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Article

Normative Data Collection of the Combined Elevation Test (CET) in Swimmers and Non-Swimmers

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Abstract: The Combined Elevation Test (CET) is a musculoskeletal screening technique (MST) replicates the streamline position in swimming and is commonly used in various sports. Although the CET is widely used, no normative data exist within an adolescent population. Therefore, the purpose of this study was to develop a normative data set for the CET within an adolescent population and to evaluate the influence various demographic and anthropometric variables. Data was collected for 416 participants aged between 8 and 18 years old. Age and arm span showed a significant correlation with CET scores (arm span r_s (105) = .478, *p* = .000, age r_s (416) = .238 *p* = .000). Regression analysis further quantified the influence of arm span and age on CET scores accounting for 23.1% and 5.3% of variability respectively. These results can be used as a reference point for clinicians and coaches who are using the CET within their assessment.

Keywords: Combined Elevation Test, Musculoskeletal Screening Test, Normative Data, Swimming, Adolescent

1. Introduction

Sport specific musculoskeletal screening techniques (MST) are used in the identification of intrinsic risk factors [1]. These risk factors may present as movement dysfunction, restriction or asymmetry and may predispose the athlete to injury or identify incomplete recovery from a previous injury [2]. The selection of MST is based on both specificity to a particular sport and the location of common injuries within that sport. In swimming in particular, shoulder pain has been shown to be prevalent in 40-91% of participants [3]. Sein, *et al*. [4] revealed higher rates (91%) of reported shoulder pain in the younger swimming populations (13-25 years). The high frequency of shoulder injury, especially in younger swimmers, provide the rationale for the use MST's to screen for injury risk.

The Combined Elevation Test (CET) is a musculoskeletal screening technique originally developed by Blanch [5] that involves a synchronised movement of thoracic extension, glenohumeral joint (GHJ) flexion, scapula retraction and upward rotation [2]. These movements replicate the streamline position required for optimal freestyle swimming and aim to assess the commonly injured shoulder region within this population.

While there appears to be adequate MST's to assess thoracic rotation [6,7], there remains a paucity of MST's which aim to assess thoracic extension [8]. However, the CET has been widely used in sports such as cricket, rugby union, triathlon and surf lifesaving [8-10]. Despite the original intention of the CET being designed for swimming, there appears to be limited research within this cohort.

When implementing a MST, a treating clinician typically compares the result against two outcomes 1) the contralateral limb and 2) published normative data. Ideally, normative data should be a large enough sample size to precisely characterise a population to allow for appropriate interpretation and generalisation of results [11]. While normative data has been established for various MST's [12,13] no normative data exists for the CET.

Considering both the high frequency of shoulder injuries in a young swimming population and the absence of normative data for the CET, the purpose of this study was to develop a normative data set for the CET within an adolescent population. In addition, a secondary aim was to evaluate the influence various demographic and anthropometric variables may have on CET scores.

2. Materials and Methods

2.1 Participants

An observational study was designed in which data collection took place between January to March 2017 at local secondary schools. This study was approved by the Queensland Department of Education and Training (550/27/1668) and the University Human Research Ethics Committee (0000015415). All participants included in this study ranged in age from 10 -18 years and were provided with a verbal explanation of expectations and relevant risks associated with participation prior to its commencement. All participants were required to have a signed consent form by an adult or guardian. Key demographical information collected included: age, arm span, sport involvement, injury history, and current training volume. Each participant was required to disclose any ongoing or past injuries which may affect their ability to complete the test. Participants who had an existing shoulder injury or upper body injury 3 months prior to testing were excluded from the study.

2.2 Equipment

A measuring stand with a 1mm incremental scale running on a single side of the stand was used to measure combined elevation; demonstrated in both figure 1 and figure 2. The height of the base of the measuring stand was added to each measure taken.

2.3 Testing Procedure

Measurements were taken by three second year post-graduate physiotherapy students. The students received formal training on the CET procedures prior to commencement of the study by a senior Physiotherapist with over 10 years of clinical experience. A small pilot study was conducted to ensure reliability of the current testing protocol. Previous research has revealed good intra and inter-rater reliability when using the CET (ICC 0.89 and 0.97 respectively) [2].

Testing procedures were based off previously established methodology [8,10] in which participants were required to lie prone on the floor and assume a streamline swimming position. They were then asked to place their forehead, chest, hips, knees and feet on the floor (figure 1). Forehead contact with the floor was used opposed to chin contact as a study by Allen (2017) found that shoulder range of motion was limited in the chin position as opposed to the forehead position.

Instruction was then provided to assume a posture with their left hand on top of their right: elbows, wrists and palms straight and fully extended. Participants were required to hold a neutral position of the wrist. This was determined by the position of the metacarpals in relation to the ulna. Measurements were only taken when the patients metacarpals were aligned with the ulna in the sagittal plane. Participants were then instructed to maximally raise their arms away from the floor, while their forehead, chest, pelvis, and feet maintained contact with the floor (Figure 1). The perpendicular distance between the base of the metacarpo-phalangeal joint (MCPJ) of the third finger and the floor was then measured and recorded for analysis.

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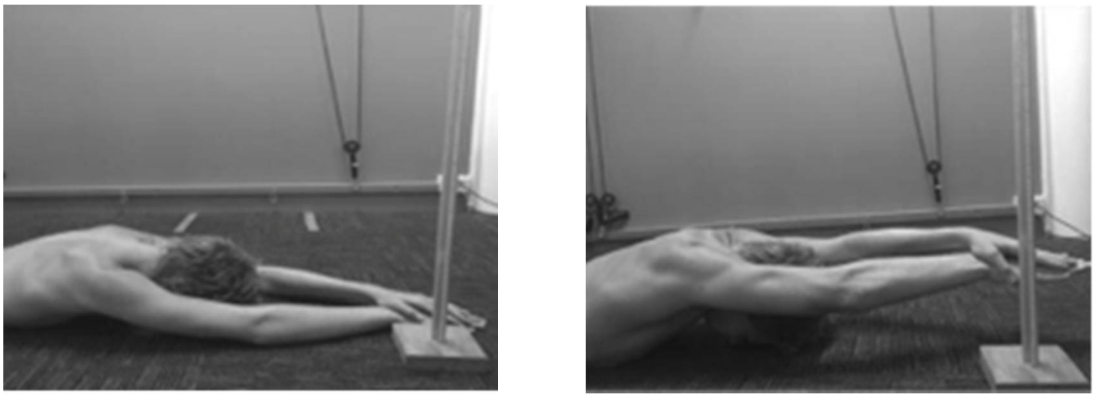
Three sub-maximal attempts were performed as a warm up to familiarize the participants with the movement required. Following the warm up, each participant performed three maximal efforts of the CET. A rest period of 10 seconds between each performance was given and measurements were then collected and entered into a spreadsheet for further analysis.



(a) (b)

Figure 1. (a) Starting position for the CET. **(b)** Finishing Position for the CET.

2.4 Data Analysis

Data analysis was performed using SPSS version 23.0. Descriptive statistics including means, standard deviations and ranges were calculated to establish a normative data set. To test for normality of the data set, a Shapiro-Wilk test ($p>0.05$) (Shapiro & Wilk, 1965) was conducted. A Mann-Whitney U test was performed to determine differences in CET scores between males and females. A Spearman's rank-order correlation test was performed to determine the association of span, average training volume and CET. To assess the influence of age and arm span on CET scores a multiple regression analysis was performed. Statistical significance was set at ($p<0.05$). Due to the diverse range of sporting involvement and poor reliability associated with retrospectively recalling average training volumes, both sporting involvement and average weekly training volume were not used within the data analysis or presented within the results.

3. Results

3.1 Reliability analysis

A subset of 23 participants were used to determine the intra-rater, within session reliability of the testing procedure. The Intra-class Coefficient Correlation ($ICC_{3,2}$) values and 95% confidence intervals were 0.991 (0.983 – 0.996) respectively. The Standard Error of Measurement (SEM) was 1.46 cm which was calculated based off the formula SEM = $\sqrt{WMS}$, where WMS is the Mean square error from the ANOVA [14].

3.2 Participant demographics

In total, 416 participants were assessed in this study, with slightly more males (56%), than females (44%). Participant characteristics of both age, and sport and gender, are shown in Tables 1 and 2 respectively. Table 1 provides a breakdown of the number of participants within each age groups for both female and males. Age groups ranged from 8 to 18 years old with the greatest number of participants being between 12-16 years of age (95.9%, Table 2). The overall average CET score for males versus females was 19.38 +/-7.53 cm and 20.09+/- 7.89 cm respectively.

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Table 1. Average CET (cm) distributed by age and gender

	Male		Female		Total	
Age	**N**	**Mean(SD)**	**N**	**Mean(SD)**	**N**	**Mean(SD)**
< 10	2	18.83(0.94)	0	0(0)	2	18.83(0.94)
11	6	20.36(6.90)	9	17.11(6.09)	15	18.4(6.40)
12	33	18.47(8.23)	27	19.05(6.80)	60	18.73(7.56)
13	36	16.34(6.09)	47	18.39(6.82)	83	17.5(6.56)
14	37	16.97(6.42)	29	16.52(8.56)	66	16.78(7.38)
15	66	19.84(8.55)	38	24.0(8.54)	104	21.35(8.74)
16	39	22.21(5.73)	20	23.8(5.68)	59	22.75(5.71)
17	14	24.24(6.79)	10	20.23(7.20)	24	22.57(7.10)
18	1	33.00(0)	2	28.08(14.02)	3	29.72(10.31)
Total	234	19.38(7.53)	182	20.09(7.89)	416	19.69(7.69)

* N = number of participants; SD = standard deviation

3.3 Comparative analysis for males vs females

A Mann-Whitney U test was used to determine differences in CET score between males and females. CET scores for males (mean = 19.38, SD = 7.53) and females (mean = 20.09, SD = 7.89) were not statistically significantly different, U = 20507.500, z = -.647, p = .518. Given this finding, for all subsequent analyses, both males and female results were pooled.

3.4 Correlations between CET and key variables: arm span, age, and average training volume

Arm span data was collected on 105 participants. Spearman's rank-order correlation tests were used to assess the relationship between arm span (N=105), age (N=416) and CET score within participants. Age, and arm span showed a significant correlation with CET, with arm span showing a moderate positive correlation r_s (105) = .478, p = .000 and age having a low correlation with CET scores r_s(416) = .238 p = .000.

3.5 Multiple Regression Analysis: Influence of arm span and age on CET scores

A multiple regression analysis was used to assess the influence of arm span and age on CET scores. The multiple regression model which included arm span and age statistically significantly predicted CET scores, F(2, 102) = 20.252, p < .001, R_2 = .284. Arm span, without the influence of age, also significantly predicted CET, F(103, 1) = 30.996, p < .001, R_2 = .231. Figure 2 presents this linear relationship graphically, with increases in arm span being associated with increases in CET scores. As seen in Table 2, 28.4% of the variation of CET scores is predicted by arm span and age (23.1% and 5.3%) respectively.

Table 2. Summary of Multiple Regression Analysis

Model	R Square	R Square Change	Significance
Arm Span	.231	.231	.000
Arm Span and Age	.284	.053	.007

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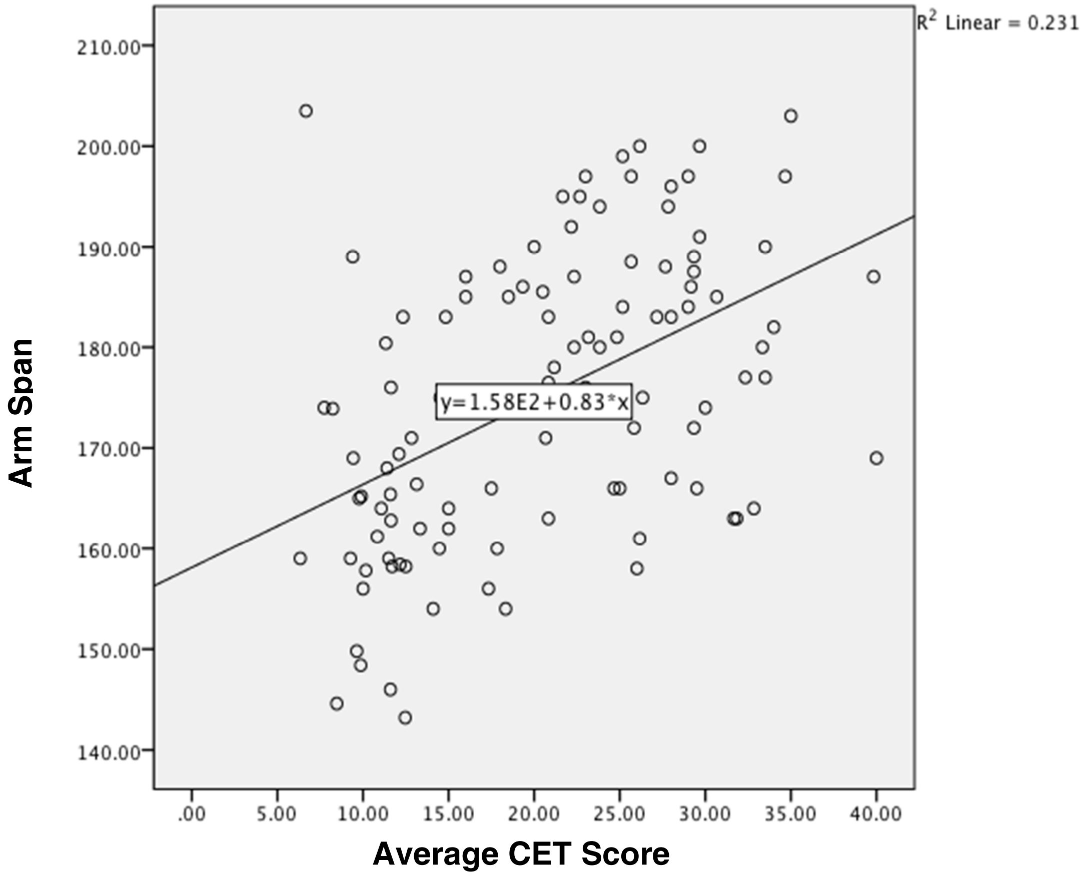

Figure 2. Scatterplot depicting the linear relationship between arm span and CET scores.

3.6 Standardized CET Scores Based on Age and Arm Span

Given the results from the multiple regression analysis, average CET score values were stratified based on age groups and arm span groups (Table 3). Age was separated into 3 groups with three corresponding arm span sub-groups. Highest average CET score was recorded for the 16 – 18 year old group within the 190 – 205 cm arm span sub group (30.3 +/- 4.4). Lowest scores were recorded for the 10 – 12 year old group within the 140 – 154 cm arm span sub group 12.5 +/- 3.5.

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Table 3. Standardized values based on age and arm span

Age (yrs)	Arm Span (cm)	Average CET Score (cm)	CET Range (cm)
10-12 (n=27)	140-154	12.5 ± 3.5	8.4 - 18.3
	155-169	16.3 ± 7.5	6.3 - 29.5
	170-184	22.0 ± 6.4	12.8 - 27.1
13-15 (n=42)	150-164	15.65 ± 7.7	9.3 - 31.8
	165-179	19.7 ± 10.4	7.7 - 40.0
	180-194	24.2 ± 11.1	9.4 - 39.8
16-18 (n=36)	160-174	27.2 ± 5.8	17.8 – 32.8
	175-189	24.0 ± 5.5	14.5 – 33.5
	190-205	30.3 ± 4.4	26.2 – 35.0

4. Discussion

The purpose of this study was to develop a normative data set for the CET within an adolescent population. To the authors knowledge this is the first study to present such data. The key findings of this study were that both age and arm span correlated with CET scores.

The results of this study found no significant differences between males and females which aligns with research findings from Allen et al. Allen, Phillips and McCaig [8] who also looked at differences in CET scores between genders. This finding may be unique to the CET as previous research has illustrated gender differences in mobility favouring females [15,16]. Rikken-Bultman, Wellink and van Dongen [15] who identified increased mobility in Dutch female school children also found that the non-dominant body side is significantly more mobile than the dominant side. This may provide some rational for the findings of the current study as the CET is a test of bilateral range of motion. This may influence CET results as outcomes would be a reflection of the participants least mobile side.

The results of the current study revealed correlations between age, arm span and CET scores with increases in both age and arm span being associated with increases in CET scores. Regression analysis further quantified the influence of arm span and age in CET scores accounting for 23% and 5% of variability respectively.

One would assume that as age increases CET scores would decrease, as reductions in flexibility with an increase in age has previously been shown [15]. The authors concede two possible explanations for the findings of the current study; 1) as age increases so does arm span [17]; and 2) as age increases in the first 2 to 3 decades of life so does muscle mass and strength [18]. While the latter was not assessed in the current study it is a well-known physical adaption associated with aging [18,19]. Therefore, it is hypothesized that increases in strength and muscle mass allow for greater arm clearance during the CET. It could also be suggested that the CET is not only a measure of flexibility within the shoulder and thorax region but also muscular strength. As both muscle mass or strength was not assessed within this current study, future research should include these variables.

Given the influence that age and arm span have on CET scores the authors were able to categorise CET scores based on both variables. To the authors knowledge this is the first study to present this information. Clinicians and coaches are able to utilize the current data as a baseline to compare with the results of the athlete they are testing. It needs to be noted that a poor CET score of an individual within their respective category in isolation would not be able to indicate any cause for this outcome. Discrepancies would require further clinical investigation as the CET does not differentiate between joints that may be contributing towards a low CET score [8].

This is the largest study to date (N = 416) specific to the CET to which presented a relatively gender matched data set for an adolescent age range. Wider age ranges (those older than 18 years) should also be investigated to allow for greater generalisation of results and further establish the effects of age on CET scores. Furthermore, for future research needs to evaluate the effectiveness of measuring shoulder joint range of motion with a goniometer, as other studies have indicated that performance in the CET is strongly related to range of glenohumeral joint flexion [8].

5. Conclusions

This study provides the largest data set in an adolescent population specific to the CET to date. These results can be used as a reference point for clinicians and coaches who are using the CET within their assessment. The results revealed that age and arm span are significant predictors of CET and given this finding normative data should account for these variables.

Author Contributions: JF designed the study; JF, BS, DC, ZT & HC collected data and analyzed the results. ZT, DC & HC drafted the manuscript & JF & BS finalized the manuscript for publication.

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Conflicts of Interest: The authors declare no conflict of interest.

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