Study Protocol with Statistical Analysis Plan

Effect of Dynamic Taping on Landing Biomechanical Characteristics in Volleyball and Basketball Players with Symptoms of Patellar Tendinopathy - Motor Control and Biomechanical Characteristics during the Landing Task

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Study background and purposes:

Patellar tendinopathy (PT) is an overuse condition characterized by repetitive stress on the patellar tendon, leading to structural changes in the tendon due to accumulated microtrauma. It is prevalent among athletes involved in sports requiring extensive jumping, such as volleyball and basketball, with a higher incidence in males than females. More than one-third of athletes may not return to their previous level of activity within six months of treatment, and severe cases may even necessitate the cessation of their athletic careers. Previous research has found that patients with PT symptoms for more than three months tend to reduce the use of the knee joint for energy absorption during landing. While this mechanism may prevent further deterioration of the injured patellar tendon, it redistributes energy loading to other joints during landing, increasing the energy absorption required at the hip joint and potentially leading to other lower limb injuries in the long term. This highlights the importance of the hip joint in addition to the knee joint for such athletes. However, previous studies have mainly focused on changes in landing patterns in the sagittal plane in athletes with patellar tendinopathy, lacking research on the other two planes and muscle activation during landing. Changes in landing patterns can be observed not only biomechanically but also through movement control. Alterations in movement patterns are also associated with muscle activation and movement control.

Similar investigations have been conducted for other knee conditions such as anterior cruciate ligament injuries and patellofemoral pain syndrome, but there is currently no research specifically addressing symptomatic athletes with patellar tendinopathy. Understanding the muscle activation and biomechanical changes during landing in athletes with patellar tendinopathy can help identify potential issues in clinical practice and implement exercise adjustments to prevent secondary problems and exacerbation of symptoms, while normalizing movement patterns in athletes. Additionally, the hip joint plays a crucial role in closed kinetic chain movements. If the relationship between joint movement control issues and patellar tendinopathy can be identified, it could serve as a simple assessment tool in clinical practice to determine the risk of developing patellar tendinopathy.

In summary, patellar tendinopathy may be associated with changes in landing patterns. However, the biomechanical alterations of the hip and knee joints in the frontal and transverse planes are still unclear. Furthermore, factors affecting movement patterns, such as movement control and muscle activation status, remain to be elucidated. Therefore, the purpose of this study is to investigate movement control in athletes with patellar tendinopathy and the biomechanical characteristics of the hip and knee joints during landing tasks. We hypothesize that athletes with PT symptoms will demonstrate poorer movement control abilities compared to those without symptoms, and during the landing phase of loaded movements, they will exhibit increased hip adduction, greater hip extension torque, higher quadriceps activation, delayed gluteal activation timing, and earlier rectus femoris activation timing.

Study design and participants:

This is a cross-sectional observational study. Participants aged 18 to 40 were recruited for the experiment. The symptomatic group was selected based on the following criteria, and then matched to find an asymptomatic group.

Inclusion criteria for the symptomatic group were:

- ✓ Experiencing anterior knee pain during loading activities for more than three months
- ✓ Pain localized only to the inferior pole of the patella
- ✓ Having participated in collegiate-level or higher volleyball/basketball-related sports training for at least two years
- ✓ Currently engaging in activities inducing knee pain for at least 90 minutes per week
- ✓ Scoring below 80 on the Chinese version of the Victorian Institute of Sport Assessment-patellar tendinopathy questionnaire (VISA-PCh).

Inclusion criteria for the asymptomatic group were:

- ✓ Having participated in collegiate-level or higher volleyball/basketball-related sports training for at least two years
- ✓ Currently engaging in related activities for more than 90 minutes per week
- ✓ Reporting no lower limb pain scores greater than 3 (on a scale of 10) in the past three months
- ✓ Scoring greater than or equal to 80 on the VISA-PCh questionnaire.

Any of the following conditions in either the symptomatic or asymptomatic group led to exclusion from recruitment:

- ✓ Undergoing relevant rehabilitation exercises for knee pain in the past three months
- ✓ Having other chronic lower limb pain issues
- ✓ Self-reporting pregnancy
- ✓ History of lower limb surgery or patellar tendon steroid injections
- ✓ Medical history of rheumatic, immune, or neurological systemic diseases.

Study methods:

Data on participants' gender, age, height, weight, exercise frequency and duration, years of sports experience, specific sports discipline, participation in highest-level competitions, history of lower limb injuries, and completion of the

Chinese version of the Victorian Institute of Sport Assessment-patellar tendinopathy questionnaire were collected via cloud-based forms. Using this information, eligible participants were screened, with the symptomatic group recruited first. Then, individuals in the asymptomatic group were matched to the symptomatic group based on gender, age (±10%), height (±10%), weight (±10%), and sports discipline.

Before testing, researchers conducted a second screening to confirm eligibility. If eligible, researchers provided detailed explanations of the study procedures and purposes to participants, who then signed informed consent forms. Prior to testing, participants warmed up for 5 minutes. Testing was conducted in the following order:

Jump height testing: Participants wore athletic shoes and performed a vertical jump test, followed by stationary and spike jump tests. Each test was performed three times for practice and three times for formal testing. The average of the formal test results, minus the average fingertip reach height, yielded the jump height results.

Ankle dorsiflexion angle measurement: Participants stood facing a wall with hands on the wall for support. While maintaining a lunge position with the front heel on the ground, participants dorsiflexed the ankle to its maximum angle. The angle formed between a line segment from the tip of the fibula to 10 cm below the lateral malleolus and the horizontal line was measured. The angle measurement was performed three times for each foot, and the average was taken.

Motor control testing: four tests were performed to assess hip and knee joint control, including hip flexion control, internal rotation control, external rotation/abduction control, and hip adduction control. Each test was practiced three times and performed formally five times.

Loading testing: Participants performed countermovement jump, drop vertical jump, and step-down test to assess lower limb function. Each test was performed according to specific protocols.

Muscle electromyography (EMG) data collection: EMG electrodes were placed on both gluteus maximus, biceps femoris, rectus femoris, vastus lateralis ,and participants performed maximal voluntary isometric contractions. Additionally, handheld dynamometry was used to measure hip extensor strength.

Finally, data processing and statistical analysis were performed to complete the experiment.

Data analysis:

The total scores of motor control tests of the symptomatic group's pain foot were summed and converted into percentages, which were then compared with the average total scores of the control group's bilateral foot tests to assess lower limb control ability between the two groups.

Reflective ball trajectories were captured using a motion capture system equipped with eight high-speed cameras, sample rate at a frequency of 100 Hz. Force data were collected using two force plates measuring 60 cm in length and 40 cm in width, sample rate at a frequency of 1000 Hz. The data were integrated via analog/digital conversion boards and analyzed using Nexus 1.8.1 motion analysis software. The plug-in gait model was employed to calculate raw data, yielding three-dimensional angles and moments of the hip and knee joints, as well as maximum ground reaction forces.

Surface electromyography (EMG) data were obtained at a sampling frequency of 1500 Hz. MATLAB programming was utilized to filter and rectify signals within the 20-450 Hz range, with root mean square calculated at 20-millisecond intervals and signal windows set at 1 millisecond to reduce signal data alterations. Muscle activation during movements was standardized using maximum voluntary contractions, computing the average and maximum activation of muscles during movements. Muscle activation onset was defined as the baseline value plus three standard deviations above the mean of the pre-movement period, with the time point indicating the onset of muscle activation identified accordingly.

For all variables except muscle activation onset time, data points within ±0.01 seconds of the required data were averaged to obtain the final results, thereby minimizing the impact of extreme values.

Statistical analysis:

Analysis was conducted using Statistical Product and Service Solution (SPSS) 25.0 (IBM Corp., USA), with a significance level set at 0.05. Descriptive statistics were used for demographic data analysis of participants, chi-square tests were employed for categorical variables, and independent samples t-tests were utilized for comparing differences between the two groups for continuous variables.

For motion analysis, kinetics, muscle activities, and motor control score percentages, independent samples t-tests were employed to compare the differences between the two groups.