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Md. Izhar Gauri
Research scholar, Singhania University, Pacheri Bari, Junjhunu, Rajasthan, India

Ranjay Kumar Choudhary
Lecturer, Department of Medical Lab. Technology, College of Applied Medical Sciences, Majmaah University, Majmaah, KSA

Moattar Raza Rizvi
Assistant Professor, Department of Nursing, College of Applied Medical Sciences, Majmaah University, Majmaah, KSA.

Correspondence
Md. Izhar Gauri
Research scholar, Singhania University, Pacheri Bari, Junjhunu, Rajasthan, India

Effect of Local Application of Turmeric and Conventional Physical Therapy on Delayed Onset Muscle Soreness (DOMS) after Eccentric Exercise in Healthy Adults

Md. Izhar Gauri, Ranjay Kumar Choudhary, Moattar Raza Rizvi

Abstract
Backgrounds: Delayed onset muscle soreness is muscular soreness and pain experienced 24 to 48 hours after a rigorous or unaccustomed session of exercise. Though DOMS is not considered a major injury, it compromises performance by decreasing range of motion, strength, and function. The severity of the symptoms leading to the decrease in performance has led to the investigation in treatment for DOMS.
Aim: The aim of this study was to determine the effectiveness of Curcuma longa (turmeric) in reducing the signs and symptoms of Delayed Onset Muscle Soreness (DOMS).
Materials and Methods: Repeated eccentric contractions were used to induce DOMS in the elbow flexors of twenty-four (n = 24) untrained healthy volunteers. Subjects were then assigned randomly to one of four groups: (1) group 1 (n=6) as control group (2) group 2 (n=6) received physical therapy (3) group 3 (n=6) received physical therapy and turmeric cream supplementation, and (4) group 4 (n=6) received only turmeric cream supplementation. Then, the measurements for all groups were taken which included the muscle soreness (as measured by VAS), the resting elbow angle (in degrees), the biceps girth (in cm), the creatine Kinase level and the total leucocytic count (TLC) was tested among the four designated groups.
Result: A total number of 24 untrained subjects participated in the study within the age group of 18-30 years. The soreness was on its peak at 48 hours post exercise in both groups. The VAS ratings of elbow flexor soreness was greatly reduced after 96 hours in group 3 (physical therapy+ turmeric) subjects receiving physical therapy and turmeric application. The group 3 (physical therapy+ turmeric) showed least loss of resting elbow angle i.e., the elbow tended to remain as close as possible to the baseline measurement after 72 and 96 hours. No Significant differences were noted in the Biceps girth measurements. There was significant difference in the creatine kinase levels after 48 hours, 72 hours and 96 hours which was more evident in the group 3 with turmeric supplementation in conjunction with physical therapy.
Conclusion: Our result showed that local application of turmeric and physical therapy intervention produced more effect on DOMS than turmeric or physical therapy only. This indicates that turmeric can be useful alternative in management of DOMS by its effects on pain intensity and muscle injury.

Keywords: Eccentric muscle contraction, Muscle soreness, turmeric

1. Introduction
Delayed onset muscle soreness (DOMS) is a phenomenon that is commonly experienced after individuals perform unaccustomed exercise or increase the load during resistance training. Eccentric exercise is believed to result in greater muscle soreness because the motion stimulates more neural activations to generate the force required to complete the exercise [1, 2]. DOMS typically occurs 24 to 48 hours after unaccustomed exercise, especially eccentric exercise, is performed. Its characteristics are similar to muscle soreness. However, muscle soreness tends to subside after a few hours while DOMS is prolonged for 5 to 7 days [3, 4]. Clinical signs and symptoms associated with DOMS include increased pain, increased edema, decreased self-reported functional ability, decreased range of motion, and decreased muscle strength [4-6].
There is a decrease in physical performance that can be attributed to functional impairment as perceived by the individual and decreases in joint kinematics, strength, and neural

recruitment patterns which increases risk factors of further injury. Although DOMS is not considered a major injury, all of these impairments can lead to an increased risk of injury; therefore, interventions to relieve the signs and symptoms of DOMS have been investigated [7-9].

Numerous interventions have been researched in order to determine their effectiveness in preventing or alleviating the clinical presentations related to DOMS [7-9]. Although there has been a considerable amount of research on the treatment of DOMS, to date no one treatment has proved dominant in consistently preventing or treating DOMS. Among popular interventions are pharmacological treatments using non-steroidal anti-inflammatory drugs (NSAIDs), therapeutic treatments utilizing physical modalities such as stretching and warm-up, and interventions using nutritional supplements. The effectiveness of these treatments remains inconclusive because of inconsistencies between studies and the limited amount of evidence of the interventions.

Curcumin, the main yellow bioactive component of turmeric has two natural analogues FHM [feruloyl-(4-hydroxycinnamoyl)-methane] and BHM [bis-(4-hydroxycinnamoyl)-methane], which has demonstrated inhibitory activity against a range of proinflammatory enzymes and cytokines [10-12] resulting in decrease in swelling and pain. Because of these in vitro effects, curcumin could plausibly be used as an alternative to NSAIDs for the control of osteoarthritic pain.

Generally, an increased perception of soreness occurs with greater intensity and a higher degree of unfamiliar activities. Other factors, which play a role in DOMS, are muscle stiffness, contraction velocity, fatigue, and angle of contraction. In order to minimize symptoms and optimize productivity in a physical training program it is vital to understand the proposed mechanisms of injury, which occur in DOMS. The purpose of this study is to determine the effect of local application of turmeric on DOMS.

2. Materials & Methods

2.1 Experimental Design

The study had 24 healthy, untrained subjects within the age group of 18-30 years. None had performed any weight training for at least 3 months before the study. The participants were requested not to use other treatments such as an oral NSAID, muscle relaxants, physiotherapy or massage. If the participants received other therapies, all details were recorded.

Repeated eccentric contractions were used to induce DOMS in the elbow flexors of all subjects untrained healthy volunteers. Subjects were then assigned randomly to one of four groups: (1) group 1 (n=6) as control group (2) group 2 (n=6) received physical therapy (3) group 3 (n=6) received physical therapy and turmeric cream supplementation, and (4) group 4 (n=6) received only turmeric cream supplementation. Muscle soreness, muscle strength, active elbow range of motion and creatine kinase were measured before and after eccentric exercise. The curcumin concentration achieved in the present study was almost 80 ng/ml (0.22 µmoles/L).

The nature & scope of methodology is to see the effect of turmeric supplement versus conventional physical therapy or both. Informed consent was taken from all the subjects before enrolling them in this study. Subjects were apprised of the procedure, possible risks of participation in study prior to giving consent. All subjects reported having no upper arm pain and had a pain free range of motion about elbow joint.

2.2. Inducement of Delayed-Onset Muscle Soreness

Repeated concentric and eccentric contractions were used to induce DOMS in the elbow flexors. A dumbbell curl exercises was used to isolate elbow flexors which enables the subject to sit with arms lying on a padded board and placed in front of the body at a 45-degree angle downward from the axilla. Resistance was applied to the elbow flexors allowing the subject to grasp a dumbbell and consecutively extend and flex elbow during a full ROM. A one-repetition maximum (1-RM) of the elbow flexors was determined. The amount of weight the subject could lift concentrically one time before the elbow flexors became fatigued represented 1-RM. Each subject used 70% of their 1RM. The eccentric phase was of 5-6 seconds and each set was separated by a 1-minute rest period.

2.3 Subject's Rating of Muscle Soreness

A visual analogue scale (VAS) was used to assess muscle soreness in each subject on each day of the study. The validity and reliability of this tool in measuring experimentally induced pain have been established elsewhere [13]. The VAS used in our study consisted of a continuous horizontal line 150 mm in length, with anchor points of "no soreness" and "worst possible soreness" at the left and right ends of the line, respectively.

An identical set of instructions was read to each subject prior to completing each VAS, and subjects indicated the amount of soreness by placing a slash somewhere along the VAS. Relative soreness was then calculated by measuring the distance of the slash from the left end of the VAS. Subjects completed a separate VAS for each upper extremity, and they were not allowed to compare one VAS result with another.

2.4. Measurement of Elbow Range of Motion

The effect of DOMS on active elbow ROM was determined using a universal full circle goniometer. The goniometer axis was placed over the lateral epicondyle of the humerus, with the stationary and movable arms aligned along the lateral midline of the humerus and the radius, respectively. Active ROM was measured as the total excursion from full elbow flexion to full elbow extension. The limbs were then marked with a permanent marker to ensure greater accuracy during measurement. Neutral was set at zero or 180 degree (arm straight). The resting elbow angle was recorded pre and post treatment. A standardized testing procedure was established to ensure proper identification of bony landmarks and goniometer alignment. Subjects were given identical instructions prior to each measurement, and a single measurement of total joint excursion was recorded at each session.

2.5 Biceps Girth Measurement

Girth of the Biceps muscle was measured with the help of a meter tape, measurement was taken of the muscle belly of biceps muscle, 3 inches above elbow joint.

2.6 Biochemical Assessment

Blood samples centrifuged at the test performance place to prevent changing in serum enzymes. Total leucocyte count (TLC) was done on all the samples and creatine kinase was measured using ELISA Kit.

2.7 Statistical Analysis

ANOVA was used for checking the differences within groups in different times and Repeated Measure and Scheffe Test post hoc were used for checking the differences between groups. Moreover, to compare the results in different measurement between groups. The interaction effect of time and group was also measured. All statistical analysis was performed using SPSS-20. The significant level was considered at $p \leq 0.05$.

3. Results

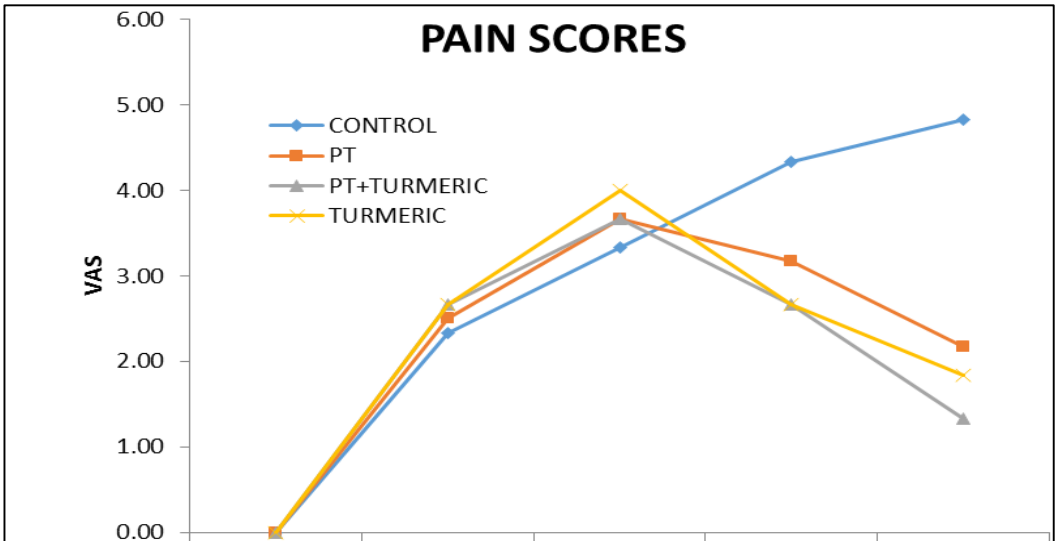
A total number of 24 untrained subjects participated in the study within the age group of 18-30 years (Table 1). The descriptive indexes (Mean±SD) of age for the different groups has been shown in table 1. No significant difference was noted between the participants in the two different groups at baseline with regard to age.

Table 1: Demographic characteristics of the subjects

GROUP	Age (yrs)	Weight (kg)
Control Group (n=6)	22.55±2.72	72.86±8.88
Physical Therapy Group (n=6)	23.55±3.58	71.52±13.28
Physical Therapy + Turmeric Supplementation Group (n=6)	23.87±3.48	73.56±10.25
Turmeric Supplementation Group (n=6)	22.38±1.76	72.46±9.78

3.1 Muscle Soreness Rating

The VAS ratings of elbow flexor soreness on day 2 through day 4 are presented for each group in Table 2. Baseline soreness levels (before inducement of DOMS) recorded are not shown in the table, because these values were essentially zero for all groups. There was no consistent or significant difference between all the control and treated group after 24 hours ($p = 0.650$) and 48 hours ($p = 0.250$). After 72 hours' soreness was significantly improved between the treated and control group ($p>0.05$; $F = 5.779$). The VAS after 72 hours was 4.33±0.51 in group 1 (control) as compared to the 3.16±0.75 in group 2 (physical therapy), 2.66±1.21 in group 3 (physical therapy+ turmeric) and 2.66±0.51 in group 4 (turmeric). There was further improvement between the treated and control group ($p<0.0001$; $F = 29.915$) after 96 hours. The VAS was 4.83±0.40 in group 1 (control) as compared to the 2.16±0.98 in group 2 (physical therapy), 1.33±0.51 in group 3 (physical therapy+ turmeric) and 1.83±0.75 in group 4 (turmeric). The VAS ratings of elbow flexor soreness was greatly reduced after 96 hours in group 3 (physical therapy+ turmeric) subjects receiving physical therapy and turmeric application.



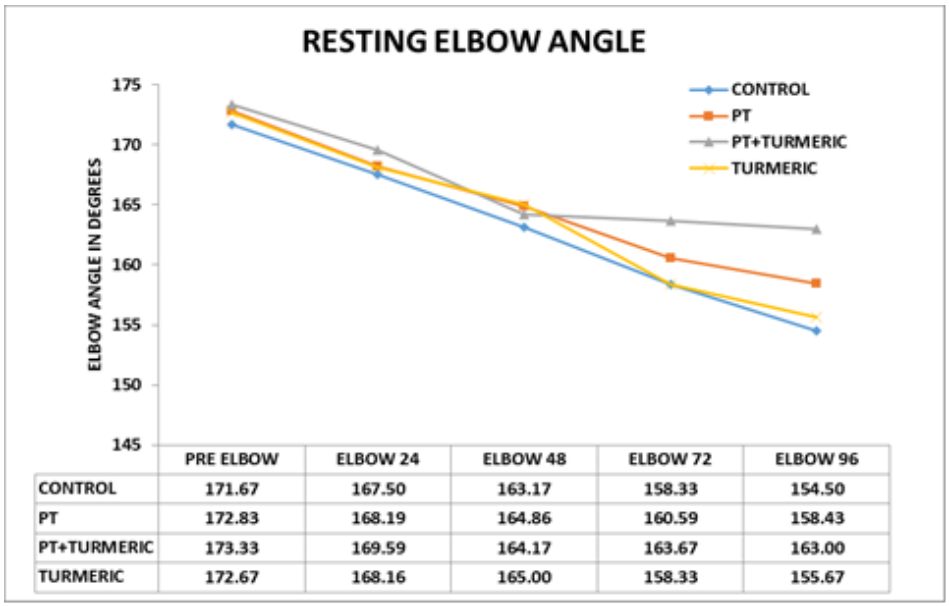
	pre VAS	VAS 24	VAS 48	VAS 72	VAS 96
CONTROL	0.00	2.33	3.33	4.33	4.83
PT	0.00	2.50	3.67	3.17	2.17
PT+TURMERIC	0.00	2.67	3.67	2.67	1.33
TURMERIC	0.00	2.67	4.00	2.67	1.83

Fig 1: Muscle Soreness as measured by VAS in four groups: (1) group 1 (n=6) as control group (2) group 2 (n=6) received physical therapy (3) group 3 (n=6) received physical therapy and turmeric cream supplementation, and (4) group 4 (n=6) turmeric only. Values are expressed as mean ± SD. PreVAS immediately after DOMS; VAS24, VAS48, VAS72 and VAS96 immediately after inducement of DOMS at 24, 48, 72 and 96 hours respectively.

3.2 Elbow Range of Motion Measurement

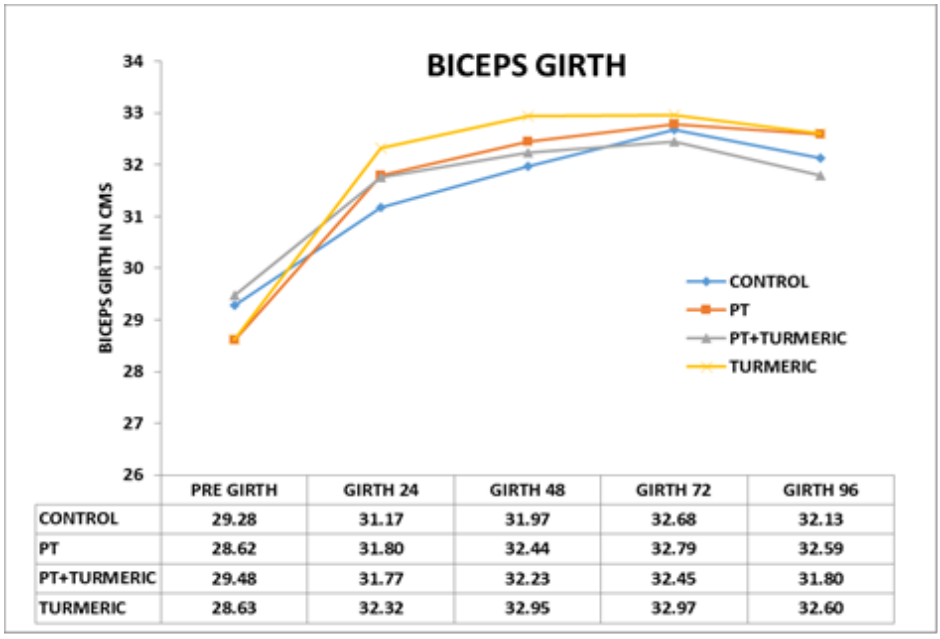
Results of the goniometric measurement of elbow ROM are shown in figure 2. There was no significant difference in the Elbow ROM between control and treated group at baseline level ($p =0.335$), after 24 hours ($p = 0.094$) and after 48 hours ($p = 0.051$). The ROM was significantly increased between the control and treated group after 72 hours ($F=13.876$; $p=0.000$). After 72 hours the ROM was 1.58±1.03 in group 1 (control) as compared to the 1.61±1.75 in group 2 (physical therapy), 1.63±1.02 in group 3 (physical therapy+ turmeric) and 1.58±2.06 in group 4 (turmeric). Similar results were seen in ROM after 96 hours

(F=23.733; p=0.000) as compared to 48 hours. In both the cases the group 3 (physical therapy+ turmeric) showed least loss of resting elbow angle i.e., the elbow tended to remain as close as possible to the baseline measurement. Strength decrease results because of the reluctance to use sore muscle and from the loss of inherent force providing capacity within the muscle, resulting in decrease in Resting elbow angle.



	PRE ELBOW	ELBOW 24	ELBOW 48	ELBOW 72	ELBOW 96
CONTROL	171.67	167.50	163.17	158.33	154.50
PT	172.83	168.19	164.86	160.59	158.43
PT+TURMERIC	173.33	169.59	164.17	163.67	163.00
TURMERIC	172.67	168.16	165.00	158.33	155.67

Fig 2: Measurement of resting elbow angle (degrees) in four groups: (1) group 1 (n=6) as control group (2) group 2 (n=6) received physical therapy (3) group 3 (n=6) received physical therapy and turmeric cream supplementation, and (4) group 4 (n=6) turmeric only. Values are expressed as mean ± SD. PreElbow immediately after DOMS; Elbow24, Elbow48, Elbow72 and Elbow96 immediately after inducement of DOMS at 24, 48, 72 and 96 hours respectively.



	PRE GIRTH	GIRTH 24	GIRTH 48	GIRTH 72	GIRTH 96
CONTROL	29.28	31.17	31.97	32.68	32.13
PT	28.62	31.80	32.44	32.79	32.59
PT+TURMERIC	29.48	31.77	32.23	32.45	31.80
TURMERIC	28.63	32.32	32.95	32.97	32.60

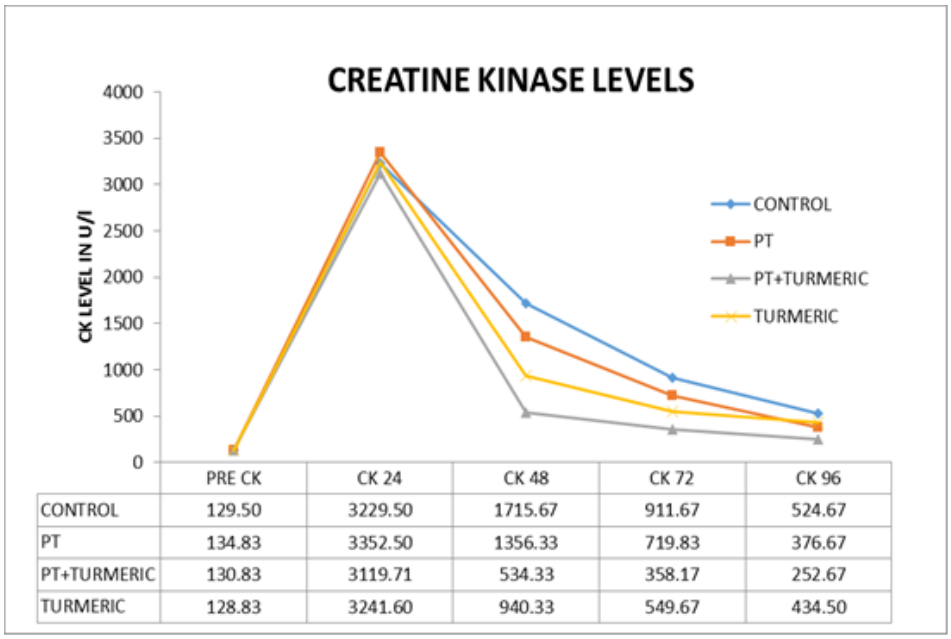
Fig 3: Biceps girth measurement (centimeter) in four groups: (1) group 1 (n=6) as control group (2) group 2 (n=6) received physical therapy (3) group 3 (n=6) received physical therapy and turmeric cream supplementation, and (4) group 4 (n=6) turmeric only. Values are expressed as mean ± SD. PreGirth immediately after DOMS; Girth24, Girth48, Girth72 and Girth96 immediately after inducement of DOMS at 24, 48, 72 and 96 hours respectively.

3.3 Biceps Girth

No Significant differences were noted in the Biceps Girth measurements. All the groups tended to remain as same as possible. No group showed clear improvement as compared to others.

3.4 Creatine Kinase Levels

It is a widely known fact that the CK levels shoot up dramatically with a bout of strenuous exercise and then falls back to pre-exercise levels gradually. The differences between the baseline measurements and the measurements at different time for different groups were analyzed and shown in figure. There was no significant difference in the creatinine kinase levels between the control and treated group at baseline level and after 24 hours. However significant difference was observed after 48 hours (F=224.779; p=0.000), 72 hours (F=39.654; p=0.000) and 96 hours (F-11.440; p=0.000).



	PRE CK	CK 24	CK 48	CK 72	CK 96
CONTROL	129.50	3229.50	1715.67	911.67	524.67
PT	134.83	3352.50	1356.33	719.83	376.67
PT+TURMERIC	130.83	3119.71	534.33	358.17	252.67
TURMERIC	128.83	3241.60	940.33	549.67	434.50

Fig 4: Creatine Kinase measured in four groups: (1) group 1 (n=6) as control group (2) group 2 (n=6) received physical therapy (3) group 3 (n=6) received physical therapy and turmeric cream supplementation, and (4) group 4 (n=6) turmeric only. Values are expressed as mean ± SD. PreCK immediately after DOMS; CK24, CK48, CK72 and CK96 immediately after inducement of DOMS at 24, 48, 72 and 96 hours respectively.

3.5 Total Leucocytic Count

As is the case with creatine kinase levels, TLC levels shoot up dramatically with a bout of strenuous exercise and then fall back to pre-exercise levels gradually. When the differences between the baseline measurements and the measurements at 96 hours were analyzed it showed that for the group PT + turmeric the difference between the two measurements was 168.83/cu.mm which amounted to a change of 2.53% when compared to the baseline. Owing to the wide variations in the normal range of TLC (4000-11000/cu.mm), significant differences were noted only at the TLC 96 (F=3.340; p=0.04).

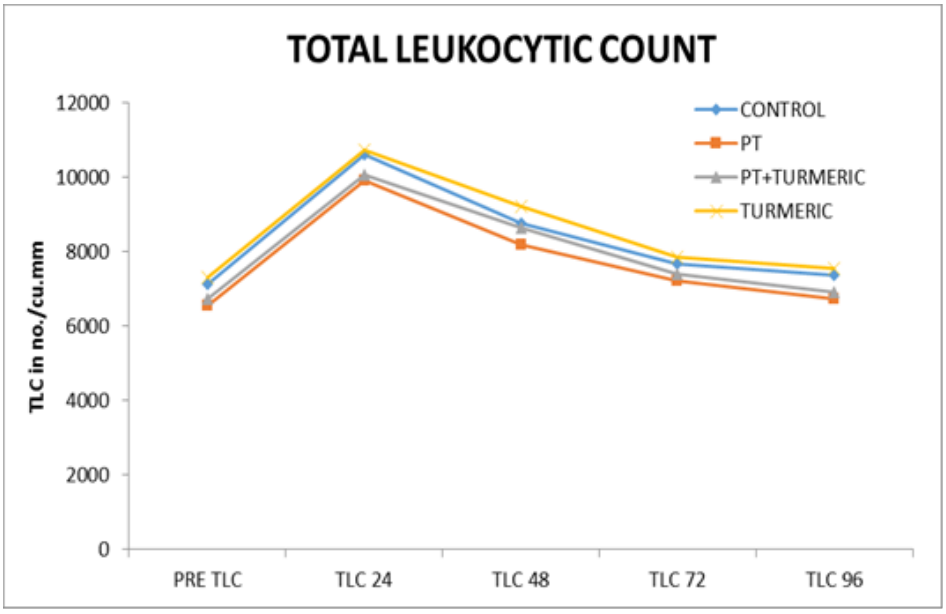


Fig 5: Measurement of total leucocytic count (TLC) in four groups: (1) group 1 (n=6) as control group (2) group 2 (n=6) received physical therapy (3) group 3 (n=6) received physical therapy and turmeric cream supplementation, and (4) group 4 (n=6) turmeric only. Values are expressed as mean ± SD. Control Placebo; Pre TLC immediately after DOMS; TLC24, TLC48, TLC72 and TLC96 immediately after inducement of DOMS at 24, 48, 72 and 96 hours respectively.

4. Discussion

The aim of the present study was to see the effect of turmeric supplementation versus physical therapy interventions on some biochemical and functional factors of delayed onset muscle soreness. DOMS is classified as a type I muscle strain injury [14, 15] and presents with tenderness or stiffness to palpation and/or movement[14]although the pathology associated with DOMS is usually sub-clinical[15], the sensations experienced with this injury can vary from slight muscle stiffness, which rapidly disappears during daily routine activities, to severe debilitating pain which restricts movement.

A number of theories have been proposed to explain the pain stimulus associated with DOMS including: lactic acid,

muscle spasm, connective tissue damage, muscle damage, inflammation, enzyme efflux theories and other proposed models [17, 14].

In a previous study, curcumin supplementation was shown to improve the inflammatory pattern and markers of muscle injury, ameliorating the performance deficits associated with exercise-induced muscle damage [18]. The active ingredient in turmeric is a polyphenol called curcumin, which is responsible for the bright yellow color [19]. Because of the increasing attention to the possible positive effects of curcumin to diseases such as Alzheimer's to cancers[20], the supplement sales of turmeric and curcuminoids have grown tremendously in the last few years. Curcumin is thought to have antioxidant and anti-inflammatory properties. Turmeric contains several anti-inflammatory compounds, including six different cyclooxygenase 2 (COX-2) inhibitors. The curcumin in turmeric is a multifaceted antiinflammatory agent. Preliminary studies have shown benefit of curcumin in inflammatory arthritis [21].

It has been found that the effect of muscle atrophy was alleviated by intraperitoneal injection of curcumin through antioxidant actions [22]. This is however not proven in human model and also the effective dose has not been characterized to achieve this. So a future studies are encouraged on human model through randomized control trials which could be beneficial for sport or clinical practice.

Muscle soreness developed post exercise in all 4 groups but significantly less for experimental (physical therapy + turmeric) group (p=0.000) as compared with control group at 72 and 96 hours of post-exercise. In a previous study that evaluated the analgesic efficacy curcumin 400 mg formulation taken as needed in patients with acute pain, curcumin had a well-defined pain-relieving effect, even greater than that of acetaminophen 500 mg, and was better tolerated than nimesulide [23].

No significant difference in pre exercise ROM was found between experimental and control group. Both experimental and control group did not show any significant difference at baseline, 24 hours and 48 hours of post-exercise. In 72 hours and 96 hours' significant recovery shown by experimental group 3 (physical therapy + turmeric).

Serum creatine kinase is accepted widely as a marker of muscle damage [24]. In the current study, creatine kinase increase from baseline occurred at 24 hour. This suggests that the eccentric exercise protocol used was successful in eliciting muscle damage. Increases in pain and reductions in muscle strength at 24 h in both groups further attest to the success of the exercise protocol in inducing DOMS. Also the creatine kinase release was higher in control group as opposed to experimental group where the effect was mitigated by the conventional physical therapy and application of turmeric supplementation. This investigation has several limitations which should to be suggestions for improvements in future studies. An increase in the number of participants would increase the power of the study and possibly result in significant differences between treatment groups.

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