Original Research Article

Comparative Effects of Cold and Heat Therapy on ACL Rehabilitation Among Teen Student-Athletes in the Western United States

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ABSTRACT

Student-athletes most frequently experience anterior cruciate ligament (ACL) injuries during sports that require sudden stopping, pivoting, jumping, or rapid changes in direction. Rehabilitation is a critical component of recovery and return to sport, with cold therapy (also known as cryotherapy) and heat therapy commonly used for symptom management. This study examines how teenage student-athletes in the Western United States use cold and heat therapy following an ACL injury and how they perceive the effectiveness of each modality. A mixed-methods approach was used, combining a structured review of peer-reviewed literature with survey-based data on rehabilitation experiences, therapy usage, and perceived outcomes. Findings indicate that cold therapy is more frequently utilized and preferred for pain and swelling management, particularly during early rehabilitation stages, whereas heat therapy is primarily used to promote flexibility and muscle relaxation during later phases of recovery. Overall, the results suggest that effective ACL rehabilitation should follow a stage-specific approach, with treatment selection tailored to the injury phase and individual recovery goals. These findings may help inform athletes, clinicians, and caregivers in developing more individualized rehabilitation strategies. The study was conducted in accordance with Glendale Unified School District (GUSD) guidance, and because it involved a minimum-risk, anonymous survey, institutional Review Board (IRB) approval was not required.

Keywords: Anterior Cruciate Ligament (ACL) injury; ACL rehabilitation; Cryotherapy (cold therapy); Heat therapy; Adolescent student-athletes; Sports injury recovery; Return-to-sport rehabilitation

INTRODUCTION

Anterior cruciate ligament (ACL) injuries are among the most common knee injuries in young athletes and frequently occur during high-intensity athletic activity. Epidemiological data from National Collegiate Athletic Association (NCAA) injury surveillance indicates that injury rates are significantly higher during games than practices and that lower extremity injuries account for more than half of all reported injuries, with anterior cruciate ligament injuries showing an increasing trend over time (1). Furthermore, ACL injuries frequently occur during dynamic athletic movements such as rapid changes in direction, pivoting, or unpredictable player contact that place excessive rotational stress on the knee joint. High-risk environments include field-based team sports as well as snow sports, where sudden deceleration or loss of balance may increase ligament strain (2). Damage to the ACL compromises knee stability and often results in prolonged rehabilitation, time away from sport, and increased risk of long-term joint complications. Because adolescence is a critical period for physical development

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and athletic participation, effective injury management during this stage has important implications for both short-term performance and long-term musculoskeletal health. Prior epidemiological research has demonstrated that injury risk in athletic populations is influenced by sport-specific demands and exposure conditions, with higher injury rates observed during games compared to practices and a predominance of lower extremity injuries across sports (1).

While substantial attention has been devoted to injury mechanisms, surgical techniques, and return-to-sport outcomes, comparatively less emphasis has been placed on how commonly used rehabilitation modalities are experienced and applied by student-athletes during recovery, particularly outside controlled clinical trials. Rehabilitation is a critical determinant of recovery following ACL injury, regardless of whether treatment is surgical or non-surgical. Among the most widely accessible and frequently used rehabilitation tools are cold therapy (cryotherapy) and heat therapy. Cold therapy is commonly employed to reduce pain and swelling, particularly during early stages of recovery, whereas heat therapy is often used to promote blood flow, reduce stiffness, and improve flexibility during later stages.

Although both modalities are routinely recommended, existing literature rarely examines their use from the perspective of adolescent athletes or directly compares how these therapies are perceived and utilized during real-world rehabilitation. This gap is especially notable in the Western United States, where youth sports participation is high and rehabilitation practices may vary based on access, education, and clinical guidance. Few studies incorporate athlete-reported experiences to assess directly how cold and heat therapy are used, preferred, or perceived as effective throughout the rehabilitation process. Therefore, the objective of this study is to examine differences in the use and perceived effectiveness of cold therapy compared to heat therapy following ACL injury among student-athletes in the Western United States. By combining a structured review of rehabilitation literature with survey-based data, this research aims to clarify how these modalities are applied in practice and to inform more stage-appropriate, athlete-centered rehabilitation strategies.

METHODS AND MATERIALS

Literature Review

A literature review was conducted using Google Scholar to identify peer-reviewed studies published up to 2023 related to ACL injuries and rehabilitation. Additional databases such as PubMed and general web-based academic sources were considered to ensure broader coverage of relevant literature. Search terms included combinations of "ACL rehabilitation," "anterior cruciate ligament," "cold therapy," "cryotherapy," "heat therapy," and "return to sport."

Studies were screened based on title and abstract for relevance to ACL rehabilitation and thermal therapy. Full-text articles were reviewed when necessary to determine eligibility. Studies were included if they focused on adolescents or young adults, addressed rehabilitation following ACL injury, or evaluated pain and symptom management strategies relevant to cold or heat therapy. Studies were excluded if they focused exclusively on unrelated knee injuries, non-rehabilitation outcomes, or populations outside the targeted age range. Duplicate or clearly irrelevant studies were removed during the screening process.

Nine peer-reviewed studies were found to meet the inclusion criteria and were reviewed to inform survey development and interpretation of rehabilitation outcomes. The literature review informed survey development and provided a framework for interpreting athlete-reported rehabilitation experiences.

Survey Data Collection

A survey was developed to assess rehabilitation experiences following ACL injury, with a specific focus on the use of cold therapy and heat therapy. The survey consisted of multiple-choice and Likert-scale questions covering the following domains: participant demographics (age at injury and gender), type of sport or activity at the time of injury, rehabilitation methods used, perceived effectiveness of cold and heat therapy, and any perceived negative effects associated with either modality. Likert-scale responses were measured using a 1–10 scale, where higher values indicated greater perceived effectiveness. No survey validation or pilot testing was conducted.

In accordance with Glendale Unified School District (GUSD) guidelines, students were permitted to conduct peer-based research surveys provided that a written disclaimer was included at the beginning of the survey informing participants of their rights. Informed consent was obtained electronically from all participants prior to survey completion, and no personally identifiable information was collected. All participants knowingly and willingly consented to participate under these conditions. Because this study was conducted as a

student-led research project within a secondary school setting and involved an anonymous, minimal-risk survey without collection of personally identifiable information, formal Institutional Review Board (IRB) approval was not required under local school district research guidelines. The study complied with GUSD policies for student research, and all participant responses were voluntarily provided, de-identified, and collected without recording names, contact information, or IP addresses.

Participants were recruited between March and May of 2024. I identified high school students in California with a known history of ACL injuries within my high school and surrounding community-based athletic networks and asked them personally to complete a survey on their experience with rehabilitation. All nine participants who were identified and invited completed the survey. Participants were informed prior to participation that involvement in the study was completely voluntary, that the survey posed minimal risk, and that they could decline to answer any question or withdraw at any time without consequence.

The survey was distributed electronically through Google Forms using a QR code or a direct link. The survey was completed anonymously, and participants were not compensated for completing the survey. Analysis of the results obtained from the survey was conducted using descriptive techniques such as frequency and percentages to describe the use of therapy, perceived helpfulness of therapy, and personal preferences. Because the sample size was small (n = 9), the analysis focused on descriptive statistics. Given the exploratory nature of the study, inferential statistical testing was not performed because the data was not sufficiently powered to support meaningful generalization. Descriptive statistics were used to summarize participant experiences and identify observable patterns rather than to establish causal relationships.

RESULTS

Literature Review Findings

Across the reviewed literature, recovery following ACL injury is consistently shown to depend on a combination of structured rehabilitation strategies and therapeutic modalities rather than any single intervention alone. Effective therapeutic interventions are evaluated through measurable physiological responses, in which variables such as timing, dosage, and intensity directly influence clinical outcomes. This includes reductions in pain, inflammation, and functional limitation following injury.

Consistent with this evidence-based approach, Shelbourne highlights that tissue healing is not solely dependent on biological capacity, but rather on the interaction between injury severity and intervention type (2). Together, these findings underscore a critical concept within ACL rehabilitation: ligament recovery and joint stability are not passive biological processes, but outcomes that are highly influenced by the timing, intensity, and type of therapeutic support implemented throughout rehabilitation (5).

Within ACL-specific rehabilitation research, Culvenor further refines this perspective by demonstrating that recovery outcomes are shaped by multiple interacting rehabilitation variables rather than by any single modality. Culvenor concludes that "rehabilitation outcomes were influenced by exercise selection, supervision, and adjunct therapeutic modalities rather than by a single intervention alone" (5). Across the studies reviewed, neuromuscular electrical stimulation consistently improved quadriceps strength, while both open and closed kinetic chain exercises yielded comparable gains in strength and self-reported function. Although supervised rehabilitation was generally associated with higher adherence, structured home-based programs produced similar outcomes for some patients, suggesting that effectiveness depends on both program design and patient engagement. Within this multifactorial framework, adjunct therapies, particularly cryotherapy, were identified as especially beneficial during early recovery phases.

Clinical evidence further supports the role of cryotherapy in acute postoperative management. Cohn, Draeger, and Jackson observed that "Hot/Ice patients required 53% less injectable Demerol and 67% less oral Vistaril" (1), following ACL reconstruction, demonstrating cryotherapy's effectiveness in reducing postoperative pain and reliance on analgesics. These findings are particularly relevant during the acute recovery phase, where effective pain management directly influences early mobility, rehabilitation participation, and long-term functional outcomes.

Beyond physiological mechanisms alone, adherence and patient engagement emerge as critical determinants of rehabilitation success. Kaye JA, Spence D, and Alexanders J emphasize that "as rehabilitation is essential for good knee function, strategies to improve adherence after non-ACLR treatment should be implemented" (6), reinforcing the importance of patient behavior in recovery outcomes.

Finally, while emerging thermal technologies such

as laser and radiofrequency therapies continue to gain attention, the current evidence supporting their clinical superiority remains limited. Khan, Sherman, and DeLay note that "over the past few years, the use of laser or radiofrequency energy to treat soft tissues… has blossomed" (8), however, existing findings do not surpass the evidence supporting established modalities such as cryotherapy, particularly during early-stage recovery. Collectively, the literature demonstrates that ACL rehabilitation effectiveness depends on individualized, stage-specific protocols integrating exercise strategy, adjunct therapies, and patient adherence. Although cryotherapy is well supported for short-term pain reduction and early recovery, no studies directly compare superficial heat and cold therapy across varying severities of ACL injury, particularly among adolescent and young adult student-athletes. Addressing this gap through systematic review is essential to determine optimal thermal intervention strategies and to strengthen evidence-based rehabilitation protocols in school-based athletic programs.

Survey Results

A total of nine participants (n = 9) completed the survey, and results are presented using descriptive statistics with counts and percentages. Participant demographics are summarized in Figures 1 and 2. As showed in Figure 1, the total sample, 5 out of 9 participants (55.6%) identified as male, while 4 out of 9 participants (44.4%) identified as female. No participants selected "prefer not to say." The data indicate a relatively balanced gender distribution, with a slight predominance of male respondents. The x-axis represents gender categories (male, female, prefer not to say), and the y-axis represents the number of participants within each category. Percentages are displayed within each segment of the pie chart to illustrate proportional representation. As shown in Figure 2, most participants sustained their ACL injury during adolescence or young adulthood, with the largest proportion reporting injury between the ages of 13–16, followed by ages 10–13 and 16–20. Figure 1 presents the gender distribution of respondents, indicating a mixed sample with a slight predominance of male participants compared to female participants. The context in which injuries occurred is summarized in Figure 3. 8/9 participants (88.9%) reported sustaining their ACL injury while participating in physical sports involving interaction with others, such as team or contact-based activities. In contrast, 1/9 participants (11.1%) reported injuries occurring in non-contact or individual sport settings. Patterns of rehabilitation modality use are presented in Figure 4. 5/9 participants (55.6%) reported primarily using cold therapy during rehabilitation. In comparison, 1/9 participants (11.1%) primarily used heat therapy. An additional 2/9 participants (22.2%) reported

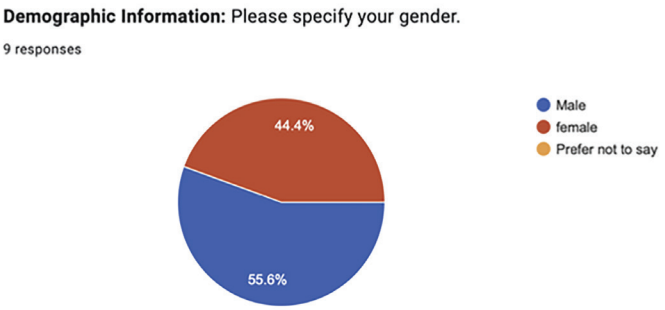

Figure 1. *Gender distribution of survey respondents (n = 9). The x-axis shows gender category, and the y-axis shows the number of participants.*

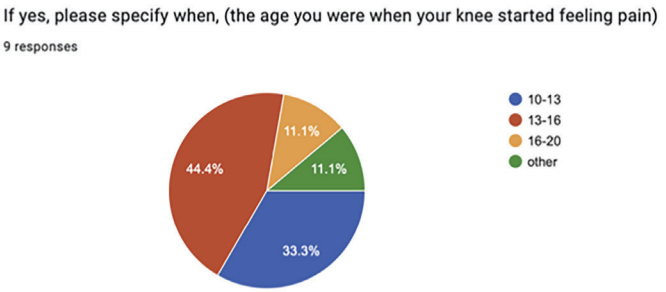

Figure 2. *Age distribution of survey respondents (n = 9). The x-axis shows age group, and the y-axis shows the number of participants.*

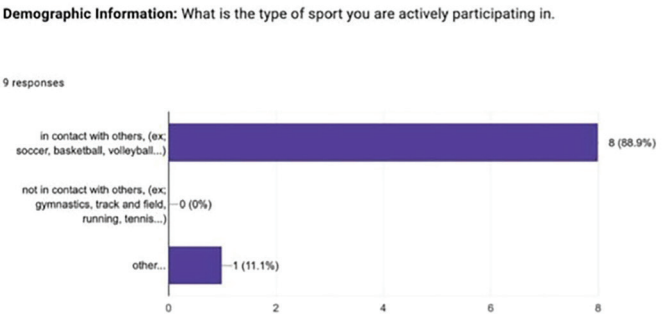

Figure 3. *Type of sport activity associated with ACL injury (n = 9). The x-axis shows activity type (contact vs. non-contact), and the y-axis shows the number of participants.*

using both cold and heat therapy, and the remaining participants reported not using either modality during their rehabilitation process. Perceived effectiveness of each therapy modality is summarized in Figures 5 and 6. Figure 5 indicates that participants generally rated cold therapy as moderately to highly effective for managing pain and swelling during rehabilitation. Most ratings clustered in the mid-to-high range of the scale. The mean rating for cold therapy was 6.0 on a 1–10 scale (SD = 2.45), with a median of 7 and a range of 8, indicating overall higher perceived effectiveness among respondents. In contrast, Figure 6 indicates greater variability in perceived effectiveness ratings for heat therapy, suggesting less consistent experiences among participants. Heat therapy demonstrated a mean rating of 4.33 on a 1–10 scale (SD = 3.20), with a median of 3 and a range of 7. Potential negative effects associated with therapy use are summarized in Figure 7. 6/9 participants (66.7%) reported that neither cold nor heat therapy worsened their rehabilitation or increased pain, while a smaller proportion reported negative effects associated with one of the modalities. Finally, participant preferences and recommendations are shown in Figure 8. 7/9 participants (77.8%) indicated a preference for and willingness to recommend cold therapy to other student-athletes with similar injuries, while the remaining

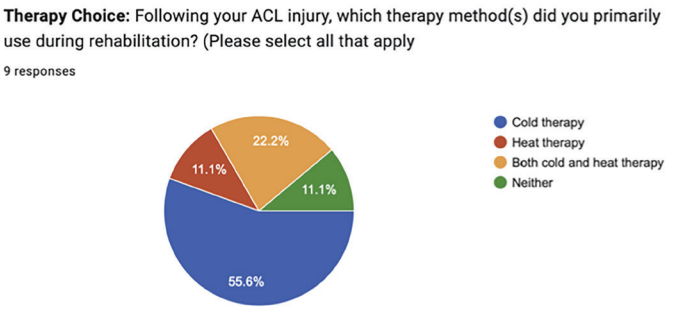

Figure 4. *Rehabilitation therapy methods used by participants (n = 9). The x-axis shows therapy type, and the y-axis shows the number of participants.*

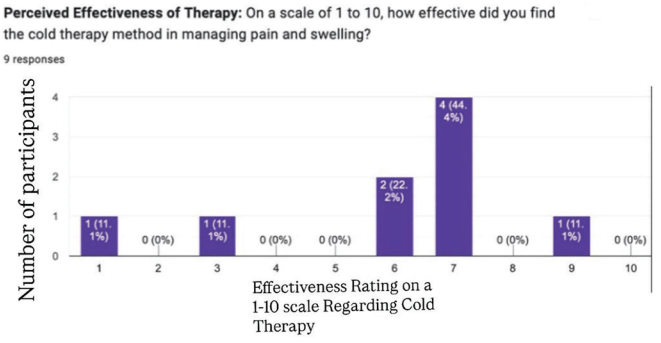

Figure 5. *Perceived effectiveness of cold therapy (n = 9). Ratings are shown on a 1–10 scale, with the x-axis representing responses and the y-axis representing effectiveness scores.*

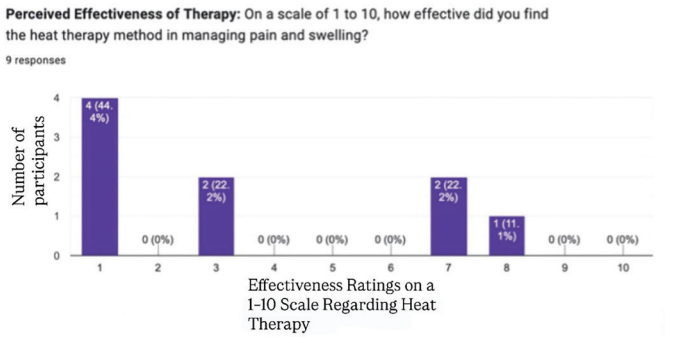

Figure 6. *Perceived effectiveness of heat therapy (n = 9). Ratings are shown on a 1–10 scale, with the x-axis representing responses and the y-axis representing effectiveness scores.*

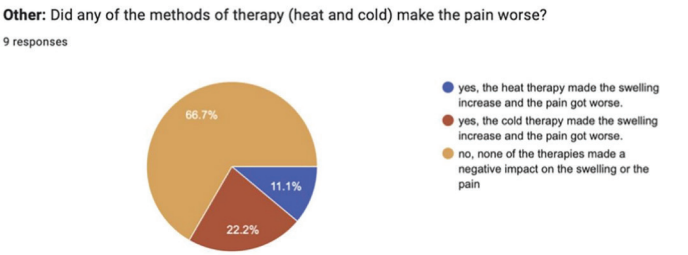

Figure 7. *Reported negative effects of therapy (n = 9). The x-axis shows response categories, and the y-axis shows the number of participants.*

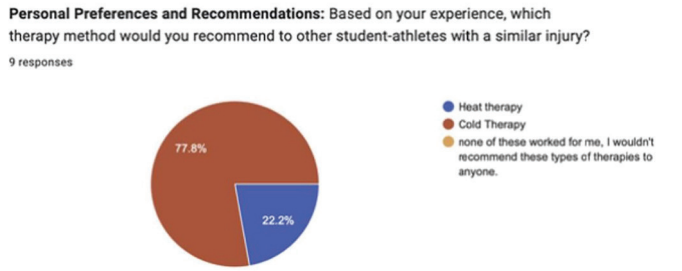

Figure 8. *Participant preference and recommendation of therapy (n = 9). The x-axis shows therapy type, and the y-axis shows the number of participants.*

participants either favored heat therapy or did not recommend either modality.

Overall, literature findings indicate that cryotherapy may provide short-term pain relief during ACL rehabilitation, while broader recovery outcomes are influenced by comprehensive rehabilitation strategies. The greater reliance on cold therapy observed in this study reflects how adolescent athletes may prioritize immediate symptom relief during early rehabilitation phases, aligning with clinical guidance that emphasizes inflammation control before progression to mobility-focused interventions. These findings provide descriptive insight into therapy usage patterns among student-athletes following ACL injury.

DISCUSSION

ACL injuries pose significant challenges for adolescent and young adult athletes, with an estimated 200,000 ACL injuries occurring annually in the United States and approximately 80,000–100,000 ACL reconstructions performed each year (9). Findings from both the literature review and the survey results indicate that rehabilitation outcomes are not optimized by reliance on a single modality, but rather through an individualized, stage-specific approach that accounts for injury severity, phase of recovery, and patient preferences. The greater reliance on cold therapy observed in this study suggests that adolescent athletes may prioritize early symptom management strategies that align with established clinical guidance on inflammation control. In contrast, heat therapy appears to be perceived as more context-dependent, suggesting that athletes may associate thermal modalities with different stages of recovery rather than viewing one approach as universally superior. These findings support a stage-specific model of rehabilitation in which cold therapy may be more relevant during acute inflammatory phases, while heat therapy may contribute to flexibility and tissue preparation during later functional recovery. For patients, clinicians, and athletic trainers, these findings emphasize that cold therapy may be most appropriate for early symptom control, while heat therapy may be more beneficial during later stages to address stiffness and mobility limitations, reinforcing the importance of shared decision-making in rehabilitation planning.

Limitations

Although this study provides preliminary insight into athlete-reported rehabilitation experiences, the literature review was limited to peer-reviewed studies available through Google Scholar and publicly accessible databases, which may have excluded unpublished studies, ongoing clinical trials, or rehabilitation research published in non-indexed journals. Additionally, while systematic reviews were prioritized, variability in study design, outcome measures, and participant populations across the included literature limits direct comparison between rehabilitation approaches.

Another significant limitation of this study is that the survey component relied on a small convenience sample of only nine participants, which significantly restricts generalizability to the broader population of teen student-athletes. Survey responses were self-reported and retrospective, making them subject to recall bias and individual interpretation of rehabilitation effectiveness. Furthermore, the absence of objective clinical outcome measures, such as strength testing or functional performance metrics, precludes causal inference regarding the effectiveness of cold versus heat therapy in terms of functional outcome. The absence of a control group without the use of either cold and heat therapy limits the interpretability of the effect of these therapeutic methods. These limitations highlight the need for future research using larger, more diverse samples and standardized outcome measures. Future research employing larger sample sizes and randomized controlled designs is needed to further clarify optimal rehabilitation strategies. Overall, this study highlights that effective ACL rehabilitation is best achieved through a tailored approach in which cold and heat therapy are applied strategically according to recovery phase and individual patient needs.

CONCLUSION

This study aimed to examine differences in the use and perceived effectiveness of cold therapy versus heat therapy following ACL injury among teen student-athletes in the Western United States. Findings from both the literature review and survey data indicate that cold therapy is more frequently used and preferred, particularly during early stages of rehabilitation for pain and swelling management, while heat therapy is more commonly applied during later stages to address stiffness and promote flexibility. These results highlight the importance of a stage-specific and individualized rehabilitation approach rather than reliance on a single modality. The study's findings have practical implications for athletes, clinicians, and athletic trainers

by emphasizing informed, phase-appropriate decision-making in rehabilitation planning. However, conclusions should be interpreted in light of limitations including a small convenience sample, reliance on self-reported data, and the absence of objective clinical outcome measures. Future research using larger, more diverse samples and controlled study designs is needed to further clarify optimal rehabilitation strategies. Overall, this study contributes athlete-centered insight into real-world rehabilitation practices and reinforces the value of tailoring cold and heat therapy to recovery stage and individual needs.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest related to this work.

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