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PREVENTION & REHABILITATION: Crossover study

The effectiveness of Biomechanical Taping Technique on visual analogue scale, static maximum handgrip strength, and Patient Rated Tennis Elbow Evaluation of patients with lateral epicondylalgia: A cross-over study

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A B S T R A C T

Introduction: Lateral epicondylalgia (LE) is a musculoskeletal injury involving the common extensor origin in elbow manifesting as pain and ineffective handgrip affecting the daily activities of the individuals with LE.

Objectives: This study determined the effectiveness of Standard Biomechanical Taping (SBMT), Vector Correcting Dysfunction Techniques 1 (VCDT 1) and Vector Correcting Dysfunction Technique 2 (VCDT 2); and compared their differences on effects on pain, grip strength and daily functions of individual with unilateral LE.

Methods: A cross-over study design was used. The senior investigator applied three BMT techniques namely: a. SBMT, b. VCDT 1, and c. VCDT 2. On Day 1, SBMT and VCDT1 were randomly assigned. On Day 3, either SBMT or VCDT1 not performed on Day 1 was applied to LE elbows. On Day 5, VCDT2 was applied on LE elbows. Visual Analogue Scale (VAS), Static Maximum Handgrip Strength Test (SMHGT) and Patient-Rated Tennis Elbow Evaluation (PRTEE) were used as outcome measures administered by three blinded junior investigators. On Days 1, 3, and 5, VAS and SMGHT were administered before and during BMT application. PRTEE was administered on Days 1 and 12.

Results: The following were found in this study: a. significantly decreased VAS scores at Days 1, 3, and 5 of BMT application ($p < 0.05$); b. significantly improved final VAS, SMHGT strength and PRTEE scores on Day 12 compared to baseline scores on Day 1 ($p = /< 0.01$); and c. significantly decreased VAS scores when using SBMT compared to VCDT2 ($p < 0.05$).

Conclusion: BMT is a novel taping technique effective in decreasing lateral elbow pain, increasing handgrip strength and improving function of patients with LE. BMT can be applied on painful elbows effecting a better grip among patients with LE.

1. Introduction

Lateral epicondylalgia (LE) is a non-inflammatory musculoskeletal injury affecting the common extensor origin of the forearm wrist extensor muscles (Fairbank and Corlett, 2002; Almquist et al., 1998; Albrecht et al., 1997). Associated symptom of LE is lateral elbow pain attributed to repetitive and forceful handgrip activities commonly observed among forestry workers, cooks, and assembly line workers potentially substantially affecting workload (Levin et al., 2005, Ono et al., 1998, Bystrom et al., 1995, Bovenzi et al., 1991). The prevalence of LE ranges from 1 to 1.3% in men and from 1.1 to 4.0% in women in the general population (Shiri and Viikari-Juntura, 2011). Albeit this condition is generally more common in individuals between 35 and 60 years of age, it can occur at any age (Kamien, 1990, Gregg and Torg, 1998).

Possible sources of lateral elbow pain in LE include the common

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List of legend

ANOVA	analysis of variance
BMT	biomechanical taping
CI	confidence interval
ICC	intra-class correlation coefficient
LE	lateral epicondylalgia
MET	muscle energy technique
MSUS	musculoskeletal ultrasound
PRTEE	patient-rated tennis elbow evaluation
SBMT	standard biomechanical taping
SGHMT	static maximum handgrip strength test
VAS	visual analogue scale
VCDT	vector correcting dysfunction technique

extensor origin, radial nerve, lateral epicondyle, capitellum, distal biceps tendon and lateral collateral ligament. The Extensor Carpi Radialis Brevis is frequently cited as cause of pain in LE followed by extensor digitorum communis, radial nerve, and the lateral epicondyle (Muehlberger et al., 2009; Bunata et al., 2007; Oskarsson et al., 2007; Erak et al., 2004; Tomaino and Towers, 2004; Fairbank and Corlett, 2002; De Smet et al., 1999; Bredella et al., 1999; Albrecht et al., 1997; Yaxley and Jull, 1993; Briggs and Elliott, 1985; Roles and Maudsley, 1972).

The common extensor origin is an intricate network of deep fascia enveloping the forearm extensor muscles connecting it to the lateral epicondyle (Dones et al., 2013; Van Der Wal, 2009). The common extensor origin consists of the extensor digitorum communis at its superficial portion and the extensor carpi radialis revis at its deepest quarter (Dones et al., 2013).

Traction stresses applied on the common extensor origin during repetitive handgrip activities is commonly known to cause LE (Chard et al., 1994). Hypoechogenicity, a musculoskeletal ultrasound (MSUS) abnormality, was commonly seen in the common extensor origin of elbows with chronic LE more than acute LE affecting the extensor carpi radialis brevis more than the extensor digitorum communis (Dones et al., 2014a). Focal hypoechoic areas in the common extensor origin relative to surrounding muscle which suggests fluid, correspond histologically to disorganised structure or degeneration of collagen or intra-substance fibre rupture (Grassi et al., 2000). Widely variable hypoechogenicity with the presence of longitudinal splits oriented from lateral epicondyle suggest partial tears of the common extensor origin, and often appear in thickened common extensor origin. This MSUS feature is supported by histological findings of scar tissue with marginal areas of degeneration in the common extensor origin (Bianchi and Martinoli, 2007; Chard et al., 1994; Grassi et al., 2000).

Standard provocation tests Cozen, Mill and Maudsley tests have acceptable levels of sensitivity when used in determining elbows with LE, with sensitivity of 91%, 76% and 88% respectively (Dones et al., 2014b). The Cozen test is the only one recommended by the United Kingdom Health Safety Executive Workshop to diagnose LE based on findings on eight elbows with LE (Palmer et al., 2000). In both clinical practice and research, the clinical diagnosis of LE is decided by health care professionals using these standard provocation tests (Lebrun, 2008). The clinical diagnosis of LE was commonly used as reference standard in researches (De Zordo et al., 2009, Du Toit et al., 2008, Lee et al., 2011, Levin et al., 2005, Maffulli et al., 1990, Miller et al., 2002, Noh et al., 2010, Struijs et al., 2005, Tarhan et al., 2009, Toprak et al., 2012, Zeisig et al., 2006, 2010). Among these provocation tests, LE is present when either one of these tests replicates pain on the lateral aspect of the elbow (Lebrun, 2008).

1.1. Movement of deep fascia in the proximal lateral aspect of elbow

Dones et al. (2015) reported a seeming increase in the linear displacement of the extensor digitorum communis near the lateral epicondyle in LE elbows, suggesting decreased fascia tightness. This is in contrast to the suggestions of a number of authors who believe that the deep fascia is tight in musculoskeletal conditions such as LE (Myers, 2009; Stecco and Stecco, 2009; Day et al., 2009; Pedrelli et al., 2009; Langevin et al., 2011). The fascia tightness, as hypothesized by Stecco et al. (2013), may be caused by the alteration in hyaluronic acid. Hyaluronic acid is found in considerable amounts at the interface between deep fascia and the surface of the muscle (Mccombe et al., 2001). An altered hyaluronic acid is adhesive rather than lubricating altering the distribution of lines of force within the fascia. Alteration in hyaluronic acid may be associated with decreased fascial slide (Stecco et al., 2013).

1.2. Physiotherapeutic intervention for LE

Taping, forearm bracing or splints, adjusting handgrip size, and extracorporeal shockwave therapy were among the popular non-invasive physical therapy treatments which aimed to alleviate pain in the elbow by decreasing stress on the common extensor origin (Bisset et al., 2005; Clements and Chow, 1993; Gerdesmeyer et al., 2003; Grimmer-Somers et al., 2009; Hatch et al., 2006; Nirschl, 1988; Wuori et al., 1998). Forearm bracing compresses the forearm extensor muscle, which is assumed to de-load the common extensor origin of stress (Wuori et al., 1998). However, its effectiveness in treating LE is debatable. It was not effective when used as the only treatment (Wuori et al., 1998), but was effective when used in routine physiotherapy inclusive of ultrasound, ice, stretching and supervised exercises (Clements and Chow, 1993). Adjusting handgrip size for optimal grip has been recommended by Nirschl (1988), to reduce the muscular force required for gripping a tool, protect the underlying elbow joint structures and reduce the risk of developing cumulative trauma associated with repetitive tasks requiring high hand grip forces (Hatch et al., 2006). However, the optimal handgrip size which promotes effective forearm muscle contraction has not yet been determined in the current literature (Hatch et al., 2006). Extracorporeal shockwave therapy has been shown to decrease the size of calcific deposits, reducing inflammation and pain in shoulders with chronic rotator cuff tendinitis (Gerdesmeyer et al., 2003). However, there was insufficient evidence regarding effectiveness of extracorporeal shockwave therapy in alleviating symptoms of chronic LE in a systematic review reported by Bisset et al. (2005).

Taping is a physiotherapy technique used in the treatment of elbows with LE (Slater et al., 2006; Perreault et al., 2012; Austin et al., 2009; Heweston et al., 2010). Grimmer-Somers et al. (2009) recommended the use of forearm bracing and taping as off-the-shelf management for LE. In the systematic review by Bisset et al. (2005), no firm conclusions on effectiveness of tape on LE elbows can be confidently drawn from the outcomes of only three studies that have different timelines for measurements and different comparison groups. In a recent study by Shamsoddini et al., 2013, the authors reported taping significantly increased grip strength ($p = 0.02$) and decreased lateral elbow pain ($p = 0.001$) of 31 participants with LE on dominant arm.

A non-elastic tape is a non-stretchable zinc oxide tape that may limit joint movement (MacDonald, 2004). An elastic tape is a stretchable tape that pulls the skin and fascia that may alter the patient's pain perception (MacDonald, 2004). The benefits of using inelastic and elastic tapes are limitation of harmful ranges of motion associated with pain-free functional movements (Thomee, 1997).

1.3. Biomechanical Taping

Biomechanical Taping Technique (BMT) is a novel taping technique that addresses the lateral elbow pain of individuals with LE by influencing the skin-fascia and muscle interface. BMT has three variations namely:

- Standard Biomechanical Taping Technique for muscles (SBMT)
- Vector Correcting Dysfunction Taping Technique 1 (VCDT 1)
- Vector Correcting Dysfunction Taping Technique 1 (VCDT 1)

SBMT uses inelastic tape (a.k.a. BMT fascia tape). The BMT fascia tape lifts the skin and deep fascia, creating a visible skin fold, tightening them. The lift is hypothesized to increase the space between the deep fascia and the muscle (O'Sullivan, 2011). The primary author of this study assumes that tightening of skin and deep fascia and the increase in space in between deep fascia and muscle may be associated with decreased lateral elbow pain.

SBMT incorporates use of muscle energy techniques (MET). MET is a gentle manipulative technique directed on forearm wrist extensors where patient exerts submaximal contraction against a counterforce applied by the therapist (Chaitow, 2013). Kucuksen et al. (2013) at 26th and 52nd week follow-up reported that MET applied on the forearm extensor muscles of 41 patients with unilateral LE had decreased lateral elbow pain ($p = 0.001$), and increased pain free grip strength ($p = 0.007$). The underlying mechanism on effectiveness of MET in LE is speculative. MET is suggested to relax muscles in spasm, improve proprioception and motor programming of individuals suffering of pain (Kucuksen et al., 2013).

Vector Correcting Dysfunction Taping Technique (VCDT) uses BMT fascia tape and BMT elastic tape (a.k.a. skin tape). The primary author of this study hypothesizes that VCDT 1 and VCDT 2 correct the movement of the deep fascia overlying the forearm extensor muscles in the coronal plane and sagittal planes, respectively.

Hutchinson et al. (2017) and Paoletti (2006) reported movement of the deep fascia beneath the skin detected through palpation. Palpation, as an evaluation procedure in examining skin, fascia and muscles of patients with musculoskeletal conditions, has an acceptable inter-tester reliability (k=>0.40) (Weiner et al., 2006; Kvale et al., 2003; Gerwin et al., 1997). In an individual whose upper extremities are at the sides and wrists in neutral position, inward movement of the deep fascia on forearm extensor muscle is predominant in the coronal plane (Paoletti, 2006). The primary author of this study suggests that in an individual whose upper extremities are at the sides and wrists in neutral position, proximal movement of the deep fascia overlying the forearm extensor muscles is predominant in the sagittal plane.

Considering the lack of articles examining the effects of BMT on clinical manifestations of LE on elbows of patients, this study aimed to determine:

1. The effectiveness of SBMT, VCDT 1 and VCDT 2 on pain, handgrip strength, and daily functions of patients with LE; and
2. Compare the results of SBMT, VCDT 1 and VCDT 2 on pain, handgrip strength, and daily functions of patients with LE.

2. Methods

2.1. Ethics

This study was approved by the University of Santo Tomas - College of Rehabilitation Sciences Ethics Review Committee (Ethics protocol number SI-2014-016-R2)

2.2. Outcome measures

The Visual Analogue Scale (VAS), Jamar Hydraulic Hand Dynamometer, Patient Rate Elbow Evaluation Questionnaire (PRTEE) were used to monitor improvements in lateral elbow pain, SMHGT, and activities of daily living of patients with LE.

2.2.1. Visual Analogue Scale (VAS)

The VAS had a 10 cm horizontal line, the ends of which defined the minimum and maximum extremes of perceived pain. VAS score of zero (0) reflected "no pain" and ten (10) reflected "worst pain possible." VAS was sensitive (sensitivity = 0.70) and reliable (between groups $r = 0.97$) in measuring intensity of pain (Williamson and Hoggart, 2005, Jamison et al., 2002, Price et al., 1983, Jensen et al., 1986, Scott and Huskisson, 1976).

2.2.1.1. Static Maximum Handgrip Strength Test (SMHGT). The static maximum handgrip strength was quantified using JAMAR hydraulic dynamometer, a handheld dynamometer widely recommended to measure handgrip strength (Roberts et al., 2011). Intra-tester and inter-tester reliability of a clinical expert using JAMAR hydraulic dynamometer was reported to be acceptable at ICC values of 0.85–0.98 respectively (Peolsson et al., 2001).

2.2.1.2. Patient Rated Tennis Elbow Evaluation (PRTEE). PRTEE is a 15-item questionnaire (see Appendix I). PRTEE measured the average pain and function of patients with LE elbow. It consisted of three subscales namely: a. pain subscale, specific activities and usual activities. Each item (ranging from 0 to 10) was graded by the patient as zero for no pain or no difficulty and 10 as worst imaginable pain or unable to do the activity. The sum of the 10 function items were divided by 2 and were added to the sum of the five (5) pain items. A score of 100 was the highest possible score corresponding to worst score. Zero was the lowest possible score corresponding to best score. Reliability of subscales was sufficiently high that both subscales and total were reported. The PRTEE was reported to have excellent reliability ($r = 0.89$), and sensitivity (sensitivity: 0.96) in assessing patients with LE (Newcomer et al., 2005, Overend et al., 1997).

3. Study parts

This study was divided into two parts: 1. Preliminary investigation: Reliability of junior researcher in measuring SMHGT and 2. Effects of BMT on LE symptoms: Cross-over study.

4. Part 1: preliminary investigation: reliability of junior researcher in measuring SMHGT

This preliminary investigation established the intra-tester reliability of Junior Investigator AE in using the JAMAR hydraulic dynamometer in quantifying the SMHGT of included patients.

4.1. Study design

Intra-tester Reliability study.

4.2. Setting

This study part was done at the Physiotherapy Skills Laboratory of the College of Rehabilitation Sciences of the University of Santo Tomas. The controlled environment in the laboratory improved the intra-tester reliability score of Junior Investigator AE.

4.3. Equipment

A JAMAR hydraulic hand dynamometer was used to measure the static maximum handgrip strength with the handle set at the 51 mm level to standardize the grip.

4.4. Recruitment protocol

Through convenience sampling, 10 healthy participants without lateral elbow pain in the past six months were recruited from University of Santo Tomas –College of Rehabilitation Sciences in February 2015. The healthy participants were negative to all Cozen, Mill and Maudsley tests. Agreeing participants signed a written consent form.

4.5. Study protocol

The SMHGT of right upper extremity was tested prior to left upper extremity. The tested upper extremity of the seated participant was positioned on a tabletop with shoulder at 90 degrees of flexion and elbow in extension. The participant was instructed by Junior Investigator AE to grip maximally for 6 s for three times with a minute of rest period between handgrips. The instructions were given by Junior Investigator AE at a controlled volume each time SMHGT was conducted.

4.6. Statistical analysis used

The Intra-class correlation coefficient (ICC) was used to determine the intra-tester reliability of Junior Investigator AE in measuring the SMHGT of included patients. ICC with same raters and of absolute agreement was used to determine the intra-tester reliability. Absolute agreement considered systematic differences involved in quantifying SMHGT of included patients. Intra-class correlation coefficients were interpreted in this study as follows:

- 0–0.2: poor agreement
- 0.3–0.4: fair agreement
- 0.5–0.6: moderate agreement
- 0.7–0.8: strong agreement
- >0.8: almost perfect agreement

Kappa score of = />0.4 is clinically acceptable in establishing the intra-tester reliability of examiner in evaluating joints and muscles of individuals with musculoskeletal conditions (Stochkendahl et al., 2006).

5. Part 2: effects of BMT on LE symptoms: cross-over study

This study part determined the effects of BMT on VAS for pain, SMHGT for handgrip strength and PRTEE for daily activities of patients with unilateral LE.

5.1. Study design

Cross-over study. Considering that LE has low prevalence in the general population and that BMT is a novel technique, the authors decided that a cross-over study design was most suitable in determining the effectiveness of BMT in LE patients. In this research study, the influence of confounding variables such as work experience, laterality of symptoms and hand dominance of included participants were reduced because each patient served as his or her own control.

5.2. Sample size

Using the results of SMGHT on LE elbows of participants in the study of Shamsoddini et al., 2010, twenty-two participants were needed to detect changes in VAS, SMGHT, and PRTEE at 80% power of 0.05 (Shamsoddini et al., 2010).

5.3. Setting

The study was conducted at Lingap Karunungan, Rehabilitation and Empowerment of Adults and Children with Handicap (REACH) foundation, Mandaluyong City serving 44 barangays[1] in Mandaluyong City. REACH is a non-profit organization established in 2005 catering to indigent special children and residents of Mandaluyong City. It provided physical therapy to its residents with musculoskeletal and neurologic conditions. It likewise provides healthcare services that promote optimum function and independence of indigent children.

6. Materials

The materials used to assess the baseline and changes in scores on pain intensity, SMHGT and activities of daily living were the following: a. Visual Analogue Scale, b. JAMAR Hand Dynamometer, and c. Patient-Rated Tennis Elbow Evaluation.

The BMT tapes used in this study were: a. BMT skin tape (Fig. 1a) and b. BMT fascia tape (Fig. 1b) (Dones, 2017). BMT tapes are highly adhesive hypoallergenic tapes with skin-like properties. BMT tapes have height of 6 cm and length of 5.5 m. BMT skin tape is an elastic tape that has similar properties like Kinesiotape and Rock Tape. BMT fascia tape is inelastic tape. It is less elastic than the BMT skin tape however more stretchable than commercially available inelastic tapes such as Leukoplast and Mueller tapes.

6.1. Biomechanical Taping Technique protocol

Three BMT Techniques were used in this study:

- Standard BMT for muscles (SBMT),
- Vector Correcting Dysfunction Technique 1 (VCDT1), and
- Vector Correcting Dysfunction Technique 2 (VCDT2).

6.1.1. Standard BMT for muscles (SBMT)

SBMT application included BMT tape application and MET. SBMT used both BMT skin tape and BMT fascia tape.

A strip of BMT fascia tape overlying the painful area was placed on patient's skin. Forearm extensor isometric contractions were sequentially performed with the wrist in full extension, in neutral position, and in full flexion. These isometric contractions relaxed the forearm wrist extensor muscles. After each isometric contraction, two strips of BMT fascia tape were applied on patient's skin overlying the painful area creating a visible skin fold (Fig. 2). As cover-up strip, the BMT skin tape was applied to the wrist in fully flexed position. The step-by-step procedure in SBMT application is found in Appendix 1.

6.1.2. Vector Correcting Dysfunction Technique (VCDT)

VCDT application included BMT tape application and palpation. VCDT used both BMT skin tape and BMT fascia tape. No muscle MET was performed.

Using palpation in VCDT 1 and VCDT 2 techniques, the

[1] Barangay-smallest administrative division in the Philippines.

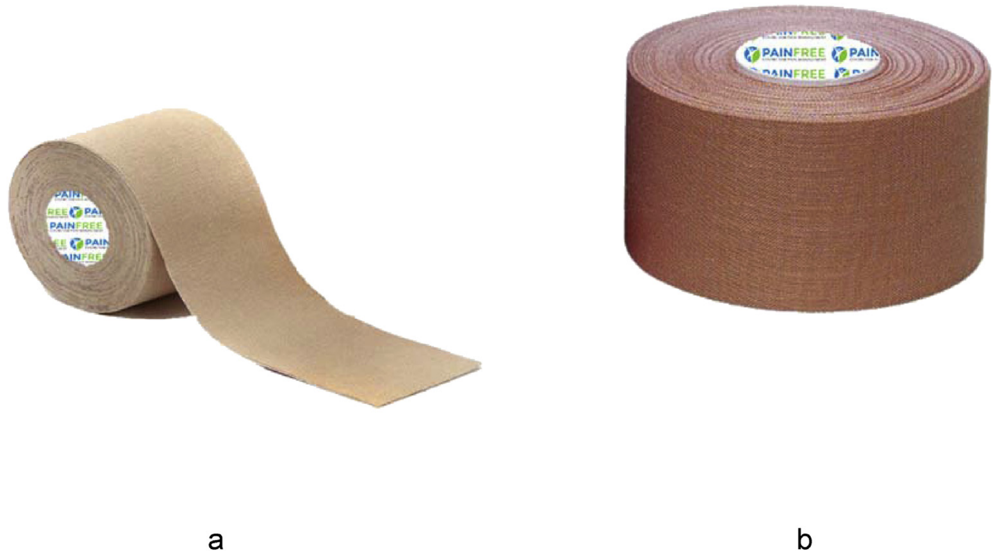


Fig. 1. a. BMT Skin Tape; b. BMT Fascia Tape.
Key: BMT, Biomechanical Tape.

Fig. 2. Skin-fascia lift by BMT fascia tape.
Key: BMT, Biomechanical Tape.

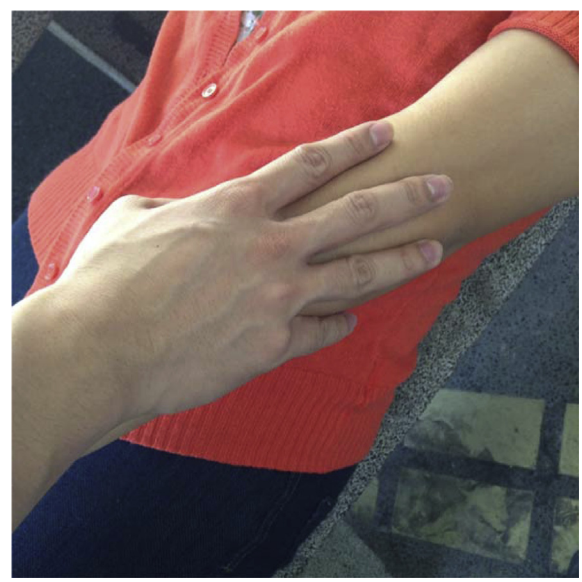


Fig. 3. Palpation on proximal third of the lateral aspect of the forearm.

determination on preferential movement of deep fascia overlying the forearm extensor muscles in the proximal forearm in the coronal plane and sagittal planes were noted respectively by the senior physiotherapist (Fig. 3). In the coronal plane, the direction of deep fascia movement was described as moving outward (towards the lateral epicondyle) or moving inward (away from the lateral epicondyle). In the sagittal plane, the direction of deep fascia movement was described as moving distally (towards the wrist) or proximally (towards the elbow). The predominant direction of deep fascia movement was described as the direction of ease. Opposite the direction of ease was the direction of resistance.

A base BMT fascia tape was applied over the painful segment. Using two strips of BMT fascia tape, a visible skin fold was created overlying the painful area. The BMT skin tape was applied over the painful segment towards the direction of resistance. The step-by-step procedure in VCDT 1 and VCDT 2 application is found in Appendices 2 and 3.

7. Recruitment of participants

Potential participants were consecutively recruited from December 2014 to March 2015 in 44 barangays of Mandaluyong City through Lingap Karunungan, REACH foundation. The inclusion criteria were as follows:

a. Positive to any one of the Cozen, Mill or Maudsley test;
b. Engaged in forceful and repetitive upper extremity activities such as laundry washing, carpentry, car mechanics, tennis playing, and golfing;
c. 14–85 years old;
d. Male or female; and
e. Not currently undergoing any physical therapy for the elbow region and in the last six months.

Exclusion criteria included orthopedic conditions in the elbow that may mimic LE (i.e fractures in the elbow, arthritic conditions, medial epicondylalgia, nerve impingement at the elbow, paresthesia occurring along the elbow region).

Junior researcher GK uniformly applied the Cozen, Mill and Maudsley tests on potential patients with lateral elbow pain. If patients were positive to any one of these provocation tests, their eligibility were confirmed and they signed the informed consent form. Consequently, junior researcher RF used the initial screening checklist to comprehensively assess patients' condition. The patients were not advised against performance of handgrip activities nor intake of analgesics and/or anti-inflammatory medications.

8. Study protocol

Using the random number generator of MS Excel 2010 on Day 1, eligible participants were randomized to SBMT or VCDT1 taping techniques. Participants were not randomised to VCDT 1 and VCDT 2 minimizing variations in the study design. The effectiveness of VCDT tapings on LE elbows is underpinned by the same mechanism that is based on the correction of pull on skin and fascia by BMT skin tape and the skin-fascia tightness created by BMT fascia tape. Considering the low prevalence rate of LE potentially limiting the number of participants that were eligible to join in the study, the authors did not randomise participants to the VCDT tapings.

8.1. BMT application

Biomechanical Taping Techniques were applied on Days 1, 3, and 5 separated by a day of no tape application. The one (1) day of no tape application served as wash-out period. Considering the capacity of the skin to recoil to its resting length after an external force (such as tape) is removed, the authors believe that a day of no tape is enough to relax the skin and fascia.

On Day 1, SBMT and VCDT1 were randomly assigned. On Day 3, either SBMT or VCDT1 not performed on Day 1 was applied on LE elbows. On Day 5, VCDT2 was applied on LE elbows.

Regardless of type of BMT technique, BMT tapes on Day 1 were worn for 24 h. BMT tapes on Days 3 and 5 were worn for 3 h per day. Skin abrasion due to visible skin fold and lift created by BMT tape is a risk in BMT application. To minimize, if not prevent, the occurrence of skin abrasion, BMT tape was applied for 24 h on Day 1 and 3 h on Day 3 and Day 5. A day of no tape was likewise observed in the BMT taping protocol. Patients were instructed to remove BMT tape with oil after indicated time dosage had ended and when skin became itchy.

8.2. Measurements

Before VAS and SMHGT assessments of patients, the taped elbows were covered with towels by senior investigator, consequently blinding the junior investigators on BMT treatment received by patients. On Day 1 and before BMT application, baseline measurements of VAS, SMGHT and PRTEE were collected by three independent and blinded junior investigators. While BMT tape was on patient's skin, VAS and SMGHT strength were re-assessed.

On Days 3 and 5, before BMT tape application, VAS and SMGHT were re-assessed. VAS and SMGHT strength were again recorded with BMT tape on patient's skin.

Seven days after Day 5 of BMT application (a.k.a. Day 12), PRTEE, VAS and SMHGT strength were re-assessed by the junior investigators.

Patients were discharged from treatment at any day of the BMT taping application when their lateral elbow pain was not replicated by all three Cozen, Mill, and Maudsley tests.

9. Statistical analyses used

Bland and Altman test was used to determine presence of systematic differences in the trial measurements for SMHGT strength by Junior Investigator AE. The Bland-Altman plot is a graphical method used to compare two measurements techniques. The differences between the two techniques were plotted against the averages of the two techniques. The line of equality was used to determine systematic differences. Lines for 95% Confidence Interval (CI) of mean of differences defined the magnitude of systematic differences. If there were significant systematic differences, the line of equality would be outside the 95% CI of mean of differences. D'Agostino-Pearson test for Normal distribution was used to determine homogeneity of VAS, SMHGT, and PRTEE results.

Paired samples T-test were used to detect differences in the following:

- VAS, and SMHGT scores before and during BMT application for each day of taping (Days 1, 3 and 5); and
- VAS, SMHGT and PRTEE scores before BMT application on Day 1, and Day 12. The final scores on Day 12 were compared with the baseline scores at Day 1.

Paired samples *t*-test was used to test the null hypothesis the average of the differences between a series of paired observations is zero (Medcalc version 15.2.2, 2015). Intention-to-treat-analysis was used through imputation method. The last VAS and SMHGT strength scores of participants who were discharged at Day 1 or Day 3 were carried forward and used in data analysis.

One-way analysis of variance (ANOVA) was used to test the difference between the means of SBMT, VCDT1 and VCDT2 tapings. Considering the suggested mechanisms underpinning the effectiveness of the three types of BMT techniques on LE elbows were different from one another, one-way ANOVA determined the most effective BMT technique in the treatment of LE elbows. Scheffe's test, a post-hoc test, was used for pairwise comparison of subgroups, when the ANOVA test is positive ($p < 0.05$). Based on the type of BMT application and regardless of the day of taping application, the differences in scores (VAS and SMHGT) were computed by subtracting the scores during taping application from scores before tape was applied.

Histogram, mean and 95% CI were used to describe demographic characteristics of participants.

10. Results

10.1. Preliminary investigation: reliability of junior researcher in measuring SMHGT

Junior investigator AE had almost perfect agreement (ICC>0.80) in the three SMHGT trial measurements of 20 non-symptomatic elbows of 10 healthy participants with mean (95%CI) age of 21.7(21.0–22.4) years.

10.2. Effects of BMT on LE symptoms: cross-over study

10.2.1. Baseline characteristics of participants

Twenty-three patients (1 male: 22 females) with unilateral LE who were residents of Mandaluyong City were included in the study with mean (95% CI) age of 51(46–56) years. Duration of LE pain [median (95%CI)] was 52 (14–156) weeks. All patients were not taking analgesic or anti-inflammatory medications. Twenty-one (21) patients were right handed and two were left handed. Of these hand dominant elbows, 14 had LE on side of handedness. No significant difference in SMGHT scores between LE and non-LE elbows was found ($p > 0.05$). Table 1 reports the baseline characteristics of the participants on outcome measures used in this study.

Among repetitive and forceful activities the patients were engaged in, 78% (18/23) of patients did laundry work. Fig. 4 shows the frequency of work distribution of included participants.

10.2.2. Homogeneity of outcomes measures of participants at baseline

D'Agostino-Pearson Test for Normal Distribution showed homogenous VAS and PRTEE scores at baseline ($p > 0.05$). Bland and Altman plot showed no systematic differences between the three SMHGT trial scores of LE elbows at baseline ($p > 0.05$) (Appendices 4-6). The average of the three SMHGT trial scores was calculated.

Fig. 5 illustrates that nine (9) participants were excluded from the study:

- eight (8) were negative to all Cozen, Mill and Maudsley tests;
- one (1) had history of elbow fracture.

On Day 3 and Day 5, six (6) and eight (8) participants respectively reported absence of lateral elbow pain and were discharged prior to BMT application. One (1) participant did not return on Day 5 of BMT application.

10.2.3. Visual Analogue Scale (VAS) scores

Table 2 reports significantly decreased VAS scores in the following (mean, 95% CI) ($p < 0.05$):

- SBMT taped LE elbows on Day 1 (−3.41, −4.79 to −2.04)) and Day 3 (−1.10, −2.09 to −0.11);
- VCDT 1 taped LE elbows on Day 1 (−2.13, −3.10 to −1.15) and Day 3 (−1.52, −2.55 to −0.50); and
- VCDT 2 taped LE elbows on Day 5 (−0.53, −0.90 to −0.15).

Regardless of type of BMT technique applied, Table 3 reports significant difference between baseline VAS scores on Day 1 and final VAS scores on Day 12 (mean, 95% CI: −5.50 (−6.46 to −4.54) ($p < 0.0001$)).

Regardless of day of BMT tape application, Table 4 reports SBMT had significantly greater decreased in VAS scores compared to VAS scores of VCDT2 ($p < 0.05$).

10.2.4. SMHGT scores

Table 5 reports no significant difference in the following SMHGT strength scores (mean, 95% CI) ($p > 0.05$):

- SBMT taped LE elbows on Day 1 (0.86,-2.02 to 3.73) and Day 3 (0.25,-0.11 to 0.61);
- VCDT 1 taped LE elbows on Day 1 (0.25,-0.11 to 0.61) and Day 3 (0.18,-0.09 to 0.45); and
- VCDT 2 taped LE elbows on Day 5 (0.34,-0.10 to 0.78).

Table 1
Baseline characteristics of participants.

Outcome Measures	Mean (95% CI)
VAS scores	6.54 (5.93–7.15)
SMHGT	15.29 (12.64–17.94)
LE elbow (in kgs)	15.09 (12.84–17.34)
Non-LE elbow (in kgs)	
PRTEE (total score)	46.15 (36.68–55.62)

Key: CI, confidence interval; kgs, kilograms; LE, lateral epicondylalgia; PRTEE, Patient Rated Tennis Elbow Evaluation; SMGHT, Static Maximum Handgrip Strength Test; VAS, Visual Analogue Scale.

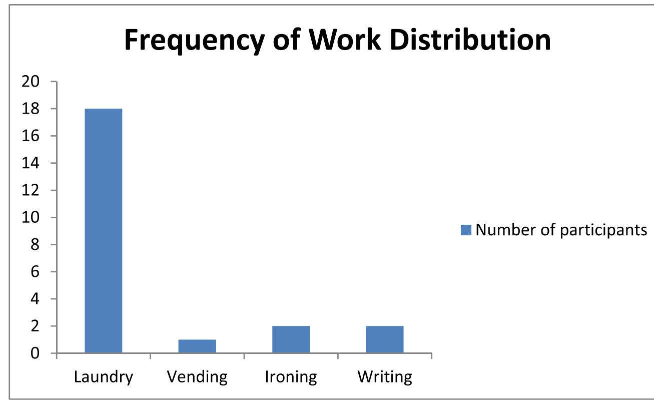


Fig. 4. Frequency on work distribution of patients with LE.
Key: LE, Lateral Epicondylalgia.

Regardless of type of BMT technique applied, Table 3 reports significant difference between baseline SMHGT scores on Day 1 and final SMGHT scores on Day 12 (mean, 95% CI: 2.97,0.70 to 5.25) ($p = 0.01$).

Regardless of day of BMT tape application, Table 4 reports no significant difference in SMHGT scores between the three BMT techniques ($p > 0.05$).

10.2.5. PRTEE scores

Table 3 reports significant difference between baseline PRTEE scores on Day 1 and final PRTEE scores on Day 12 (mean, 95% CI: −36.57, −46.19 to −26.94) ($p < 0.0001$). Significant improvement in specific PRTEE scores on pain (mean, 95% CI: −18.87, −24.25 to −13.49) and functional subscales (mean, 95% CI: −17.70, −22.94 to −12.45) was noted ($p < 0.0001$).

10.2.6. Adverse reactions on BMT tape

One (1) of 23 participants developed blister on taped elbow, on which the investigators provided treatment.

11. Discussion

This is the first cross-over study that examined the effects of SBMT, VCDT1 and VCDT2 on patients with unilateral LE. Regardless of the type of BMT technique used, the following were found in this study: a. a significantly decreased VAS scores at Days 1, 3, and 5 of BMT application ($p < 0.05$); b. a significantly improved final VAS, SMHGT strength and PRTEE scores on Day 12 compared to baseline scores on Day 1 ($p = /<0.01$); and c. a significantly decreased VAS scores when using SBMT compared to VCDT2 ($p < 0.05$).

The significant improvement in VAS and SMHGT scores ($p < 0.05$) supported by significant improvement in PRTEE scores ($p < 0.0001$) may be secondary to the physical changes effected by BMT tapings on injured common extensor origin near the lateral epicondyle and on the decreased slide between the fascia and extensor digitorum communis distal to common extensor origin and lateral epicondyle in the forearm. In LE, the weakness in the common extensor origin was reflected by presence of hypoechogenicity in MSUS in LE elbows (Dones et al., 2014a). The hypoechogenicity that may likely be histologically intra-substance fibre rupture reflects weak areas in LE elbows (Grassi et al., 2000). Dones et al. (2015) reported a seemingly increased linear displacement of the extensor digitorum communis near the lateral epicondyle in LE elbows suggesting decreased resistance in common extensor origin. The authors hypothesized that the visible skin fold created by the BMT tapes may have caused tightening of the

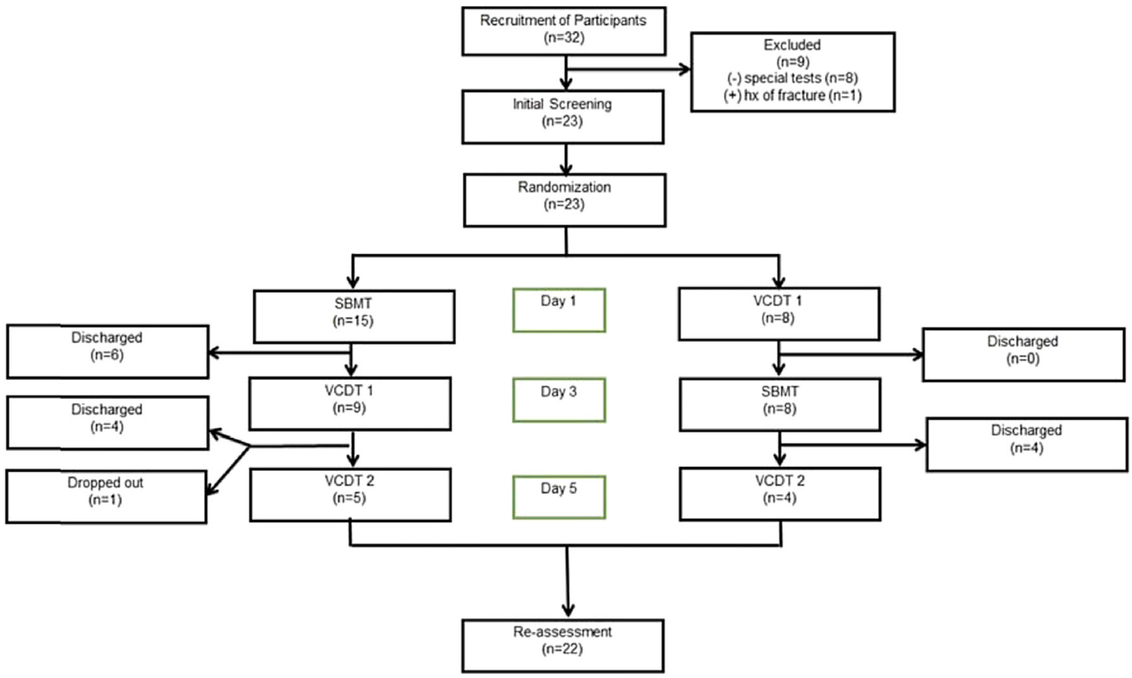


Fig. 5. Workflow of participants.
Key: PRTEE, Patient Rated Tennis Elbow Evaluation; SBMT, Standard Biomechanical Taping Technique; SMHGT, Static Maximum Handgrip Test; VAS, Visual Analogue Scale; VCDT, Vector Correcting Dysfunction Technique.

Table 2
Visual Analogue Scale scores of participants with LE.

Day	Type of BMT	N = elbows	Before BMT VAS Mean (95%CI)	During BMT VAS Mean (95%CI)	Difference VAS Mean (95%CI)	P value
1	SBMT	15	6.94 (6.10–7.78)	3.53 (2.16–4.89)	−3.41 (−4.79 to −2.04)	0.0001[a]
	VCDT1	8	4.24 (2.75–5.73)	2.11 (1.01–3.21)	−2.13 (−3.10 to −1.15)	0.0014[a]
3	SBMT	8	5.13 (3.75–6.49)	4.03 (2.44–5.61)	−1.10 (−2.09 to −0.11)	0.0346[a]
	VCDT1	15	3.35 (1.60–5.10)	1.83 (0.67–3.00)	−1.52 (−2.55 to −0.50)	0.0068
5	VCDT2	23	1.13 (0.30–1.96)	0.60 (0.04–1.16)	−0.53 (−0.90 to −0.15)	0.0083[a]

Key: BMT, Biomechanical Taping Technique; CI, confidence interval; LE, lateral epicondylalgia; N, number; SBMT, Standard Biomechanical Taping; VAS, Visual Analogue Scale; VCDT, Vector Correcting Dysfunction Technique.
[a] Significant findings.

Table 3
Comparison in VAS, SMHGT and PRTEE baseline scores and final scores.

	Day 1 Mean (95%CI)	Day 12 Mean (95%CI)	Difference Mean (95%CI)	p-value
VAS	6.54 (5.93–7.15)	1.04 (0.20–1.88)	−5.50 (−6.46 to −4.54)	**<0.0001**[a]
SMHGT	15.29 (12.64–17.93)	18.26 (15.44–21.08)	2.97 (0.70–5.25)	**0.01**[a]
PRTEE Pain Subscale	24.65 (20.09–29.21)	5.78 (2.10–9.46)	−18.87 (−24.25 to −13.49)	< **0.0001**[a]
PRTEE Function Subscale	21.50 (15.91–27.09)	3.80 (0.03–7.58)	−17.70 (−22.94 to −12.45)	< **0.0001**[a]
PRTEE Total Score	46.15 (36.68–55.62)	9.59 (2.37–16.80)	−36.57 (−46.19 to −26.94)	< **0.0001**[a]

Key: BMT, Biomechanical Taping Technique; CI, confidence interval; LE, lateral epicondylalgia; PRTEE, Patient Rated Tennis Elbow Evaluation; SMHGT, Static Maximum Handgrip Strength Test; VAS, Visual Analogue Scale.
[a] Significant finding.

skin-fascia possibly providing stability to the common extensor origin.

The decreased fascia slide assumed by the authors to be found between fascia and extensor digitorum communis distal to the common extensor origin and lateral epicondyle could be present in LE elbows. A number of authors have suggested presence of decreased slide in between fascia and muscles in musculoskeletal injuries (Myers, 2009; Stecco and Stecco, 2009; Day et al., 2009; Pedrelli et al., 2009; Langevin et al., 2011). The elasticity of BMT skin tape used in VCDT 1 and VCDT 2 could have facilitated the slide in between fascia and extensor digitorum communis distal to the lateral epicondyle. The effected possible increase in slide may likely underpin improvement in VAS, SMHGT and PRTEE scores.

SBMT was significantly better in improving VAS scores of participants compared to VCDT 2 ($p < 0.05$). METs used in SBMT relaxed the tightened forearm extensor muscles. No MET was performed in VCDT 2 application. The MET, in addition to the suggested skin-fascia stability created in the common extensor origin by the BMT fascia tape, could have effected more physical changes in the extensor digitorum communis during SBMT

Table 4
Comparison in VAS and SMHGT strength scores between BMT techniques.

Outcome Measures	Types of BMT	Mean (SD)	Different ($P < 0.05$) from BMT Taping Techniques
VAS	SBMT	2.61 (2.38)	SBMT vs VCDT2[a]
	VCDT1	1.73 (1.65)	No significant difference
	VCDT2	0.53 (0.87)	VCDT2 vs SBMT[a]
SMHGT	SBMT	−1.03 (3.20)	No significant difference
	VCDT1	−0.72 (1.25)	No significant difference
	VCDT2	−0.24 (0.76)	No significant difference

Key: BMT, Biomechanical Taping; LE, lateral epicondylalgia; N, number; SBMT, Standard Biomechanical Taping Technique for muscles; SD, standard deviation; SMHGT, Static Maximum Handgrip Strength Test; VAS, Visual Analogue Scale; VCDT, Vector Correcting Dysfunction Technique; vs, versus.
[a] Significant findings at $p = 0.03$.

Table 5
Static Maximum Handgrip Strength Test of participants with LE.

Day	Type of BMT	N = elbows	Before BMT Mean (95%CI)	During BMT Mean (95%CI)	Difference Mean (95%CI)	P value
1	SBMT	15	15.78 (13.33–18.23)	15.23 (7.40–23.06)	0.86 (−2.02 to 3.73)	0.50
	VCDT1	8	14.37 (7.04–21.70)	14.46 (7.15–21.76)	0.25 (−0.11 to 0.61)	0.14
3	SBMT	8	14.21 (6.91–21.51)	14.46 (7.16–21.76)	0.25 (−0.11 to 0.61)	0.14
	VCDT1	15	15.96 (12.92–18.99)	16.13 (13.06–19.20)	0.18 (−0.09 to 0.45)	0.18
5	VCDT2	23	16.28 (13.01–19.56)	16.62 (13.48–19.76)	0.34 (−0.10 to 0.78)	0.13

Key: BMT, Biomechanical Taping Technique; CI, confidence interval; LE, lateral epicondylalgia; N, number; SBMT, Standard Biomechanical Taping; VCDT, Vector Correcting Dysfunction Technique.

application compared to VCDT 2 application. Additionally, the 24-h taping application and likelihood for greater improvement in clinical symptoms of LE elbows on Day 1 compared to Days 3 and 5 could have contributed to the significantly better improvement on VAS scores in SBMT compared to VCDT 2 taping. These suggested underpinning mechanisms on the effectiveness of SBMT do not discount the effectiveness of VCDT 2 in significantly decreasing VAS scores of participants with LE, as shown in the Results Section on Pages 22 and 23.

This study used a cross-over design where participants received three BMT techniques. Considering the one day wash-out period provided for between the three BMT techniques, the authors are cognizant of the possible carry-over effects of SBMT, VCDT 1 and VCDT 2 tapings. The relaxation of the skin and fascia after BMT tape removal was not investigated in this study.

Skin irritation is a complication of repetitive adhesive tape application (Kerkhoffs et al., 2002; Jongen et al., 1992). BMT tape application applied for 24 h caused skin blisters in one (1) of the 23 participants. This may be secondary to the visible skin fold created by BMT fascia tape. Tokumura et al. (2005) explained that as adhesive tapes were applied repetitively, dermal peeling force gradually increased leading to increased destruction of the skin surface topography.

This study had applied BMT on participants presenting with true LE although on a specific sample population dominated by women who did laundry work. These patients were positive to either one of the Cozen, Mill or Maudsley test. The participants had lateral elbow pain with VAS mean (95% CI) of 6.54 (5.93–7.15) with restricted daily function reflected by high PRTEE score with mean (95% CI) of 46.15 (36.68–55.62). There was no significant difference in SMGHT strength between LE and non LE elbows that is not typical of LE presentation.

11.1. Implication to practice

Considering that BMT offers instant and significant pain relief in patients with unilateral LE, BMT can be used as an adjunct treatment to physiotherapy exercise regimen. During handgrip exercise, BMT may be worn to decrease the lateral elbow pain experienced by patients.

Considering that multiple strips of BMT tapes are applied on the patient's skin, reddening, itchiness and blister formation on the skin should be observed under the transparent strips of BMT tapes. The authors recommend maximum of three (3) hours of BMT application with a day of no tape in between days of BMT application. This is to ensure skin integrity during and after BMT application.

11.2. Implications to research

A large scale prospective randomized controlled trial should be conducted comparing the effects of BMT to a reference standard taping technique in decreasing pain and improving function of a patient with unilateral LE. Basic science studies on slide of skin-fascia over muscle and skin-fascia lift on common extensor origin using MSUS are recommended. Research based knowledge on science behind the effectiveness of BMT will strengthen its role as pain reducing physiotherapy intervention promoting increased function in patients with unilateral LE.

12. Conclusion

BMT is a novel taping technique effective in decreasing lateral elbow pain, increasing handgrip strength and improving function of patients with lateral epicondylalgia. The BMT fascia tape through skin-fascia lift may be effective in holding the hypoechogenicity in the common extensor origin and BMT skin tape through its elasticity may be effective in increasing slide in between fascia and muscle improving pain and function of patients with LE.

Declaration of conflict of interest

The senior physiotherapist who is one of the authors is the creator of Biomechanical Taping Technique. During data collection, the senior physiotherapist was blinded to the results of VAS, SMHGT and PRTEE. The results from these outcome measures were independently collected by the junior investigators of the study.

Appendix 1. Steps in applying Standard Biomechanical Taping for muscles

1.A base BMT fascia tape was placed without tension over the painful area.
2.During isoconcentric contraction, the patient's wrist held in full extension performed resisted wrist extension with pronated forearm against the counterforce provided by the senior physiotherapist, within the pain-free limit. Two strips of BMT fascia tape were applied on the patient's skin. The first strip of BMT fascia tape was anchored on the lateral aspect of the base BMT fascia tape. A skin-fascia lift was created overlying the painful area. The second strip of BMT fascia tape was anchored on the medial aspect of the base BMT fascia tape.
3.During isocentric contraction, the patient's wrist in neutral position performed resisted wrist extension with pronated forearm against the counterforce provided by the senior physiotherapist, within the pain-free limit. Two strips of BMT fascia tape (as discussed in Step 2) were sequentially applied on painful area.
4.During isoeccentric contraction, the patient's wrist in full flexion performed resisted wrist extension with pronated forearm against the counterforce provided by the senior physiotherapist, within the pain-free limit. Two strips of BMT fascia tape (as discussed in Step 2) were sequentially applied on painful area.
5.As cover-up strip, the BMT skin tape without tension was applied over the painful segment with the wrist in full flexed position.

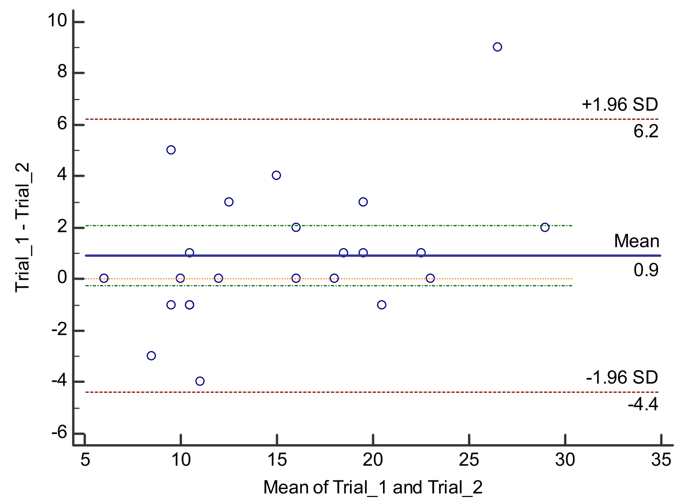
Appendix 2. Steps in applying the Vector Correcting Dysfunction Technique 1

1.The senior physiotherapist's dominant hand was placed on the lateral aspect of the elbow with fingers pointing towards the lateral epicondyle to determine the direction of ease of movement of the deep fascia in the coronal plane.
2.With the wrist in neutral position, a base BMT fascia tape was placed over the painful area.
3.Two strips of BMT fascia tape were cut. The first strip of BMT fascia tape was anchored on the lateral aspect of the base BMT fascia tape. The second strip of BMT fascia tape was anchored on the medial aspect of the base BMT fascia tape.
4.The BMT skin tape was applied with the wrist in neutral position. The proximal end of the BMT skin tape (without tension) was anchored on anterior aspect of the junction of the distal and middle third of the supinated forearm. The middle third of the BMT skin tape (with 75% tension) was stretched outward from anterior aspect of the middle third of the forearm up to the dorsal aspect of the forearm immediately distal to the lateral epicondyle. The distal end of the BMT skin tape (without tension) was overlying the lateral epicondyle and the area one (1) above it.

Appendix 3. Steps in applying the Vector Correcting Dysfunction Technique 2

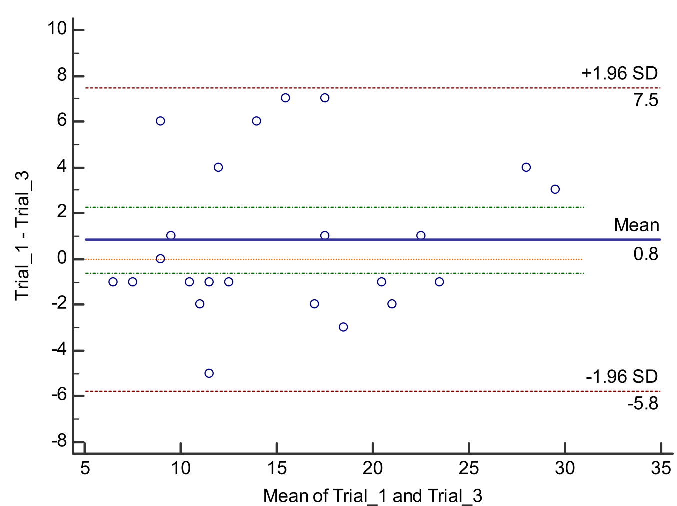
1.The senior physiotherapist's dominant hand was placed on the lateral aspect of the elbow with fingers pointing towards the lateral epicondyle to determine the direction of ease of movement of the deep fascia in the sagittal plane.
2.With the wrist in neutral position, a base BMT fascia tape was placed over the painful area.
3.Two strips of BMT fascia tape were cut. The first strip of BMT fascia tape was anchored on the lateral aspect of the base BMT fascia tape. The second strip of BMT fascia tape was anchored on the medial aspect of the base BMT fascia tape.
4.The BMT skin tape was applied with the wrist in flexed position. The proximal end of the BMT skin tape (without tension) was anchored on the upper arm one (1) inch above the lateral epicondyle and overlying the lateral epicondyle. The middle third of the BMT skin tape (with 75% tension) was stretched overlying the forearm immediately distal to the common extensor origin and lateral epicondyle. The distal end of the BMT skin tape (without tension) was anchored on the distal end of the forearm.

Appendix 4. Bland and Altman plot for Static Maximum Handgrip Strength Test (SMHGT) between trials 1 and 2 of Junior Investigator AE



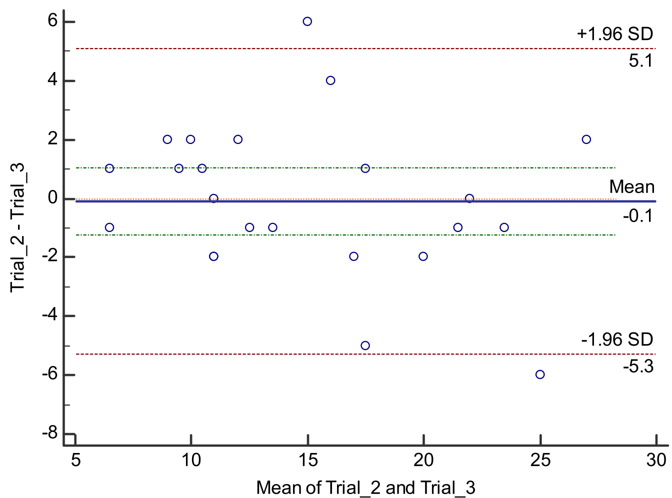
The line of equality (broken orange line) was found between 95% CI of mean of differences (broken green lines) indicating no systematic differences in between SMHGT trials.

Appendix 5. Bland and Altman plot for Static Maximum Handgrip Strength Test (SMHGT) between trials 1 and 3 of Junior Investigator AE



The line of equality (broken orange line) was found between 95% CI of mean of differences (broken green lines) indicating no systematic differences in between SMHGT trials.

Appendix 6. Bland and Altman plot for Static Maximum Handgrip Strength Test (SMHGT) between trials 2 and 3 of Junior Investigator AE



The line of equality (broken orange line) was found between 95% CI of mean of differences (broken green lines) indicating no systematic differences in between SMHGT trials.

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