Functional Effects of Tendon Neuroplastic Training in Wrestlers With Shoulder Tendinopathy: a Randomized Controlled Trial

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Study design

This was a single-blinded randomized controlled study with a pretest-posttest design. The research protocol was designed according to the CONSORT (Consolidated Standards of Reporting Trials) guidelines. Based on the Declaration of Helsinki, the study was carried out with the approval of the noninvasive clinical research ethics committee of Nuh Naci Yazgan University (2022/10123). Cognitive function, upper extremity balance, coordination, pain, functional status of shoulder and quality of life were evaluated at the baseline and at the end of the training after 4 weeks.

Participants

This study was conducted at the Kayseri Şeker Sports Club, Kayseri, Turkey. Twentysix male wrestlers participated in this study. The following criteria were required for inclusion:

- Being a licensed athlete for at least one year
- Having a diagnosis of tendinopathy based on clinical and radiological examination
- To be tested positive in at least three of the following diagnostic tests: Neer Test, Hawkins-Kennedy Test, Jobe-Supraspinatus Test, Painful arc at 60-120 degrees of shoulder abduction (26,27),
- Pain level is below 2 out of 10 at rest and below 3 out of 10 during active movement according to the visual pain scale,
- No limitation in joint range of motion (at least 85% of the healthy side).

Exclusion criteria were:

- Having any vision or hearing problems
- Having undergone surgery fort he past 6 months
- Having diagnose complete tendon rupture.

Written informed consent was obtained from athletes before participation. Also for under 18 aged athletes written informed consent was obtained from their guardian.

Sample size

Power analysis calculations were performed using G*Power 3.1.9.2 software (Universit€at Kiel, Germany). The sample size calculations were based on an effect size of previous study. An alpha level of 0.05, power of 85%. These parameters generated a sample

size of at least 13 athletes per group. Allowing for a 10% conservative dropout rate, we recruited 30 athletes for the study.

Randomization and blinding

The simple randomization technique of computer-generated random numbers was used to assign the athletes to either the Tendon Neuroplastic Training or control group. Online randomization web service random.org used to create a randomization list. Each envelope contained 1 number that the program had randomly selected. After determining eligibility based on inclusion criteria, each athlete was asked to choose an envelope. Patients were then allocated to 1 of the 2 groups based on the selected number. Participants were blinded to group assignments.

Interventions

Athletes in TNT group received Tendon Neuroplastic Training protocol and control group received selfpaced standardized eccentric training. Both group exercise program included standard warm up, strengthening exercises with the weights calculated for each athlete individually for the supraspinatus, the infraspinatus, the subscapularis and the biceps brachii muscles and stretching exercises (posterior shoulder stretching, corner pec stretching, biceps brachii stretching) as a protective for Delayed Muscle Onset Soreness. The most effective exercises that shown in previous EMG studies were selected for shoulder muscles strengthening: “Prone horizontal abduction at 100° with full external rotation” for supraspinatus, “Sidelying external rotation” for infraspinatus, “Diagonal internal rotation” for subscapularis, “Concentrated curl” for biceps brachii exercises were chose. Physiotherapist-supervised exercises programs carried out four a week for four consecutive weeks in both groups. Participants were instructed to perform a single dumbbell lift to determine the maximum weight they could comfortably lift for a single repetition. After a comfortable weight was determined, the 8-repetition maximum (RM) was determined according to the training load chart. Once determining the 8 Repeat Maximum of each exercise, the starting load was set at 80% of 8 RM and progressed by increasing by 2.5% if was possible for both group . In TNT group, the exercises paced to an external audio cue on the participant’s smartphone digital metronome application (ProMetronome; http://eumlab.com/prometronome/). The athletes were to listen to the beat sound of a 1 Hz metronome and track the movement of the metronome with their eyes, as pacing to these types of external cues has been shown to modulate corticospinal

excitability. The beats of the metronome were set to allow a three second concentric and four second eccentric phase. Four sets of eight repetitions were to be completed with a two minute rest in between each set. These parameters were adapted from previous supplementary data by Rio et al. In the control group, without any external timing cues (such as visual or auditory) athletes were told to perform the concentric phase of the exercises as fast as possible and the eccentric phase as slowly and long as possible.

Progressing of exercise loading was controlled according to the "Pain Monitoring System". Pain experienced momentarily during any exercise was allowed up to a Visual Analog Scale pain level of 5, on condition that the pain subsided immediately after the exercise was completed. Care was taken to ensure that the pain did not increase day by day.

Outcome measures

Cognitive function

Cognitive function was assessed with the Stroop Test TBAG Form (ICC: 0,88). The Stroop Test also referred to as the Color– Word Task, was used to assess executive abilities, selective attention, and the ability to inhibit a habitual response. In sports psychology research, the Stroop test and its derivations are commonly used to investigate the benefits of exercise on cognitive function.

Stroop Test TBAG Form consists of five cards measuring 14.0 x 21.5 centimeter. Each card has six rows of four items arranged randomly. During the test, participants were asked to read the words on the stimulus cards. The cards used were as follows: 1. Black-and-White Word Reading, 2. Coloured Word Reading, 3. Coloured do not Reading, 4. Coloured Nonsense Word Reading, and 5. Naming the Colours of Coloured Words. For each section, the time taken by participants during the application was measured using a 0.01-second precision smartphone chronometer. The completion time, the number of errors, and the number of corrections (if any) for each section were recorded on an evaluation form for each participant.

Upper Extremity Balance

Upper Extremity Balance Performance was measured with Upper Quarter-Y Balance Test. A previous study showed good reliability of the Upper Quarter Y Balance Test in wrestlers (ICC: 0,80-0,99). The test was performed on a stance platform which consists of 3 pieces pipe are

attached in the medial, inferolateral, and superolateral reach directions. The posterior pipes are positioned 135° from the anterior pipe, and there is 90° between the posterior pipes. Each pipe is marked in 0.5-cm increments for measurement.

The upper limb length of the athletes was determined by measuring the distance between the C7 spinous process and the distal tip of the middle finger of the hand while the arm was in a 90-degree abduction position. Performance on the test consisted of the athlete reaching in the 3 reach directions with the free hand while maintaining a push-up position with feet shoulder width apart. This process was repeated until 3 trials in each direction on each hand had been performed. The greatest successful reach for each direction was used for analysis. The maximum reach distances were divided by the athlete's upper limb length to normalize each reach distance. The composite reach distance was calculated by averaging the greatest trial in each of the 3 normalized reach distances for an analysis of overall performance on the test.

Coordination

Coordination was assessed by Alternate Hand Wall Toss test. The Alternate Hand Wall Toss test is a representative test used in sports medicine to measure eye–hand coordination. It has also been shown to be a valid and reliable test in the athlete groups (ICC: 0,87). For this test athletes positioned behind the line 2 meters facing to the wall. Athletes threw the tennis ball (standard size) against the wall by one hand and caught it with another hand, then the ball was thrown back against the wall and to be caught by initial hand. The total number of successful catches in 30 seconds was recorded. The ball which hits the ground before it is caught was not counted. Athletes were supervised by physiotherapist during the test.

Functional Status of Upper Extremity and Quality of Life

The Kerlan-Jobe Orthopaedic Clinic (KJOC) score was used to assess functional status of the upper extremities. The KJOC is a 10-item questionnaire, developed as a self-assessed patient-reported outcome measure. This questionnaire includes questions on shoulder and elbow function during sportive performance, impairment, activity limitations, and participation restrictions. The KJOC questionnaire contains a demographics cover sheet and the main questionnaire, including questions evaluated using a visual analogue scale (VAS) from 0 to 100 mm. The total score is calculated as an average of the total scores of the 10 questions. Higher scores are indicative of higher functional response (ICC: 0,93).

Western Ontario Rotator Cuff Index (WORC) was used to assess the quality of life and is a condition-specific self-reported instrument. The WORC questionnaire consists of 21 items divided into 5 domains. There are six questions in the physical symptoms domain, four in the sports and recreation domain, four in the work domain, four in the lifestyle domain, and three in the emotions domain. Each question is answered on a 100-mm visual analog scale. The scores of 21 items are added to give a total score from 0 to 2100. A score of 0 implies no reduction in health related quality of life and a score of 2100 is the worst score possible (ICC: 0,92). Additionally, the emotions domain was also analyzed to assess the emotional state.

Pain

Pain of shoulder at rest was evaluated with visual analog scale (VAS). Athletes were asked to mark their pain intensity on a 10 cm horizontal line for the VAS, scoring between 0 (no pain) and 10 (unbearable pain) (ICC: 0,81). In addition, athletes were asked whether their pain intensity was above 5 on the VAS in each training session.

Statistical Analysis

Statistical analyses were performed using SPSS software (version 22.0; IBM, Armonk, NY, USA). Values are presented as the means, standard deviation and the 95% confidence interval (CI), and median values with minimum and maximum. Before the statistical analysis, a Shapiro–Wilk test, Skewness-Kurtosis values and Q-Q Plots were used to assess the normal distributions of the data. Before and after training, 2 groups were compared to normally distributed variables using Independent Samples T-Test, undistributed variables using the Mann–Whitney U Test. Pre and post-training data within groups compared to normally distributed variables using Paired Sample T-Test, undistributed variables using the Wilcoxon Test.

The between-group effect sizes were calculated using the Cohen's d and categorized as trivial ($\leq$ 0.20), small (0.21-0.49), moderate (0.50-0.79), or large (0.80). P <.05 was considered statistically significant.