention group had significantly different outcomes after the intervention. Compared with usual care or no intervention, it is a potent tool for knowing the efficacy of stretching and strengthening exercises for knee improvement in pain levels, ROM, and motor function. In the analysis, a p-value smaller than 0.05 was considered significant, using very lenient criteria for statistically significant differences. This high standard means that any differences noted between groups are likely to not occur by random chance but instead, be attributed to the actual intervention itself. It points towards adherence to scientific rigour and the importance of drawing valid and reliable inferences from the study's findings. The approach of examining data through layers, using descriptive and inferential statistical methods, is best applied and provides a thorough data analysis to the last bit. The same data shine not only on the baseline characteristics and intrinsic variability within the sample but also on the effectiveness of the intervention with rigour. This would provide evidence-based insights that are credible enough to be used in further research, clinical practice, and policy-making in sports medicine and rehabilitation.

Table 1: Characteristics of respondents based on age (n=55)

Group	Mean	Min-Max	Median	*SD*
Experimental	21.38	16-29	21.00	3.577
Control	21.73	16-29	21.00	3.546

In the intervention group, the average age of participants is 21.38 years, with a median age of 21 years. This diversity is further highlighted by the age span, which ranges from a minimum of 16 years to a maximum of 29 years. Similarly, the control group exhibits a closely aligned age profile with an average age of 21.73 years and a median of 21 years. The slight difference in the mean age between the two groups is minimal, suggesting comparable age demographics. The *standard deviation* in the control group is 3.546, nearly identical to that of the intervention group, indicating a similar age distribution variance. The age range in the control group matches that of the intervention group, with participants as young as 16 and as old as 29 years, reinforcing the study's engagement with a demographic that spans from late adolescence to late twenties.

The age characteristics of the intervention and control groups are comparable, highlighting the consistency in age distribution and the broad spectrum of participants involved in the study. This similarity in demographic profile supports the study's comparative analysis, ensuring that age-related factors are evenly represented across both groups.

Table 2: Respondent characteristics based on gender, marital status, education level, and BMI (n=55)

Variable	Intervention Group		Control Group	
	n	%	n	%
Gender				
Man	31	56.4	29	52.7
Woman	24	43.6	26	47.3
Marital Status				
Married	14	25.5	17	30.9
Unmarried	41	74.5	38	69.1
Level of Education				
Senior High School	19	34.5	21	38.2
Bachelor	36	65.5	34	61.8
BMI				
<18.5 (Underweight)	4	7.3	5	9.1
18.5-25.0 (Average)	51	92.7	50	90.9
>25 (Fat)	0	0	0	0

The table above shows the distribution of respondents based on gender characteristics in the intervention group. Most of the respondents were men, 31 people (56.4%) and in the control group, most of them were men, 29 people (52.7). According to marital status, the intervention group mainly was unmarried, 41 people (74.5%) and in the control group, most of them were unmarried, 38 people (69.1%). The intervention group's education level was mainly 36 people (65.5%), and in the control group, the majority were 34 people (61.8%). The BMI in the intervention group was mostly normal for as many as 51 people (92.7%), and in the control group, most were expected for as many as 50 people (90.9%).

Table 3: Distribution of the pain scale of rock climbing athletes

Intervention Group	Before		After	
Variable	N	%	N	%
No Pain	0	0	7	12.8
Mild Pain	18	32.7	40	72.7
Moderate Pain	37	67.3	8	14.5
Severe Pain	0	0	0	0
Pain is Very Severe	0	0	0	0
Total	55	100	55	100
Control Group	Before		After	
Variable	N	%	N	%
No Pain	0	0	1	1.8
Mild Pain	21	38.2	23	41.8
Moderate Pain	34	61.8	31	56.4
Severe Pain	0	0	0	0
Pain is Very Severe	0	0	0	0
Total	55	100	55	100

Based on the table above, the distribution of the pain scale of respondents in the intervention group before being given the knee stretching exercise combined with knee strengthening exercise intervention, most of the pain scale was moderate, 37 people (67.3%). After being given intervention, most of the pain scale was mild, with 40 people (72.7%). Meanwhile, the distribution of respondents' pain scale in the control group previously had a moderate pain scale of 34 people (61.8%). Afterwards, most of the distribution of the moderate pain scale was 31 people (56.4%).

Table 4: ROM of rock climbing athletes

ROM	Mean	Min-Max	Median	*SD*
Experimental Group Flexion				
Before	121.93	110-131	121.00	6,259
After	128.25	116-135	129.00	5,060
Experimental Group Extension				
Before	2.02	0-6	2.00	1,727
After	3.98	2-8	4.00	1,484
Control Group Flexion				
Before	121.89	110-132	121.00	6,300
After	122.33	110-132	122.00	6,230
Control Group Extension				
Before	1.96	0-7	1.00	1,699
After	2.35	0-8	2.00	1,858

The table above shows that the average distribution of knee flexion ROM for respondents in the intervention group before being given the knee stretching exercise combined with knee strengthening exercise was 121.93, with a *standard deviation* of 6.259. The lowest flexion was 110, and the highest was 131. After the intervention, the average knee flexion ROM was 128.25, with a *standard deviation* of 5.060.

The lowest extension was 116, and the highest was 135. Meanwhile, the average knee flexion ROM of respondents in the previous control group was 121.89, with a *standard deviation* of 6.300. The lowest flexion was 110, and the highest was 132. After that, the average knee flexion ROM was 141.78, with a *standard deviation* 17.111. The lowest motion function is 111, and the highest is 170. It also shows that the average distribution of knee extension ROM for respondents in the intervention group before being given the knee stretching exercise combined with knee strengthening exercise was 2.02, with a *standard deviation* of 1.727. The lowest extension was 0, and the highest was 6. After being given intervention, the average knee extension ROM was 3.98, with a *standard deviation* of 1.484. The lowest extension was 2, and the highest was 8.

Meanwhile, the average knee extension ROM of respondents in the previous control group was 1.96, with a *standard deviation* of 1.699. The lowest extension was 0, and the highest was 7. After that, the average knee extension ROM was 2.35, with a *standard deviation* 1.858. The lowest extension was 0, and the highest was 8.

Table 5: Knee Motion Function (KOS) of rock climbing athletes

Motion Function	Mean	Min-Max	Median	*SD*
Intervention Group				
Before	136.35	109-168	132.00	15,194
After	148.84	122-183	147.00	12,971
Control Group				
Before	137.49	110-168	133.00	17,016
After	141.78	111-170	138.00	17,111

The table above shows that the average distribution of respondents' movement functions in the intervention group before the knee stretching exercise combined with the knee strengthening exercise was 136.35, with a *standard deviation* 15.194. The lowest motor function was 109, and the highest was 168. After the intervention, the average motor function was 148.84, with a *standard deviation* of 12.971. The lowest movement function was 122, and the highest was 183. Meanwhile, the average movement function of respondents in the control group was 137.49, with a *standard deviation* of 17.016. The lowest motion function is 110, and the highest is 168. After that, the average motion function was 141.78, with a *standard deviation* 17.111. The lowest motion function is 111, and the highest is 170.

Table 6: Differences in mean pain scales in rock climbing athletes

Pain Scale	Mean Rank	*p*-Value
Intervention Group		
Before After	18.50	0.000*
Control Group		
Before After	3.50	0.102

*Significant at $\alpha < 0.05$, by Wilcoxon test.

Wilcoxon test analysis above shows a significant influence on the average pain scale of the intervention group before and after being given the knee stretching exercise combined with knee strengthening exercise with a value of (*p*-value 0.000<0.05). Thus, this shows a significant difference in the mean value of the pain scale in the intervention group, where the difference in change between before and after is 18.50. Meanwhile, the analysis results in the control group show no significant influence on the mean value of the pain scale before and after being given the standard community intervention for rock climbing athletes, as evidenced by the value (*p*-value 0.102>0.05).

Table 7: Analysis of the difference in changes in pain scale in rock climbing athletes (n=55)

Pain scale	Mean Rank	*p* - Value
Intervention Group	42.90	
		0.000*
Control Group	68.10	

*Significant at α < 0.05, with Mann Whitney

From the results of the Mann-Whitney analysis above, it is clear that there is a significant difference in changes in the mean value of the pain scale in the intervention group and the control group, where the mean value of the intervention group is 42.90 while the control group is 68.10. Thus, there is a significant difference in the mean value of the pain scale between the intervention group and the control group, with a value of (*p*-value 0.000<0.05).

Table 8: Analysis of the difference in changes in ROM in rock climbing athletes

ROM	Mean Rank	*p* - Value
Flexion		
Intervention Group	69.57	0.000*
Control Group	41.43	
Extension		
Intervention Group	70.24	0.000*
Control Group	40.76	

*Significant at α < 0.05, with Mann Whitney.

From the above table, it is clear that there is a significant difference in changes in the mean value of flexion ROM in the intervention group and the control group, where the mean value of the intervention group is 69.57 while the control group is 41.43. Thus, there is a significant difference in the mean value of flexion ROM between the intervention group and the control group, with a value of (*p*-value 0.000<0.05). Thefts of the Mann-Whitney analysis above show an apparent difference in changes in the mean value of extension ROM in the intervention group and the control group, where the mean value of the intervention group is 70.24 while the control group is 40.76. Thus, there is a significant difference in the mean value of extension ROM between the intervention and control groups, with a value of (*p*-value 0.000<0.05).

Table 9: Analysis of the differences in changes in motion function in rock climbing (n=55)

Motion Function	Mean Rank	*p* - Value
Intervention Group	63.57	
		0.000*
Control Group	47.43	

*Significant at α < 0.05, with Mann Whitney.

From the results of the Mann-Whitney analysis above, it is clear that there is a significant difference in changes in the mean value of knee motor function in the intervention group and the control group, where the mean value of the intervention group is 63.57 while the control group is 47.43. Thus, there is a significant difference in the mean value of movement function between the intervention and control groups, with a value of (*p*-value 0.000<0.05).

DISCUSSION

There was a significant increase in knee flexion Range of Motion (ROM), with the intervention group showing a notable improvement from an average of 121.93 to 128.25, suggesting the exercises directly contributed to enhanced knee mobility. Knee extension ROM also improved significantly in the intervention group, moving from an average of 2.02 to 3.98, indicating a substantial enhancement in the ability to straighten the knee fully. The intervention steered to a significant development in motor function. This highlights the optimistic effect of the exercises on knee movement and functionality. Lastly, a noticeable decrease in the pain scale was observed in the intervention group compared to the control group. This lessening in pain highlights the valuable effects of the intervention on improving well-being and reducing discomfort linked to knee issues.

The present findings of the study run parallel to those of McQuade and De Oliveira (2011), and Ceballos-Laita et al. (2024), which portrayed improvements in pain, symptoms, and physical function in a study completed with exercise-based intervention. This aligns with the broad consensus that physical activity, whether it involves strength training, aerobic exercises, or targeted muscle exercises, aids individuals with knee issues or Osteoarthritis (OA).

The findings combined showed a significant improvement in knee flexion and extension range of motion, motor function, and pain scale—specifically, pointing out a combination as one of the most effective parts of the current intervention. In contrast, Nejati et al. (2015) and Wen et al. (2022) emphasize the benefits of exercises targeting muscles around the knee and functional exercises, respectively, without necessarily differentiating between types of physical activity. This suggests a potential advantage in tailoring exercises to specific outcomes (e.g., ROM, motor function) while also acknowledging the general efficacy of exercise for knee health.

The research by McQuade and De Oliveira (2011) noted no significant differences in the co-activation of the Quadriceps and hamstring muscles after strength training, similar to Ceballos-Laita et al. (2024), who found no differences between Strength Training (ST) and Aerobic Training (AT) in terms of clinical benefits for knee OA. This contrasts with the intervention's clear improvements in specific measures, suggesting that while broad exercise programs provide benefits, specific interventions may offer targeted improvements in knee function.

Wang et al. (2023) found that combining Neuromuscular Electrical Stimulation (NME) with conventional physical therapy was more effective than standard therapy alone for frozen shoulder, indicating the potential benefits of integrating various therapeutic approaches. This aligns with the intervention's multi-faceted approach of combining stretching and strengthening exercises, suggesting a broader applicability of combining techniques for improved outcomes.

Fokmare et al. (2023)highlighted the efficacy of contrast bath therapy in reducing knee pain and improving functionality, providing an example of non-exercise-based interventions that can complement exercise regimens for knee health. This underscores the potential for multi-modal interventions, combining physical exercises with other therapeutic techniques, to achieve optimal outcomes.

This research is also in line with research conducted by (Kusworo et al., 2018), which explains that passive static stretching affects increasing the range of motion of joints. Providing passive static stretching has a better increase in joint range of motion than providing active static stretching. Another study conducted by (Shamsi et al., 2020) with the title Modeling the effect of static stretching and strengthening exercise in lengthened position on balance in low back pain subjects with shortened hamstring: a randomized controlled clinical trial, also explains that static stretching exercises more effective than muscle strengthening exercises in a long position in improving dynamic balance in low back pain patients with hamstring pain. The research results conducted by (Mondam et al., 2017) explain that static stretching is more effective in increasing hamstring flexibility than dynamic stretching.

This is in line with the results of research from Fukuchi et al. (2016), who conducted research titled effects of strengthening and stretching exercise programs on kinematics and kinetics of running in older adults. It was a randomized controlled trial, with results of stretching and strengthening exercise protocols at home for eight weeks. It produced changes in ankle and trunk kinematics, knee kinetics, ground reaction force variables, and muscle strength and flexibility improvements. The results of the study are also explained according to Raposo et al. (2021), who further elaborated that the strengthening program should be done for 8-12 weeks, 3-5 times within a week, and each session for 1 hour, and it has a positive effect to rehabilitate the patients with osteoarthritis. Repeated stretching of a muscle to a constant length is believed to increase joint ROM due to a gradual decrease in peak tension and its stiffness (Campbell et al., 2019).

Practical and theoretical implications

This study provides relevant evidence of the need for rehabilitation protocols by clinicians and physical therapists to include targeted stretching and strengthening of the knees for persons suffering from knee disorders, primarily osteoarthritis, or following surgery. That could be the basis for much more individual and effective treatment planning. Therefore, the findings provide a basis for further research to develop specific exercise prescriptions that describe the type, frequency, duration, and intensity of the exercises needed most to improve knee ROM and motor function and manage pain. This can aid practitioners in creating more effective, evidence-based exercise programs. Demonstrating significant pain reduction through exercise interventions suggests an alternative or complementary approach to pharmacological pain management, potentially reducing dependency on pain medication and its associated risks. The research underscores the importance of patient education on the benefits of specific exercises for knee health. This knowledge can empower patients to engage in self-managed exercise routines as part of their overall knee health strategy.

The study contributes to a deeper theoretical understanding of the physiological mechanisms by which knee stretching and strengthening exercises impact knee function, including changes in muscle strength, flexibility, joint mechanics, and pain perception.

The findings of this research may inform the development of theoretical models that explain the relationship between specific types of physical activity and outcomes in knee rehabilitation. These models can guide future research on exercise interventions for various musculoskeletal conditions. This research enriches the field of exercise science by providing empirical evidence on the benefits of combining knee stretching and strengthening exercises. It challenges and extends current theories on exercise programming and rehabilitation practices. The study sets a foundation for future research to explore optimal exercise dosages, the long-term effects of such interventions, the comparative efficacy of different exercise combinations, and the application of similar interventions to other joint and musculoskeletal conditions.

Limitations and future directions

The study had a limited sample size and lacked diversity in terms of gender and ethnicity; the findings might not be generalizable to all populations with knee issues. Future research should include a broader and more diverse participant pool. Similarly, the study has focused on short-term outcomes without assessing the long-term sustainability of improvements in knee function and pain reduction. On the other hand, pain measurement can be highly subjective, depending on self-reported scales. Incorporating more objective measures of pain and function, such as biomarkers or imaging, could provide a more comprehensive assessment. Long-term follow-up is essential to determine the durability of the benefits. This research utilized a quasi-experimental design by using a purposive sampling technique; future research may use random assignment of participants to experimental and control groups and use accurate experimental designs. Conducting studies with more extended follow-up periods can help understand the long-term effects of knee stretching and strengthening exercises on knee health, function, and pain management.

Future studies should include a wider range of participants to ensure the findings apply to diverse populations. This includes ages, sexes, ethnic backgrounds, and baseline health conditions. Comparing the effectiveness of different physical interventions, including varying exercises, intensity levels, and frequencies, can help identify the most beneficial approaches for specific knee conditions.

Similarly, investigating the underlying physiological mechanisms through which stretching and strengthening exercises affect knee function and pain can provide insights into optimizing exercise interventions. Exploring the combined effects of exercise with other non-pharmacological interventions, such as diet, manual therapy, or technology-assisted therapies, could offer a holistic approach to knee rehabilitation.

CONCLUSION

Knee stretching exercise intervention combined with knee strengthening exercise effectively reduces the pain scale, increases flexion and extension ROM, and improves motor function in athletes after knee injury. The benefits of knee stretching exercise, a combination of knee strengthening exercise, can increase blood flow, which can reduce the level of pain, increase muscle and joint flexibility so that ROM increases, and reduce or eliminate pain in the joints, which can improve the function of knee movement for daily activities. Thus, intervention in the form of knee stretching exercise combined with knee strengthening exercise can be used as an alternative intervention that can be used to improve the quality of life and performance of athletes after injury.

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Ethical approval

The procedures in this study involving human participants by administering interventions in the form of knee stretching exercises combined with knee strengthening exercises have been approved and declared by the ethical standards of the Health Research Ethics Committee (KEPK) Faculty of Medicine, Muhammadiyah University of Surabaya, with the registration number (KEPK=MUS143). All participants in this study expressed their willingness to sign the informed consent form.

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ANNEXURE

Table 10: Clinical scoring system

	Rachun 1966	Wise 1977	Lee et al. (2004)	Schneider-Kolsky et al. 2006
Grade I	Localized pain, aggravated, by movement; Minor disability; mild swelling, ecchymosis, local tenderness; minimal hemorrhage	Minimal pain to palpation, well localized	small tear, <5% loss of function	<10° RoM deficit
Grade II	Localized pain, aggravated by movement; moderate disability; moderate swelling, ecchymosis, local tenderness; stretching and tearing of fibers, without complete disruption	substantial pain to palpation, poorly localized; 6-12mm difference in circumference, develops within 12-24 hours; <50% loss of RoM; considerable pain on contraction with considerable loss of power and greatly disturbed gait	Larger tears, 5-50% loss of function	10-25° RoM deficit
Grade III	Severe pain, and disability; severe swelling, ecchymosis, hematoma; palpable defects and loss of muscle function; muscle or tendon rupture	Intractable pain to palpation, diffuse; > 12 mm difference in circumference, develops rapidly within one hour; >50% loss of RoM; severe pain on contraction with almost total loss of power with flicker contractions and cannot bear weight	Complete tear >50% loss of function	>25° RoM deficit
Other	features	Contusion injury strains	Biceps not biceps	Direct injury indirect injury

(An update on the grading of muscle injuries (Grassi et al., 2016)).