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External wrist ratio is not a proxy for internal carpal tunnel shape: Implications for evaluating carpal tunnel syndrome risk

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Abstract

Carpal tunnel syndrome (CTS) is highly prevalent, resulting in decreased function and increased need for costly healthcare services. External wrist ratio (depth/width>0.70) is a strong predictor of the development of CTS and has been suggested to be a proxy for internal carpal tunnel shape. Conversely, sonography can more directly evaluate carpal tunnel shape. The purpose of our study was to explore the relationship between wrist ratio and sonographic carpal tunnel measurements to (1) evaluate the reliability of sonographic carpal tunnel measurements and (2) explore how external wrist measures relate to anthropometric features of the carpal tunnel. We used sonographic imaging on a sample of healthy participants (n=226) to measure carpal tunnel cross-sectional area, depth, width, and depth/width ratio. We conducted exploratory correlation and regression analyses to identify relationships of these measures with external wrist ratio. Reliability for dominant and non-dominant sonographic carpal tunnel measures ranged from good to excellent (0.79–0.95). Despite a moderate correlation between carpal tunnel width and depth and their external wrist counterparts (0.33–0.41, p<0.001), wrist ratio and carpal tunnel ratio demonstrated weak to no correlation (dominant: r=0.12, p=0.053; non-dominant: r=0.20, p=0.002) and the mean carpal tunnel ratio was far lower than the mean wrist ratio (0.45 vs. 0.71 bilaterally). Supporting this, we observed several key differences in the relationship between external wrist measures compared to corresponding carpal tunnel measures. Additionally, regression analyses combining participant factors and carpal tunnel measurements produced models accounting for less than 15% of the variability in external wrist ratio (linear models) or correctly predicting less than 68% of wrist ratio-based risk categorization (logistic models). Overall, among healthy young adults, wrist shape is not an adequate proxy for carpal tunnel shape.

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ETHICS APPROVAL
The study protocol was approved by the institutional review boards of The University of Southern California and Loma Linda University.

PARTICIPANT CONSENT
Informed consent was obtained from all study participants prior to involvement.

CONFLICT OF INTEREST
The authors do not have any conflicts of interest to disclose.

Keywords

anthropometric measurement; carpal tunnel; carpal tunnel syndrome; sonography; wrist ratio

MeSH TERMS:

Median Neuropathy; Wrist; Ultrasonography

1. Introduction

Carpal tunnel syndrome (CTS) involves the focal compression of the median nerve within the carpal tunnel.[1] CTS is highly prevalent and persistent among workers and within the general population,[2–5] causing significant activity limitations,[6] missed work days,[7] and increased burden on the healthcare system.[8–12] Moreover, CTS involves considerable variability in its course, treatment, and outcomes,[5,10,13–17] indicating the need for more precise identification of patient-specific etiology. Early identification, prevention, and targeted intervention for those at risk for CTS can avert the need for invasive and expensive surgical techniques[9,11,12,18,19] and associated complications or side effects.[20]

Wrist ratio (wrist palmodorsal depth / mediolateral width) is a powerful predictor of the development of CTS, with ‘square-shaped’ wrists (wrist ratio > 0.7) developing CTS at a rate of three or more times that of those with smaller wrist ratios.[21–24] Wrist ratio also may impact the outcomes of patients treated for CTS.[25] Despite being an external measure of the boney structure, wrist ratio has been suggested to be an adequate approximation of the internal carpal tunnel shape,[26] a potentially important factor in the mechanical compression of the median nerve in CTS.

Sonography is a valuable point-of-care tool for the treatment of musculoskeletal disorders.[27] Sonographic imaging enables clinicians and researchers to visualize static and dynamic characteristics of otherwise inaccessible internal musculoskeletal structures, improving diagnostic accuracy, treatment monitoring, outcomes measurement, and precision treatment planning.[28,29] While sonographic imaging has been used extensively to evaluate median nerve size and shape related to CTS,[30–33] it has rarely been used to explore the relationship between carpal tunnel shape and development of CTS.[21,26] Furthermore, there has been limited examination of the relationship between the external wrist shape and the internal carpal tunnel shape.[26] To our knowledge, no study has presented a detailed comparison between individual external wrist and multiple carpal tunnel measures to explore and validate the assumed anthropometric association between these measures. Exploring sonographic assessment of carpal tunnel shape and how external wrist shape relates to carpal tunnel structure can inform more effective targeted preventative interventions, aid early CTS identification, and improve knowledge on variations in etiology.

Considering this, our study aimed to explore this relationship between external wrist ratio and sonographic carpal tunnel measurements to (1) describe and evaluate the reliability of sonographic measurements of the carpal tunnel and (2) explore how external wrist measures relate to anthropometric features of the carpal tunnel. Because limited evidence exists, we conducted this study using a large sample of healthy young adults as a critical foundational step in understanding these measures and their relationship before attempting to develop applications or interpret findings in clinical populations.

2. Methods and Materials

2.1 Participants and procedures

A cross-sectional observational study was completed with a convenience sample of asymptomatic students recruited from clinical healthcare programs at two universities between June 2015 and September 2018. The institutional review boards of both universities approved the study protocol, and informed consent was obtained from all study participants prior to data collection. Participants were excluded if they had a known history of carpal tunnel release surgery, diagnosis of median nerve pathology, or any other history of trauma, surgery, or congenital condition that would alter the morphology of anatomical structures in the wrist region. Following enrollment, nerve conduction studies and clinical evaluations (e.g., provocative tests, Boston Carpal Tunnel Questionnaire) were performed to confirm the absence of median nerve pathology. No other exclusion criteria were used.

Demographic data, including age, gender, hand dominance, and race/ethnicity, were self-reported by participants. Body mass index (BMI, kg/m^2) was calculated from participants' height and weight measurements. External wrist width (mediolateral, mm) and depth (palmodorsal, mm) were measured by a single researcher [SCR] using a digital caliper at the distal wrist crease; these values were used to calculate external wrist ratio (depth/width). Sonographic imaging was performed by two sonographers, each with more than 10 years of experience, using a Logiq-e (GE Healthcare, Milwaukee, WI) ultrasound machine with a 12-MHz linear array transducer. During imaging, participants were seated facing the sonographer, with the shoulder adducted, elbow comfortably extended, forearm resting on the table in full supination, and hand relaxed. Transverse images of the carpal tunnel were obtained at the level of the pisiform.

2.2 Sonographic Measures and Reliability Analysis

All transverse sonographic images were imported into ViewPoint version 6 (GE Healthcare) for post-processing review and measurement. The primary measures of carpal tunnel (CT) cross-sectional area (CSA, mm^2), width (mm), and depth (mm) were collected from pisiform-level images (Figure 1). CT CSA was calculated using a multi-point trace around the inner perimeter of the CT using the transverse carpal ligament and the proximal row of carpal bones as the boundary markers. CT width was measured as the distance between insertions of the transverse carpal ligament on the scaphoid and pisiform bones, and CT depth was measured as the length of the longest vertical line from the interior border of the transverse carpal ligament to the surface of the deep carpal bone. CT ratio was calculated by dividing CT depth by width. CT depth and width were collected via a single measurement, while CT CSA used an average of three successive measurements to minimize error.

Inter-rater reliability of each sonographic CT measure was assessed via intraclass correlation coefficient (ICC) between two raters on images from a random sample of 20 participants.

ICC analyses used a two-way random model defined by absolute agreement based on single CT height and width measures and an average measure for CT CSA. ICC analyses were completed using SPSS version 28.0 (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, ver.28.0. Armonk, NY: IBM Corp.). A single rater who participated in the reliability testing completed all measurements used in the descriptive and comparative analyses.

2.3 Exploratory Data Analysis

Exploratory analyses were completed using SAS software version 9.4 (SAS Institute, Inc, Cary, NC), and $p < 0.05$ was considered statistically significant for comparative tests. As this was an anthropometric study, all data for an individual participant was excluded from analysis if any individual wrist or carpal tunnel measurements were at least four standard deviations above or below the mean. Normality was assessed for continuous measures based on distribution skewness (> 1.0) and kurtosis (> 3.0), the Shapiro-Wilk test, and histogram and QQ plot appearance. Paired t-tests or Wilcoxon signed rank tests examined within-participant differences between dominant and non-dominant measurements. Independent samples t-tests or Mann-Whitney U tests were used to investigate differences between genders, and analysis of variance (ANOVA) or Kruskal-Wallis Tests were used to examine differences between races. Post-hoc pairwise tests used Scheffe's adjustments for ANOVA and Bonferroni corrections for Kruskal-Wallis tests.

Pearson's and Spearman's correlations (PROC CORR) were used to examine bivariate relationships among external wrist and sonographic carpal tunnel measures. Next, regression analyses were conducted to determine if a combination of internal wrist structures and participant factors could adequately explain the external wrist ratio. Potential sonographic predictor variables considered for inclusion were CT depth, width, and CSA. Potential participant factors included age, race, BMI, and gender; all levels of categorical predictors were kept together for model selection. All eligible continuous predictor variables were centered (via mean), and those with correlations > 0.60 were evaluated for collinearity using variance inflation factor (VIF) >10. Stepwise regression model selection (PROC GLMSELECT and PROC LOGISTIC, entry/exit cutoff of $p < 0.10$) was cross-referenced with best subsets regression (PROC REG and PROC LOGISTIC) to build linear and logistic regression models for dominant/non-dominant wrist ratio and wrist ratio-based CTS risk categories (<0.7 vs. ≥ 0.7), respectively. Best subsets models were evaluated using adjusted R^2 and Mallow's C_p for linear models and correct classification percentage, Hosmer-Lemeshow goodness of fit, Akaike's information criterion (AIC), and Bayesian information criterion (BIC) tests for logistic models. The resulting regression models were evaluated for the need for statistical transformations via the distribution of residuals and plots of predicted versus residual values.

3. Results

We recruited and collected data from 228 participants; two were excluded from final analyses due to an extreme value in at least one measure (±4 standard deviations from the mean). The remaining 226 participants (Table 1) were predominantly female (86.7%), White or Asian (45.1%, 40.3%), right-handed (93.8%), with a mean age of 24.7 (SD: ±3.3) years and a healthy BMI. For all exploratory analyses, race categories other than White or Asian were collapsed into a third group due to small sample sizes. Age and BMI were determined to be non-normally distributed and were analyzed using nonparametric tests for between-group and within-participant comparisons.

Reliability for all CT sonographic measures ranged from good to excellent[34] for dominant and non-dominant wrists (Table 2). The average values for all external wrist and internal sonographic CT measures are presented in Table 3. The mean CT ratios for dominant and non-dominant wrists (0.45) were far lower than those of corresponding average wrist ratios (0.71). Using a wrist ratio threshold of ≥ 0.70 for risk classification, approximately two-thirds of participants fell into the ‘at risk’ category for dominant (n=148; 65.5%) and non-dominant (n=153, 67.7%) wrists. Variances of both wrist width and CT width exceeded those of the corresponding depth measurements, though the variance difference between width and depth was larger for CT measures than for wrist measures. That is, CT width variance was 2.8- and 3.7-times depth variance for dominant and non-dominant wrists—more than double that of the corresponding external measures (i.e., width variance 1.4- and 1.3-times depth variance).

Minor differences were observed in non-dominant wrist ratios and dominant CT depth (Cohen’s $d = 0.39, 0.47$). While male participants exhibited larger measurements for both external wrist and sonographic CT measures, no significant difference between genders was detected for wrist or CT ratios. Between Asian and White participants, moderate effect size differences (Cohen’s d between 0.50 and 0.65) were detected for dominant/non-dominant wrist width, dominant/non-dominant CT CSA, and non-dominant CT depth.

Correlations between wrist and CT shape measures are detailed in Table 4. Carpal tunnel width and depth were moderately correlated with the external counterparts (0.33–0.41, $p<0.001$); however, there was weak to no correlation between the external wrist ratio and internal CT ratio (dominant: $r = 0.12$, $p = 0.053$; non-dominant: $r = 0.20$, $p = 0.002$). These results were not significantly altered when controlling for age, gender, race, or BMI. Wrist width was equivalently associated with both CT width and depth (dominant: 0.41; non-dominant: 0.35–0.42), yet CT width and depth were not significantly correlated with each other. In contrast, wrist width and depth were strongly correlated. Furthermore, neither wrist ratio nor CT ratio was associated with CT CSA. Lastly, CT width was strongly associated with CT ratio (dominant: −0.54; non-dominant: −0.60), while wrist width was not associated with wrist ratio.

No collinearity was detected among potential internal measure predictors of carpal wrist shape (all VIFs ≤ 2.5). Among the final regression models (Figure 2), transformation of continuous variables did not significantly improve residual distributions or model fit. Additionally, no significant interactions were detected within the final models; therefore, no further adjustments were made to the final models. BMI was included in all final models, while race and CT width were included in three of the four final models. CT ratio replaced CT width in the non-dominant logistic model. However, linear models only accounted for < 15% of the variability of wrist ratio, and logistic models only correctly predicted participants' risk category < 68% of the time (i.e., based on wrist ratio ≥ 0.70).

4. Discussion

We conducted a cross-sectional study of 226 healthy young adults to assess inter-rater reliability for basic sonographic measures of carpal tunnel shape and to explore the relationship between external wrist shape and sonographic carpal tunnel features, accounting for several demographic characteristics. Our results demonstrate good to excellent reliability between raters for basic sonographic measures of CT CSA, depth, and width, which builds upon previous findings establishing the validity[35,36] and reliability[36–39] of sonographic measurement of structural features of the carpal tunnel. To our knowledge, our study is the first to report observed relationships among individual wrist and carpal tunnel shape measurements beyond simple ratios. Importantly, our findings of limited associations between external wrist shape and internal carpal tunnel shape raise questions about the validity of using external wrist measures as a proxy for internal anatomical features of the carpal tunnel. Additionally, consideration of internal CT measures and personal demographics may help advance understanding of carpal tunnel syndrome risk based on external wrist measures.

Our findings on the relationship between wrist ratio and CT ratio (dominant: 0.13, $p = 0.053$; non-dominant: 0.20, $p = 0.002$) are numerically similar to Chiotis et al. (2013),[26] who observed a correlation of 0.22 ($p = 0.054$) at the pisiform-level and 0.32 ($p = 0.002$) at the hamate-level of the carpal tunnel. The weak overall correlation demonstrated within these two studies, as well as apparent differences in mean wrist and CT ratios (0.71 vs. 0.45 in our study, 0.68–0.71 vs. 0.42–0.56 in healthy controls of other studies),[21,26] suggests that external wrist shape is not necessarily a proxy or equivalent measure for CT shape. Furthermore, our finding of no association between wrist width and wrist ratio vs. a strong association between wrist depth and wrist ratio (dominant 0.55; non-dominant: 0.58) contradicts other studies on wrist ratio, which have identified wrist width as the primary contributor to differences in wrist shape.[23,40]

We observed several key indicators among the relationships of individual wrist and carpal tunnel measures that help explain the lack of similarity between wrist and carpal tunnel shapes (Figure 3). First, for dominant and non-dominant wrists, there was greater variance in CT width than wrist width relative to corresponding depth measures (CT: width variance 2.8- and 3.7-times depth variance; wrist: width variance 1.4- and 1.3-times depth variance). Second, wrist width was equivalently associated with CT width and depth, while wrist depth was more strongly associated with CT depth than CT width. Additionally, counter to expectations, wrist width was equally or more strongly associated with CT depth than wrist depth itself (wrist width vs. CT depth: 0.41, 0.42; wrist depth vs. CT depth: 0.33, 0.40) for dominant and non-dominant wrists. Stated another way, wrist width seems to be the most strongly associated external measure with individual CT measures (width, depth); however, wrist width is not associated with CT ratio due to its equivalent associations with both CT width and depth. Conversely, wrist depth's differential association with CT width and depth (depth > width) produces a significant but small correlation with CT ratio (dominant:

0.15; non-dominant: 0.22). Third, there appear to be differential relationships between wrist width and depth (strongly correlated at 0.76, 0.77) and their analogous CT measures (not correlated) for dominant and non-dominant wrists. Fourth, CT width is strongly correlated with CT ratio (dominant: −0.54; non-dominant: −0.60), yet wrist width is not associated with wrist ratio. Overall, the relationship between external wrist shape and internal CT shape seems far more complex than previously thought. Thus, when clinicians use wrist shape to assess the risk of CTS, they must be mindful that the outcome does not necessarily indicate compression or pathology related to carpal tunnel shape, and in fact, the relationship between wrist shape and CTS risk continues to be ambiguous.

In our regression modeling, race, BMI, CT width, and CT ratio were identified as predictors of wrist ratio. However, the identified combinations of factors still did not sufficiently explain external wrist shape, as linear models represented < 15% of wrist ratio variability and logistic models correctly predicted < 68% of risk category assignment. These predictors should be considered highly preliminary due to the relaxed requirements of our model building. BMI has previously been found to have a weak to moderate relationship with wrist ratio[41–43] and to be an effect modifier of the relationship between wrist ratio and CTS.[24] Moreover, CT width demonstrated a stronger correlation with wrist ratio (−0.21, bilaterally) than did CT ratio or CT depth, possibly due to CT width's comparatively larger variance. Overall, the combination of basic health/demographic factors and measures of carpal tunnel shape still do not adequately account for external wrist shape and therefore cannot be used to theoretically explain the relationship between wrist shape and CTS risk.

Wrist ratio,[21–23] CT ratio,[21,26,44] and CT CSA (especially relative to median nerve CSA)[38,45,46] all have been previously linked to developing CTS, with significant differences in wrist and CT ratio observed between participants with CTS and controls. However, our data demonstrated little to no correlation between these three measures. This occurs not only because of the previously discussed differences between internal and external height and width but also because the CT is not a perfect ellipse, such that the CT ratio is also not a perfect approximation of the CT CSA. As such, all three of these measures may be independent risk factors for CTS rather than approximations or reflections of each other. Further exploration of the interrelationship or combined predictive validity of these factors among a sample of participants who have developed CTS would assist in understanding the interrelationship and predictive value of varied combinations of these factors. Combining the external measure of wrist ratio with sonographic measures of CT shape could provide more precise information on the risk and etiology of CTS than wrist ratio alone.

Finally, we note that the mean wrist ratio of our sample (0.71) was higher than healthy control participants of several other studies (0.67–0.70),[21,40–42,47–51] resulting in a larger proportion of participants falling into the 'at risk' (≥ 0.7) category for CTS (66–68% vs. 44–48% in other studies).[42,50] The finding of average wrist ratios above the risk threshold in a healthy participant sample around 0.71 is not uncommon[26,33] and may result from differences in sample demographics. For example, we observed a significant difference in wrist width between White and Asian participants (dominant: 1.9mm, non-dominant: 2.2mm, $p < 0.001$) within our sample. Unfortunately, we could not compare this finding or the distribution of race-based groups to other studies, as race differences or distributions for wrist ratio have not previously been reported. In addition, the mean age of our sample (25 years) was lower than the healthy control participants in other studies (43–54 years), such that those individuals with a higher wrist ratio may not yet have been exposed to other factors contributing to CTS. Although there were few males in our study (n=30), we did not detect gender-based differences in wrist ratio as noted in previous studies.[47,48] It is also possible that the anatomical differences we observed between participants and between dominant/non-dominant wrists were in part due to varying activity levels and usage of upper extremities over time, consistent with phenomena such as Wolff's Law.[52] Overall, our data suggests there may be population-related differences in wrist ratio, which calls into question the conventional CTS risk threshold of 0.70. Further investigation of the relationship between CTS risk, wrist shape, and demographic characteristics is needed.

4.1 Limitations

Due to insufficient sample size in several race-based categories, all participants who were not White or Asian were combined into a third category of 'other.' Therefore, between-race comparisons were limited to White, Asian, and neither White nor Asian. The heterogeneity of this third group limits the ability to draw inferences regarding the impact of membership in that group on wrist and carpal tunnel measures. Furthermore, our sample's relatively narrow demographics potentially limits external validity, and our limited sample of male participants may have prevented us from detecting sex-related anatomical differences. Additionally, many morphological studies of the carpal tunnel examine cross-sectional features at the level of the hook of the hamate.[53] Our analysis was limited to pisiform-level cross-sectional images of the carpal tunnel and does not necessarily generalize to other cross-sectional levels of the carpal tunnel (e.g., the hook of the hamate); however, there is some evidence that width, depth, and CSA are similar throughout the length of the carpal tunnel.[54] It is also possible that confounders such varying activity level or upper extremity usage contributed to anatomical differences, as these factors were not captured in our data collection.

Thus, our findings should be considered preliminary. Moreover, this study did not include participants diagnosed with CTS or follow participants longitudinally to monitor for CTS development. Therefore, within our sample, no conclusive inferences can be drawn on the direct relationship between wrist or CT shape and risk for CTS. Likewise, as the mean age of our sample was far younger than the age at which CTS typically develops, it is impossible to determine whether this asymptomatic sample is analogous to healthy controls in other studies investigating the relationship between wrist shape and risk for CTS.

5. Conclusions

Basic sonographic measures of CT shape are reliable between raters. Overall, among young, healthy adults there appears to be a different relationship between external wrist measures than between analogous CT measures, indicating that wrist shape is not a direct proxy for CT shape. Moreover, even when combined with other anatomical and demographic factors, basic carpal tunnel dimensions do not adequately explain external wrist shape. Instead, wrist ratio, CT ratio, and CT CSA may be independent predictors of carpal CTS risk, though this requires confirmation among a sample that includes participants diagnosed with CTS. Future investigations on the relationship between wrist shape and CT features should examine additional CT characteristics (e.g., carpal bone or flexor tendon size, shape, and positioning). Lastly, our data suggests that there may be population-related differences in wrist shape, which has implications for the validity of established CTS risk thresholds among different populations.

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DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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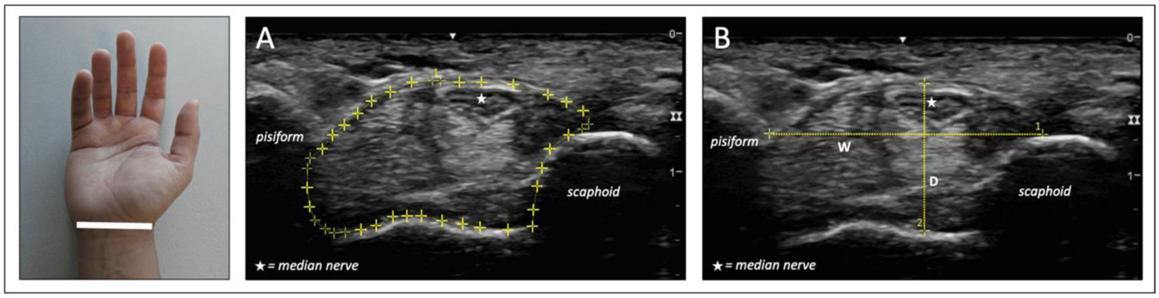

Figure 1.

Carpal tunnel measures from cross-sectional sonographic images at the pisiform level. **A:** carpal tunnel cross-sectional area, calculated via tracing the inner perimeter of the carpal tunnel using the transverse carpal ligament and proximal row of carpal bones as the boundaries. **B:** carpal tunnel width, measured as the distance between insertions of the transverse carpal ligament, and carpal tunnel depth, measured as the longest vertical from the transverse carpal ligament to the deep carpal bone.

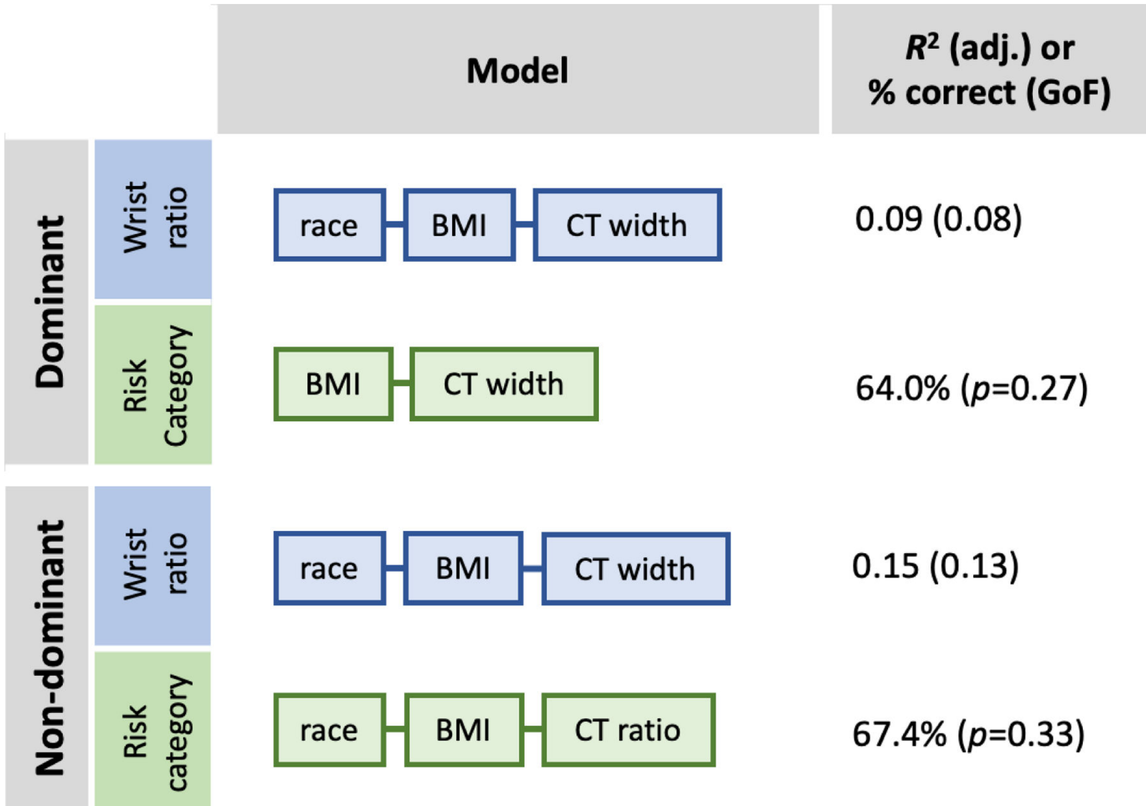

Figure 2.

Final linear (blue) and logistic (green) regression models predicting dominant and non-dominant external wrist shape, created by cross-referencing stepwise regression (entry/exit p=0.10) and best subsets model selection. *Abbreviations: GoF = Hosmer Lemeshow goodness of fit test (non-significant p-value indicates acceptable fit), BMI = body mass index, CT = carpal tunnel, CSA = cross-sectional area.*

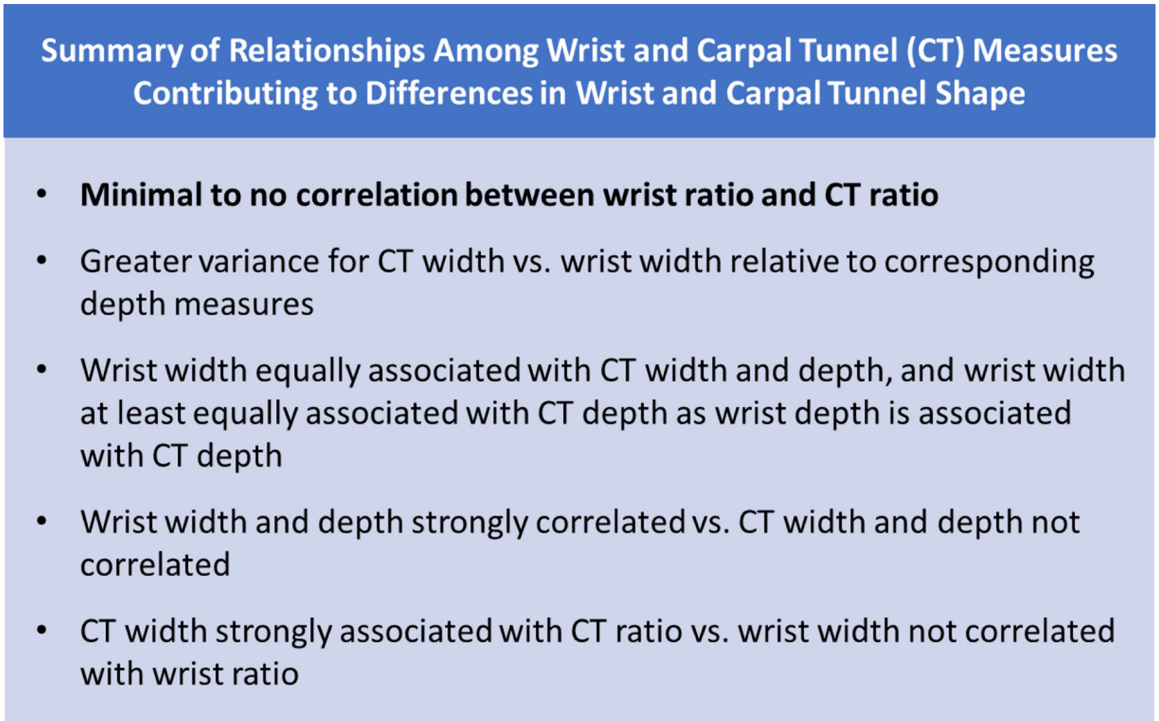

Figure 3.

Observed relationships among external wrist and internal carpal tunnel measures that highlight the complexity of the relationship between wrist shape and carpal tunnel shape and indicate the potential independence of these anthropometric measures relative to predicting risk for disease development.

Table 1.

Descriptive statistics of the healthy participant sample evaluated in this study (n = 226)

	Mean (SD) or frequency (%)
Age, years	24.7 (3.3)
BMI, kg/m^2	22.9 (3.9)
Gender, male	30 (13.3%)
Handedness, right	212 (93.8%)
Race	
American Indian/Alaska Native	2 (0.9%)
Asian	91 (40.3%)
Native Hawaiian or other Pacific Islander	1 (0.4%)
Black	4 (1.8%)
White	102 (45.1%)
Other	26 (11.5%)
Ethnicity, Hispanic	46 (20.4%)

Table 2.

Inter-rater reliability of sonographic carpal tunnel measures

Carpal Tunnel Measure	Dominant (n=20) ICC (95% CI)	Non-dominant (n=20) ICC (95% CI)
Height	0.88 (0.73–0.95)	0.95 (0.87–0.98)
Width	0.79 (0.54–0.91)	0.92 (0.80–0.97)
CSA	0.89 (0.73–0.96)	0.95 (0.88–0.98)

ICC = Intraclass correlation coefficient, CSA = cross-sectional area

Table 3.

Mean (SD) for all external wrist and internal sonographic carpal tunnel measures (n=226)

	Dominant mean (SD)	Non-dominant mean (SD)
Wrist ratio (depth/width)	0.71 (0.04)	0.71 (0.04)
Wrist depth (mm)	36.11 (2.97)	35.78 (2.98)
Wrist width (mm)	50.63 (3.51)	50.06 (3.42)
Carpal tunnel ratio (depth/width)	0.45 (0.06)	0.45 (0.06)
Carpal tunnel depth (mm)	10.33 (1.21)	10.28 (1.15)
Carpal tunnel width (mm)	23.25 (2.03)	22.80 (2.23)
Carpal tunnel CSA (mm^2)	191.03 (27.60)	186.70 (27.15)

CTS = carpal tunnel syndrome, CSA = cross-sectional area

Table 4.

Correlations among external wrist measures, internal sonographic carpal tunnel measures, and combinations of the external and internal measures (n=226)

	Dominant	Non-dominant
External wrist – external wrist		
Wrist depth, wrist width	**0.76** **	**0.77** **
Wrist ratio, wrist depth	**0.55** **	**0.58** **
Wrist ratio, wrist width	−0.13	−0.08
Carpal tunnel – carpal tunnel		
Carpal tunnel depth, carpal tunnel width	0.11	0.08
Carpal tunnel ratio, carpal tunnel depth	**0.77** **	**0.74** **
Carpal tunnel ratio, carpal tunnel width	**−0.54** **	**−0.60** **
Carpal tunnel ratio, carpal tunnel CSA	**0.19** *	0.12
Carpal tunnel CSA, carpal tunnel depth	**0.69** **	**0.65** **
Carpal tunnel CSA, carpal tunnel width	**0.61** **	**0.62** **
External wrist – carpal tunnel		
Wrist depth, carpal tunnel depth	**0.33** **	**0.40** **
Wrist depth, carpal tunnel width	**0.21** *	**0.15** *
Wrist depth, carpal tunnel ratio	**0.15** *	**0.22** *
Wrist depth, carpal tunnel CSA	**0.46** **	**0.40** **
Wrist width, carpal tunnel width	**0.41** **	**0.35** **
Wrist width, carpal tunnel depth	**0.41** **	**0.42** **
Wrist width, carpal tunnel ratio	0.08	0.10
Wrist width, carpal tunnel CSA	**0.61** **	**0.55** **
Wrist ratio, carpal tunnel ratio	0.13	**0.20** *
Wrist ratio, carpal tunnel depth	−0.01	0.09
Wrist ratio, carpal tunnel width	**−0.21** *	**−0.21** *
Wrist ratio, carpal tunnel CSA	−0.08	−0.09

* Significant at $p < 0.05$

** Significant at $p < 0.001$

CSA = cross-sectional area