Importance of Tissue Morphology Relative to Patient Reports of Symptoms and Functional Limitations Resulting From Median Nerve Pathology

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MeSH TERMS
- carpal tunnel syndrome
- median nerve
- risk factors
- signs and symptoms
- tissues
- ultrasonography

Significant data exist for the personal, environmental, and occupational risk factors for carpal tunnel syndrome. Few data, however, explain the interrelationship of tissue morphology to these factors among patients with clinical presentation of median nerve pathology. Therefore, our primary objective was to examine the relationship of various risk factors that may be predictive of subjective reports of symptoms or functional deficits accounting for median nerve morphology. Using diagnostic ultrasonography, we observed real-time median nerve morphology among 88 participants with varying reports of symptoms or functional limitations resulting from median nerve pathology. Body mass index, educational level, and nerve morphology were the primary predictive factors. Monitoring median nerve morphology with ultrasonography may provide valuable information for clinicians treating patients with symptoms of median nerve pathology. Sonographic measurements may be a useful clinical tool for improving treatment planning and provision, documenting patient status, or measuring clinical outcomes of prevention and rehabilitation interventions.


Carpal tunnel syndrome (CTS), the most frequently occurring of all compression neuropathies, primarily occurs as a result of compression of the median nerve in the carpal tunnel, which eventually leads to sensorimotor and occupational performance deficits. Significant research has investigated physical, occupational exposure, and personal factors related to CTS, and limited research has investigated the impact of psychosocial risk factors. However, little research has evaluated how these factors relate to the physiological status of the median nerve among people with varying levels of symptomatology.

Hazardous occupational exposures, such as vibration, direct compression, and prolonged highly repetitive and forceful hand–wrist tasks, are the most common risk factors researched for CTS (Barr, Barbe, & Clark, 2004; Bongers, Ijzmer, van den Heuvel, & Blatter, 2006). Additionally, evidence has indicated that increased compression of the median nerve occurs as a result of various wrist positions (Viikari-Juntura & Silverstein, 1999). Forearm pronation and supination increase pressure in the carpal tunnel (Rempel, Bach, Gordon, & So, 1998), wrist flexion and extension can reduce the area within the carpal tunnel (Skie, Zeiss, Ebraheim, & Jackson, 1997), and prolonged or repetitive ulnar deviation of the wrist causes lateral compression of the median nerve (Hägg, Öster, & Byström, 1997). Of all positions, the anterior movement of the large flexor tendons during wrist flexion, combined with decreased space in the canal, creates the greatest compression of the median nerve (Keir, 2001).

Gender and anthropometry are two personal factors with the highest association with CTS (Feuerstein, Shaw, Nicholas, & Huang, 2004; Huang,
Feuerstein, & Sauter, 2002). The prevalence of musculoskeletal disorders is 2–4 times higher among women (Lundberg, 2002; Park, Krebs, & Mirer, 1996), and women are significantly more likely to develop symptoms in the hand and wrist (Hagberg, Vilhemsson, Tornqvist, & Toomingas, 2007). Secondary to gender, wrist ratio (anterioposterior depth divided by mediolateral width) is one of the primary factors with a strong relationship to CTS (Gordon, Johnson, Gatens, & Ashton, 1988; Kamolz et al., 2004; Radecki, 1994). Among people with CTS, >75% have a square-shaped wrist (ratio >0.70; Radecki, 1994), and as the ratio increases (>0.75), so does the association with CTS (Lim, Tan, & Ahmad, 2008).

Despite the extent of hazardous occupational exposures and contributory personal factors, an increase in exposure to psychological stressors in the environment can be related to musculoskeletal symptoms (Devereux, Vlachonikolis, & Buckle, 2002). Negative psychological stress is correlated with a significant increase in motor unit activation in muscles of the upper extremity (Rissén, Melin, Sandsjö, Dohns, & Lundberg, 2000), and psychological demands of a job and the ability to control work tasks have been linked to changes in health (Bongers, Kremer, & ter Laak, 2002). Additionally, increased psychological strain can have a fundamental impact on quality of life and health across various occupations (Brisson et al., 1999; Edimansyah, Rusli, Naing, Mohamed Rusli, & Winn, 2007; Kawakami, Kobayashi, Arakı, Haratanı, & Furui, 1995).

Physiological changes in the median nerve leading to increased incidence of CTS are likely the result of a combination of occupational, personal, and environmental factors. Although a plethora of researchers have evaluated the predictive relationship of various personal and physical exposures to subjective symptoms (Farmer & Davis, 2008; Mattioli et al., 2009; Moghtaderi, Izadi, & Sharafadinzadeh, 2005; Sharifi-Mollayousefi et al., 2008), no studies have commented on the relationship of risk factors to median nerve morphology as predictors of these subjective reports.

Diagnostic ultrasonography is an accepted tool for observing median nerve morphology for diagnosis of CTS (Roll, Case-Smith, & Evans, 2011), and ultrasonography may be a valuable screening tool to identify median nerve pathology in an acute stage (Roll, Evans, Li, Freimer, & Sommerich, 2011). Ultrasonography is a pain-free, relatively inexpensive, and portable technology that can provide real-time images of tissues under the skin. Using ultrasonography, the size, shape, and overall appearance of the median nerve can be visualized, documented, and measured. Sonographic measurements are correlated to subjective symptoms of median nerve pathology (Kaymak et al., 2008), and these measures provide a method for documenting outcomes after carpal tunnel release (Mondelli, Filippou, Aretini, Frediani, & Reale, 2008). No studies have investigated the relationship of acute median nerve morphology to various risk factors, nor has it been investigated as an outcome measure for conservative treatments.

Successful prevention and rehabilitation techniques for median nerve pathology require an understanding of the acute physiology of the median nerve. The objectives of this research were to identify risk factors that may be predictive of subjective reports of symptoms or functional deficits and to determine the utility of including a measurement of morphology when planning or providing interventions for median nerve pathology. Our primary research question was, What is the relationship between current evidence-based risk factors for CTS and innovative measures of median nerve morphology, using gray-scale diagnostic ultrasonography, among people with varying symptomatology?

**Method**

The biomedical institutional review board of The Ohio State University approved the protocol, and all participants provided signed consent to participate.

**Participants**

The study sample was heterogeneous, maximizing the distribution and variability of data for an exploratory regression analysis. The sample included patients referred to a neurology clinic for evaluation of median nerve pathology and participants from a convenience population of nonpatient working adults. To be included, participants had to be of working age (18–65 yr old). Before consent, history of fracture or surgery in the dominant wrist, pregnancy or ≤3 mo postpartum, or any known rheumatic disorder, polyneuropathy, or uncontrolled thyroid disorder led to participant exclusion. The discovery of anatomic anomalies during data collection (i.e., bifurcated median nerve or Martin Gruber anastomosis) was a cause for exclusion after consent.

**Independent Variables**

A chart review provided each participant’s gender and date of birth for calculation of age (in years). Participants provided hand dominance, level of education, and occupational information on a questionnaire. Level of education was categorized as high school, college (i.e., associate’s or bachelor’s degree), or graduate education...
(i.e., master’s or doctoral degree). Participants indicated their level of employment (i.e., unemployed, part time, full
time, retired) and provided their occupational title. Body
mass index (BMI) was calculated for each participant on
the basis of height (cm) and mass (kg). Researchers used
an electronic caliper to measure the dominant wrist. We
calculated wrist ratio as the depth (mm) divided by the
width (mm) of the wrist.

We used a modified version of the Job Content
Questionnaire (JCQ; Karasek et al., 1998) to obtain
ratings of psychosocial strain in the workplace on the
basis of decision latitude (control) and psychological
demands. The JCQ has high validity ($\alpha = .73-.74$), and
responses to psychological demands have a moderate
Correlation to job control ($r = .20-.293$), making it
a good tool for categorizing job strain in various occu-
pations (Karasek et al., 1998). Job control and psycho-
logical demand scores on the modified version of the
questionnaire can range from 12 to 48. Participants
categorized as having active jobs had both control and
demands scale scores $>30$ points, and those in passive
occupations had scores $<30$ on both scales. Participants
who indicated having high control and low demands
were categorized as having low-strain occupations, and
participants who indicated having high demands and
low control were categorized as having high-strain
occupations.

A Logiq i hand-carried ultrasound console with a 12-
MHz linear array transducer (GE Healthcare Ultrasound,
Milwaukee, WI) was used to collect images of the median
nerve for every participant. Ultrasonography was com-
pleted using a previously published protocol (Roll &
Evans, 2009). Locations for collection of cross-sectional
images in the dominant upper extremity of each partic-
ent included (1) forearm 6 cm from the distal wrist
crease, (2) middle carpal tunnel at the level of the pisi-
form, and (3) distal carpal tunnel at the hook of the
hamate.

After collection of the three cross-sectional images,
researchers blinded to participant complaints completed
measurements of the median nerve images. Median nerve
morphology was observed using three different measures:
1. A direct trace along the inner hypoechoic (i.e.,
bright) border of the median nerve provided a mea-
surement of the cross-sectional area (CSA) of the
median nerve in forearm and mid–carpal tunnel.
2. Subtracting the CSA at the pisiform from the CSA in
the forearm provided a measurement of the change in
CSA, an indication of median nerve swelling.
3. Measurement of the perpendicular distance from the
outer edge of the flexor retinaculum to a line drawn
from the insertion points of the ligament on the
trapezium and hook of the hamate indicated the
amount of anterior bulging of the retinaculum.

To minimize error resulting from overestimating or un-
derestimating the measures, the researchers completed
each measurement 5 times, dropped the highest and lowest
measures, and averaged the remaining three measures.

**Dependent Variable**

Subjective report of symptoms or functional deficit re-
sulting from median nerve pathology (e.g., numbness and
pain, decreased ability to complete fine motor tasks)
provided a grouping mechanism that served as the de-
pendent measure in the regression model. Participants
completed the Boston Carpal Tunnel Questionnaire
(BCTQ; Levine et al., 1993) to provide a measure of
subjective symptom and functional status in the domi-
nant hand. Cronbach’s $\alpha$ values for the BCTQ range
from .80 to .90 for the Symptom Severity scale and from
.88 to .93 for the Functional Status scale, and both scales
have high test–retest reliability ($r = .91$ and .93, re-
spectively; Leite, Jerorsch-Herold, & Song, 2006). Re-
pondents to this questionnaire provide a rating that
indicates severity of symptoms or functional deficits re-
sulting from median nerve pathology on a scale ranging
from 1 to 5, where $1 = \text{no symptoms or limitations}$ and
$5 = \text{maximum symptoms or limitations}$. Participant
responses to questions on each scale were coded, and av-
average scores for both symptom severity and functional
status were obtained. Categorization as having complaints
of median nerve pathology included those participants
with average symptom severity or functional status
scores $>1.0$, and participants with average scores of 1.0 on
both scales had no complaints related to median nerve
pathology.

**Statistical Analysis**

We calculated descriptive statistics for each independent
variable, and participants were categorized on the basis of
BCTQ results. Occupations were categorized on the basis
of JCQ results to obtain a descriptive grouping for
qualitative discussion and comparison. We evaluated
differences between participants with and without com-
plaints for each independent variable, using $t$ tests or $\chi^2$
analysis as indicated by the level of measurement. Un-
adjusted odds ratios were calculated for the contribution
of each individual variable to the BCTQ grouping out-
come. Variables with small units of measure were ad-
justed to provide appropriate odds ratios relative to the
other variables. Multicollinearity analysis was completed
to ensure that no variables were highly correlated.
An exploratory stepwise binary logistic regression analysis was completed to evaluate the relationship of the independent variables to complaints of median nerve pathology. We entered variables into the stepwise model on the basis of unadjusted odds ratios. Because of published literature relating gender, age, and wrist ratio to symptoms, these variables were included in the final stepwise regression regardless of individual significance to ensure the model controlled for the contribution of these factors to the other variables. Final odds ratios were calculated for variables that met the selection criteria ($p = .10$) and that remained in the model after forward and backward stepwise iterations.

### Results

Ninety-five participants consented to participate in the study; anatomic anomalies led to the exclusion of 7 participants after consent. On the basis of BCTQ scores, 56 of the remaining 88 participants (63.6%) reported symptoms or functional limitations in their dominant hand. The $t$ tests and $\chi^2$ analyses indicated no differences in age, gender, hand dominance, height, or wrist ratio between the two groups (Table 1). Participants with complaints had less education and higher BMI ($p < .05$). Additionally, participants with complaints of symptoms and functional deficits had larger median nerve measurements than participants without complaints.

Categorization of the reported occupations by JCQ scores resulted in most participants being categorized as having active (42.0%; $n = 37$) or low-strain jobs (36.4%; $n = 32$). Ten participants (11.4%) reported being unemployed and were not included in the descriptive report. Nearly all participants with high-strain or passive jobs (10.2%; $n = 9$) were in the complaint group. Approximately two-thirds of participants with active jobs (e.g., nurse assistant, registered nurse, attorney) fell into the complaint group, whereas only half of participants with low-strain jobs (e.g., occupational therapists, physical therapists, professor) had complaints. Table 2 provides a descriptive listing of all the occupational titles reported by participants, categorized by responses on the JCQ and BCTQ.

Of the unadjusted odds ratios, those for BMI, education, and all sonography measures were significant predictors of symptoms or functional deficits ($p < .05$). CSA change was highly correlated with CSA at the pisiform and CSA in the forearm, but the latter two measures were not highly correlated. Therefore, the evaluation of the final model did not include CSA change because of the assumption that this measure shared too much information with the other uncorrelated variables. Although age, gender, and wrist ratio were not individually significant, previous literature dictated consideration of these variables in the final regression model. Independent variables were entered into the iterative stepwise model on the basis of the unadjusted odds ratios (Table 3) for predicting complaints of median nerve pathology on the basis of BCTQ responses.

A significant stepwise binary logistic regression model ($R^2 = .281$, $p = .002$) combined BMI, education, and CSA at the pisiform to predict the presence of complaints of symptoms or decreased function among the participants (Table 4). For every $1 \text{ mm}^2$ increase in CSA at the pisiform, participants were 1.3 times more likely to complain of symptoms, and odds were 1.1 times higher for each unit increase in BMI. Although not significant,

### Table 1. Participant Demographic Characteristics, by Subjective Complaints of Symptoms or Functional Deficits ($N = 88$)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Participants With Complaints ($n = 56$)</th>
<th>Participants Without Complaints ($n = 32$)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequencies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender, female:male</td>
<td>44:12</td>
<td>22:10</td>
<td>.306</td>
</tr>
<tr>
<td>Hand dominance, right:left</td>
<td>51:5</td>
<td>27:5</td>
<td>.341</td>
</tr>
<tr>
<td>Education, high school:college:graduate</td>
<td>27:18:11</td>
<td>5:17:10</td>
<td>.001</td>
</tr>
<tr>
<td><strong>Mean (Standard Deviation)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, yr</td>
<td>44.4 (11.5)</td>
<td>40.8 (12.3)</td>
<td>.163</td>
</tr>
<tr>
<td>Height, cm</td>
<td>166.3 (8.4)</td>
<td>169.0 (8.6)</td>
<td>.155</td>
</tr>
<tr>
<td>Mass, kg</td>
<td>88.5 (21.6)</td>
<td>74.2 (17.5)</td>
<td>.002</td>
</tr>
<tr>
<td>Body mass index</td>
<td>32.1 (7.7)</td>
<td>26.0 (6.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Wrist ratio</td>
<td>0.726 (0.044)</td>
<td>0.717 (0.044)</td>
<td>.351</td>
</tr>
<tr>
<td>Cross-sectional area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forearm, mm$^2$</td>
<td>6.06 (1.30)</td>
<td>5.55 (0.94)</td>
<td>.038</td>
</tr>
<tr>
<td>Pisiform, mm$^2$</td>
<td>11.11 (4.01)</td>
<td>8.32 (1.68)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Change, mm$^2$</td>
<td>5.06 (3.82)</td>
<td>2.77 (1.62)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Retinacular bulge, mm</td>
<td>3.26 (0.49)</td>
<td>2.86 (0.49)</td>
<td>.001</td>
</tr>
</tbody>
</table>
this exploratory model indicated a trend resulting from education whereby individuals with a high school education were 3.5 times more likely to complain of symptoms or functional limitations than those with graduate-level education.

**Discussion**

This preliminary study indicates that measures of median nerve morphology (i.e., CSA) may be more valuable for understanding symptoms of median nerve pathology than other previously studied factors. Previously, gender and wrist ratio were the primary personal factors studied for their relationship to CTS, whereas this analysis indicates that physiological measures of the median nerve using diagnostic ultrasonography have a stronger contribution to this disorder when considered with a patient’s BMI and level of education.

The outcomes of this exploratory analysis contrast with the results of previous studies exploring the predictability of sonographic measures. Kaymak et al. (2008) indicated that CSA measurements of the median nerve in the carpal tunnel had no correlation to the BCTQ symptom severity and functional status scales (−0.04–0.18).

### Table 2. Occupations Reported by Participants With and Without Complaints of Symptoms or Functional Deficits, by Job Content Questionnaire Results

<table>
<thead>
<tr>
<th>Active (n = 37)</th>
<th>Passive (n = 2)</th>
<th>Low Strain (n = 32)</th>
<th>High Strain (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants With Complaints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administrative assistant (2)</td>
<td>Personal banker</td>
<td>Administrative assistant (2)</td>
<td>Bus driver (2)</td>
</tr>
<tr>
<td>Attorney</td>
<td>Surgical technician</td>
<td>Babysitter</td>
<td>Registered nurse (3)</td>
</tr>
<tr>
<td>Audiologist</td>
<td></td>
<td>Customer service representative</td>
<td>Telemarketing representative</td>
</tr>
<tr>
<td>Cook, food service (2)</td>
<td></td>
<td>Dock worker</td>
<td></td>
</tr>
<tr>
<td>Educator, faculty (5)</td>
<td></td>
<td>Fellowship coordinator</td>
<td></td>
</tr>
<tr>
<td>Hospital administrator</td>
<td></td>
<td>Home health aide</td>
<td></td>
</tr>
<tr>
<td>Lifeguard</td>
<td></td>
<td>Homemaker</td>
<td></td>
</tr>
<tr>
<td>Lift operator</td>
<td></td>
<td>Insurance broker</td>
<td></td>
</tr>
<tr>
<td>Medical technologist</td>
<td></td>
<td>Janitor</td>
<td></td>
</tr>
<tr>
<td>Nurse anesthetist</td>
<td></td>
<td>Physical therapist</td>
<td></td>
</tr>
<tr>
<td>Nurse assistant</td>
<td></td>
<td>Physical therapist assistant</td>
<td></td>
</tr>
<tr>
<td>Painter, drywall (union)</td>
<td></td>
<td>Respiratory therapist</td>
<td></td>
</tr>
<tr>
<td>Paramedic</td>
<td></td>
<td>School librarian</td>
<td></td>
</tr>
<tr>
<td>Pharmacist</td>
<td></td>
<td>Therapy attendant</td>
<td></td>
</tr>
<tr>
<td>Registered nurse (2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scheduler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service manager</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprinkler fitter</td>
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</table>

| Participants Without Complaints | | | |
| Accountant | Administrative assistant (3) | | Undergraduate student |
| Administrative assistant | Electromyography technician | | |
| Educator, faculty (3) | Graduate student (5) | | |
| Finance director | Manager | | |
| Medical transcriptionist | Occupational or physical therapist (2) | | |
| Nurse case manager | Physical therapist assistant (2) | | |
| Registered nurse | Professor | | |
| Sonographer (2) | Speech–language pathologist | | |
| Tax reporting manager | Substitute teacher, emergency medical technician | | |

Note. N = 88; 10 participants were unemployed and not included in the analyses.

### Table 3. Unadjusted Odds Ratios of Predicting Symptoms and Functional Deficits on the Basis of Individual Characteristic Variables (N = 88)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.027</td>
<td>0.989, 1.067</td>
<td>.163</td>
</tr>
<tr>
<td>Gender (female vs. male)</td>
<td>1.667</td>
<td>0.624, 4.454</td>
<td>.308</td>
</tr>
<tr>
<td>Body mass index</td>
<td>1.146</td>
<td>1.057, 1.242</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school vs. graduate</td>
<td>4.909</td>
<td>1.362, 17.692</td>
<td>.015</td>
</tr>
<tr>
<td>Undergraduate vs. graduate</td>
<td>0.963</td>
<td>0.326, 2.843</td>
<td>.945</td>
</tr>
<tr>
<td>Wrist ratio (×100)</td>
<td>1.050</td>
<td>0.949, 1.163</td>
<td>.345</td>
</tr>
<tr>
<td>CSA at pisiform</td>
<td>1.390</td>
<td>1.137, 1.699</td>
<td>.001</td>
</tr>
<tr>
<td>Retinacular bulge (×10)</td>
<td>1.193</td>
<td>1.069, 1.331</td>
<td>.002</td>
</tr>
<tr>
<td>CSA change forearm–pisiform</td>
<td>1.326</td>
<td>1.091, 1.611</td>
<td>.005</td>
</tr>
</tbody>
</table>

Note. CSA = cross-sectional area.
Similarly, Mondelli et al. (2008) found no direct correlation between sonographic measures and the BCTQ in a surgical population with median nerve pathology. However, after including additional personal and occupational factors in a regression analysis of the same data, a relationship of sonographic measures to subjective reports was found (Mondelli et al., 2008). For every reduction in 1 mm² of CSA after surgery, the odds of subjective symptoms being normalized on the BCTQ increased by 20%-24%. Although this regression may support the success of surgical intervention rather than the relationship of physiology to symptoms, when combined with the results of our study, the data support continued investigation of the utility of sonographic measures in clinical practice.

The results in our study support previous research identifying BMI as a significant predictor of median nerve pathology. Our regression analysis indicated a slightly increased chance of symptoms with each unit increase in BMI, but the increased risk of CTS per unit increase in BMI has been noted to be as much as nearly double (Mohktaderi et al., 2005). Although the current study sample was not large enough to allow for a stratified comparison of various BMI levels, those with BMI >30 may be 4-9 times more likely to require surgical intervention for CTS than those with BMI <25 (Mattioli et al., 2009). Further evaluation is needed to better understand the relationship of BMI to tissue morphology and the presence of symptoms or functional deficits.

The significant influence of education on subjective reports was an unexpected outcome. Although we did not control for occupation, in theory more physically demanding jobs frequently require less education, whereas college and graduate education often lead to less physical occupations. Workers in blue-collar occupations may be up to 9 times more likely to have been surgically treated for CTS than workers in white-collar jobs (Mattioli et al., 2009). In a study of medical transcriptionists, those without a college education self-reported more upper-extremity symptoms than those with college education (Gelfman, Beebe, Amadio, Larson, & Basford, 2010). In our study, although the limited distribution of data from the JCQ disqualified those data from inclusion in the regression analysis, blue-collar occupations tended to be more typically associated with complaints. However, on the basis of the descriptive data set, many participants with skilled occupations also had complaints.

Although interesting, because none of these studies measured physical exposure, the relative importance of educational level and other occupational exposure data in development of pathology remains unclear. Moreover, the relative relationship of all personal, environmental, and occupational factors to tissue morphology requires further investigation. Use of sonography to measure CSA of the median nerve within the carpal tunnel appears to have value for predicting symptoms and functional deficits. Future studies using linear regression of the various independent factors on sonographic measures would provide stronger evidence and understanding of these relationships.

**Limitations**

A small, heterogeneous sample limits the ability to make broad generalizations on the basis of the results. Because of the disproportionate ratio of female to male participants in our sample, statistical power may not have been adequate to identify the contribution of gender. Matching participants on age and gender between clinical and nonclinical populations would provide better control of variables previously considered important. Categorization of participants relied on subjective reports, and diagnosis by electrodiagnostic studies was not considered; therefore, the study’s results are more applicable to an acute, clinical population with symptoms of median nerve pathology instead of a population with a chronic disorder. Finally, inclusion of precise psychosocial and physical exposure variables may enhance the interpretation of this study’s results.

**Implications for Occupational Therapy Practice**

The goal of rehabilitation research is to inform interventions that will prevent, reduce, or remediate disorders. CTS is often managed with splinting (Rempel, Dahlin, & Lundborg, 1999), but protective equipment alone will usually not completely remediate the problem. Similarly, effectiveness of workplace redesign to reduce physical loads remains inconclusive (van den Heuvel, de Looze, Hildebrandt, & Thé, 2003). A better understanding of physiology and tissue morphology may provide valuable...
information to improve or validate positive effects of therapeutic treatments.

The results of this cross-sectional data collection indicate that the physiological state of the median nerve is related to a person’s subjective experiences and occupational performance. Diagnostic ultrasonography has been successfully used in the workplace to quickly collect images of median nerve physiology without being obtrusive (Evans, Roll, Li, & Sammet, 2010), demonstrating significant implications for clinical practice. With the ability to visualize and appreciate swelling of the median nerve at the start of treatment, a therapist can confirm the pathophysiology that requires treatment.

The portability and advancing quality of sonographic equipment situates this technology perfectly for documentation of physiological changes within rehabilitation clinical practice (Roll & Evans, 2009). Continuous innovation in equipment designs and development of preset sonography parameters is making sonography equipment easier for nontraditional users to adopt. Sonography could be a highly useful tool for monitoring changes in the median nerve resulting from various physical exposures (Missere et al., 1998), and it follows that it could be useful in monitoring changes resulting from treatment exposure.

To summarize, the results of this study have the following implications for occupational therapy practice:
- Clinicians providing interventions for carpal tunnel syndrome and other work-related musculoskeletal disorders should consider how to best target these interventions to the underlying physiological mechanisms, an approach that may ultimately affect symptoms and functional status.
- Real-time visualization of pathophysiology and tissue morphology may improve the evaluation and interpretation of personal, environmental, or occupational risk factors for musculoskeletal disorders, leading to improved individualized treatment planning.
- Sonographic imaging is highly portable and can provide real-time visualization of tissue morphology. It may be a valuable clinical and research tool to enhance decision making and monitor changes in tissue morphology subsequent to therapeutic interventions.

Conclusion

In summary, this study demonstrates that morphology of the median nerve measured with diagnostic ultrasonography has an important relationship to subjective complaints of symptoms and functional limitations resulting from median nerve pathology. Additional research with larger samples is required to understand the interrelationship of various personal, environmental, and occupational factors with physiological changes. This study provides preliminary evidence for the use of sonography as a clinical tool for evaluating and monitoring median nerve pathology and measuring intervention outcomes.

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