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Association between Lateral Epicondylalgia and Upper Extremity Anthropometric Measurements: A Case Control Study

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Abstract

Objectives: Directional asymmetry is a measure of departure from bilateral symmetry. In the upper extremities, directional asymmetry can be determined by comparing the anthropometric measurements of arm length, elbow circumference and elbow breadth of individuals with and without Lateral epicondylalgia. This study aimed to detect the presence of significant directional asymmetry in the upper extremities of individuals with Lateral epicondylalgia.

Methods: Potential case and control participants were recruited from January 2011 to September 2011 in Manila, Philippines. To qualify as a case with Lateral epicondylalgia in the study, participants must have lateral elbow pain on at least one elbow, which was replicated by at least one of the provocation tests (Cozen, Mill or Maudsley test). A single case was ideally matched with two control participants based on gender, age, and occupation. Bilateral arm length, elbow circumference (at the level of the elbow joint, at 5cm above and 5cm below the elbow joint) were measured by the senior physiotherapist. The odds ratio using the using a General Linear Model Univariate Analysis approach was applied to examine the relationship between the differences in the upper extremity anthropometric measurements, diagnosis of LE (case or control) and hand dominance (right or left).

Results: 52 individuals with 48 unilateral elbow pain and 4 bilateral elbow pain were eligible for the study. The cases were matched with 99 control participants with 198 non-symptomatic elbows. Hand dominance was found to be significantly associated with elbow circumferential measurements taken at the level of the lateral epicondyle, 5cm above the lateral epicondyle and 5cm below the lateral epicondyle ($p<0.05$). Presence or absence of Lateral epicondylalgia (case or control) was not significantly associated with any of the upper extremity anthropometric measurements ($p>0.05$)

Conclusion: Arm length, elbow circumference, and elbow breadth were not associated with Lateral epicondylalgia in our sample.

Keywords: Lateral epicondylalgia; Directional asymmetry; Tennis elbow; Anthropometric measurements; Elbow breadth; Elbow circumference; Arm length

Introduction

Anthropometry is the comparative study of sizes and proportions of the human body. It involves the use of non-invasive, quantitative techniques for determining an individual's body dimensions, which can include breadth measures (i.e., epicondylar distance), circumferential measures (i.e. waist, hip, chest, limb circumference) and linear dimensions (i.e. stature, limb length) [1].

An individual's anthropometry influences his interaction with his workstation. A mismatch between an anthropometry and workstation may increase the physical stresses on the body as the individual may be forced to assume awkward postures to accommodate to the workstation design [1] such as observed in individuals with Lateral epicondylalgia (LE). Lateral epicondylalgia is a common musculoskeletal condition affecting the common extensor origin manifesting as pain on the lateral aspect of the elbow [2-3]. Physical stresses associated with LE include highly repetitive movements of the upper extremities [4], use of heavy tools (usually weighing more than 1 kg) for at least one quarter of the work time [4], extreme, non-neutral posturing of the upper extremities [2], and extended exposure to strenuous jobs [5-6].

Considering the physical stress applied on elbows with LE, directional asymmetries in upper extremity anthropometry such as elbow breadth, elbow circumference and arm length may provide a measure of physical strain. Directional asymmetry is the presence of significantly larger upper extremity anthropometric measurements when right and left sides are compared, observed in the playing extremities of racquetball, tennis, baseball and rodeo athletes [7-12]. This asymmetry reflects asymmetrical growth of bones and muscles [13-15].

Directional asymmetries are reflective of bodily adaptations to physical stress [16] that may be used as objective tools in determining the anatomical structure which may be involved in elbows with LE [17]. Elbow breadth reflects lateral epicondyle growth [17]. Directional asymmetry in elbow breadth may be related to the pull of the lower arm muscles on the epicondyles in handgrip activities [17]. Circumferential measurements (arm and forearm) reflect the forearm muscle mass including the muscle, skin, subcutaneous tissue and bone [18]. Directional asymmetry in circumferential measurements of greater than 2 cm may suggest pathologies associated with pain [19]. Arm length measurements reflect linear skeletal growth of upper extremity bones [20]. Directional asymmetry in arm length may indicate longitudinal bone growth abnormalities such as seen in bone dysplasias [21-22] and idiopathic scoliosis [20].

Considering the lack of evidence in the current literature on presence of directional asymmetries in LE, this study compared the presence of directional asymmetries in arm length, elbow circumferential measurements and elbow breadth between a group of participants with unilateral LE and a group of healthy participants without LE, matched by age, gender and occupation. We hypothesise that directional asymmetry is present in the upper extremity anthropometric measurements of individuals with LE, reflecting the biomechanical stresses endured by the symptomatic elbows.

Materials and Methods

This section is divided into two interlinked studies namely: a. Preliminary investigation: reliability of the primary investigator and b. Research proper: observational cross-sectional study.

Ethics

Both studies were approved by the Human Research Ethics Committee (HREC) of the University of South Australia (UniSA) with ethics approval number of 22328 and by the Ethics Review Board (ERB) of the Santo Tomas University Hospital (STUH) with ethics code of IRB-AP210-D-LEPS.

Preliminary investigations

Reliability of the primary investigator: This reports the procedures which established the reliability of the primary investigator in taking the anthropometric measurements of healthy participants. An acceptable intra-tester reliability prevents an unreliable replication of anthropometric readings resulting in erroneous interpretation of data on directional asymmetry [14,23].

Examiner and setting: Anthropometric measurements were performed by the primary investigator who was senior physiotherapist (VCD) with 10 years of experience in musculoskeletal physiotherapy. The physiotherapy evaluation took place at the Physiotherapy Skills Laboratory of the College of Rehabilitation Sciences (CRS) of the University of Santo Tomas (UST), Manila, Philippines.

Physiotherapy evaluation: Through convenience sampling, 20 healthy students were recruited from CRS in UST in December 2010. Both elbows of healthy participants were pain-free in the past 6 months. The elbows were not positive to all Cozen's, Mill's and Maudsley's tests. The healthy participants did not report of any previous surgeries and fractures in the shoulder, elbow and/or wrist/hand.

Once the eligibility was confirmed, the participants were oriented by the primary investigator as to the purpose and mechanics of the study, and they signed a written consent form. The anthropometric measurements were collected twice every afternoon for four alternating days. The junior research assistant recorded all observations and measurements of the primary investigator.

Research proper

Observational cross-sectional study: This reports the procedures taken in collecting the anthropometric measurements of case and control participants involved in the study. The collected data were used to determine presence of directional asymmetries in the upper extremity anthropometric measurements of eligible participants.

Examiners and setting: Screening examinations were performed by a junior physiotherapist (with four years of musculoskeletal physiotherapy experience) trained in the examination by the senior physiotherapist and principal author of this paper (VCD). Collection of anthropometric measurements was by the senior physiotherapist performed at the Physiotherapy Skills Laboratory.

Physiotherapy evaluation: Potential case and control participants were recruited from January 2011 to September 2011. Volunteer participants were recruited from private and public hospitals, private clinics, sporting clubs, marketplace, factories, local health centres and schools in Manila, Philippines. To qualify as a case in the study, participants had lateral elbow pain on at least one elbow, which was replicated by at least one of the provocation tests (Cozen's, Mill's or Maudsley test) used in the diagnosis of LE. A single case was ideally matched with two control participants based on gender, age, and occupation. The matched control participants were:

- Recommended by participants with LE (colleagues at work, peers)
- Recruited from the same workplace where participants with LE came from i.e. vendors working at the same marketplace, tennis players in the same sports club, and
- Recruited house-to-house by the primary investigator in three local communities.

The control participants did not report of any elbow pain for the past six months nor had any previous surgeries in the shoulder, elbow and/or wrist/hand.

Case and control participants were ineligible for inclusion if they had current general body malaise (which may be indicative of systemic illness), current diagnosis of cancer, previous or current fractures in arm and forearm, osteoarthritis of elbow, recent blunt trauma to the elbow, cervical pain at rest and with neck movement, cervical radiculopathy, peripheral neuropathy, stroke or previous surgery to the elbow, or were pregnant.

The junior physiotherapist used the initial screening checklist that included the inclusion and exclusion criteria (Appendix 1).The senior physiotherapist measured the participant's elbow breadth, elbow circumference and arm length with the specific protocols outlined below:

Elbow breadth: The participant was asked to stand three feet away facing the seated senior physiotherapist. The tested elbow was bent at 90 degrees with supinated forearm. A Vernier caliper with precision of up to 0.01 millimetres (mm) was used by the senior physiotherapist to measure the distance between the lateral epicondyle and medial epicondyle, read in mm.

Elbow circumference: The participant was asked to sit facing the seated primary investigator with the participant's palm resting on the primary investigator's shoulder with elbow kept in full extension. Each elbow was marked at three points. The marks were at the following levels:

- Elbow at the level of the lateral epicondyle,
- 5 cm above the lateral epicondyle and
- 5 cm below the lateral epicondyle

Measurements were read in cm using a standard tape measure.

Arm length

A standard plastic tape measure with linear measurement markings in cm was used. The participant was asked to stand facing a body mirror with the shoulders against the tape measure. The shoulder was abducted to 90 degrees with the elbow extended and the tip of the middle finger exactly on the 0 cm mark of the standard tape measure. The distance from the tip of the middle finger to the acromion process on the same side was measured in cm.

Research Questions

To address the aim of this study, three questions were asked:

Is there a significant influence of age, gender, duration of symptoms, activities, and hand dominance on anthropometric measurements?

Other than LE, this research question was asked to identify the variables that might be associated with anthropometric measurements.

Is there directional asymmetry in the upper extremity anthropometric measurements of case and control participants?

This question determined whether directional asymmetry is present in the upper extremity anthropometric measurements of the participants in this study, in accordance with the commonly reported right directional asymmetry in the current literature (hypothesised to be secondary to greater biomechanical stresses occurring on the right upper extremity compared to the left upper extremity) [14].

Is there a significant association between LE, hand dominance and anthropometric measurements?

This question determined whether hand dominance or presence/absence of LE underpins the significant directional asymmetries present in the upper extremity anthropometric measurements of case and control participants.

Statistical Analyses Used

The Intra-class correlation coefficients (ICCs) and the Standard Error of Measurement (SEM) were used to establish the intra-tester reliability of the senior physiotherapist in evaluating the upper extremity anthropometric measurements. Intra-class correlation coefficients (ICCs) were interpreted as follows: [24]

- 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

The Standard Error of Measurement (SEM) was used to estimate the error of the senior physiotherapist in reading the anthropometric measurements using the formula:

Eq 1: SEM=SD* square root of (1-ICC).

Key: SD, Standard Deviation of differences; ICC, Intraclass Coefficient

Using Pearson-correlation coefficients, the independent continuous variables of age were tested for their correlation with ratios of anthropometric measurements. Using the same test, the independent variable duration of symptoms was correlated with raw anthropometric measurements taken from the UE(s) of case and control participants. These independent variables were tested for association on combined (case and control), or grouped (case or control) anthropometric measurements (ratios or raw).

Independent nominal data variables, such as gender, activities, and hand dominance were tested for association with anthropometric measurements using the Eta measure of association. Eta is a statistical test used for asymmetric measures which have identifiable independent and dependent variables. It is suitable where independent variable is nominal and dependent variable is interval [25]. Additionally, using a p-value of <0.01, independent samples t-tests were used to determine significant differences in anthropometric measurements between genders.

Prior to the computation of directional asymmetry, the Kolmogorov-Smirnov test for normal distribution was used to each anthropometric measurement on each side of the UE with p-value of <0.05 indicating non-normality of data distribution. Anthropometric data were converted into percentage directional asymmetry (%DA) using the formula used by Auerbach and Ruff (2006) and Steele and Mays (1995) [14,23].

Eq 2: % DA=(right-left)/(average of left and right)*100

According to Auerbach and Ruff (2006), this method standardises all raw asymmetric differences within the same anthropometric measurement allowing for direct comparison of asymmetries across the case and control groups. This results in positive values for right-sided asymmetries and negative values for left-sided asymmetries [14].

The differences in anthropometric measurements between upper extremities of each of the case and control participants were determined. The odds ratio using the using a General Linear Model (GLM) Univariate Analysis approach (to account for non-parametric distributions) was applied to examine the relationship between the differences in the upper extremity anthropometric measurements, diagnosis of LE (case or control) and hand dominance (right or left). Odds ratios are appropriate statistics to test association in this instance because of the categorical nature of the diagnosis (presence or absence of LE)

Results

Intra-tester reliability of primary investigator

The senior physiotherapist had good inter-rater agreement in all repeated anthropometric measurements (ICC ≥ 0.93). The least SEM was found for elbow breadth measurements (SEM=0.17 mm). The largest SEM was found for arm length measurements (SEM=0.81 cm).

Baseline characteristics of participants

Sixty-nine (69) case participants with one or two painful lateral elbows responded to the invitation to participate in the study. On initial screening by the junior physiotherapist, 17 potential cases were excluded, the reasons for which are outlined in Figure 1. Overall, 52 individuals with 48 unilateral elbow pain and 4 bilateral elbow pain were eligible for the study. Their lateral elbow pain was replicated (test positive) by one of the three clinical provocation tests (namely the Cozen's, Mill's and Maudsley tests), confirming the diagnosis of clinical LE. The cases were matched with 99 control participants with 198 non-symptomatic elbows (Figure 1).

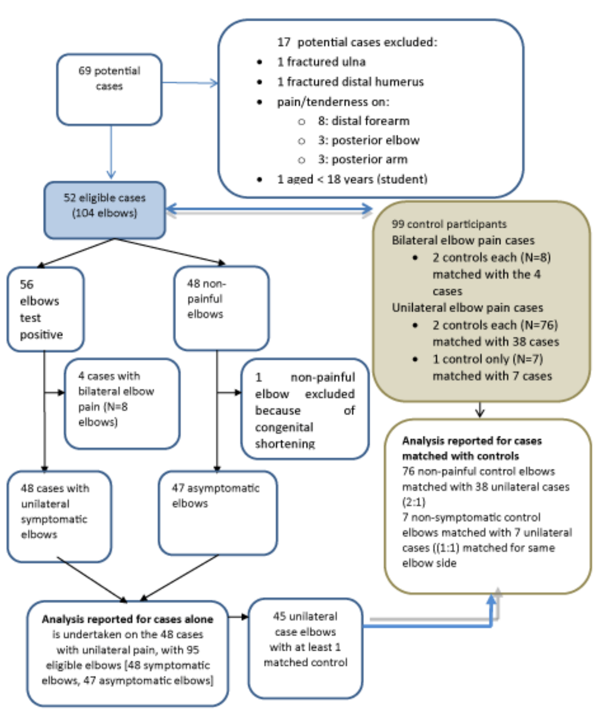

Figure 1: Flow diagram of case and control participants Key: LE, Lateral epicondylalgia

Age and gender

The age range for the 52 cases with unilateral and bilateral elbow pain included in this research was from 20 to 66 years old (mean age, 42; SD, 12). The age range for the 99 control participants included in this research was from 19-65 years old (mean age, 41; SD, 12). No significant differences in age range between cases and controls were noted (p=0.91). Ninety-two percent (92%) of participants who completed the physical evaluation had unilateral LE, with the female gender constituting 73% of the tested sample population. As controls were matched with cases by gender, age and activities, there was no significant difference in the ratio of men: women between cases (14:38) and controls (24:75).

Duration of elbow symptoms

The largest percentage of cases with unilateral elbow pain (45.8%; 22/48)] presented with acute symptoms of less than 6 weeks, with the percentage diminishing over categories of acuity, listed as follows:

- 33.3% (16/48) elbows with early chronic pain (1.6-3months)
- 18.8% (9/48) elbows with middle chronic pain (4-12 months) and
- 2.08% (1/48) elbow with late chronic pain (>12 months)

No significant differences in age was found between the four groups based on LE duration (p>0.01)

Activities and hand dominance of participants

Repetitive activities such as laundry work, writing, typing, and playing racket sports were activities which were commonly reported as triggers for lateral elbow pain in LE cases. Among these activities, 48% of the triggers for LE were due to laundry washing. Considering the reported number of participants investigated in this study and grouped by gender, activities appear to be gender-specific for both case and control participants. Laundry wash and vending appear to be female-specific activities. Vending is buying-and-selling of food products involving repetitive lifting and carrying of goods to be handed over to buyers. Playing racket sports, pistol cleaning and fixing equipment appear to be male-specific activities.

Of the 48 participants with unilateral elbow pain, 42 were right hand dominant, 5 were left hand dominant and 1 was ambidextrous. 92% of the right dominant elbows had LE, compared to only 22% of the left dominant elbows which developed LE.

Association of age, gender, duration of symptoms, activities, hand dominance, anthropometric measurements and LE

The association of the investigated variables was presented based on the posed research questions. Initially, the relationship of age, gender, duration of symptoms, activities and hand dominance with the anthropometric measurements was explored. Consequently, the association of presence of LE on anthropometric measurements was investigated.

Is there a significant influence of and age, gender, duration of symptoms, activities, hand dominance and anthropometric measurements?

Table 1 reports that there is no significant association between age, gender, duration of symptoms, activities, and anthropometric measurements. Hand dominance was significantly and moderately associated with elbow circumference taken at 5cm above and 5cm below the healthy elbow joints of control participants.

	Groups	Age	Gender	Duration of symptoms	Activities	Hand dominance
		Pearson correlation coefficient	Eta coefficient			
Elbow breadth	Combined	0.46	0.02	NA	0.08	0.12
	Case	0.90	0.20	0.82	0.36	0.03
	Control	0.40	0.08	NA	0.17	0.18
EC-Elbjt	Combined	0.30	0.02	NA	0.09	0.27
	Case	0.57	0.01	0.82	0.12	0.05
	Control	0.16	0.02	NA	0.10	0.33
EC-Abjt	Combined	0.08	0.03	NA	0.12	0.32
	Case	0.78	0.009	0.86	0.15	0.10

		0.02*				
	Control	0.24*	0.04	NA	0.12	0.42*
EC-Beljt	Combined	0.81	0.02	NA	0.23	0.44*
	Case	0.29	0.02	0.62	0.25	0.20
	Control	0.28	0.02	NA	0.24	0.53*
Arm length	Combined	0.76	0.09	NA	0.07	0.06
	Case	0.64	0.02	0.23	0.14	0.005
	Control	0.97	0.14	NA	0.17	0.10

Table 1: Association of anthropometric measurements with age, gender, duration of symptoms, activities, and hand dominance

*indicates moderate correlation

Key: EC-Abjt, elbow circumference five cm above the elbow joint; EC-Eljt, elbow circumference at the level of the elbow joint; EC-Beljt, elbow circumference five cm below the elbow joint; NA, not applicable; r=Eta coefficient

Anthropometric measurements by gender

Table 2 reports that men with unilateral LE had significantly larger arm length, elbow circumference (at the elbow joint, 5cm above the elbow joint and 5cm below the elbow joint), compared to women with unilateral LE (p≤0.01).

Anthropometric measurements	Men	Women	p-value
	Mean (SD) (95% CI)		
(R) Elbow breadth (mm)	7.13 (0.77) (6.67-7.60)	6.46 (0.71) (6.22-6.71)	0.007**
(L) Elbow breadth (mm)	7.02 (0.69) (6.60-7.43)	6.45 (0.68) (6.20-6.70)	0.02*
(R) Elbow circumference at elbow joint (cm)	25 (2) (24-27)	23 (2) (22-24)	0.0004**
(L) Elbow circumference at elbow joint (cm)	25 (2) (24-26)	23 (3) (22-23)	0.0003**
(R) Elbow circumference at 5cm above the elbow joint (cm)	27 (3) (25-29)	25 (2) (24-26)	0.004**
(L) Elbow circumference at 5cm above the elbow joint (cm)	27 (4) (25-29)	25 (2) (24-25)	0.007**
(R) Elbow circumference at 5 cm below the elbow joint (cm)	26 (2) (25-27)	23 (2) (22-24)	<0.0001**
(L) Elbow circumference at 5 cm below the elbow joint (cm)	26 (2) (25-27)	23 (2) (22-23)	<0.0001**
(R) Arm length (cm)	71 (4) (68-73)	65 (3) (64-67)	<0.0001**
(L) Arm length (cm)	71 (4) (69-74)	66 (3) (65-67)	0.0001**

Table 2: Anthropometric measurements of case participants with unilateral LE reported by gender

*trending toward significant difference

**denotes significant difference (p<0.01)

Key: CI, confidence interval; cm(s), centimetre(s); (L), left; LE, Lateral epicondylalgia; mm, millimetres; (R), right; SD, standard deviation

Table 3 reports that men without LE had significantly larger anthropometric measurements compared to women without LE but not for (R)/(L) elbow circumference at 5cm above the elbow joint and (R)/(L) elbow breadth measurements.

Anthropometric measurements	Men	Women	p-value
	Mean (SD) (95% CI)		
(R) Elbow Breadth (mm)	6.95 (0.58) (6.71-7.20)	6.73 (0.91) (6.52-6.94)	0.16
(L) Elbow Breadth (mm)	6.89 (0.63) (6.63-7.16)	6.70 (0.87) (6.50-6.90)	0.33
(R) Elbow circumference at elbow joint (cm)	25 (2) (24-27)	24 (3) (23-24)	0.005**
(L) Elbow circumference at elbow joint (cm)	25 (2) (24-26)	23 (2) (23-24)	0.003**
(R) Elbow circumference at 5 cm above the elbow joint (cm)	27 (3) (26-28)	26 (3) (25-26)	0.06
(L) Elbow circumference at 5 cm above the elbow joint (cm)	27 (3) (25-28)	25 (3) (24-26)	0.06
(R) Elbow circumference at 5 cm below the elbow joint (cm)	26 (2) (25-27)	24 (2) (23-24)	<0.0001**
(L) Elbow circumference at 5 cm below the elbow joint (cm)	26 (2) (25-27)	23 (2) (23-24)	<0.0001**
(R) Arm length (cm)	70 (4) (68-71)	63 (3) (63-64)	<0.0001**
(L) Arm length (cm)	71 (3) (69-72)	64 (3) (63-65)	<0.0001**

Table 3: Anthropometric measures of the control participants reported by gender

**denotes significant difference

Key: CI, confidence interval; cm (s), centimeter (s); kg (s), kilogram (s); (L), left; LE, Lateral epicondylalgia; mm (s), millimeter (s); NA, not applicable; (R), right; SD, standard deviation.

- Is there directional asymmetry in the upper extremity anthropometric measurements of case and control participants?

All anthropometric measurements collected by the primary investigator were normally distributed (p>0.05).In both case and control participants, significant bilateral asymmetries were noted in all anthropometric measurements, except for elbow breadth measurements of control participants. As shown by directional asymmetries of >0.50 difference between upper extremity anthropometric measurements notwithstanding measurements errors [22], arm length measurements demonstrated left directional asymmetry and elbow circumferential measurements (at all three levels) demonstrated right directional asymmetry in both case and control participants. Right directional asymmetry was found in elbow breadth measurements of case participant's only. Table 4 lists the % directional asymmetry of the anthropometric measurements between upper extremities of case and control participants.

Anthropometric Measurements	Case % DA Mean	Control % DA Mean
Elbow breadth	0.55*	0.49
EC-Eljt	1.56*	1.27*
EC-Abjt	0.96*	1.62*
EC-Beljt	2.14*	1.71*
Arm length	-0.62*	-0.75*

Table 4: Mean %DA of anthropometric measurements in UE(s) of case and control participants

*denotes significance at $p<0.05$

Key: DA, directional asymmetry; EC-Abjt, elbow circumference 5 cm above the elbow joint; EC-Eljt, elbow circumference at the level of the elbow joint; EC-Beljt, elbow circumference 5 cm below the elbow joint; UE(s), upper extremity(ies); (-), indicating left sided asymmetry

- Is there a significant association between LE, hand dominance and anthropometric measurements?

Based on the odds ratios reported in Table 5, hand dominance was found to be significantly associated with elbow circumferential measurements taken at the level of the lateral epicondyle, 5cm above the lateral epicondyle and 5cm below the lateral epicondyle. Presence or absence of LE (case or control) was not significantly associated with any of the upper extremity anthropometric measurements.

Area	Case or control OR (95%CI)	Hand dominance OR (95% CI)
Diff Elbow breadth	(0.4, 1.5)	2.2 (0.8, 6.1)
Diff EC-Eljt	(0.69, 2.84)	4.3 (1.4, 14.2)*
Diff EC-Abjt	(0.3, 1.1)	5.9 (1.9, 19.2)*
Diff EC-Beljt	(0.5, 2.2)	8.0 (2.2, 28.8)*
Diff Arm length	(0.6, 2.5)	1.7 (0.6, 3.5)

Table 5: Association between diagnosis (as case or control), hand dominance and upper extremity anthropometric measurements using the odds ratio (95% CI)

*denotes significance at $p<0.05$

Key: CI, confidence interval; diff, difference; EC-Abjt, elbow circumference 5 cm above the elbow joint; EC-Eljt, elbow circumference at the level of the elbow joint; EC-Beljt, elbow circumference 5 cm below the elbow joint; OR, odds ratio.

Discussion

To the authors' knowledge, this is the first study which investigated the relationship of Lateral epicondylalgia with anthropometric measures, namely elbow breadth, and elbow circumference and arm length measurements. None of these anthropometric measurements were found to be significantly associated with LE.

Elbow breadth measurements initially appeared to be influenced by the side of LE as shown by presence of significant directional asymmetry in the upper extremities of case participants but not in the upper extremities of control participants. However, the association between differences in elbow breadth measurements of right and left upper extremities; and the presence or absence of LE (case or control) was not significant. Our findings do not support the assumption that elbow breadth measurements reflect increased transversal growth of the lateral epicondyle due to the presence of significant biomechanical stresses associated with the pull of the lower arm muscles.

Elbow circumferential measurements at the three levels of interest in both case and control participants were significantly associated with hand dominance as listed in Table 5. The elbow circumferential measurement found on the hand dominant side could still be considered normal as it has been reported that less than 2cm difference in elbow circumferential measurements between upper extremities is not secondary to musculoskeletal pathologies in the upper extremity (i.e., LE, medial epicondylalgia, fractures) [13]. Considering that hand dominance and not LE as a possible influence for the differences found in elbow circumferential measurements at all three levels, 86% of case and control participants were right-hand dominant, which is associated with right directional asymmetry. The frequent use of the dominant hand in activities such as gripping may have developed the forearm muscles leading to increased elbow circumference. Our findings of right directional asymmetry in elbow circumferential measurements (at 5cm above and at 5cm below the elbow joint) in a predominantly right handed sample population (42/48) add support to those reported in the literature [22,28-30]. The percentage of right hand dominant case and control participants (88%) in our study approximates the percentage of handedness in the general population, i.e. 80% right handed and 15% left handed [23,26-28].

As anticipated, men generally demonstrated significantly larger anthropometric measurements compared to women [1]. Similar to other reports of anthropometric measures from around the world, males in this study had significantly larger height, weight, elbow circumference, arm length and elbow breadth compared to females [29-31]. Of note, elbow breadth measurements appeared to be significantly larger in men than in women with unilateral LE. This gender difference appeared only to be relevant to the engaged activities of LE sufferers, as gender per se was not a predictor of LE. The repetitive, yet apparently more forceful UE movements when playing racket sports in men compared to laundry wash in women could have strained the lateral epicondyle by the contracting common extensor origin. This could have led to the greater increase in transversal growth of the lateral epicondyle in men compared to women which may underpin the differences in elbow breadth measurements between genders.

Limitations of the Study

This study was conducted on Filipino participants only. This necessarily introduces a potential cultural, genetic and occupational bias to the findings. It did, however, provide a specific description of one group of genetically-homogenous individuals, whose findings could be compared with other populations.

Whilst recruitment of cases needed to be purposive, due to the lack of a comprehensive register of LE cases of the continuum of acuity, the controls could have been randomly selected and then case-matched. Many of the case-control matches were less than perfect, with some cases unable to be matched with any controls, due to the nature of their activities. However, the sample size of cases and the attempts at a 2:1 control: case matching enhances the study power, to identify potential case-control differences in anthropometry.

Measurement errors by the primary investigator may be expected as these are influenced by the position of the segment being evaluated, the position of the joints proximal and distal to the segment being measured, the position of the participant during measurement, the tester's field of observation during time of reading and the instrument used for measuring UE anthropometry. To minimise the variation in reading measurements, only the primary investigator read all anthropometric measurements. The primary investigator read the measurements with grid of measuring tool placed at 90 degrees to the primary investigator's eyes. Specifically for arm length measurements, the highest point on the acromion process was used to standardize the starting point of measuring arm length.

Conclusion

The results of this study did not find any anthropometric measurement that will objectively determine the abnormal anatomical structures in elbows with LE. The current diagnostic system for LE primarily depends on the reported elbow pain by the patient; and replication of this elbow pain by any one of the Cozen's, Mill's or Maudsley's tests. Despite that this diagnostic system is subjective and does not assist healthcare professionals in identifying the anatomical structures which may be injured in elbows with LE, it is still the simplest to perform thus commonly used in both clinical and research practice [32].

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