Development of Risk Assessment Models for Carpal Tunnel Syndrome

Heecheon You

Industrial and Manufacturing Engineering

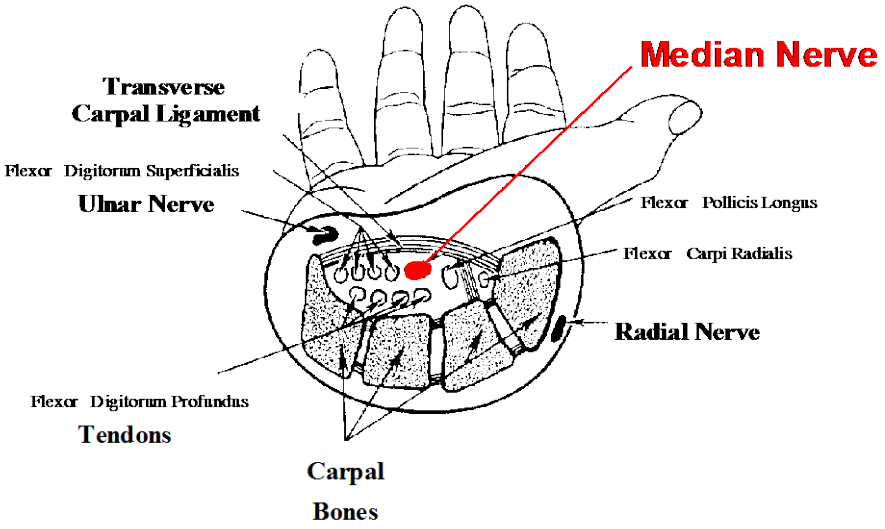
Wichita State University

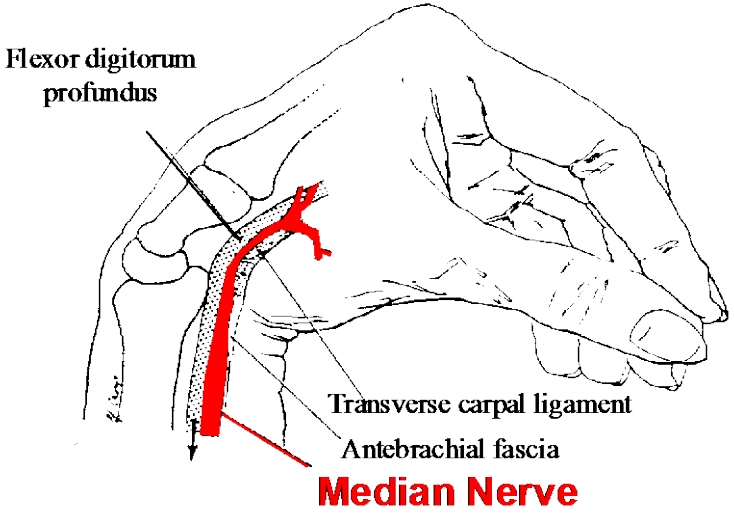
Agenda

- Introduction
  - ✓ Carpal Tunnel Syndrome
  - ✓ Problem Statement
  - ✓ Objectives
- Study Design & Materials
  - ✓ Case-Reference Design
  - ✓ Risk Exposure Assessment Method
- Model Development & Validation
- Conclusions

Carpal Tunnel Syndrome

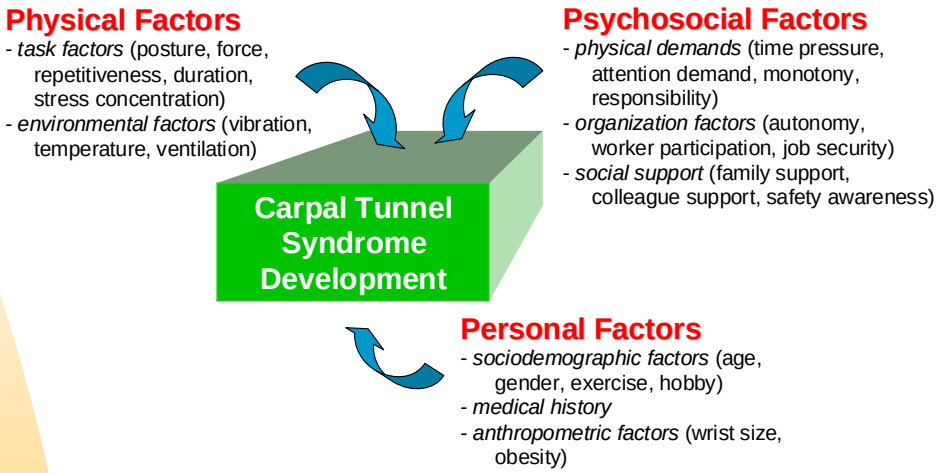
Peripheral neuropathy due to localized compression to the median nerve within the carpal tunnel at the wrist.





Limitations of Previous CTS Research

- Incomprehensiveness: Included a partial set of CTS risk factors.



⇒ Insufficient understanding of the relative contributions of risk factors to the development of CTS

- Differences in research protocol
- Qualitative findings

Limitations of Previous CTS Research (cont'd)

- Differences in research protocol
  - ✓ Case definition criteria
  - ✓ Risk exposure assessment methods

  ⇒ Difficult to compare and integrate various study results.

- Qualitative findings
  - ✓ Females, heavy individuals ⇒ more susceptible to CTS
  - ✓ Awkward postures, excessive grip forces, repetitive motions ⇒ increasing the risk of CTS

  ⇒ Need quantitative models explaining the relationship between risk exposure and CTS development.

Objectives

- Examine relative contributions of risk factors to the development of CTS by contrasting the risk exposures of case group with those of reference group.

- Develop quantitative risk assessment models for CTS.

  $\Rightarrow$ Estimate the likelihood of developing CTS for an individual exposed to certain occupational risks.

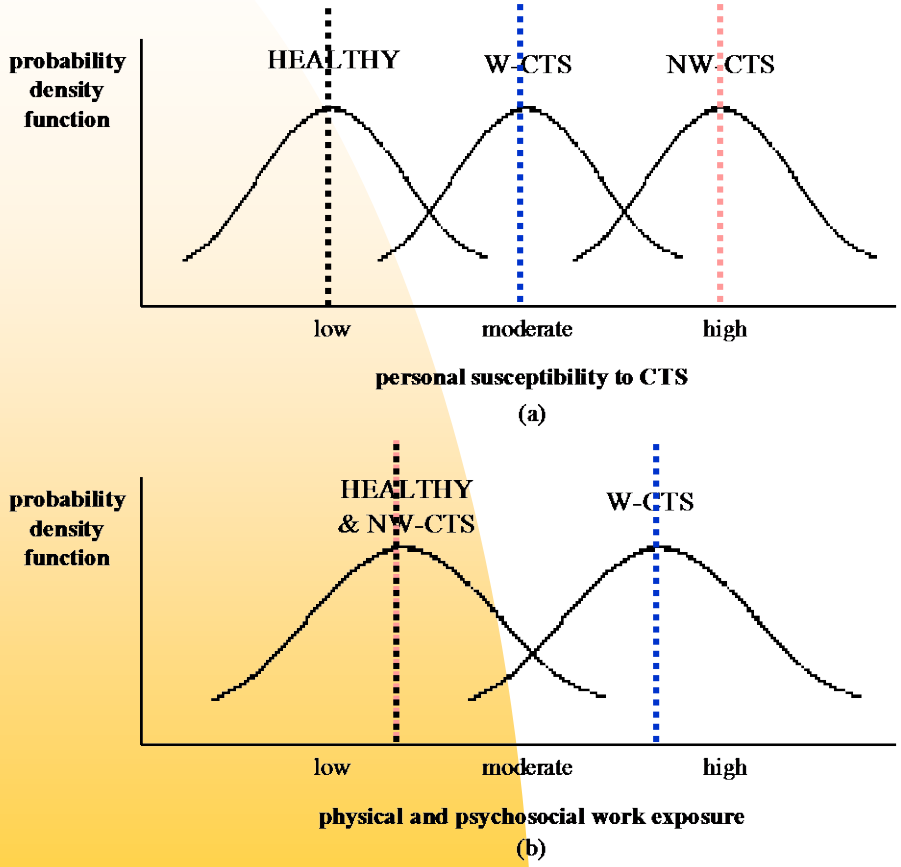
Study Design

- Case-reference design

Group		Size	Remarks
Case	Work-related CTS patients (W-CTS)	22	• Symptomatic CTS patients • Classification based on the type of medical insurance (W-CTS: workers' comp.; NW-CTS: others)
	Non-work related CTS patients (NW-CTS)	25	
Reference	Healthy workers (HEALTHY)	50	• No CTS symptom history

- ✓ Work experience on the current job > 1 year
  - Exclude cases due to pre-existing CTS conditions.
  - Obtain more valid occupational risk exposure assessment.

Hypothetical Features of Study Groups



Causation Matrix

Cause / Case	Personal susceptibility	Occupational exposure
W-CTS	●	●
NW-CTS	●	

Risk Exposure Assessment

- Used a CTS risk assessment questionnaire developed by You (1999).
  - ✓ Time: 1 to 1.5 hr/participant
  - ✓ Retrospective assessment of risk exposures
  - ✓ Contents

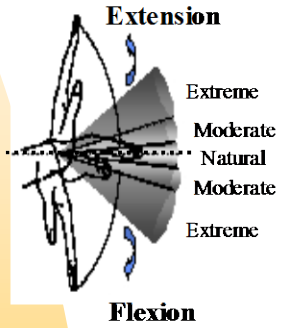
Risk Factor Category	# factors	Instruments adapted
Personal	29	Edinburgh handedness inventory, Bortner scale
Psychosocial	7	Kasl & Amick's questionnaire
Physical	9	Dynamometers

Physical Risk Assessment (example)

1. **Daily Hours of Work**: _____8____ *hours/day*

2. **Daily Hand-Wrist Use**

	Right hand						
	Almost Never (< 1%)	Rarely (1-10%)	Occa-sionally (11-20%)	Often (20-40%)	Frequently (40-60%)	Most of the time (60-80%)	Almost always (> 80%)
No use of the hands	☐ 1	☑ 2	☐ 3	☑ 4	☐ 5	☐ 6	☐ 7
Use of the hands	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☑ 7



3. **Wrist Flexion/Extension**

	Right hand						
	Almost never (< 1%)	Rarely (1-10%)	Occa-sionally (11-20%)	Often (20-40%)	Frequently (40-60%)	Most of the time (60-80%)	Almost always (> 80%)
Use of the hands	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☑ 7
Natural (within 5 degrees)	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5	☐ 6	☐ 7
Moderate (5 to 30 degrees)	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5	☐ 6	☐ 7
Extreme (above 30 degrees)	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	☐ 6	☐ 7

Risk exposure level

= *f* {duration, frequency, severity}

Risk Scale & Reliability

- Defined 106 risk exposure scales.

  (e.g.) smoking

  (1) smoking status (never/ex-smoker/current smoker)

  (2) smoking experience (no/yes)

  (3) smoking history during last 5 years (no/yes)

  (4) current status of smoking (no/yes)

  (5) years of smoking (never smoked/1-10/11-20/>20)

  (6) years of smoking (years)

  (7) smoking level (never smoked/1-10/11-20/>20 cigarettes/day)

- Screened 98 reliable risk scales.
  - ✓ Test-retest (>1 week apart) for 20 participants
  - ✓ correlation ≥ .7

Model Development Procedure

No	Phases	Technique
1	Variable screening	• Pseudo-univariate logistic regression
2	Risk prediction model development	• Multiple logistic regression
3	Model adequacy checking	• Hosmer-Lemeshow test
4	Classification model development	• ROC analysis
5	Model cross-validation	• Jack-knife technique

Pseudo-Univariate Logistic Regression

- Conducted multiple logistic regression for each risk scale including age, gender, and age×gender (common confounders for CTS risk).

- Screened risk scales if:
  - ✓ OR (odds ratio) agrees with previous findings
  - ✓ $P < .25$ (Afifi and Clark, 1990)

Risk Scale	NW-CTS / HEALTHY									
	Frequency				Adjusted for age and gender			χ^2 test		
	Cases		Referents		Odds Ratio	*P*	95% CI	χ^2	*d.f.*	*P*
Repetitive use of the hands and wrists for recreational activity										
Minimal (<1 hr/week)	6	24%	20	40%	1					
Low (1-3 hrs/week)	7	28%	8	16%	**3.87**	0.076	0.87 - 17.32	4.30	3	0.231
Moderate (3-5 hrs/week)	5	20%	14	28%	2.21	0.320	0.46 - 10.50			
Heavy (>5 hrs/week)	7	28%	8	16%	**3.91**	0.084	0.83 - 18.41			

Increased CTS risk

Multiple Logistic Regression

- Conducted multiple logistic regression with the screened risk scales.

Risk Scales	NW-CTS / HEALTHY					
	Coefficient (β)	Standard Error (SE(β))	Wald (*W*)	*d.f.*	*P*	Partial Correlation (*R*)
Age (AGE)						
Gender (GENDER)						
Hard Driving and Competitiveness (HD)			5.91	2	0.05	0.14
Low (<= 3.7)						
Moderate (3.8 to 4.7)	1.29	0.814	2.52	1	0.11	0.07
High (> 4.7)	1.97	0.818	5.81	1	0.02	0.20
Weight (WT)						
Wrist ratio - right hand (WR_R)	0.23	0.090	6.80	1	0.01	0.22
Female by WT	0.01	0.0041	6.40	1	0.01	0.21
AGE by WR_R	0.0012	0.0005	5.55	1	0.02	0.19
Constant	-23.46	6.974	11.32	1	<.01	

relative contribution

(risk scales whose *R*>.1 are bolded)

- Risk prediction: $$p = \frac{1}{1+e^{-(\alpha+\beta_1 X_1+\beta_2 X_2+...+\beta_p X_p)}}$$

CTS Risk Assessment Models

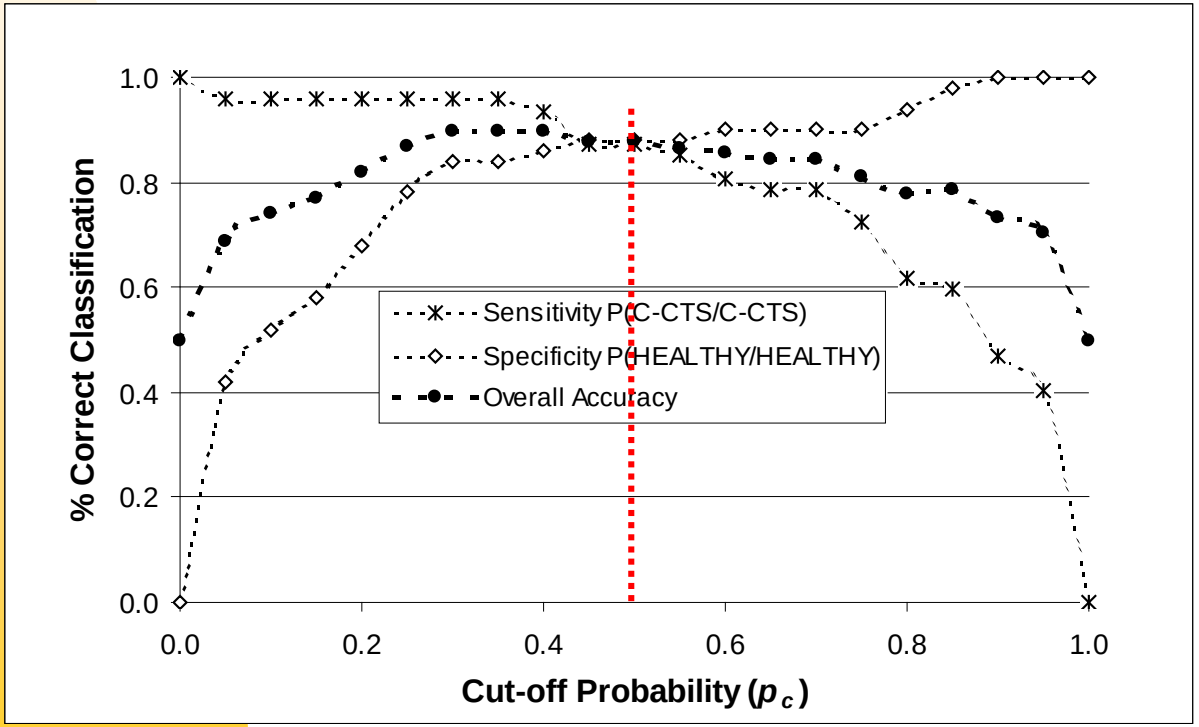
Risk Factors	Multiple Logistic Regression Models		
	W-CTS/ HEALTHY	NW-CTS/ HEALTHY	C-CTS/ HEALTHY
Personal Factors	1. **gender** (GENDER) 2. **wrist ratio of the right hand** (WR_R) 3. **musculoskeletal disorder history during last 5 years at the hands/wrists** (MD_5_D)	1. age (AGE) 2. gender (GENDER) 3. **behavioral pattern-hard driving and competitiveness** (HD) 4. weight (WT) 5. **wrist ratio of the right hand** (WR_R)	1. **age** (AGE) 2. gender (GENDER) 3. light of use of the hands/wrists for recreational activity (LU) † 4. weight (WT) 5. **wrist ratio of the right hand** (WR_R) 6. **musculoskeletal disorder history during last 5 years at the hands/wrists** (MD_5_D)
Psychosocial Factors	-	-	-
Physical Factors	1. use of heavy power grip forces (>20 lbs.) of the dominant hand (PW_20_D) 2. **use of heavy pinch grip forces (>5 lbs.) of the dominant hand** (PC_5_D) 3. **very highly repetitive motions (<1 sec./operation) of the dominant hands** (RE_1_D)	-	1. use of heavy pinch grip forces (>5 lbs.) of the dominant hand (PC_5_D) 2. very highly repetitive motions (<1 sec./operation) of the dominant hands (RE_1_D) 3. **exposure of the hands/wrists to extremely cold temperature (<50 deg. F)** (CO_E)

Causation Matrix

Cause / Case	Personal susceptibility	Occupational exposure
W-CTS	●	●
NW-CTS	●	

Classification Model

- Determined the cut-off probability (p_c) for each model which maximizes both sensitivity (Pr(case/case)) and specificity (Pr(referent/referent)) in an equal manner.



Classification Performance

Model	P_c	Sensitivity [P(case/case]	Specificity [P(referent/ referent)]	Overall accuracy	*d'*
W-CTS/ HEALTHY	.35	91%	88%	89%	2.5
NW-CTS/ HEALTHY	.37	84%	82%	83%	1.9
C-CTS/ HEALTHY	.50	87%	88%	88%	2.3

Model Cross-Validation

Model	Overall accuracy		Difference
	Original	Cross-validation (by Jack-knife method)	
W-CTS/ HEALTHY	89%	84%	-5%
NW-CTS/ HEALTHY	83%	76%	-7%
C-CTS/ HEALTHY	88%	86%	-2%

Conclusions

- Three multiple logistic models for CTS risk assessment were developed by a holistic approach.
- The risk assessment models showed a satisfactory discriminability and high classification accuracy.
- The assessment models indicates the significant variation in relative contribution of CTS risk factors depending on the work-relatedness of the nerve injury.
- Future work is needed to improve the CTS risk assessment models with more elaborated study group definitions and risk exposure assessment methods.

Q & A

Thank you for your attention!