ABSTRACT: To determine the role of personal variables as risk factors for carpal tunnel syndrome (CTS) and their relationship to severity of nerve conduction abnormality, we studied 210 consecutive symptomatic CTS patients and 320 control subjects without CTS symptomatology or known systemic disorders. The CTS group was classified according to the severity of nerve conduction changes. The risk factors for CTS and its severity were assessed by means of univariate and multivariate analysis. Presence of CTS was significantly related to increase of body mass index (BMI) and wrist index. More severe nerve conduction abnormalities were associated with greater age and wrist index but not with higher BMI.

EVALUATION OF AGE, BODY MASS INDEX, AND WRIST INDEX AS RISK FACTORS FOR CARPAL TUNNEL SYNDROME SEVERITY

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Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy in the upper limbs.3,24 Certain medical conditions, such as diabetes mellitus, thyroid disease, connective tissue disorders, amyloidosis, and acromegaly, are risk factors for developing CTS, as also is pregnancy.18 Personal factors such as age, body mass index (BMI, weight in kg/height2 in meters), and squarer wrist are also reported to be important risk factors.7,8,18 Dieck and Kelsey,5 after reviewing 40 CTS cases and 1,043 controls, identified a recent increase in body weight as a possible risk factor. Subsequently, Vessey et al.,27 studying 156 women with CTS in Oxford (out of a population of 17,092 women), found a statistically significant relationship between BMI and first consultation for CTS, and De Krom et al.4 found that obese persons had twice the risk for developing CTS than non-obese subjects. Others have published similar findings since that time.1,11–13,17,28 Nordstrom et al.14 found an increased BMI (≥30) in 46% of a CTS group compared to just 18% in controls. Tanaka et al.26 found an adjusted odds ratio for CTS of 2.0 for BMI ≥25.0, and Sungpet et al.25 observed that higher BMI increased the risk of bilateral CTS.

Johnson et al.7 in 1983 first described the association between wrist index (wrist depth/wrist width in millimeters) and CTS; their observations suggested a critical wrist index value of 0.70 above which median sensory distal latencies would be increased. Studying industrial workers, others found that 74% of subjects with wrist index >0.70 had CTS compared to 24% of subjects with an index of <0.70,6 and that wrist index was an important risk factor for CTS after BMI and age.12 Kuhlman and Hennessey10 recommended wrist measurement as part of physical examination in CTS patients. Some, however, found only a weak association between wrist index and distal median latencies19,21 or no abrupt risk increase above 0.70.16 Obese and inactive persons with a squarer wrist (high wrist index) may have more chance of developing CTS13 although a relationship of higher wrist index and CTS exists regardless of professional activities.17

The present study was done in a Brazilian population in order to determine the role of age, BMI,
and wrist index, in the development of CTS, and their relationship to the severity of nerve conduction abnormalities.

**METHODS**

**Patients.** From September 1998 to May 1999, we studied 210 consecutive patients with an electrophysiologically confirmed diagnosis of symptomatic CTS including hand paraesthesia, numbness, and pain mainly at night; isolated pain was not considered. Patients with diabetes mellitus but no electrophysiological evidence of polyneuropathy were included. Cases with only unilateral nerve conduction studies or previous CTS surgery, asymptomatic subjects, and those with clinical or electrophysiological evidence of polyneuropathy were excluded.

**Controls.** During the same period, 320 subjects without any known systemic disease or symptoms of CTS were studied as a control group; age and gender were matched by group. The controls were recruited outside the electromyography laboratory or hospital, and most of them were accompanying patients.

**Electrophysiology (Nerve Conduction Studies).** Patients were studied using LBM4-E (Bio-logics, Neuro Diagnostics Inc., Mundelein, Illinois) and Cantata (Dantec, Skovlunde, Denmark) electromyography machines. Palmar temperatures were maintained above 31°C (digital thermometer, Braile Biomedica, São Jose do Rio Preto, SP, Brazil). Electrophysiological diagnosis of CTS was based on median distal sensory latency (wrist-index finger; 14 cm), which was defined as abnormal when ≥3.7 ms; sensory median-ulnar difference (wrist–ring finger; 14 cm), considered abnormal when ≥0.50 ms; and median palm latency (palm to wrist; 8 cm) designated abnormal when ≥2.3 ms. All latencies were measured to the negative peak. Three groups were defined according to the severity of nerve conduction changes. Severity was designated as mild when median distal sensory latency was 3.7 to 4.4 ms, sensory median-ulnar difference was ≥0.50 ms, or median palm latency was ≥2.3 ms. Moderate severity was indicated by median distal sensory latency ≥4.5 ms, and marked severity (“severe”) by unrecordable median distal sensory nerve action potentials.

**Anthropometric Measures.** Patients and controls had BMI and wrist index calculated using an ordinary gauge and a plastic pachimeter. Wrist measurements were made at the wrist crease. Two of the authors (J.A.K. and M.P.A.M.) made the anthropometric measurements on the patients; measurements on the control group were made by three medical students.

**Reliability of Wrist Index Measurement between Examiners.** Measurements were made by all five examiners (two authors and three medical students) on a group of 15 subjects (30 hands), and the significance of the difference in means was calculated.

**Statistical Analysis.** The mean wrist index results obtained by the five examiners were compared using ANOVA with repeated measures (BMDP-2V, Statistical Software, Inc., Los Angeles, California). Univariate analysis (Epi Info 6, Atlanta, Georgia) was used for description and comparison of patients and controls. Continuous variables are presented as means ± SD. Student’s t-test was used for comparison between two means, and ANOVA for comparisons between more than two means. Multiple comparisons were done using Bonferroni’s correction. Categorical variables are presented by frequency of occurrence and evaluated using chi-square tests. A logistic regression analysis (BMDP-LR, Statistical Software, Inc.) was used to test the association between presence or absence of CTS and BMI and wrist index. An ordinal polychotomous logistic regression analysis (BMDP-PR, Statistical Software, Inc.) was used to test the association between the severity of nerve conduction abnormalities in CTS cases (mild/moderate/severe) and BMI, wrist index, and age. The final results of the ordinal polychotomous logistic regression model were used to calculate the predicted probabilities for each category of severity, with different ages and wrist index.

For both regression analyses only the right hand was used. The independent variables were analyzed in continuous form. The significance of each variable in the model was analyzed using Wald’s test. Adjusted odds ratios were calculated with 95% confidence intervals. The significance level used in all statistics was P = 0.05.

**Ethics.** The protocol was approved by the local ethics committee, and all studies were performed after informed consent had been obtained.

**RESULTS**

The wrist index measurements made by the five examiners showed no significant difference in means (F = 1.16; P = 0.333), implying measurements without any systematic bias by the examiners.

CTS was identified in 366 hands (200 right, 166 left) from 210 patients, being mild in 241, moderate in 91, and severe in 34. Table 1 shows gender, age,
right wrist index, and BMI in patients and controls; higher BMI and greater right wrist index were found in CTS cases when compared to controls ($P < 0.001$).

Table 2 shows age, right wrist index, and BMI for groups of patients with CTS of varying severity. Comparison of means between groups (ANOVA) showed significant differences for the variables BMI ($F_3 = 15.9; P < 0.001$) and wrist index ($F_3 = 8.8; P < 0.001$). Multiple comparison of means for the four groups with Bonferroni’s correction revealed that the differences in BMI between controls and mild CTS ($P < 0.01$) and between controls and moderate CTS ($P < 0.01$) were significant; the absence of a significant difference between controls and severe CTS was probably due to the small number of the latter (20 hands). The differences in right wrist index between controls and moderate CTS ($P < 0.01$) and between controls and severe CTS ($P < 0.05$) were significant; no significant difference was found between controls and mild CTS.

Logistic regression was used to evaluate risk factors for CTS. In the model, independent variables were wrist index and BMI, and the dependent variable was CTS. We were not able to include age, a known risk factor for CTS, because it was used for group matching. However, the final sample showed a small but statistically significant difference between the mean ages of the groups studied, so age was included in the model to control for potential confounding in the evaluation of BMI and wrist index as risk factors for CTS. The variables wrist index, BMI, and age were continuous. In the final model, the variables statistically associated with the presence of CTS were wrist index (OR = 1.11 for each increase of 0.01 units; 95% CI = 1.07–1.16; $P < 0.001$) and BMI (OR = 1.11 for each increase of 1.0; 95% CI = 1.05–1.16; $P < 0.001$).

Ordinal polychotomous logistic regression was performed to evaluate risk factors for severity of CTS, graded as mild, moderate, and severe (dependent variable). The model included age, wrist index, and BMI as independent variables. The final model showed that the variables that remained in the model significantly associated with an increase in CTS severity were increase in age (OR = 1.20 for each 5-year increase; 95% CI = 1.00–1.30; $P = 0.027$) and increase in wrist index (OR = 1.10 for each 0.01 units increase; 95% CI = 1.00–1.20; $P = 0.015$). Increase in BMI did not influence CTS severity.

The estimated parameters of the final model allowed us to calculate the probability that a given case will have electrophysiologically mild, moderate, or severe CTS. For example, if a person with CTS is 50 years old with a wrist index of 0.70, the probability of mild CTS would be 67.8%, moderate 23.6%, and severe 8.6% (Table 3).

DISCUSSION

The distribution of CTS patients by age and gender was similar to the existing literature.3,9,23 The BMI and wrist index were studied as risk factors for CTS after controlling for age (patients versus controls). Personal factors were also studied as risk factors for having more severe CTS and, in this case, age was added to BMI and wrist index. There is no consensus in the literature about the expression of electrophysiological severity in CTS, and in our study the three groups at least have a clear gradation.15,22 This study was not concerned specifically with classification of severity. We used only the right CTS in analyzing the relationship with personal variables in or-

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### Table 1. Comparison of wrist index, BMI and age* between patients and controls.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Controls</th>
<th>CTS</th>
<th>t-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>320</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Male gender</td>
<td>35 (10.9%)</td>
<td>26 (12.4%)</td>
<td>$\chi^2 = 0.610$</td>
</tr>
<tr>
<td>Age</td>
<td>47.3 ± 14.8</td>
<td>50.3 ± 10.8</td>
<td>$P = 0.012$</td>
</tr>
<tr>
<td>Right wrist index</td>
<td>0.689 ± 0.037</td>
<td>0.706 ± 0.041</td>
<td>$P &lt; 0.001$</td>
</tr>
<tr>
<td>BMI</td>
<td>25.4 ± 4.70</td>
<td>28.4 ± 5.00</td>
<td>$P &lt; 0.001$</td>
</tr>
</tbody>
</table>

BMI: body mass index; CTS, carpal tunnel syndrome.

*Mean ± SD.

### Table 2. Wrist index, BMI, and age* among controls and CTS groups of increasing electrophysiological severity.

<table>
<thead>
<tr>
<th>Right hand</th>
<th>n</th>
<th>Wrist index</th>
<th>BMI</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>320</td>
<td>0.689 ± 0.037</td>
<td>25.4 ± 4.7</td>
<td>47.3 ± 14.8</td>
</tr>
<tr>
<td>CTS mild</td>
<td>131</td>
<td>0.700 ± 0.039</td>
<td>28.3 ± 4.9</td>
<td>49.5 ± 10.7</td>
</tr>
<tr>
<td>CTS moderate</td>
<td>49</td>
<td>0.713 ± 0.045</td>
<td>28.6 ± 4.9</td>
<td>52.9 ± 10.9</td>
</tr>
<tr>
<td>CTS severe</td>
<td>20</td>
<td>0.715 ± 0.035</td>
<td>28.2 ± 4.6</td>
<td>52.6 ± 10.7</td>
</tr>
</tbody>
</table>

BMI: body mass index; CTS, carpal tunnel syndrome.

*Mean ± SD.

### Table 3. CTS severity: probability of occurrence.

<table>
<thead>
<tr>
<th>Age</th>
<th>Wrist index</th>
<th>Mild (%)</th>
<th>Moderate (%)</th>
<th>Severe (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.65</td>
<td>87.6</td>
<td>9.6</td>
<td>2.7</td>
</tr>
<tr>
<td>25</td>
<td>0.70</td>
<td>82.0</td>
<td>13.8</td>
<td>4.2</td>
</tr>
<tr>
<td>25</td>
<td>0.75</td>
<td>74.5</td>
<td>19.1</td>
<td>6.4</td>
</tr>
<tr>
<td>50</td>
<td>0.65</td>
<td>76.6</td>
<td>17.7</td>
<td>5.7</td>
</tr>
<tr>
<td>50</td>
<td>0.70</td>
<td>67.8</td>
<td>23.6</td>
<td>8.6</td>
</tr>
<tr>
<td>50</td>
<td>0.75</td>
<td>57.4</td>
<td>29.7</td>
<td>12.8</td>
</tr>
<tr>
<td>75</td>
<td>0.65</td>
<td>60.2</td>
<td>28.2</td>
<td>11.6</td>
</tr>
<tr>
<td>75</td>
<td>0.70</td>
<td>49.2</td>
<td>33.8</td>
<td>17.0</td>
</tr>
<tr>
<td>75</td>
<td>0.75</td>
<td>38.4</td>
<td>37.4</td>
<td>24.2</td>
</tr>
</tbody>
</table>

CTS, carpal tunnel syndrome.
order to minimize the problem of one fixed variable (BMI or age) and double structures (two wrists, two nerves) that can be clinically and electrophysiologically different.

The descriptive statistics comparing patients and controls showed statistically significant differences between BMI and wrist index, which were both increased in patients. Statistical comparisons between the three CTS groups of increasing severity revealed proportional increases in wrist index and age, but not in BMI. Logistic regression revealed a significant risk for developing CTS (adjusted odds ratio) with BMI and wrist index increase after controlling for age. An ordinal polychotomous logistic regression revealed a significant risk of more severe CTS (proportional odds ratio) with higher wrist index and greater age; BMI did not show an association with severity of CTS.

The relationship between BMI and CTS could be due to increased fat deposition in the carpal canal or higher hydrostatic pressure in the carpal tunnel in obese subjects. We are not aware of any references to the influence of BMI on CTS severity. The findings of the present article confirm the higher BMI of CTS patients compared to controls, but do not show increasing severity of CTS with higher BMI. There is no consensus about the etiopathological role of increased wrist index in CTS. There was no clear relationship between wrist dimensions and carpal canal dimensions. We are unaware of any previous studies regarding the influence of wrist index on CTS severity. The findings of the present article confirm the presence of a higher wrist index in CTS patients compared to controls, and also show an increased risk of more severe disease with higher wrist index.

The increasing risk of more severe CTS with increasing age was clearly demonstrated in the present work as in others. Axonal loss and vascular abnormalities associated with aging could increase peripheral nerve susceptibility to compression regardless of duration of symptomatology. In conclusion, the presence of CTS was associated with increasing BMI and wrist index; more severe electrophysiologic changes were associated with greater age and higher wrist index but not with BMI.

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REFERENCES


23. Stevens JC, Sun S, Beard CM, Ofallon WM, Kurland LT.


