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Relation between Index Finger Width and Hand Width Anthropometric Measures

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Abstract--- **Measures of hand and finger anthropometry are very important for designing many hand held devices as well as understanding anthropometric effects on the operation of such devices. Many historical datasets have measured and recorded gross hand dimensions but do not often record the finer dimensions of the hand such as finger anthropometry. Knowing the size and mass of fingers across genders can be critical to the design and operation of hand held devices. In this paper we compare two empirical linear models that predicts index finger width at the proximal interphalangeal (PIP) joint (a finger anthropometric measure) based on hand-width (hand anthropometric measure). This will be especially useful for deriving population measures of finger anthropometry from large historical data sets where only gross hand dimensions are available.**

I. INTRODUCTION

Anthropometric measures of the hand can provide crucial information for design of hand-held devices (e.g. surgical stapler, computer mice, lanthoscopic devices, etc.). The continued development in microsurgical techniques will require better design of surgical instruments which combine miniature size and high accuracy [8]. The design of such instruments is critically dependent on finer dimensions of the hand such as finger anthropometry. While many studies often record gross external hand measurements such as hand-width and hand-length, they do not record finer dimensions such as finger masses, which can be derived from finger length and finger width. To tap the potential wealth of information from past datasets it could be useful to employ models based on gross measures of hand dimensions to derive the finer measures of finger. This would enable the design of hand-held devices/instruments on the basis of a much larger population size.

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Some studies have developed such models based on hand length or hand width [1], [2], and [3]. In one study, finger-lengths were derived from a single measure of hand-length [1]. This sort of approach has been very useful in predicting unavailable finger dimensions from large historical datasets with only gross hand dimensions. An example of such a large historical datasets is the National Health and Nutrition Examination Survey III conducted in 1994 [9]. This database is currently considered to be the most comprehensive and representative for the US population [9]. This will be useful as design input for hand-held device design. In the following paper we want to determine the suitability and applicability two empirical linear equations which predict index finger-width at the proximal interphalangeal joint (PIP) based on hand-width. We also compare the two empirical linear equations.

Index finger is of unique importance amongst the digits of the hand: "It serves to exemplify the precise movements of the human hand" [4]. A study has found that the index finger to be the dominant finger in most people [7]. Index finger width is critical for estimating finger masses which in turn can assist in determining finger actuation forces of index-finger dominant hand-held devices. Index finger width at the PIP joint along with the index finger length can be used to estimate finger mass with an estimation error no greater than 10% [6].

II. METHODS

Nineteen right hand dominant adult subjects (11 male, 8 female) participated in this study. The mean age of the subjects was 32.5 years (range 20 to 57 years). Approval for this study was received from the Human subjects division at the University of Washington.

Hand width and index finger width at the proximal interphalangeal joint (PIP joint) were measured using a standard vernier calipers. The index finger width was measured as shown in figure 1. The hand width was measured as shown in figure 2. The distance between the ulnar edge and radial edge of the projection of the proximal interphalangeal joint crease was measured and recorded as the index finger width at the PIP joint as shown in figure 1. The hand width was measured as the distance between metacarpal II and metacarpal V land marks as shown in figure 2. For simplicity we refer to index finger width at PIP joint with the shortened abbreviation 'IFW' and hand width as 'HW' in equations.

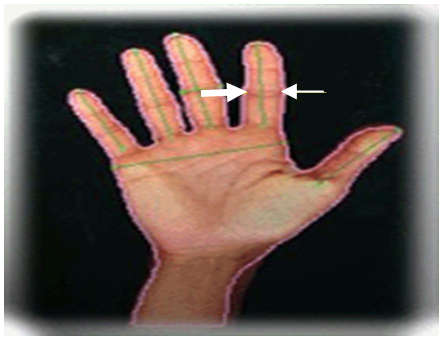

Fig 1. Index finger width at PIP joint

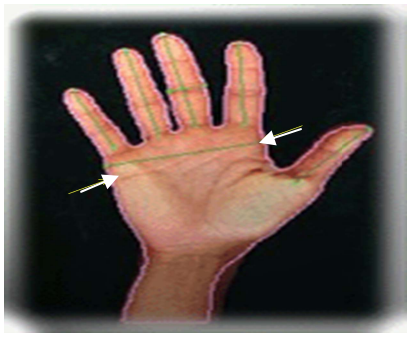

Fig 2. Hand width

The *first empirical linear equation* employed is a gender based model to predict index finger width, based on hand – width, was a method developed by Greiner 1991. The equations, using hand width as the input variable, are shown below. All measurements are in cm.

{Greiner 1991 model}
For females
$IFW = (10*0.15*HW + 7.91)/10$ cm (1)

For males
$IFW = (10*0.16*HW + 8.79)/10$ cm (2)

Equations 1 & 2 are based on an anthropometric survey of army personnel [5] in which hand anthropometric measures were recorded including index finger width at the PIP joint and hand width. Equation 1 is based on 63 female subjects. Equation 2 is based on 63 male subjects. For simplicity we will refer to equations 1 & 2 as the 'Greiner 1991 model'. Index finger width and hand width were measured using a special photometric system. The photometric system consists of a hand photo box and a hand dimensioning system. The purpose of the photo box is to produce images that will allow identification of anthropometric landmarks. The hand dimensioning system then accurately located the anthropometric landmarks based on a high resolution image. For all subjects, measurements were taken from the right hand.

The *second empirical linear equation* that employed to predict index finger width was based on a study by Buchholz & Armstrong (1991). Buchholz & Armstrong also used hand width to determine index finger width, but had scaling factors specific to each finger. All measurements are in cm.

{Buchholz & Armstrong 1991 model}
For Males and Females

$IFW = 0.215*HW$ cm (3)

Equation 3 is based on 30 subjects (15 male and 15 female) in which hand anthropometric measures were recorded including index finger width at the PIP joint and hand width [2]. For simplicity we will refer to equation 3 as 'Buchholz & Armstrong 1991 model'. Index finger width and hand width were measured using a 300 mm calipers with a vernier resolution of 0.02 mm. For all subjects, measurements were taken from the right hand.

The measured values of index finger PIP joint width from the 19 subjects in our study were compared to the predicted values based on the *equation 1*, *equation 2 and equation 3* shown above. Significance was accepted when p-values were less than 0.05.

III. RESULTS

As shown in figure 3 there was a significant correlation (p-value < 0.05) between measured hand width and index finger width at PIP joint. The correlation coefficient was 0.84.

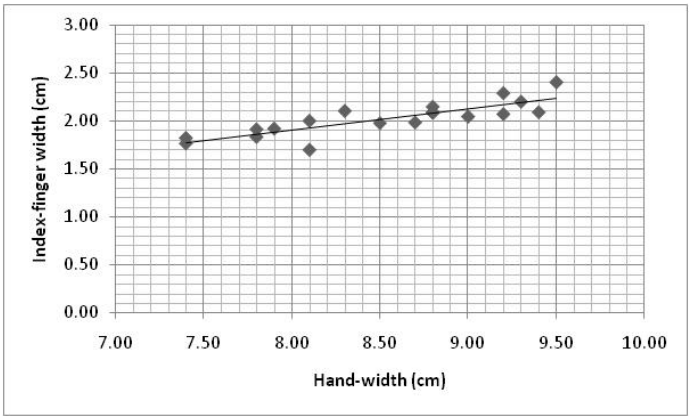

Fig 3: Correlation between hand width and index finger width at PIP joint.

Figure 4 shows a comparison between the actual values and the predicted values for male subjects. The 'Greiner 1991' model as well as the 'Buchholz & Armstrong 1991' model were significantly different from the actual index finger PIP joint width measurements ($p<0.05$) for males. The Greiner 1991 model values were consistently higher and the Buchholz & Armstrong 1991 model values were consistently lower than the actual measurements.

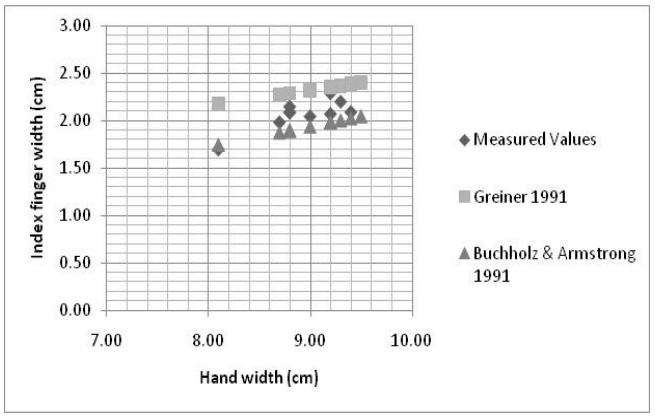

Fig 4: Comparison of predicted and actual index finger width at PIP joint for males.

Figure 5 shows a comparison between the actual values and the predicted values for female subjects. The Greiner 1991 model is not significantly different from the measured values for females ($p = 0.2$). However, the Buchholz & Armstrong 1991 model was significantly different from the measured index finger PIP joint width measurements for females ($p < 0.05$).

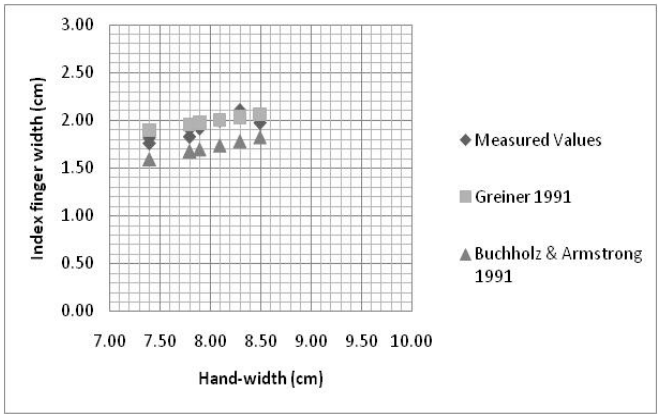

Fig 5: Comparison of predicted and actual index finger width at PIP joint for females

Figure 6 shows the difference (similarity) between the mean measured index finger PIP joint widths and the predicted values. The difference between predicted value from 'Greiner 1991' model (equation 1 & 2) and measured value was significant for males (p-value < 0.05) but for females it was not significant (p-value = 0.2). The difference between predicted value using 'Buchholz & Armstrong 1991' model (equation 3) and measured value was significant for both males (p-value < 0.05) and females (p-value <0.05) As shown in figure 6 the predicted values follow the same trend in differences of anthropometric measures between males and females. Greiner's model overestimated and Buchholz & Armstrong's model underestimated index finger width at the PIP joint.

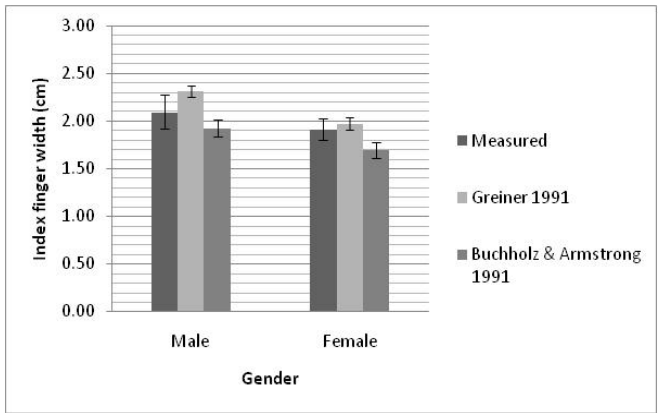

Fig 6: Comparison between mean predicted and mean actual index finger width at PIP joint (11 males and 8 females).

IV. DISCUSSION

The difference between the predicted values from the 'Greiner 1991' model and measured values for the index finger width at the PIP joint was not significant (p-value = 0.2) for females but was significant for males(p-value <0.05). The difference between the predicted values from the Buchholz 1991 model and measured values for the index finger width at the PIP joint was significant (p-value <0.05) for both males and females. From figure 4 & 5 we can observe that the 'Greiner 1991' model consistently predicts larger values than the measured value for index finger width for males and almost the same values for females. On the other hand the 'Buchholz & Armstrong 1991' model consistently predicts smaller values for index finger width for both females and males. The significance tests indicate that gender based models as proposed by 'Greiner 1991' may be more appropriate than 'Buchholz & Armstrong 1991' model. On the other hand together they bound the values for measured finger width for both genders; these models can be employed to provide an upper and lower limit for the index finger width. This should be especially considered as the 'Greiner 1991' model as well as 'Buchholz & Armstrong 1991' model was based on datasets that were derived using sophisticated instrumentation which would be hard to employ in a field study. Moreover it might be helpful to have a range of values for index finger width derived from different sources for better device design. Using this approach datasets which provide gross hand measurements such as hand –width can be used to predict index finger width at PIP joint within a range.

V. CONCLUSIONS

Deriving the index finger width accurately from a much larger population size where only gross hand dimensions are available (rather than depend only on databases of smaller population size for which the finer dimensions have been directly recorded) is of practical importance for better design of hand-held devices.

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