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TITLE: Differences in Elbow Stiffness Comparing Massage to Stretching in Tennis Players (DESMS)

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MATERIALS AND METHODS

Description of Study Personnel and Research Participants

The primary investigator was a licensed physical therapist with 20 years of clinical experience and with 13 years of research and musculoskeletal imaging experience. The primary investigator trained all personnel associated with the study including administrative duties, participant screening, ultrasound SWE examination, and intervention procedures.

Thirty-two healthy recreational tennis players (12 male/20 female, mean age =54.4± 13.8yr, mean BMI = 25.69 ±3.73) were randomized into the STM (n=16) or stretching group (n=16). The participants were recruited from local tennis clubs by flyers and word of mouth. Initial screenings of the study criteria were reviewed over the phone with interested candidates prior to participation. The inclusion criteria required; adults older than 18 years old and participants had to report playing tennis at least one time a week on average. The exclusion criteria included; prior upper extremity surgery within the last 6 months, any diagnosed upper extremity pathologies or injuries within the last 6 months, rehabilitative/medical treatment of the upper extremity in the past year, and unable to tolerate soft tissue massage or stretching treatments. The national tennis rating program identifies and describes the characteristics of tennis players on a scale of 1.5 (beginner) to 7.0 (touring professional)(Association, 2024). Seventy-two percent of participants had a national tennis rating of 3.0-3.5, 19% were rated 4.0-4.5, and 6% were rated 2.5, and 3% were rated 4.5. Before participation, all participants were fully informed of the purpose and experimental procedures and gave their written consent. This study was approved by the internal review board at the xxx (approval no: 20597767).

Procedures

All participants completed a general health history questionnaire, and demographic information including age, gender, arm dominance, frequency of tennis play, shoulder activity levels, national tennis rating program rating, weight, and height. While seated, participants dominant arm, defined as the serving arm, was placed in following resting position: shoulder at 70°of abduction, elbow at 90° of flexion, and forearm in pronation. Stiffness measures were obtained at rest on the dominant common extensor tendon (CET) using 2D SWE ultrasound imaging (GE Logiq S8, 9L, linear transducer). The side of the probe indicator along the transducer was placed directly over the lateral epicondyle while the distal end of the transducer was in line with the middle of the radiocarpal joint (Figure 1). Three images were taken and stiffness values were recorded for each image. The region of interest (ROI) on the CET was outlined on screen between the lateral epicondyle and head of the radius(Day and Merriman). The shear wave modulus was then automatically generated in kilopascals (kPa) (Figure 2). Following these measurements, the participants were given a 5-minute rest. For the purpose of establishing intra-rater reliability, a second set of resting measurements were taken.

After the two initial collections were taken, participants were randomized to either common wrist extensor stretching or soft tissue mobilization(STM). Participants undergoing stretching were placed in the following position: shoulder at 90° of flexion on plinth, elbow at 0° of extension, forearm in full pronation, and wrist flexion. Participants were asked to report the comfort level of wrist flexion as tolerable ',' strong but tolerable, 'uncomfortable', or 'intolerable'. The intensity was maintained at a 'strong but tolerable' level for consistency and efficacy (Ylinen, Kautiainen, Wiren, and Hakkinen, 2007). Participants underwent a self-stretch holding this position for 30 seconds and repeating 5 times with a 30 second rest between

repetitions yielding a total time of 5 minutes. Three images of tendon stiffness were measured again using SWE immediately after the intervention. Participants were then given a 15-minute rest period after the post-intervention measurements and then 3 images of stiffness of the CET were taken in resting position.

Participants randomized to the STM group received 5 minutes of petrissage (a deep kneading) with linked effleurage (more superficial strokes) on the dominant test side. Deep prep massage cream was used to minimize patient discomfort from skin friction. Participants were asked to report the intensity of the STM as 'completely tolerable', 'strong but tolerable', 'uncomfortable', or 'intolerable'. Similar to the self-stretching, the intensity of the STM was maintained at a 'strong but tolerable' level for consistency and efficacy"(Ylinen, Kautiainen, Wiren, and Hakkinen, 2007). After the STM, three tissue stiffness measures were taken using SWE. Participants were then given a 15-minute rest period after the post-intervention measurements and then 3 images of stiffness of the CET were taken in resting position.

Statistics

Statistical analysis included measures of central tendency and variability of the descriptive data for each of the groups using Statistical Package for the Social Sciences 25.0 (Chicago, Illinois). An *a priori* power analysis indicated that at an alpha level of 0.05, and a conventional large effect size of 1.4 for a power of 0.95, a minimum sample of 15 per group was required(Zhu et al.,, 2020). The Kolmogorov-Smirnov test revealed a normal distribution of data. Frequencies and unpaired t-test were used to compare group characteristics (STM vs self-stretching) prior to statistical analysis. Within examiner intraclass correlation coefficients (ICC (3, 1)) with 95% confidence intervals were calculated using a two way mixed model average

measure for absolute agreement. Standard error of the measure (SEM) and minimal detectable changes (MDC) were also calculated. A repeated measures ANOVA using one between variable group (STM or stretching) and one within variable group (initial, post-treatment, and 15 minutes post-treatment)) was used in the main analysis. Significance was set at $p \leq 0.05$ with a Bonferroni correction.