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Original Article

Physiotherapy Section

# Measurement of Pain, Delayed Onset of Muscle Soreness and Muscle Strengths after Performing Various Eccentric Exercise Protocols with Partial Range of Motion

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## ABSTRACT

**Introduction:** Physical activity and unaccustomed exercise induces muscle pain, muscle soreness that can decrease the muscle strength at joints initially.

**Aim:** To understand the level of muscle strength, Delayed Onset of Muscle Soreness (DOMS), pain and functional limitations after completing various intensities of Eccentric Exercise (ECC) through Partial Range of Motion (PROM).

**Materials and Methods:** Eighteen participants (men and women) aged between 18 and 30 years were recruited from the students of the University of New England assigned into 3 groups. Participants performed ECC protocol through 60° of total Range of Motion (ROM) using dynamic adjustable ROM controlled elbow and knee joint splints (on elbow flexors, elbow extensors, knee flexors and/or knee extensors; one muscle group/limb). Before and after ECC protocols, the Maximal Voluntary Isometric Contraction (MVIC) was calculated for all the muscles. Group-1 performed ECC exercise only; group-2 performed yoga poses prior to ECC exercise; and group-3 performed ECC exercise prior to yoga poses. Participants performed ECC exercise (5×10 repetitions) on all four limbs at 60° of total ROM using their 15%/25%/35% of MVICs on day 1 and subjective {health Activities of Daily Living (ADL) difficulty scale, Visual Analogue Scale (VAS)} and objective assessments {Pain Pressure Threshold (PPT), arm and thigh circumference, and ROM} from day 2-6 of weeks 2, 3 and 4.

**Results:** The post-ECC MVIC was higher than pre-ECC MVIC values in all tested muscles and showed statistically significant differences ($p<0.05$) within each group. ADLs, VAS, and PPT for the elbow extensors and knee flexors showed a minimal pain (0-2) and didn't show a statistically significant difference ($p>0.05$) between groups. The elbow flexors and knee extensors didn't show pain within and between the groups. There was no significant difference in the ROM and, arm and thigh circumference between the groups.

**Conclusion:** Four weeks of ECC exercise protocol with and without yoga improved the muscle strength, reduced muscle soreness and pain in elbow and knee for ADLs in the younger individuals.

Current research protocol can be applied to the older adults' who are in chronic conditions with co-morbidities to improve their muscle strength, and ROM to fulfill their ADL and healthy independent life.


**Keywords:** Isometric Contraction, Knee flexors, Physical acitivity, Yoga

## INTRODUCTION

Regular physical activity improves the quality of life. Individuals can experience pain, Delayed Onset of Muscle Soreness (DOMS) in varying degrees depending upon their level of fitness and the intensity of physical activity or exercise performed. DOMS is characterised by tender and aching muscles, which can be assessed by palpation of the muscle that was previously employed by physical exercise or activity. DOMS develops within 24 hours of exercise, the intensity of the pain reaching a peak within three days post-exercise and disappearing entirely within 7-10 days [1].

Studies suggested that the ROM can affect the magnitude of DOMS in animals [2,3]. Talbot JA and Morgan DL observed a strong correlation between exercise through greater ROM and greater DOMS in the animals [4]. Perhaps if one moves through greater ROM using ECC, then this may induce more DOMS for humans as well. In humans, experiments were performed with ECC on elbow flexors at various percentages of ROM and concluded that ECC of the elbow flexors with greater ROM promotes a greater magnitude of DOMS compared to a protocol with lesser ROM [5-9]. In the published literature, DOMS studies were performed on one or two groups of muscles [10-13].

Yoga popularity has grown tremendously in the past several years and showed increased usage of Complementary and Alternative Medicine (CAM) treatments [14]. Yoga poses are recommended as independent exercises or with workout session at gym. Yoga is widely practiced for the health benefits like relief pain [15] and improves flexibility and balance [16], and muscle strength [17].

Several factors can affect the magnitude of ECC which induced DOMS, but little is known regarding the effect of the ROM in ECC-induced DOMS [2,3]. We hypothesise that individuals who complete lower intensity ECC through PROM (60° of total ROM) will experience lesser DOMS, pain, and functional limitation.

This pilot study was conducted to understand the effect of various intensities of ECC with PROM on the DOMS, pain, and functional limitations.

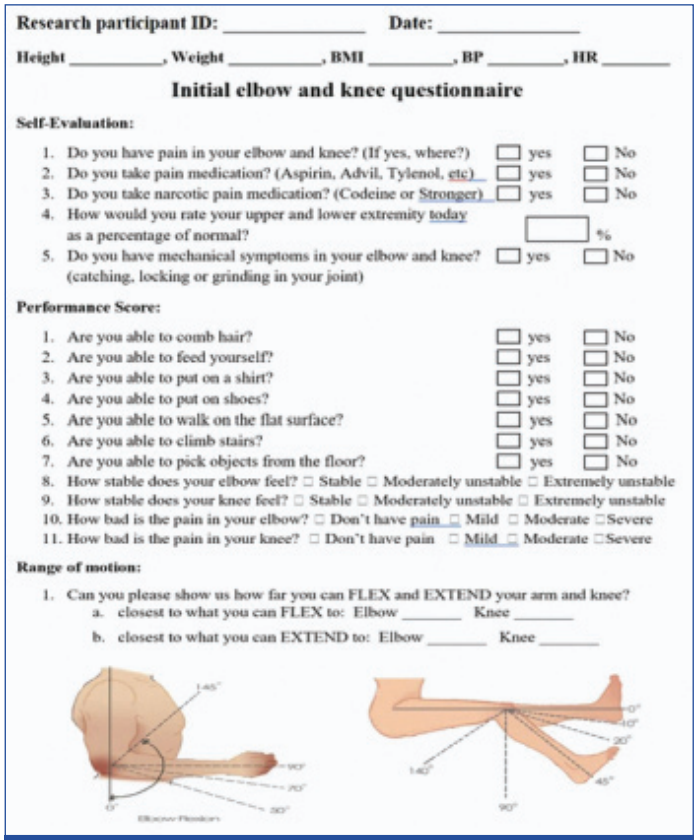
## MATERIALS AND METHODS

### Research Participants and Screening

Eighteen untrained active healthy men and women were recruited from the University of New England (UNE) students aged between 18 and 30 years. This study was conducted in the Biology Research lab 247 at Alfond Center for Health Sciences (ACHS) building and Campus Center Gym, Biddeford, UNE. The study has been approved by the authors' Institutional Review Board (20180508-004), University of New England (UNE), Maine, USA and conducted in July 2018. The sample size in this study is less (n=6) in all groups as it involves

effects that take advantage of multiple observations per subject. The expected large correlations in outcomes within the yoga and non-yoga groups across time, hence the analysis data is expected to be sufficiently large. To ensure all data were in normal distribution among the small sample size, Shapiro-Wilks test was used.

**Screening:** To determine the eligibility of the research participants, health screening (height, weight, body mass index, blood pressure, and heart rate) was carried out at UNE Student Health Center, Biddeford. Also, subjective initial elbow and knee questionnaires were administered [Table/Fig-1].



**Research participant ID:** _____ **Date:** _____

**Height** _____, **Weight** _____, **BMI** _____, **BP** _____, **HR** _____

**Initial elbow and knee questionnaire**

**Self-Evaluation:**

1. Do you have pain in your elbow and knee? (If yes, where?) ☐ yes ☐ No
2. Do you take pain medication? (Aspirin, Advil, Tylenol, etc) ☐ yes ☐ No
3. Do you take narcotic pain medication? (Codeine or Stronger) ☐ yes ☐ No
4. How would you rate your upper and lower extremity today as a percentage of normal? ☐ %
5. Do you have mechanical symptoms in your elbow and knee? (catching, locking or grinding in your joint) ☐ yes ☐ No

**Performance Score:**

1. Are you able to comb hair? ☐ yes ☐ No
2. Are you able to feed yourself? ☐ yes ☐ No
3. Are you able to put on a shirt? ☐ yes ☐ No
4. Are you able to put on shoes? ☐ yes ☐ No
5. Are you able to walk on the flat surface? ☐ yes ☐ No
6. Are you able to climb stairs? ☐ yes ☐ No
7. Are you able to pick objects from the floor? ☐ yes ☐ No
8. How stable does your elbow feel? ☐ Stable ☐ Moderately unstable ☐ Extremely unstable
9. How stable does your knee feel? ☐ Stable ☐ Moderately unstable ☐ Extremely unstable
10. How bad is the pain in your elbow? ☐ Don't have pain ☐ Mild ☐ Moderate ☐ Severe
11. How bad is the pain in your knee? ☐ Don't have pain ☐ Mild ☐ Moderate ☐ Severe

**Range of motion:**

1. Can you please show us how far you can FLEX and EXTEND your arm and knee?
   a. closest to what you can FLEX to: Elbow _____ Knee _____
   b. closest to what you can EXTEND to: Elbow _____ Knee _____

**[Table/Fig-1]:** Subjective initial elbow and knee questionnaires.

## Inclusion Criteria

An untrained, active, healthy, man or woman (not involved in any kind of physical exercise protocols; involved in day to day regular activities), Between 18-30 years of age, and free of pain in the arms and legs.

## Exclusion Criteria

Have had an injury in the arms and/or legs that caused a visit to a medical provider, high blood pressure (systolic >130 or diastolic >90), pregnant, diabetes (type 1 or type 2) and any nerve, muscle, or joint disorder. Participants could perform their normal activities of daily living during the testing period and asked to refrain from consuming any anti-inflammatory drugs and nutritional supplements two hours before the exercise protocol and alcohol 12 hours before the exercise protocol.

## Study Design

This is a multi-group experimental design with eighteen participants divided into three groups (six participants each). This study was carried out for three weeks including the pre-test screening, the familiarisation session, the post- MVIC subjective and objective assessment (week 1), eccentric exercise protocol (week 2, 3 and 4), and the post eccentric exercise protocol MVIC [Table/Fig-2].

Eccentric exercise protocol-Each week, all three research group participants were called for six days. All participants performed eccentric exercise protocol using 15% of MVIC in the first day of week 2, 25% of MVIC in the first day of week 3 and 35% of MVIC in the first day of week 4. In each week, after day-1 eccentric exercise protocol, in the remaining days 2-6 of each week, the research participants were evaluated by the subjective and objective assessments on the tested muscles and joints (ADLs, pain, ROM and circumference) [Table/Fig-3].

**Table 1: Randomized Sample (Untrained Active Healthy Individuals)**

(N=6 in each group) (Age - 18-30 years)

**Screening Session:** a) Medical (Height, weight, BMI, BP and HR) + b) Questionnaire

| Group-I | Group-2 | Group-3 |
|---|---|---|
| **Visit 1: Familiarization & MVIC calculation** | | |
| a. Over view of the reseach study | | |
| b. Informed Consent Form | | |
| c. MVIC calculation for elbow flexors, elbow extensors, knee flexors and knee extensors | | |
| ↓ 24 hours | | |
| **Visit 2: Baseline DOMS testing after MVIC testing** | | |
| a. Assessment of ROM, DOMS, Pain & ADL Questionnaire | | |
| **A. Subjective Assessment** | **B. Objective Assessment** | |
| a. Health activities of daily living (ADL) | a. Arm and Thigh circumference | |
| difficulty scale | b. Pain pressure threshold (PPT) | |
| b. Visual analog scale (VAS) | c. Range of motion (ROM) | |
| ↓ 48hours | **Same as Group-I and changes below** | |
| **Visit 3: Eccentric Exercise Protocol (5 X 10 Repetitions)** | **Pre Yoga** | **Post Yoga** |
| Eccentric Exercise with 15% of MVIC @ partial ROM (60•) | Streching + | Streching + |
| ↓ 24, 48, 72, 96, 120- hours | Ecc. Exs | Ecc. Exs |
| **Visits 4-8: Post-eccentric exercise assessment (as visit 2)** | with 15% | with 15% |
| Assessment of ROM, DOMS, Pain & ADL Questionnaire | of MVIC + | of MVIC + |
| **A. Subjective Assessment** **B. Objective Assessment** | partial ROM (60•) | partial ROM (60•) |
| ↓ 4 days after visit 8 | | |
| **Visit 9: Eccentric Exercise Protocol (5 X 10 Repetition)** | **Pre Yoga** | **Post Yoga** |
| MVIC calculation+Eccentric Exs with 25% of MVIC @partial ROM (60•) | Streching + | Streching + |
| ↓ 24, 48, 72, 96, 120- hours | Ecc. Exs | Ecc. Exs |
| **Visits 10-14: Post-eccentric exercise assessment (as visit 2)** | with 25% | with 25% |
| Assessment of ROM, DOMS, Pain & ADL Questionnaire | of MVIC + | of MVIC + |
| **A. Subjective Assessment** **B. Objective Assessment** | partial ROM (60•) | partial ROM (60•) |
| ↓ 4days after visit 14 | | |
| **Visit 15: Eccentric Exercise Protocol (5 X 10 Repetition)** | **Pre Yoga** | **Post Yoga** |
| MVIC calculation+Eccentric Exs with 35% of MVIC @ partial ROM (60•) | Streching + | Streching + |
| ↓ 24, 48, 72, 96, 120- hours | Ecc. Exs | Ecc. Exs |
| **Visits 16-20: Post-eccentric exercise assessment (as visit 2)** | with 35% | with 35% |
| Assessment of ROM, DOMS, Pain & ADL Questionnaire | of MVIC + | of MVIC + |
| **A. Subjective Assessment** **B. Objective Assessment** | partial ROM (60•) | partial ROM (60•) |

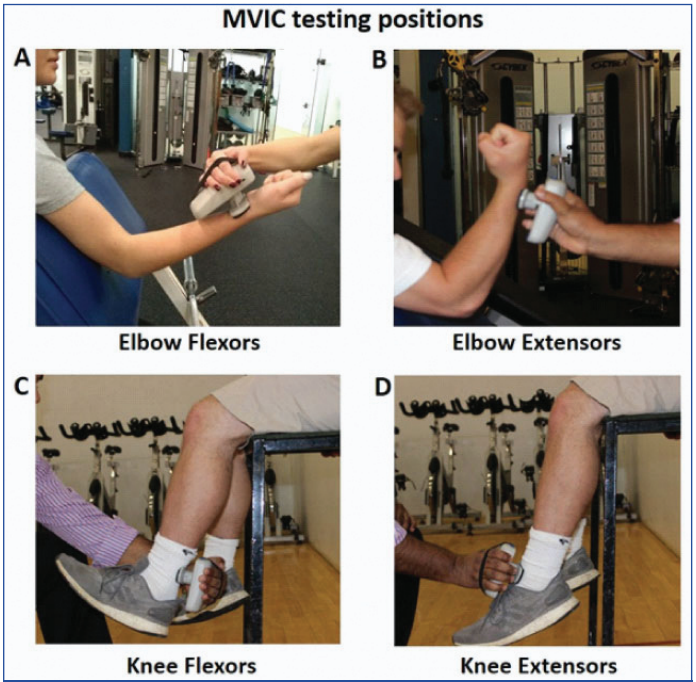
**[Table/Fig-2]:** The schematic flow diagram of the study design.
Exs: Exercises

| Subjective | B. Objective |
|---|---|
| a. Health Activities of Daily Living (ADL) difficulty scale | a. Arm and thigh circumference |
| b. Visual Analog Scale (VAS) | b. Pain Pressure Threshold (PPT) |
| | c. Range of Motion (ROM) |

**[Table/Fig-3]:** Subjective and objective assessments.

**Visit 1: Familiarisation and MVIC:** The study procedure, associated risks that may arise due to their participation and the benefit of this research project were explained to the research participants before obtaining written consent. The Blood Pressure (BP) was checked for every research participant at the beginning of each exercise session. Participants were instructed step by step to do MVIC and ECC strengthening exercises in four of their muscle groups (elbow flexors, elbow extensors, knee flexors, and knee extensors). The dynamic adjustable ROM controlled elbow and knee joint splints (T Scope® Elbow Premier (07254) and T Scope® Premier Post-Op Knee Brace (08814), BREG, USA) were used to limit the partial ROM (60° of total ROM- the outer ROM) while performing ECC protocols. These splints have locks to control the ROM so unexpected or uncontrolled movements at the elbow and knee of the subjects were prevented. The participants performed ECC using all four limbs on one muscle group per limb and on each limb individually (right and left elbows and right and left knee). The participants completed a strength testing protocol in all four selected muscles where he/she was asked to perform a MVIC using a hand-held dynamometer (Lafayette Instrument, MMT Device, Pro-Health Care, USA) for 4 positions: 1) Elbow flexion at 90 degrees; 2) Elbow extension at 90 degrees; 3) Knee flexion at 90 degrees; and 4) Knee extension at 90 degrees. MVICs were carried out only during familiarisation session and the first day of every week (mentioned in every week's exercise protocol) in three weeks (weeks 2-4) of exercise protocol and verbal encouragement was given during the MVICs. Measurements were

taken twice and the peak force of the 2 contractions was used as the MVIC force [Table/Fig-4].




**[Table/Fig-4]:** Maximal Voluntary Isometric Contraction (MVIC) positions for elbow flexors, elbow extensors, knee flexors and knee extensors.

Participants were allowed 30-seconds rest between upper and lower limb muscles MVIC measurements. Depending on the visit 15%, or 30% or 45% of MVICs were calculated for each muscle group. Ultimately Fit Adjustable Ankle Weights (Hayneedle Company, USA) were used for resistance during the eccentric exercise protocol with partial ROM (60° of total ROM-the outer ROM).

**Visit 2: Baseline DOMS assessment after MVIC testing:** After 24 hours of familiarisation, the assessment of the ADL, active ROM at elbow and knee, DOMS, and pain were carried out.

**Subjective assessment: a. Health ADL difficulty scale**- The following questions were asked. The pain scale ranged from 0 (no pain) to 10 (worst pain). For elbow: 1) Combing hair; 2) Eating with a fork or spoon; 3) Pulling a heavy object; 4) Using arm to rise from a chair; 5) Carrying an object above the shoulder; 6) Putting on shirt/coat; 7) Washing opposite armpit and back For knee: 1) Getting in and out of car; 2) Walking on the flat ground; 3) Ascending stairs; 4) Descending stairs; 5) Getting in and out of bed; 6) Bending to pick up from the floor.

**b. Visual Analog Scale (VAS):** The level of muscle soreness was quantified using an 11 points VAS in which 0 indicated "no pain" and 10 represented "extreme pain". The participants were asked to mark the level of perceived soreness on the VAS when the elbow flexors, elbow extensors, knee flexors, and knee extensors are palpated in a circular motion by the investigator. The palpating points are mid-belly of the biceps brachii, mid-belly of triceps brachii, mid-upper anterior thigh and mid-upper posterior thigh. Each site was palpated twice, slowly, in 5 circular movements by the same investigator using his/her index and middle fingers for approximately 3 seconds. One measurement was taken from each site with 10-second intervals between measurements. All measurements were taken by the same investigator throughout the experiment.

**Objective assessments: a. Arm and thigh circumference measurements:** In a sitting position, using the Health-o-Meter digital measuring tape, arm circumference measurements were taken at 6 sites: the mid-upper-arm (0), 3 centimeters below the mid-point of the upper arm, 3 centimeters above the mid-point of the upper arm, the mid-upper-thigh (0), 5 cm below the mid-point of upper thigh, and the distal portion of the thigh.

**b. Pressure Pain Threshold (PPT):** PPT is the minimum amount of force that can be applied to induce pain that was measured using an electronic algometer (Baseline 60-pound Dolorimeter/Algometer Pain Threshold Meter, Pro-Health Care, USA). The probe head of the algometer (area of 1.0 $cm^2$) was placed (the same sites as the palpation muscle soreness measures by VAS) and pressed against the tester in a vertical direction while increasing the force at a constant rate of 1 $kg/cm^2$ until the research participant reports the first feeling of noticeable pain of the muscle.

**c. Active ROM:** The active ROM of the elbow and knee joints were assessed with a digital stainless-steel goniometer (Taytools Digital Goniometer with Stainless Steel Blades).

**ECC protocol:** ECC Protocol with PROM for the elbow flexors, elbow extensors, Knee flexors and knee extensors. At comfortable position, the dynamic adjustable ROM controlled elbow and knee joint splints were used to the exercising limb and the lock was adjusted to 60° flexion. The calculated elbow flexors or extensors, 15% or 25% or 35% of MVIC was attached to the research participant's wrist using adjustable ankle weights and facilitated the PROM ECC exercise protocols [Table/Fig-5]. After every 10-15 ECC repetitions, there was a 60 seconds rest period given to all the research participants.


**[Table/Fig-5]:** Eccentric exercise protocol positions with dynamic adjustable range of motion (ROM) controlled elbow and knee joint splints for the elbow flexors, elbow extensors, knee flexors and knee extensors.

### Yoga stretching poses [18]

The yoga stretching poses (Child's pose, thread the needle, eagle arms, cow face pose, and hands overhead in a wide-legged forward bend) were performed by participants before or after ECC exercise protocol for groups 2 and 3. Yoga poses were conducted as a group activity and repeated five times in every eccentric exercise session (visits 3, 9 and 15) for groups 2 and 3. A total duration of 15-20 minutes was spent on each yoga session.

**Visit 3: Eccentric exercise protocol (5×10 Repetition) (week 2):** After 48 hours of baseline DOMS assessment, participants were introduced to ECC (for all four muscle groups; 5 sets of 10 repetitions) at PROM with 15% of MVIC for the elbow flexors, elbow extensors, knee flexors, and knee extensors. Group-1 (control group=eccentric exercise only + no yoga); Group-2 (pre-yoga group=pre-yoga for 15-20 min + eccentric exercise); Group-3 (post-yoga group=eccentric exercise + post-yoga for 15-20 min). Group 2 performed yoga stretching before the ECC protocol whereas group 3 performed yoga stretching after the ECC protocol.

**Visits 4-8: Post-eccentric exercise assessment:** After 24 hours

of ECC (visit 3), subjective and objective assessments were carried out at 24, 48, 72, 96, 120-hours (visits 4-8).

**Visit 9: Eccentric exercise protocol (5×10 repetition) (week 3):** After 24 hours of ECC (visit 8), week 3 ECC protocol was performed. This protocol was the same as visits 3-8 except for the change in the percentage of MVIC (25%).

**Visits 10-14: Post-eccentric exercise assessment:** For these visits, the protocol was the same as visits 4-8. After the eccentric exercise protocol (visit 9), the subjective and the objective assessments were carried out at 24, 48, 72, 96, 120-hours (visits 10-14).

**Visit 15: Eccentric exercise protocol (5×10 repetition) (week 4):** After 24 hours of ECC (visit 14), week 3 ECC protocol is performed. This protocol was the same as visits 3-8 or 9-14 except for the change in the percentage of MVIC (35%).

**Visits 16-20: Post-eccentric exercise assessment:** For these visits, the protocol was the same as visits 4-8 and 10-14. After the eccentric exercise protocol (visit 15), the subjective and the objective assessments were carried out at 24, 48, 72, 96, 120-hours (visits 16-20).

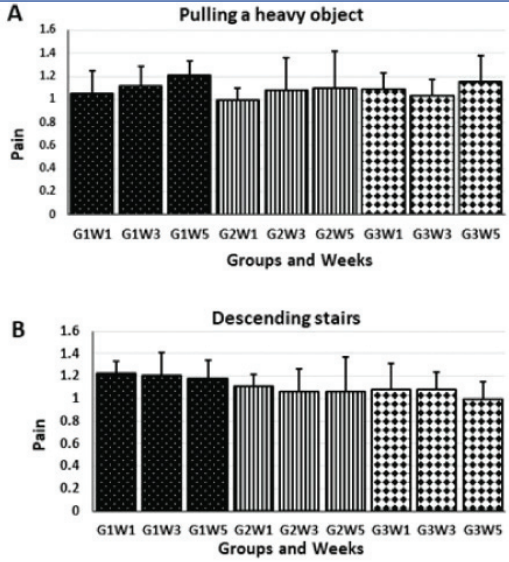
## STATISTICAL ANALYSIS

Statistical analysis was carried out using GraphPad Prism software (version 8.2.0). The paired t-test statistical formula was used to calculate the significant difference between pre- and post-ECC protocol MVICs. We explored the subjective and objective values after the 15% (week 2), 25% (week 3), and 35% (week 4) of MVIC time periods and ran statistical analysis on the worse scores observed during the 24 to 48-hour window of time.

## RESULTS

DOMS developed within 24 hours of exercise, the intensity of pain ranged from 0 to 2 (mild) between 24-48 hours post-exercise. No pain was felt by all research participants after 48 hours of post ECC exercise. So, the subjective and objective assessment data were statistically analysed for 24-48 hours of post-exercise. Group-1 is mentioned as the control group (eccentric exercise only).

The ADL questions were asked to the research participants of all three groups and their pain levels were recorded. Pulling a heavy object (elbow extensors), and descending stairs (knee flexors) activities questionnaire pain levels {mean and Standard Error of the Mean (SEM)} were mild (0-2) and didn't show a statistically significant difference (p>0.05) between groups and shown [Table/Fig-6]. Mean values of other ADL activities pain level did not show any statistically significant difference within each group (weeks 2, 3 and 4) and between three groups in each week.




**[Table/Fig-6]:** Pulling a heavy object, and descending stairs ADL activities questionnaire pain levels (mean and SEM) are shown. G1W2-group-1 and week-2; G1W3-group-1 and week-3; G1W4-group-1 and week-4; G2W2-group-2 and week-2; G2W3-group-2 and week-3; G2W4-group-2 and week-4; G3W2-group-3 and week-2; G3W3-group-3 and week-3; G3W4-group-3 and week-4.

MVICs were calculated to all the participants before starting the exercise protocol (pre-ECC protocol) and again calculated after completing the entire study post-ECC protocol. We compared pre-ECC protocol MVIC values of elbow flexors, elbow extensors, knee flexors, and knee extensors with post-ECC protocol MVIC values to quantify the overall improvement of muscle strength at end of the study [Table/Fig-2].

The four weeks of PROM ECC protocol with yoga poses prior to or post-exercise have increased the muscle strength in all selected four muscle groups of the participants. The post-ECC MVIC values were higher when compared with pre-ECC MVIC values of the elbow flexors, elbow extensors, knee flexors and knee extensors in all the groups and showed statistically significant differences ($p<0.05$) within each group. There was no statistically significant difference noted between pre- and post-ECC MVIC values of the elbow extensors within group 2 [Table/Fig-7]. We didn't compare the MVICs between weeks and groups of the study protocol. VAS and PPT for the elbow extensors and knee flexors showed a minimal pain (0-2) and didn't show a statistically significant difference ($p>0.05$) between groups whereas elbow flexors and knee extensors didn't show pain within and between the groups. The measurement of arm and thigh circumferences and ROM at elbow and knee were carried out and their mean values were compared between the weeks for each group but did not show a statistically significant difference. The ROM at elbow and knee was pain-free and performed at the full ROM. The arm and thigh circumference and ROM were not compared between the groups because of individual research participant's actual arm and thigh circumference and ROM variability and can cause a statistical error.

| | Pre-ECC protocol MVIC (in lbs.) | | | Post-ECC protocol MVIC (in lbs.) | | | Paired t-test p-value (significance) |
|---|---|---|---|---|---|---|---|
| | Range | Mean | SEM | Range | Mean | SEM | |
| **Elbow flexors** | | | | | | | |
| Group 1 | 23.25-45.3 | 36 | 3.345 | 27.5-49 | 40.5 | 3.175 | 0.0009 (***) |
| Group 2 | 24.8-44.5 | 38.05 | 2.805 | 29.4-48.9 | 43.27 | 2.857 | <0.0001 (***) |
| Group 3 | 24.6-28.7 | 36.1 | 3.054 | 28.7-47.8 | 41.93 | 3.23 | 0.0012 (**) |
| **Elbow extensors** | | | | | | | |
| Group 1 | 20.3-40.2 | 30.77 | 2.799 | 22.2-47 | 35.07 | 3.342 | 0.0201 (*) |
| Group 2 | 19.5-38.7 | 31.47 | 2.627 | 24.5-51.5 | 40.62 | 3.909 | 0.0911 (NS) |
| Group 3 | 21.2-39.4 | 31.28 | 2.939 | 24.6-42.4 | 34.28 | 2.748 | 0.0056 (**) |
| **Knee flexors** | | | | | | | |
| Group 1 | 27-43.5 | 34.85 | 3.104 | 31.4-45.6 | 39.33 | 2.643 | 0.0053 (**) |
| Group 2 | 30.1-48.6 | 41.52 | 2.738 | 33.1-51.6 | 45.02 | 2.657 | 0.0034 (**) |
| Group 3 | 28.4-42.7 | 38.27 | 2.084 | 32.8-46.9 | 42.27 | 2.117 | 0.0026 (**) |
| **Knee extensors** | | | | | | | |
| Group 1 | 36-56.5 | 45.68 | 3.003 | 40-59.3 | 50.63 | 2.904 | 0.0016 (**) |
| Group 2 | 36.7-51.2 | 46.88 | 2.128 | 42.7-55.4 | 52.2 | 1.94 | 0.0041 (**) |
| Group 3 | 30.5-51.9 | 44.05 | 3.132 | 35.2-55 | 48.12 | 2.861 | 0.0031 (**) |

**[Table/Fig-7]:** Comparison between Pre-ECC Protocol MVICs and Post-ECC Protocol MVICs of elbow flexors (EF), elbow extensors (EE), knee flexors (KF) and knee extensors (KE) in the groups (1, 2 and 3).
MVIC: Maximal voluntary isometric contraction; ECC: Eccentric contraction
*Significant; **Moderatily significant; ***Highly significant

## DISCUSSION

This was the first study to compare PROM ECC-induced DOMS and pain on elbow flexors, elbow extensors, knee flexors and knee extensors. The main results confirmed the initial hypothesis that individuals who completed 15% of MVIC ECC through partial ROM (60° of total ROM) demonstrated with lesser DOMS, pain, and functional limitations than individuals who completed 35% of MVIC

ECC through partial ROM.

Previously, published studies have investigated DOMS and pain after ECC with different ranges of muscle fiber or whole muscle stretching using animal models. The magnitude of muscle stretching can affect the magnitude of muscle damage that leads to muscle soreness and pain [4].

In humans, few studies have investigated the effect of partial ROMs on the magnitude of muscle damage [5,6,8]. Vaczi M et al., studied at partial ROMs (20-80°) using 6 sets of 15 knee ECC exercise and their results showed reduced muscle soreness [8]. The final phase (outer part) of ROM developed in the ECC is reported to be very important for inducing muscle damage in DOMS [6]. Vaczi M et al., study didn't conduct ECC exercise protocol at the final phase of ROM at the knee [8].

Nosaka K and Sakamoto K conducted an ECC exercise protocol on elbow flexors at two different angle conditions namely 50° to 130° (small angle) and 100° to 180° (large angle) with 80° ROM [6]. The muscle damage was found to be increased in the 50° to 130° angle condition than 100° to 180° angle condition. The authors also carried out another study with same angular conditions but with 50° as ROM and found the muscle damage was greater in the 100° to 180° angle condition than 50° to 130° angle condition [7]. Kachanathu SJ et al., performed an experiment with eccentric contractions at 75% ROM 50% ROM and 25% ROM in knee extensors [19]. This study result showed that in a group of men age approximately 25 years, DOMS is not measurable on the VAS scale with a 25% ROM eccentric work out; meaning that 25% of ROM will not cause muscle soreness to a beginner during a workout. Fochi AG et al. on twelve healthy young men elbow flexors performed the ECC with partial 60° ROM and were tested before and 24, 48, 72 and 96 hrs after ECC for MVIC, ROM and muscle soreness [5]. The results showed that smaller ROM ECC protocol reduced the level of muscle soreness. But, Fochi AG et al., study did conduct ECC protocol at the final phase of ROM at elbow flexors [5]. In the published literature, DOMS studies with partial ROM were performed on one group of muscles (elbow flexors, or knee extensors) [5,6,8,20,21]. The muscle damage between limbs was relatively similar between knee extensors and elbow flexors in the younger individuals.

Our study research participants performed the final phase of partial ROM ECC on two upper limbs (flexors and extensors of the elbow) and two lower limbs (flexors and extensors of the knee) muscle groups that are prone for the DOMS. If someone performs through lesser ROM using ECC, then this may not induce muscle injury for soreness. The low-intensity ECC with partial ROM may have a protective and preventive effect on muscle damage to cause reduced DOMS. Results of the upper and lower limb ADL questionnaire showed that upper limb elbow extensor muscles and knee flexors perceived mild pain (0-2). The low-intensity eccentric exercise at partial ROM (60° of total ROM) not inducing muscle soreness in the elbow flexors and knee extensors may be due to less used and weak muscle in day to day ADL activities and the type of skeletal muscle fibers present in it. All three groups of participants did not feel pain during the ECC study protocol at partial ROM (60° of total ROM). Since participants didn't feel DOMS and pain during the study period, it will be hard to find the significant effect of yoga stretching possess on the partial ROM (60° of total ROM) ECC protocol. There was no significant difference in the ROM and, arm and thigh circumference between the groups. The limitations of this study include, smaller number of participants, carried out only in young age group (ages between 18-30 years) and each study group had a greater number of female participants.

The present study was performed to see the results of the effect on younger individuals that can be used for older adults if there are less pain and more health benefits like improvements in their muscle strengths and ROM. The aging process leads to a decrease in muscle mass and muscle strength [22]. Physical inactivity and insufficient nutrient intake are important factors for loosing muscle mass and muscle strength that lead to muscle disuse atrophy especially in older adults. Strengthening exercise training will be the solution to prevent this problem [23]. ROM is important to older adults for the quality of life. The optimal range of motion contributes significantly to older adults' ability to perform Activities of Daily Living (ADL). Many factors can affect ROM in the joints of older adults. Lack of movement and muscle strength are the causes of reduced ROM and pain in the joints of older adults. In older adults, the ROM can be improved by ECC strengthening exercises. To carry out this, they can be encouraged to take advice from qualified individuals like physical therapists or healthy and wellness professionals to choose for specific strengthening exercise program suitable for them [24].

## CONCLUSION(S)

Older adults may have reduced muscle strength, ROM and energy to perform ADL. The present study on younger individuals showed that muscle strengths (post-ECC protocol MVICs) have significantly increased with minimal or no soreness and pain. The participants could perform this ECC protocol with less energy expenditure. Yoga stretching poses may prevent muscle shortening or contracture that will help in maintaining or increasing ROM at the joints. Present study protocol can be used as a guide for future research and applied to the older adults who are in chronic conditions with co-morbidities to improve their muscle strength, and ROM to fulfill their ADL and healthy independent life. The result of the study will help the rehabilitation professionals to carry out this protocol in geriatric group of people with 15% of MVIC and a small partial range of motion. This might result in best and speedy recovery with minimal pain and DOMS, there by strengthening the various muscle groups.

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