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# A Theoretical Analysis of the Etiology of Idiopathic Carpal Tunnel Syndrome

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# A Theoretical Analysis of the Etiology of Idiopathic Carpal Tunnel Syndrome

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## Abstract

The etiology of carpal tunnel syndrome was studied by comparing the role of genetics, sleep position and sexual intercourse as possible causes of idiopathic carpal tunnel syndrome. The etiologic potential of the three theories was analyzed using a modified version of the Bradford Hill criteria of causation. All three theories scored equally well according to eight of the nine Bradford Hill criteria. When evaluated according to the ninth criterion which represented coherence, and comprised of seven non occupational risk factors for carpal tunnel syndrome, sexual intercourse emerged with the highest score. It is concluded that among the three etiologic mechanisms under consideration, repetitive motion during sexual intercourse is the most likely cause of non occupational carpal tunnel syndrome.

## Introduction

Carpal Tunnel Syndrome is a common form of neuropathic wrist pain that affects a significant part of the population (1, 2). Repetitive motion related to certain occupations is known to have an etiologic role in the development of carpal tunnel syndrome (3), but the cause of non occupational idiopathic carpal tunnel syndrome remains the subject of speculation (4).

There are currently three competing theories defining the etiology of idiopathic carpal tunnel syndrome. The first theory attributes the etiology of carpal tunnel syndrome to genetics (5, 6). The second theory proposes that sleeping on the side is a causal step in the etiology of carpal tunnel syndrome (7), whereas the third theory postulates that repetitive motion during sexual intercourse represents the most common cause of idiopathic carpal tunnel syndrome (8).

The present study is an attempt to determine the etiology of idiopathic carpal tunnel syndrome by analyzing the evidence for or against the three theories according to the Bradford Hill criteria of causation (9).

## Materials and Methods

The Bradford Hill criteria represent a set of theoretical tests that were developed by Sir Austin Bradford Hill in order to decide whether a particular association between a disease and a variable factor constitutes causation (9). By analyzing the evidence relevant to each criterion, a particular theory can be evaluated as to its etiologic validity. Below is a brief description of the Bradford Hill criteria. For an in depth understanding of the criteria, readers are advised to consult the original article by Bradford Hill (9) or a discussion of it (10).

- 1) **Strength:** The size of the effect of a factor as measured by statistical tests represents the strength of a particular factor. The greater the effect of the factor, the greater its likelihood of being an etiological factor.
- 2) **Consistency.** A particular factor has greater consistency if it has been reported by other investigators.
- 3) **Specificity:** A particular factor is specific if it is not associated with other factors that might be related to the disease under study, or does not cause a number of other diseases.
- 4) **Temporality:** A particular factor must precede a disease and not follow it in order to be considered etiologically relevant.
- 5) **Biological gradient:** A dose response relationship between a factor and a disease will argue in favor of an etiologic role for that factor.
- 6) **Plausibility:** A proposed theory would be plausible if it makes sense and does not contradict known biological principles.
- 7) **Experiment:** A disease often exhibits certain epidemiological trends which can be used as quasi experimental conditions in which a particular theory can be tested.
- 8) **Analogy:** In some cases parallels can be drawn between the disease/factor relationship under study and another known relationship composed of a similar disease and a similar factor.
- 9) **Coherence:** A theory provides coherence if it can explain currently known epidemiological phenomena. In the present study, coherence was expanded into seven sub-criteria each representing a known risk

factor for non- occupational carpal tunnel syndrome. The seven risk factors were obesity (11, 12), gender (1, 12), carpal canal size/shape (13, 14), contraceptive use (11, 15), breast/chest size (16, 17), marital status (18), and pregnancy (19).

#### Scoring:

The three theories were scored according to a method published earlier(20). A theory received no points if it was inconceivable or illogical with respect to a particular criterion, or if it was contradicted by available evidence. A theory received one point if it was conceivable or logical according to a particular criterion or the evidence supporting it was indirect or modest. A theory received two points if it was highly conceivable with respect to that particular criterion, or the evidence supporting it was substantial.

## Results

### 1) Strength:

According to a twin study of carpal tunnel syndrome (5) the ratio of case-wise concordance in monozygotic twins over the case-wise concordance in dizygotic twins was 1.48, a relatively modest ratio with a level of significance of  $P = 0.03$ . Therefore, genetics received one point for strength. The authors of the sleep position theory found a strong association between preference for sleeping on the side and the presence of carpal tunnel syndrome (7). Therefore, sleep position received two points for strength. Sexual intercourse received no points for strength since there are no statistical studies of the association between sexual intercourse and carpal tunnel syndrome.

### 2) Consistency:

Several studies have connected genetics with carpal tunnel syndrome (5, 6, 21). Therefore, genetics received two points for consistency. Sleep position received no points for consistency since the original study implicating sleep position as a cause of carpal tunnel syndrome has not yet been confirmed by others. No other studies have so far implicated sexual intercourse in the etiology of carpal tunnel syndrome; therefore sexual intercourse did not receive any points for consistency.

### 3) Specificity:

Genetics has been implicated in a variety of musculoskeletal disorders such as frozen shoulder (22) tennis elbow (22), back pain (23) and neck pain (24). Furthermore, cases of familial carpal tunnel syndrome are usually associated with other hereditary conditions

(25) Therefore, genetics received no points for specificity. Sleep position has also been implicated in a few other disorders such as shoulder pain (26) and temporomandibular disorder (27). On the other hand, it is known that there are different types of positions by which people can sleep on the side and it is possible that a particular type of side position may be relevant to the etiology of carpal tunnel syndrome. Therefore sleep position received one point for specificity. Sexual intercourse seems to be a specific cause of carpal tunnel syndrome since no other musculoskeletal disorder has been linked to it so far. Furthermore, it has been postulated that only those positions that involve supporting the upper body with the hands are likely to cause carpal tunnel syndrome (8). Therefore, sexual intercourse received two points for specificity.

### 4) Temporality:

If genetic factors are involved in the etiology of carpal tunnel syndrome, they would certainly precede the development of carpal tunnel syndrome since they are inborn. Therefore, genetics received two points for temporality. An increased prevalence of sleeping on the side was observed among those who suffered from carpal tunnel syndrome. However, no increased incidence of carpal tunnel syndrome was observed among side sleepers in the general population, making it impossible to rule out that carpal tunnel syndrome may have caused those individuals to sleep on the side. Sleeping on the side is known to improve respiratory function during sleep (28). It is therefore conceivable that those who suffer from carpal tunnel syndrome may choose the lateral position in order to obtain relief through improved breathing. Therefore, sleep position received one point for temporality. Although there are no observational studies to show that sexual intercourse preceded the development of carpal tunnel syndrome, it is highly inconceivable that a painful and disabling condition such as carpal tunnel syndrome would result in increased sexual activity. Therefore, sexual intercourse received two points for temporality.

### 5) Biological Gradient:

A study of carpal tunnel syndrome in twins found that the prevalence of carpal tunnel syndrome in monozygotic twins was only 4% higher than its prevalence in dizygotic twins (5), suggesting that either a biological gradient did not exist between the two groups, or if it did, it did not result in a significant difference in the prevalence of carpal tunnel syndrome. Therefore, genetics received no points for biological gradient. A greater preference for sleeping on the side was observed in patients with more severe symptoms of carpal tunnel syndrome (7). Since this biological

gradient referred to the severity of the disease, and not its occurrence, sleep position received only one point for biological gradient. A partial biological gradient was shown between sexual intercourse and carpal tunnel syndrome by demonstrating a parallel decrease in the incidence of carpal tunnel syndrome and the frequency of sexual intercourse between the sixth and seventh decades of life (8). Therefore, sexual intercourse received one point for biological gradient.

#### 6) Plausibility:

Genetics as a cause of carpal tunnel syndrome is highly plausible since there are well documented cases of familial carpal tunnel syndrome and other diseases (6, 22). Therefore, genetics received two points for plausibility. Deviation of the wrist is known to result in an increase in intra-carpal pressure (29). Such a deviation during sleep would be a plausible cause of carpal tunnel syndrome. Therefore, sleep position received two points for plausibility. Damage to the median nerve due to repeated hyperextension of the wrist under pressure during sexual intercourse is highly plausible. Therefore, sexual intercourse received two points for plausibility.

#### 7) Analogy:

Genetics has been implicated in a few other musculoskeletal disorders such as frozen shoulder (22) back pain (23) and neck pain (24). Due to such examples, genetics received two points for analogy. A few studies have proposed that sleep position could cause certain pain syndromes such as shoulder pain (26) and temporomandibular disorder (27). Therefore, sleep position received two points for analogy. Repetitive motion, of which sexual intercourse is an example, has been shown through many studies to be involved in the etiology of carpal tunnel syndrome (3,30), and other musculoskeletal disorders (31). Therefore, sexual intercourse received two points for analogy.

#### 8) Experiment:

Since there is no reason to believe that genetic factors would shift over time, quasi experimental conditions in the form of epidemiological trends that would affect the role of genetics are not expected to occur. Therefore, genetics received no points for experiment. There is evidence to suggest that preference for sleeping on the side increases with age and older individuals perform fewer position changes during sleep (32). These two trends should amplify the effect of sleeping on the side and cause an increase in the prevalence of carpal tunnel syndrome with old age. Numerous studies have shown that the prevalence of carpal

tunnel syndrome declines, rather than increases in old age (33, 34, and 35). Therefore, sleep position received no points for experiment. Certain developments such as the introduction of oral contraceptives (36) and erectile dysfunction treatment are likely to increase the frequency of sexual intercourse. An increase in the prevalence of carpal tunnel syndrome in the United States in the 1960s (37) coincided with the introduction of oral contraceptives during the same period. Furthermore, an increase in the prevalence of carpal tunnel syndrome among the middle aged and the elderly in Britain in the late 1990s and early 2000s (35) coincided with the introduction of erectile dysfunction therapy in the late 1990s. Therefore, sexual intercourse received one point for experiment.

#### 9) Coherence:

Obesity: A study of carpal tunnel syndrome in twins found that there was no overall effect of BMI other than a modest increase in the prevalence of carpal tunnel syndrome in the group aged 45-50years (5), suggesting a weak association between obesity and carpal tunnel syndrome of suspected genetic origin. Consequently, genetics received one point for obesity. No association was found between increased weight and preference for sleeping on the side (7) suggesting that obesity as a risk factor for carpal tunnel syndrome could not be explained by sleep position. Therefore, sleep position received no points for obesity. A heavier body is expected impose a heavier load on the wrists during sexual intercourse and increase the likelihood of overweight people to develop carpal tunnel syndrome. Therefore, sexual intercourse received two points for obesity.

Gender: Females were at a greater risk of having genetically acquired carpal tunnel syndrome than males but this risk (female/male ratio= 1.25) (6) was smaller than the risk in the general population (female/male ratio= 1.4) (1). Therefore, genetics received one point for gender. Women were found to prefer to sleep on the side more than men (38). Therefore sleep position received two points for gender. There are no firm data about any possible difference in the likelihood of using the wrists between men and women during intercourse. Therefore, sexual intercourse received no points with regard to gender.

Contraceptive Use: There is no reason to believe that there would be any genetic disposition for contraceptive use. Therefore genetics received no points for contraceptive use. Likewise, there is no reason to believe that there would be any connection between contraceptive use and preference for any sleep position. Therefore, sleep position received no

points for contraceptive use. The use of oral contraceptives has been shown to increase the frequency of sexual intercourse (36). Therefore, sexual intercourse received two points for contraceptive use.

**Breast/Chest Size:** Even though larger breasts and chests are likely to be genetically determined, it is difficult to conceive a mechanism in which genetics and larger breasts/chests would interact in the etiology of carpal tunnel syndrome. Besides, no increased occurrence of larger chests or breasts has been reported so far among those who suffer from genetically induced carpal tunnel syndrome. Therefore, genetics received no points for breast/chest size. Likewise, there is no reason to believe that breast/chest size would influence one's preference for sleep position. Therefore, sleep position received no points for breast/chest size. A larger chest or larger breasts would impose a heavier load on the wrists during sexual intercourse and increase the likelihood of injury to the median nerve. Therefore sexual intercourse received two points for breast/chest size.

**Carpal canal size/shape:** Even though carpal canal size is most likely to be genetically determined, there is no specific mechanism that would connect carpal canal size or shape to carpal tunnel syndrome, other than the nonspecific mechanism of increased intra canal pressure due to smaller canal size. Therefore, genetics received one point for carpal canal size/shape. The compression of the median nerve due to deviation of the wrist during sleep may be affected by carpal canal size/shape. However the load on the wrists during sleep is not likely to be greater than that experienced in other situations. Therefore sleep position received one point for carpal canal size/shape. It is conceivable that a smaller carpal canal would experience a somewhat greater per unit area pressure from the weight of the upper body than the normal sized canal during sexual intercourse. Therefore sexual intercourse received one point with regard to carpal canal size/shape.

**Marital Status:** There are no data to suggest that marital status would be related to genetics or sleep position. Therefore, both genetics and sleep position received no points for marital status. On the other hand, it would be expected that a married person would be more likely to engage in sexual intercourse than an unmarried person since the percentage of unmarried people who never had sex was found to be two and a half times greater than the percentage of married people who never had sex (39). Therefore sexual intercourse received two points for marital status.

**Pregnancy:** There is no reason to believe that there would be a genetic predisposition for pregnancy. Therefore genetics received no points for pregnancy. Pregnant women were found to prefer the side position during sleep more than non pregnant women (40). Therefore, sleep position received two points for pregnancy. Pregnancy is likely to be preceded by frequent sexual intercourse. However, since the increase in the frequency of sexual intercourse prior to conception is probably modest, sexual intercourse received one point for pregnancy.

Total scores:

The genetic theory did well in the general Bradford Hill criteria with a score of nine out of sixteen possible points, but did poorly in the risk factor criteria with a score of three out of fourteen possible points, for a total score of twelve out of thirty possible points. (Table I) The sleep position theory also scored nine points in the general Bradford Hill criteria but did better in the risk factor criteria with a score of five out of fourteen possible points for a total score of fourteen out of thirty possible points. The sexual intercourse theory did slightly better than the other two theories in the general Bradford Hill criteria with a score of ten out of sixteen possible points, but did much better than the other theories in the risk factor criteria with a score of ten out of fourteen possible points, for a total score of twenty out of thirty possible points.

## Discussion

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All three theories achieved essentially similar scores in the general section of the Bradford Hill criteria, even though they obtained different scores for several individual criteria. It was only in the risk factor section of the criteria that significant differences emerged among the three theories with respect to their scores. Thus, the expansion of coherence into seven sub-criteria, each representing a risk factor, made it possible for a clear winner to emerge among the three competing theories. A heavy emphasis was placed on coherence, because the seven risk factors comprising coherence represent quantitative epidemiological observations that may have etiologic implications. In contrast, some of the other general criteria such as plausibility, specificity and analogy are abstract concepts that involve a certain degree of subjectivity.

Even though the genetic theory did well in the general criteria, it did very poorly in the risk factor section of the criteria. This would suggest that genetics may not be a primary cause of carpal tunnel syndrome. A large scale twin study of carpal tunnel syndrome has found

the pair-wise concordance of monozygotic twins with carpal tunnel syndrome to be 21% (5). This would imply that the percentage of cases in the general population that can be attributed to genetic factors cannot exceed 21%. The contribution of genetics might even be smaller than the 21% reported by the twin study. It is quite conceivable that the identical twins who suffered from carpal tunnel syndrome may have shared certain behavioral traits that had made them susceptible to the disease. Another phenomenon that undermines the genetic theory is the rarity of childhood or juvenile carpal tunnel syndrome in the general population (41, 34, 33). The onset of a disease that is caused by genetic factors typically occurs in childhood. Most reports of carpal tunnel syndrome among children are anecdotal (41, 42, 21). Therefore it is quite likely that at least a portion of the cases perceived to be of genetic origin could be attributed to other factors. Genetics may produce a carpal canal of certain shape or size which would make the wrist more susceptible to pressure, or it may influence an individual's preference for certain activities which might put that individual at a greater risk of acquiring carpal tunnel syndrome. In both cases the role of genetics may be predisposing rather than precipitating.

The authors of the sleep position theory have suggested that the deviation of the wrist and the resultant increase in intra-carpal pressure during sleep may be a step in the etiology of carpal tunnel syndrome (7). The increase in intra-carpal pressure during sleep might be of longer duration than any increase experienced during daytime but the pressure on the wrist imposed by the weight of the arm would not be strong enough to injure the median nerve. Another phenomenon that would be difficult to explain by the sleep position theory is the high percentage of bilateral cases of carpal tunnel syndrome in the general population (12, 43). Sleeping on the side would rarely result in both hands assuming the same posture. Hence, another mechanism would be necessary to explain bilateral carpal tunnel syndrome. These two observations would suggest that sleep position may more likely act as an exacerbating or perpetuating factor.

Based on its score, the sexual intercourse theory emerged as the most plausible theory for the etiology of idiopathic carpal tunnel syndrome. It postulates that repeated hyperextension of the wrist, while under pressure from the weight of the upper body during sexual intercourse, could damage the median nerve by extending it beyond its capacity to stretch. In this respect, sexual intercourse resembles wheelchair use

in its tendency to cause carpal tunnel syndrome. Carpal tunnel syndrome is about fifteen to twenty times more prevalent among wheelchair users (30, 44) than in the general population (1, 2), and the mechanism of its causation through wheelchair use is well defined (45). In both sexual intercourse and wheelchair propulsion, the wrists become hyper-extended repeatedly. In sexual intercourse the repeated extension of the wrists is caused by the movement of the torso, and the pressure on the wrists is provided by the weight of the upper body. In wheelchair use, the repeated extension of the wrists is caused by spinning the wheels forward and the pressure on the wrists is provided by the force needed to move the wheelchair and its occupant. The prevalence of carpal tunnel syndrome among wheelchair users is greater than its prevalence in the general population because wheelchair propulsion is performed more frequently by wheelchair users than sexual intercourse is by the general population. Nevertheless, the ergonomic similarity between the two activities makes sexual intercourse a highly plausible cause of carpal tunnel syndrome.

After analyzing the available evidence in the light of the Bradford Hill criteria, it is concluded that among the three proposed etiologies, sexual intercourse is the most likely primary cause of idiopathic carpal tunnel syndrome, with genetics acting as a predisposing factor and sleep position acting as an exacerbating factor.

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## Illustrations

### Illustration 1

Evaluation of the Causal Theories of Carpal Tunnel Syndrome According to the Bradford Hill Criteria

	Genetics	Sleep Position	Sexual Intercourse
Criteria	Score (a)		
Strength	1	2	0
Consistency	2	0	0
Specificity	0	1	2
Temporality	2	1	2
Biological Gradient	0	1	1
Plausibility	2	2	2
Analogy	2	2	2
Experiment	0	0	1
Coherence			
Obesity	1	0	2
Gender	1	2	0
Contraceptive use	0	0	2
Breast/Chest size	0	0	2
Carpal canal/size/shape	1	1	1
Marital status	0	0	2
Pregnancy	0	2	1
<b>Total</b>	12	14	20

a) Score is 0 if theory is inconceivable or contradicted by evidence; score 1 if theory is conceivable or supported by modest or partial evidence; score 2 if theory is highly conceivable or supported by substantial evidence according to each criterion.