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Research Article

Comparative Effects of Mulligan Mobilization, Kinesiotaping, and Placebo on Functional Outcomes and Overuse Symptoms in Young Basketball Players: A Three-Arm Randomized Controlled Trial

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Abstract

This study comparatively evaluated the short-term effects of Mulligan Mobilization with Movement (MWM), Kinesiotaping, and placebo on knee function and overuse-related symptoms in young basketball players (U16–U20) with knee injuries. A three-arm, parallel-group randomized controlled trial was conducted from December 2024 to March 2026 in Tirana, Albania, involving 60 participants randomly allocated to the MWM, Kinesiotaping, and placebo groups. Knee function was quantitatively assessed using the Knee Outcome Survey–Activities of Daily Living Scale (KOS-ADLS) and Sports Activity Scale (KOS-SAS), while overuse-related symptoms were evaluated using the Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire. Assessments were performed at baseline, 1 h after treatment, and at 2 weeks of follow-up. Statistical analyses were performed using JASP version 0.19.2 to evaluate temporal changes and differences among the intervention groups. No significant main Group effects were observed ($p > 0.05$), indicating no overall superiority of MWM or Kinesiotaping over placebo. Significant Time effects and Group × Time interactions were observed for KOS-ADLS, KOS-SAS, and OSTRC scores ($p < 0.001$), indicating significant improvements over time and distinct patterns of change across the intervention groups. Post hoc analyses demonstrated greater improvements at the 2-week follow-up than at 1 h after treatment. Overall, the findings demonstrate measurable improvements in knee function and overuse-related symptoms during the study period, without evidence of overall superiority of any intervention. These findings provide quantitative evidence for the comparative evaluation of conservative rehabilitation interventions and may support individualized, evidence-based rehabilitation strategies for young basketball players with knee injuries.

Keywords: Mulligan Mobilization with Movement; Kinesiotaping; Knee Injuries; Functional Outcomes; Overuse Symptoms; Randomized Controlled Trial.

INTRODUCTION

Basketball involves high-speed, high-intensity movements, including jumping, landing, sprinting, turning, and rapid changes of direction [1, 2]. These physical demands contribute to a high incidence of musculoskeletal injuries, particularly knee injuries, among basketball players, with young athletes under 21 years of age being especially vulnerable [3]. Current epidemiological evidence highlights the increased risk of knee injuries in young basketball players [3, 4], while studies conducted in Albania have also examined trauma-related risks in this population [5]. Common knee-related conditions reported among basketball players include anterior knee pain, patellofemoral pain, tendinopathy, anterior cruciate ligament (ACL) injuries, and meniscal injuries [2, 6].

In young basketball players, the development of overuse injuries may be influenced by sport-specific movements and biomechanical loading, together with factors such as excessive sports participation, rapid biological growth, and age-related neuromuscular changes [2, 6–9]. The impact of overuse injuries can be assessed using the Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire, a validated and standardized instrument designed to identify overuse injuries and related health problems in athletic populations [8, 9]. Assessment of young athletes typically includes evaluation of functional capacity and monitoring of symptoms, neuromuscular control, and dynamic stability, providing quantitative measures for evaluating physical function and rehabilitation outcomes.

The Knee Outcome Survey-Sports Activity Scale (KOS-SAS) and Knee Outcome Survey -Activities of Daily Living Scale (KOS-ADLS) are self-report instruments with two subscales, characterized by a high reliability rate ICC> 0.9 [10], that help in assessing the sports activities and functional level of the knee of young basketball players [11]. Currently, there are several conservative physiotherapy approaches aimed at improving sports participation and functional performance in basketball players. Mulligan's is one of the techniques that is used in the field of sports physiotherapy, and which combines joint mobilization with active movement by the patient, aiming to influence the mechanics of the joints during the affected functional movements. On the other hand, it acts with a neurophysiological mechanism by affecting pain and remodelling sensorimotor control and thus affects the short-term effect of functional improvement [12, 13]. Also, in our literature review study, the Mulligan Mobilization with Movement technique was reported to have a significant effect on the management of knee injuries in basketball players [14]. Another technique that finds use in the field of sports rehabilitation is Kinesiotaping. It requires the application of Kinesio ® Tex tape with the aim of activating nociceptive impulses, affecting the level of pain, muscles, and functionality [15]. Current literature has demonstrated the benefits of Kinesiotaping on pain, edema, balance, and functionality in knee injuries, often with unstable effects [16, 17].

Regarding the mechanism of action, Kinesiotaping acts through nociceptive sensory [15], unlike Mulligan, which acts by directly mobilizing the joint. The dynamic load of basketball players and the impact of each intervention may lead to changes in clinical responses. Meanwhile, in the current studies of recent years, placebo interventions with their active mechanisms have been used, and not only the use of active rehabilitative interventions in nociceptive, biomechanical improvements or neuromuscular adaptations in the progressive improvement of outcomes in knee injuries [18, 19]. Therefore, the combination of treatment between active interventions and placebo helps in determining the clinical contribution and its specific effect. Nowadays, the number of randomized studies regarding the conservative management of knee injuries in young basketball players is numerous. However, there are still gaps in the literature. First, there is a lack of randomized studies that compare the effect of the Mulligan intervention, Kinesiotaping, and Placebo in the same study design. Second, there is a lack of randomized studies in young basketball players with knee injuries that simultaneously assess general and sports function related to overuse symptoms using validated instruments such as KOS-ADLS, KOS-SAS, and OSTRC. Third, despite numerous studies regarding the epidemiology of knee injuries in basketball players [2, 3], limited studies are related to the application of active rehabilitation interventions in young basketball players. After reviewing the current literature, we can say that this is a novel study in the field of sports physiotherapy, as it is considered one of the first randomized studies in young basketball players with knee injuries on which the Mulligan MWM, Kinesiotaping, and Placebo interventions are applied, and the KOS-ADLS, KOS-SAS knee function and symptoms related to overuse are assessed.

The current literature supports the use of rehabilitation interventions such as Mulligan MWM, Kinesiotaping, and placebo in knee problems or injuries. However, most studies have focused on adult populations, postoperative conditions, and non-basketball samples, see Table 1. It is worth noting that no randomized study has simultaneously compared the three interventions: Mulligan, Kinesiotaping, and Placebo. Furthermore, no RCT study has examined the outcomes of KOS-ADLS, KOS-SAS, and OSTRC in young female basketball players. Therefore, this RCT study was designed to address this gap in the current literature. Therefore, the purpose of this randomized controlled trial was to compare short-term changes in knee function and overuse-related symptoms following Mulligan MWM, Kinesiotaping, or placebo intervention in U16-U20 basketball players with knee injuries. This study, in its final design, was guided by several Research Questions:

- RQ1: Do Mulligan MWM, Kinesiotaping, and Placebo produce changes over time in primary outcomes KOS-ADLS and KOS-SAS?
- RQ2: Does injury type influence treatment response to Mulligan, Kinesiotaping, and Placebo?
- RQ3: Do Mulligan MWM and Kinesiotaping demonstrate different patterns of change in OSTRC outcome?

Based on the available evidence, the hypotheses of this randomized study were also built:

- H1: The Mulligan MWM group will have greater improvement in KOS-ADLS and KOS-SAS outcomes compared to the Kinesiotaping and Placebo group at 2 weeks.

- H2: The effect of the Mulligan MWM and Kinesiotaping groups will vary depending on the type of injury in the young basketball players. Tertiary Hypothesis
- H3: Mulligan MWM will have acute improvement in OSTRC outcomes while the Kinesiotaping group will have progressive improvement.

Table 1 State of the Art Evidence on Conservative Rehabilitations and Interventions

Study	Study Design	Participant/ Population	Injury	Intervention	Main Findings and Analytical
[10]	Instrument Validation Study	Patients with various knee disorders	Knee dysfunction	Validation, reliability, and responsiveness of the Knee Outcome Survey, an instrument for KOS-ADLS and KOS-SAS.	Developed and validated the KOS self-report instrument as reliable and applicable to daily functioning and sports-related functions for knee problems. This instrument remains one of the most useful outcomes for individuals with knee problems.
[8]	Validation study	Athletes from multiple sports	Knee, LBP, and shoulder problems	OSTRC questionnaire	Developed and validated the OSTRC Overuse Injury Questionnaire as a standardized instrument. In our study, we used only the specific knee section.
[12]	Systematic Review and Meta-analysis	Athletes and patients with ankle sprains	Ankle sprain	Mulligan Mobilization with movement MWM	MWM improved pain, joint flexibility, and function compared to the control group. However, the findings are primarily related to ankle sprains and not knee injuries, adding to the need for the RCT study on the knee in young basketball players.
[16]	Systematic Review and Meta-Analysis of	Patients undergoing ACL reconstructio	Post-operative knee disorders	Kinesiotaping	The results demonstrated the effect of kinesiotaping in reducing pain, edema,

	Randomized Clinical Trials	n and total knee arthroplasty			and range-of-motion limitations during post-operative rehabilitation. However, a limitation of this study was the lack of intervention in young basketball players and non-operative conditions.
[20]	Systematic Review and Meta-Analysis	Patients with patella-femoral pain syndrome PFPS	Patello-femoral syndrome	Kinesiotaping	Kinesiotaping improved pain and short-term function compared to the control group. The included studies were not specific to young basketball players.
[18]	Systematic Review, Meta-Analysis, and Meta-Regression	Patients with patellar tendinopathy	Patellar tendinopathy	Placebo Interventions	Placebo interventions demonstrated clinical effects on pain and function, supporting the inclusion of placebo-controlled rehabilitation. These findings support the inclusion of Placebo in rehabilitation RCT studies.
[13]	RCT	Adults with patella-femoral pain syndrome	Patella-femoral syndrome	Mulligan Mobilization with movements MWM Mulligan Knee Taping	MWM demonstrated greater improvements in pain, joint flexibility, and function than Mulligan taping. However, it did not include young basketball players and overuse-related symptoms were not assessed.
[17]	Pilot clinical trial	Athletes after ACL reconstruction	ACL injury	Kinesiotaping Placebo	Kinesiotaping improved function and balance. However, participants included post-operative patients aged 18-45 years and not young basketball players.

[21]	RCT	Youth basketball players	Functional performance deficits	PNF(Propioception neuromuscular facilitation) NMES(Neuromuscular Electrical Stimulation)	This study demonstrated a short-term effect of functional improvement. However, this study did not use the interventions of our study.
[14]	Systematic Review	Patients with various knee pathologies	PFPS, meniscal injuries, knee osteoarthritis, and post-traumatic stiffness	Mulligan Concept MWM technique	MWM demonstrated improvement in pain, joint flexibility, muscle strength, and function. Studies were heterogeneous, and follow-up was short-term with limitations in young basketball players.

METHODOLOGY

Study Design

This study was conducted as a parallel -group randomized controlled clinical trial design and was retrospectively registered at ClinicalTrials.gov Identifier: NCT07510243 [22]. This study included three treatment arms: Mulligan mobilization MWM, Kinesiotaping, and Placebo. Outcomes were assessed before treatment, 1 hour after treatment, and at the 2- week follow-up. The intervention phase lasted two weeks and formed part of a doctoral research project. This trial was reported in accordance with the CONSORT guidelines.

Ethical Approval

This study is part of a doctoral research project approved by the Ethics Committee of the University of Sports, Tirana (ethical code: 3736, 3736/1,3(13)736/2). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from the participants themselves and their parents for those under 18 years of age. All data were treated confidentially in accordance with international guidelines.

Participants

The participants were young basketball players from the U16, U18, and U20 age groups. Presenting with overuse-related knee symptoms associated with sports participation were recruited from local sports clubs. The participants were young basketball players from U16, U18, and U20 age groups who were recruited from local sports clubs. To be included in this study, participants had to be male or female, have at least two years of sports experience, have a current knee injury, be actively participating in sports, and provide written consent. Meanwhile, participants with previous knee surgery, knee instability, neurological disorders, or those who did not agree to receive the Mulligan MWM intervention were excluded. The participants provided their data, which was used in the study.

Participants were categorized into two clinical subgroups: the structural injury group, which included basketball players diagnosed with anterior cruciate ligament ACL injuries and medial meniscus injuries, and the other group was the overuse-related injury group, which included basketball players diagnosed with tendinopathy and patellofemoral pain syndrome. This classification was performed to address the potential heterogeneity of the knee pathologies among the participating basketball players. Furthermore, this approach was adapted due to the very limited number of participants within individual diagnostic categories. The classification was subsequently used in exploratory stratified analyses to investigate whether treatment response differed according to injury category.

Sample Size Calculation

The sample size was calculated using the G*Power 3.1 program [23], keeping the significance level as α = 0.05, effect size f = 0.35, and study power = 0.85. The sample size was found to be 63 in total, but a total of 60 basketball players. Although the a priori sample size calculation suggested a slightly larger sample size, the final sample size included 60 participants. However, based on the observed interaction effect of the primary outcome in the Mixed-design ANOVA, post hoc power analysis demonstrated a statistical power of 1.00, indicating sufficient power to detect the treatment effects.

Randomization and Blinding

This is a single-blinded study design; participants were blinded and randomly allocated into three groups using a computer–generated sequence [24] with balance for gender. Meanwhile, the investigator, care provider, and outcome assessors were not blinded due to the nature of the interventions. However, to reduce the risk of bias, standardized outcomes and protocols were used.

Procedure and Interventions

Mulligan MWM Group

To ensure homogeneity, the same standardized MWM intervention in a weight-bearing position was used for all participants, regardless of the specific knee injury. The intervention consisted of a sustained medial tibial glide by the physiotherapist while participants actively performed a pain-free squat movement according to the principles of the Mulligan Concepts [25]. The weight-bearing squat position and medial tibial glide were selected based on previous evidence reporting improvements in pain, joint mobility, and functional outcomes in individuals with knee joint disorder [26, 27]. Treatment was delivered twice weekly over a two-week period, with each session lasting approximately five minutes. All procedures were performed by a physiotherapist certified in the Mulligan Concept.

Kinesiotaping Group

The protocol for applying Kinesiotaping to study participants was selected based on the principles of Kinesiotaping and clinical applications in the sports population [15]. According to Kenzo, combined corrective approaches are recommended to address functional requirements, stabilize the knee, and simultaneously control knee flexion and extension movements [15]. The same Kinesiotaping procedure was used for all participants, regardless of the specific knee injury. Tape length was measured according to the medial and lateral femoral condyles. A Y- shaped strip was applied from the tibial tuberosity toward the femoral condyles, and an additional strip was placed horizontally over the patella, combining patellar support and another Y-shaped Kinesiotaping application. The intervention was applied twice a week for two weeks, with each application lasting approximately five minutes.

Placebo Group

Participants in the Placebo group underwent a sham intervention that mimicked the Mulligan MWM technique through positioning and glide application, but did not actually apply the glide, only weight-bearing position and active flexion and extension without any specific mechanical treatment effect. The procedures were performed with the same duration and frequency as the active intervention groups (twice weekly for two weeks, approximately 5 minutes per session). The Placebo group was included in the study to control for contextual effects related to the expected effects associated with the active interventions.

Outcome Measures

The outcome measures in the Mulligan, Kinesiotaping, and Placebo groups in all three treatment periods: baseline, 1 h, and 2-week follow-up. These outcomes were selected because they are used in the sports population to assess functional and sports activity of the knee and overuse-related knee symptoms.

KOS

The Knee Outcome Survey (KOS) was used in this study to assess functional limitation related to the knee joint. This questionnaire consists of two subscales: 1. The Activities of Daily Living (KOS-ADLS) scale and the Sports Activity Scale (KOS-SAS). These instruments were used because, although it is self-report questionnaires, has demonstrated validity and reliability in clinical populations [10].

OSTRC

The Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire is a self-reported instrument that has demonstrated acceptable validity and reliability for monitoring overuse-related symptoms in athletic populations [8]. This questionnaire has 3 parts, but in our study, the focus was on the knee, so the shoulder and lower back sections of the questionnaire were excluded. The four OSTRC items evaluate how symptoms affect participation in sport, athletic performance, training volume, and symptom severity. The OSTRC was selected as an outcome measure because it is specifically designed to monitor overuse-related symptoms and their consequences in athletes, making it appropriate for sports rehabilitation research.

Statistical Analysis

The collected data were processed and analyzed using the statistical software JASP (version 0.19.2). Initially, descriptive statistics were used to assess the basic comparability between groups. Descriptive analysis included mean, standard deviation (SD)for age, body mass index (BMI), and sports experience. Normality was assessed using the Shapiro-Wilk test. When normality assumptions were violated, the Kruskal-Wallis test was applied.

Descriptive statistics were reported for outcomes (KOS-ADLS, KOS-SAS, and OSTRC) measurement in three-time pre-treatment, 1 h, and 2 weeks follow-up. Assumptions for repeated measures analysis were assessed using tests of normality, homogeneity, and sphericity. For sphericity, we used Mauchly’s test for KOS-ADLS, and Greenhouse-Geisser correction was applied for KOS-SAS and OSTRC.

Analysis of Covariance (ANCOVA) was performed to control for possible differences between groups for KOS-ADLS, KOS-SAS, and OSTRC outcomes, using the corresponding baseline scores as covariates.

The primary analysis used Mixed ANOVA to evaluate the effects of time, group, and interaction on the KOS-ADLS, KOS-SAS, and OSTRC. Post Hoc analysis was used on all outcomes to assess pairwise differences between groups and times. Cohen's effect at the group and time levels of treatment was used to determine the size of the effect.

Reliability analysis was performed for the instruments used in this study, the KOS-ADLS, KOS-SAS, and OSTRC, to demonstrate the internal consistency of these questionnaires. During the reliability analysis, Cronbach's alpha coefficient α and McDonald's omega ω were used, and the 95% CI confidence interval was calculated using the baseline data of translated versions of the questionnaires to the study population.

To address the heterogeneity of the participants' knee injuries, we categorized them into two groups due to the small number of participants in each injury category. The structural injury group (ACL injuries and medial meniscus injuries) and the overuse injury group (patellar tendinopathy and patellofemoral pain syndrome). An exploratory analysis of injury stratification was conducted by including injury category as an additional factor between subjects to assess which of the interventions could affect injury categories.

To strengthen the robustness of the findings, Linear Mixed Models LMM analysis was also performed for the KOS-ADLS, KOS-SAS, and OSTRC study outcomes using REML estimation. The time effect, group effect, and interaction effect were used as fixed effects, while participant identification was treated as a random intercept.

Finally, a sensitivity analysis was performed for the primary outcome, KOS-ADLS, to assess the robustness of the findings.

RESULTS

Among the 75 screened participants, 15 were excluded, and a total of 3 participants dropped out during the intervention. Represented in the CONSORT 2025 Flow diagram (Figure 1) [28]. In all three groups, Mulligan, Kinesiotaping, and Placebo, the number of participants was equal, N=20. In the table are the baseline anthropometric data and descriptive statistics of the participants.

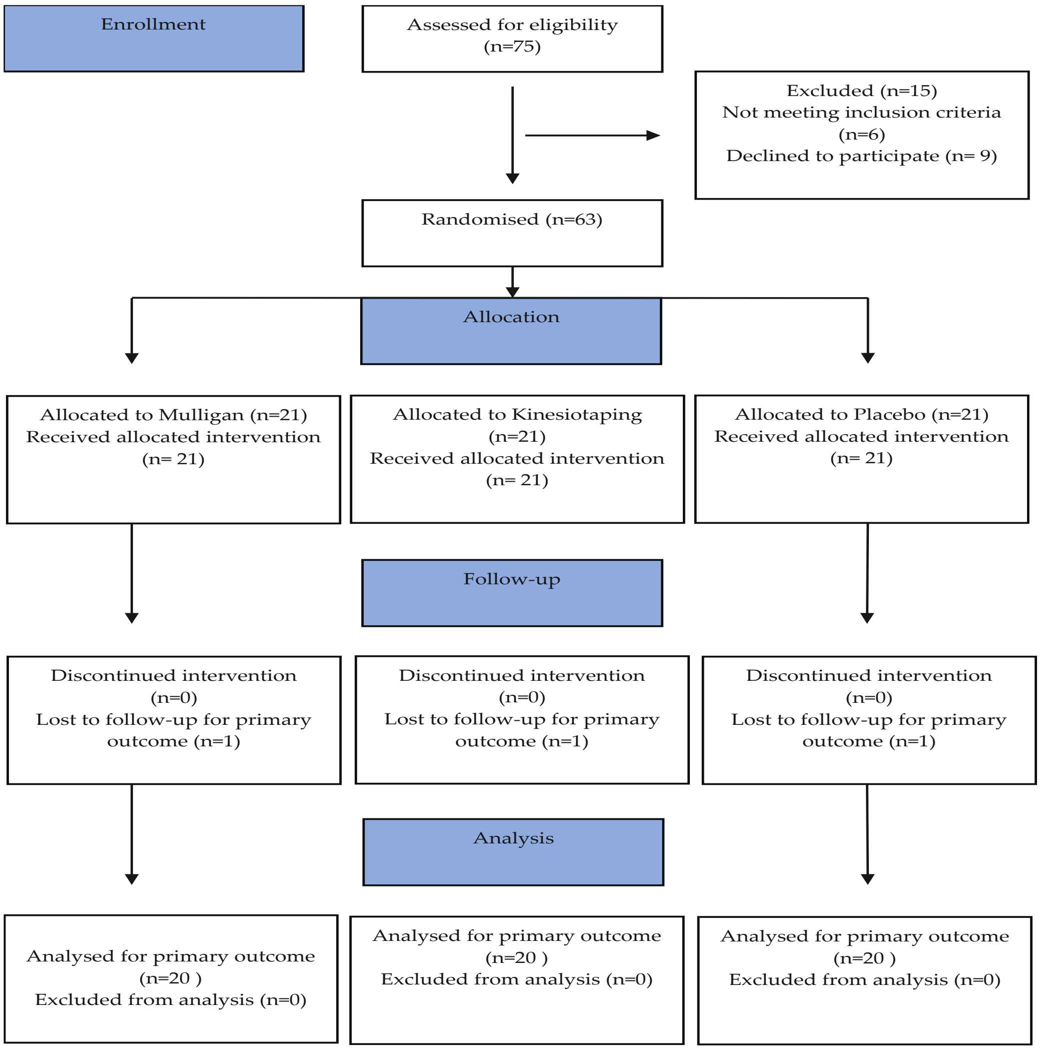

Figure 1. CONSORT 2025 Flow Diagram

Baseline Anthropometrics characteristic of the participants is presented in Table 2. Anthropometric data for athletes were presented as mean ± SD across the three intervention groups. One-way ANOVA was used to compare differences between groups, and p-values <0.05.

The descriptive statistics for KOS-ADLS, KOS-SAS, and OSTRC across three time points are presented in Table 3. Mean± SD values are presented for KOS-ADLS and OSTRC outcomes for each group. Scores tended to increase in all three groups, especially in the

Mulligan MWM group, indicating improved knee function, while OSTRC values decreased, especially in the Mulligan MWM group, reflecting reduced injury -related problems.

Table 2. Baseline Anthropometrics of Participants N=60

Variable	Mulligan MWM (n=20) Mean±SD	Kinesiotaping (n=20)Mean±SD	Placebo (n=20) Mean±SD	p(value)
Age (years)	17.2±1.15	17.4±2.39	17.5±1.98	0.881
BMI (kg/m2)	22.99±1.92	22.26±3.26	22.7±3.19	0.720
Sport experience (years)	6.3±2.94	5.6±2.72	5.9±2.19	0.703

*Note: * Significant (p<0.05),** Non-Significant (p>0.05), BMI: Body Mass Index, Mean, SD: Standard Deviation.*

Table 3. The Descriptive Results of KOS-ADLS, KOS-SAS and OSTRC at Three Measurement Times.

Outcome	**Time**	**Mulligan MWM (Mean ± SD)**	**Kinesiotaping (Mean±SD)**	**Placebo (Mean±SD)**	**p-value**
KOS-ADLS	Baseline	66±18.94	59.13±17.47	64.4±16.78	p=0.47
	1 h	63.89±17.24	66.46±18.83	64.41±16.78	p=0.898
	2 weeks	72.07±17.7	74.97±18.65	67.25±16.41	p=0.380
KOS-SAS	Baseline	50.85±22.86	62.4±21.49	65.62±15.76	p=0.214
	1 h	52.97±25.4	58.05±20.73	66.43±15.38	p=0.106
	2 weeks	63.72±22.29	65.24±21.19	68.79±15.83	p=0.678
OSTRC	Baseline	59.15±25.1	49.4±28.75	46.4±19.91	p=0.215
	1h	52.25±26.21	38.95±29.88	46.2±19.6	p=0.345
	2 weeks	33.45±28.84	5.9±2.198	39±20.34	p=0.731

*Note: *Significant (p<0.05),** Non-Significant (p>0.05), Mean± Standard Deviation, KOS-ADLS: Knee Outcome Survey-Activities of Daily Living, KOS-SAS: Knee Outcome Survey -Sports Activity Scale, OSTRC: Overuse Injury Questionnaire, 1h: one hours post treatment, 2 weeks: 2 weeks post-treatment.*

An Analysis of Covariance (ANCOVA) was performed on all three questionnaires presented in Table 4, using baseline questionnaire scores as covariates, to control for baseline differences between treatment groups. After performing the analysis, a significant group effect was observed for KOS-ADLS ($F(2.56)=186.70$, $p<0.001$, $\eta^2 p=0.870$), for KOS-SAS ($F(2.56)=211.70$, $p<0.001$, $\eta^2 p=0.883$), and for OSTRC($F(2.56)=158.70$, $p<0.001$, $\eta^2 p=0.850$), for all three outcomes at 2-week follow-up. These findings indicate that, after adjustment for baseline scores, significant differences between treatment groups remained, while functional status was a strong predictor of post-treatment outcomes.

Table 4. Baseline-Adjusted Analysis of Covariance ANCOVA for the Study Outcomes

Outcome	Group F(df)	p	Partial eta η^2p
KOS-ADLS	F(2.56)=186.70	<0.001	0.870
KOS-SAS	F(2.56)=211.70	<0.001	0.883
OSTRC	F(2.56)=158.70	<0.001	0.850

*Note: *Significant (p<0.001), KOS-ADLS: Knee Outcome Survey-Activities of Daily Living, KOS-SAS: Knee Outcome Survey -Sports Activity Scale, OSTRC: Overuse Injury Questionnaire, F: F-value from ACOVA, Df: degrees of freedom, Partial η^2p: eta squared effect size.*

The results of a mixed ANOVA examining the effects of time, group, and their interaction are shown in Table 5. A mixed ANOVA was used to examine the effects of time, group, and interaction for the KOS-ADLS and OSTRC outcomes. F values, degrees of freedom (df), p values, and η^2p partial eta squared are presented in the table. The effect of time was statistically significant for KOS-ADLS and OSTRC; ADLS (F=1026.6, p<0.001); SAS (F=191.39, p<0.001); OSTRC (F=774.84, p<0.001). The main effect interaction was also statistically significant for the Activities of Daily Living Scale (ADLS), the Sports Activity Scale (SAS), and the overuse injury OSTRC, suggesting that the pattern of change over time differed between the three treatment groups. Regarding the effect of Group, in the Mixed ANOVA, there were no significant changes.

Table 5. The Results of the Mixed Repeated Measures ANOVA, Examining the Effect of Time, Group, and Group*Time on Functional and Overuse Injury Outcomes.

Outcome	Effect	F	Df	p-value	Partial η^2p
KOS-ADLS	Time	1026.6	1.382,76.007	<0.001	0.949
	Group	0.521	2,55	=0.597	0.019
	Group*Time	122.1	2.764,76.007	<0.001	0.816
KOS-SAS	Time	191.39	1.173,66.864	<0.001	0.771
	Group	1.537	2,57	=0.224	0.051
	Group*Time	22.75	2.346,66.864	<0.001	0.444
OSTRC	Time	774.84	1.531,81.581	<0.001	0.931
	Group	0.169	2,57	=0.845	0.006
	Group*Time	82.03	2.863,81.581	<0.001	0.742

Note: KOS-ADLS: Knee Outcome Survey-Activities of Daily Living, KOS-SAS: Knee Outcome Survey - Sports Activity Scale, OSTRC: Overuse Injury Questionnaire, F: F-value from ANOVA, Df: degrees of freedom, Significant (p<0.05), Partial η^2p: eta squared effect size.

Post hoc Time effect analysis is presented in Table 6. Post hoc analysis showed a moderate time effect, especially 2 weeks after the intervention, with high values of Cohen's d (d=0.629, d=-0.409, and d=-0.499). The effect size for the study outcomes shows a minimal effect immediately after the treatment and a moderate effect only after a 2-week follow-up. These findings indicate that clinically reducing the scale of overuse injury and improving functionality takes time.

In Table 7, the internal consistency of all the study questionnaires was excellent. Respectively, the KOS-ADLS demonstrated a Cronbach's alpha of 0.973 (95% CI: 0.962-0.985) and McDonald's omega of 0.974 (95% CI: 0.965-0.984). Similarly, for the KOS-SAS demonstrated excellent internal consistency a Cronbach's alpha of 0.970(95%CI:0.952-0.988), and McDonald's omega of 0.972(95% CI:0.961-0.982), also for OSTRC questionnaire showed excellent internal consistency with a Cronbach's alpha of 0.948(95%CI: 0.906-0.990), and McDonald's omega of 0.952(95% CI:0.932-0.972).

Additionally, in Table 8, an exploratory stratified mixed ANOVA was performed by classifying participants into structural injury (ACL and medial meniscus injuries) and overuse injuries (patellar tendinopathy and patellofemoral pain syndrome). Significant main effects of Time and Time✻ Group were observed for all study outcomes ($p<0.001$). While not statistically significant, differences were observed for the Time ✻ injury category and the interaction Time ✻ Group✻ Injury category ($p>0.05$), indicating that the treatment effects were comparable between structural and overuse knee injuries.

Table 6. Post hoc Time Effect Analysis

Variables	Comparisons	Cohen's d	Interpretation
KOS-ADLS	Pre -treatment-1h	-0.132	Minimal effect
	Pre-treatment-2 weeks follow-up	-0.499	Moderate effect
	1h -2 weeks follow-up	-0.367	Small to medium effect
KOS-SAS	Pre-treatment-1h	-0.077	Minimal effect
	2 weeks follow-up	-0.409	Moderate effect
	1h -2 weeks follow-up	-0.332	Moderate effect
OSTRC	Pre-treatment-1h	0.149	Minimal effect
	2 weeks follow-up	0.629	Moderate effect
	1h -2 weeks follow-up	0.48	Moderate effect

*Note: *Significant (p<0.05), Mean± Standard Deviation, KOS-ADLS: Knee Outcome Survey-Activities of Daily Living, KOS-SAS: Knee Outcome Survey -Sports Activity Scale, OSTRC: Overuse Injury Questionnaire, Effect Sizes are Reported as Cohen's d.*

Table 7. Internal Consistency of the Questionnaires Study

Questionnaire	Cronbach's α(95% CI)	McDonald's ω (95% CI)	Interpretation
KOS-ADLS	0.973(0.962-0.985)	0.974(0.965-0.984)	Excellent
KOS-SAS	0.970(0.952-0.988)	0.972(0.961-0.982)	Excellent
OSTRC	0.948(0.906-0.990)	0.952(0.932-0.972)	Excellent

Note: *α= Cronbach's; ω =McDonald's; CI= 95% Confidence interval*

To confirm the robustness of the repeated measures analysis, Linear Mixed Models (LMM) were performed. As shown in Table 9, statistically significant effect of Time and TIME ✻ Group interaction for all study outcomes ($p< 0.001$), whereas the main effect of Group was not statistically significant for any outcome ($p >0.05$). These findings were consistent with the Mixed ANOVA results, confirming the robustness and stability of the primary analyses.

Table 8. Exploratory Stratified Mixed ANOVA According to Knee Injury Category (Structural Vs Overuse)

Outcome	Effect	F	p-value	Partial eta $\eta^2 p$
KOS-ADLS	Time	635.20	<0.001	0.922
	Time✻ Group	90.80	<0.001	0.771
	Time ✻ injury	0.711	0.493	0.013
	Time ✻ Group✻ Injury category	2.337	0.060	0.080
KOS-SAS	Time	430.6	<0.001	0.889
	Time✻ Group	48.93	<0.001	0.644
	Time ✻ injury	1.579	.211	0.028
	Time ✻ Group✻ Injury category	0.150	0.962	0.006
OSTRC	Time	439.1	<0.001	0.89
	Time✻ Group	50.39	<0.001	0.651
	Time ✻ injury	0.230	0.795	0.004
	Time ✻ Group✻ Injury category	1.404	0.238	0.049

Note: KOS-ADLS: Knee Outcome Survey-Activities of Daily Living, KOS-SAS: Knee Outcome Survey -Sports Activity Scale, OSTRC: Overuse Injury Questionnaire, F: F-value from ANOVA, Df: degrees of freedom, Significant ($p<0.001$), Partial $\eta^2 p$: eta squared effect size. Structural injuries included (anterior cruciate ligament ACL and medial meniscus injuries; overuse injuries included (patellar tendinopathy and patellofemoral pain syndrome).

Additionally, a sensitivity analysis was performed for the primary outcome (KOS-ADLS) after excluding five participants to evaluate the robustness of the findings. The results remained consistent with the primary analysis, demonstrating a significant effect of Time ($F=1071.00$, $p<0.001$, $\eta^2 p=0.954$) and a significant TIME ✻ Group interaction ($F=133.20$, $p<0.001$, $\eta^2 p=0.837$), whereas the main effect of Group ($F=0.171$, $p=0.843$, $\eta^2 p=0.007$) was not statistically significant. These findings confirm the robustness and stability of the primary results.

Table 9. Linear Mixed Model Analysis for Study Outcomes

Outcome	Effect	F(df)	p-value
KOS-ADLS	Time	F(2,114)=1078.00	<0.001
	Group	F(2,57)=0.25	0.78
	Time * Group	F(4,114)=125.50	<0.001
KOS-SAS	Time	F(2,114)=751.9	<0.001
	Group	F(2,57)=1.459	0.241
	Time * Group	F(4,114)=85.06	<0.001
OSTRC	Time	F(2,114)=774.8	<0.001
	Group	F(2,57)=0.169	0.845
	Time * Group	F(4,114)=82.03	<0.001

Note: LMM: Linear Mixed Model; KOS-ADLS: Knee Outcome Survey-Activities of Daily Living, KOS-SAS: Knee Outcome Survey -Sports Activity Scale, OSTRC: Overuse Injury Questionnaire, F: F-value from Mixed ANOVA, Df: degrees of freedom, Significant (p<0.05).

DISCUSSION

In this three-group RCT, short-term changes in self-reported knee function and overuse-related symptoms were examined following Mulligan MWM, Kinesiotaping, or Placebo intervention in young basketball players. The main findings of this study demonstrated significant improvements over time across all study outcomes. However, no intervention showed statistically significant superiority over the others. Additional analyses were performed to confirm the robustness of the findings, including analysis of covariance (ANCOVA), mixed ANOVA, post hoc effect size analysis, internal consistency assessment of the study questionnaires, injury stratification analysis, Linear Mixed Models (LMM) for all study outcomes, and sensitivity analysis for the primary outcome (KOS-ADLS).

The primary hypothesis was not supported, indicating no superiority of the Mulligan mobilization with movement over Kinesiotaping and Placebo in improving KOS-ADLS, KOS-SAS, and OSTRC outcomes after two weeks of follow-up. The primary findings were supported by complementary statistical analyses, including Mixed ANOVA, ANCOVA, Linear Mixed Models (LMM), and injury stratification analyses, which together assessed the effect of interventions. Overall, findings showed significant improvement occurred over time in all three intervention groups.

The different mechanisms underlying these interventions may explain the variability in clinical findings. Mulligan MWM to provide neurophysiological remodeling of pain and proprioceptive stimulation acts through biomechanical mechanisms on knee joint kinematics [25, 29]. In contrast, Kinesiotaping continuously stimulates cutaneous receptors, potentially enhancing sensorimotor function [15]. Despite their different mechanisms of action, both interventions may improve knee function and reduce overuse symptoms in the short-term follow-up.

The current literature partially supports the findings of this study by not giving superiority to Mulligan MWM over Kinesiotaping [30, 31]. Did not demonstrate clear superiority of Mulligan MWM over Kinesiotaping, as both interventions improved knee functionality in the short term. Similarly, in the study of [13], which used a similar follow-up protocol as in our study, the findings reported functional improvement following both Mulligan MWM and Mulligan knee. Although greater improvements were observed in the Mulligan MWM group. In contrast, the systematic review by [27] supported the superiority of Mulligan MWM. Whereas the meta-analysis study by [20], reported that the effect of Kinesiotaping on knee functionality remains heterogeneous across studies. The findings of the present study should be interpreted in the context of the current heterogeneous evidence from randomized controlled trials, systematic reviews, and meta-analyses. While several studies have reported that both Mulligan MWM and Kinesiotaping are effective in improving knee function, others have demonstrated greater functional benefits following Mulligan MWM. The present study adds to the limited evidence comparing Mulligan MWM, Kinesiotaping, and Placebo in young basketball players using KOS-ADLS, KOS-SAS, and OSTRC outcomes.

Post hoc time-effect analysis demonstrated that functional improvement and reduction in overuse injury symptoms were greater at the 2-week follow-up than at 1-hour post-intervention, indicating progressive short-term clinical recovery without evidence of superiority among the three interventions. These findings are consistent with the current literature suggesting that clinical improvement following conservative physiotherapy interventions generally requires repeated treatment sessions and a short recovery period before becoming fully apparent [13, 21]. Nevertheless, some studies have reported functional improvements in the first 48-hour period after treatment, as demonstrated by [26].

Based on the findings of the present study, the secondary hypothesis was not supported, as the effects of Mulligan MWM, Kinesiotaping, and Placebo did not differ according to injury type in young basketball players. Exploratory injury stratification analysis demonstrated that treatment response was comparable across the different knee pathologies included in the study, with the time effect improving regardless of the type of injury classification. These findings suggest that despite classifying injuries into two structural and overuse subtypes, the short-term benefits were consistent across all three intervention groups.

The current evidence on whether treatment response varies according to knee injury subtype in young basketball players remains limited. Most randomized controlled trials have evaluated Mulligan MWM, Kinesiotaping, or Placebo in a single knee pathology, such as patellofemoral pain syndrome, meniscal pathology, or postoperative ACL rehabilitation [13, 16, 17, 32]. Therefore, the present study extends the available evidence by suggesting comparable short-term treatment responses across both structural and overuse- related knee injuries in young basketball players.

The tertiary hypothesis was partially supported. The study findings demonstrated significant improvement in OSTRC scores, reflecting a reduction in overuse injury symptoms during the follow-up period. However, the hypothesized pattern of rapid improvement in the Mulligan MWM group and progressive improvement in the Kinesiotaping group was not fully confirmed, as neither intervention demonstrated superiority in reducing overuse symptoms. Post hoc time effect analysis further confirmed that clinical improvements were more evident after 2 weeks of follow-up than 1 hour after treatment, supporting a progressive short-term reduction in overuse-related symptoms.

The reduction in overuse-related symptoms may be explained by the different physiological mechanisms underlying the three interventions. Mulligan MWM may reduce symptoms through pain-free joint mobilization, improving joint kinematics while simultaneously inducing neurophysiological pain modulation [25]. Kinesiotaping may contribute through continues cutaneous sensory stimulation, enhancing nociceptive modulation and sensorimotor function [15]. In contrast, the improvements observed in the placebo group may be related to perceptual and self-reported effects, which can influence in reducing pain and function recovery and the reporting of overuse injury symptoms [18, 19].

The current evidence regarding the effect of Mulligan MWM, Kinesiotaping, and Placebo on OSTRC outcome remains limited. The OSTRC questionnaire is recognized as a sensitive tool for monitoring overuse-related symptoms in athletes [8]. Evidence also suggests that the Placebo interventions may influence self-reported overuse symptoms through contextual treatment effects and athletes’ expectations [18, 19]. However, studies comparing Mulligan MWM, Kinesiotherapy, and Placebo interventions using OSTRC outcomes in young basketball players with knee injuries are currently lacking.

Additional statistical analyses were conducted to evaluate the robustness of the primary findings. Although ANCOVA identified significant between-group differences at the 2-week follow-up after adjustment for baseline scores, these findings were interpreted as time-specific adjusted differences rather than evidence of consistent overall superiority, as the longitudinal Mixed ANOVA and LMM showed no significant main effect of group. This analysis reinforced and provided stability to the Mixed ANOVA analysis by not showing superiority of any of the interventions but showing progressive improvement over time for all functional outcomes. All these analyses strengthen the methodological rigor and overall robustness of the present study [33, 34].

The reliability analysis demonstrated excellent internal consistency for the KOS-ADLS, KOS-SAS, and OSTRC questionnaires used in the present study. The high Cronbach's α and McDonald's ω coefficients indicated that these instruments consistently measured the intended constructs in this population of young basketball players. The findings are consistent with previous studies reporting good psychometric properties of the KOS-ADLS, KOS-SAS questionnaires [10] and the OSTRC questionnaire for monitoring musculoskeletal problems in the athletic population [8]. These findings support the use of these patient-reported outcome measures for assessing functional changes and overuse injury symptoms in young basketball players.

Sensitivity analysis conducted on the primary outcome KOS-ADLS, following the exclusion of the prespecified observations, further supported the robustness of the primary findings by demonstrating consistent time and group * Time interaction effects, while confirming the absence of a superior treatment effect among the study interventions. The consistency of these findings suggests that the overall conclusions were not driven by influential observations or sample-specific stability, reproducibility, and internal validity of the study results [33, 34].

The current findings suggest that Mulligan Mobilization with Movement, Kinesiotaping, and Placebo were all associated with short-term improvement in knee function and reductions in overuse-related symptoms at the 2-week follow-up in young basketball players. As no intervention demonstrated clear superiority, physiotherapy interventions should be individualized according to the athlete's clinical presentation, rehabilitation goals, and the physiotherapist's expertise [20, 27]. The use of validated patient-reported outcome measures, including the KOS-ADLS, KOS-SAS, and OSTRC questionnaires, may further support clinical decision-making and monitoring throughout rehabilitation [8,10]. Clinically, greater improvements were observed at the 2-week follow-up than at 1 hour after treatment, suggesting that functional recovery becomes more evident during the early stages of rehabilitation.

The present study has several strengths. To the best of our knowledge, this is the first randomized controlled trial to compare Mulligan Mobilization with Movement, Kinesiotaping, and Placebo in young basketball players with knee injuries using the patient- reported outcome measures KOS-ADLS, KOS-SAS, and OSTRC. Furthermore, the methodological rigor of this study was strengthened by the use of complementary statistical approaches, including Repeated Measures ANOVA, post- hoc effect size analysis, ANCOVA, Linear Mixed Models (LMM), exploratory pathological stratification analysis, internal consistency assessment of the questionnaires, and sensitivity analyses, which increased the robustness of the study findings.

Regarding limitations, this study included follow-up assessment at 1 hour and 2 weeks, which did not allow for the long-term effects of the interventions. Although an exploratory pathology stratification analysis was performed, the relatively small number of participants within each injury subgroup limited the statistical power to detect treatment effect within structural and overuse injury classifications. Furthermore, although the sample size was relatively moderate, high post hoc statistical power and large effect sizes were observed for the study outcomes. Future randomized controlled trials should include larger sample sizes and longer follow-up periods to further evaluate the effectiveness of conservative interventions in young basketball players.

CONCLUSION

This randomized controlled trial demonstrated that Mulligan Mobilization with Movement, Kinesiotaping, and placebo interventions were associated with short-term improvements in knee function and reductions in overuse-related symptoms among young basketball players with knee injuries. Positive changes were observed at both the 1-hour and 2-week follow-up assessments, with significant improvements in KOS-ADLS, KOS-SAS, and OSTRC scores evident at 2 weeks. However, none of the interventions demonstrated clear superiority over the others, supporting the use of individualized conservative rehabilitation strategies in this population.

The primary analysis revealed significant time effects ($p < 0.001$) for all three outcomes (KOS-ADLS, KOS-SAS, and OSTRC), together with significant Time × Group interactions, indicating different trajectories of change across the intervention groups. Post-hoc comparisons showed greater improvements at the 2-week follow-up than immediately after treatment. Although the main Group effect was not statistically significant in the primary analysis, baseline-adjusted ANCOVA identified significant between-group differences at 2 weeks for all outcomes ($p < 0.001$). Furthermore, Linear Mixed Models and sensitivity analyses confirmed the robustness and consistency of the findings.

AUTHOR CONTRIBUTIONS

Conceptualization, SV.S., and A.Z.; Methodology, SV.S., and L.S.; Resources, SV.S., A.Z, and L.S.; Data Curation, SV.S.; Formal Analysis, SV.S., and M. E-R.; Investigation, SV.S., A.Z., and L.S.; Critical review- K.V; Writing- Original Draft Preparation, SV.S.; Writing-Review & Editing, SV.S., A.L., and L.S.; Supervision, K.V. Both authors have read and agreed to the published version of the manuscript.

DATA AVAILABILITY STATEMENT

Data is contained within the article.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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