Epidemiology of Temporomandibular Disorders: Implications for the Investigation of Etiologic Factors

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ABSTRACT: Epidemiology is the study of the distribution, determinants, and natural history of disease in populations. Epidemiology has several uses in addition to its traditional role of documenting the public health significance of a condition. Notably, epidemiologic methods and data can be used to identify and verify causes of disease. This article reviews the epidemiologic data on pain in the temporomandibular region, and on signs and symptoms associated with specific subtypes of temporomandibular disorders, with the aim of identifying possible etiologic factors for these conditions that deserve further study. Despite methodologic and population differences, several consistencies are apparent in the epidemiologic literature. Pain in the temporomandibular region appears to be relatively common, occurring in approximately 10% of the population over age 18; it is primarily a condition of young and middle-aged adults, rather than of children or the elderly, and is approximately twice as common in women as in men. This prevalence pattern suggests that etiologic investigations should be directed at biologic and psychosocial factors that are more common in women than in men, and diminish in older age groups. Most signs and symptoms associated with particular temporomandibular disorders (*e.g.*, joint sounds, pain in the joint) also appear to be more prevalent in women than in men, although age patterns for these signs and symptoms are not as clear as for temporomandibular pain. The available data highlight the need for further research on etiologic factors associated with temporomandibular pain and with specific diagnostic subtypes of temporomandibular disorders.

Key words. Temporomandibular disorders, epidemiology, etiologic factors, sex factors, age factors.

(I) *Temporomandibular Disorders*

The term "temporomandibular disorders" (or TMD) is a collective used to describe a group of musculoskeletal conditions occurring in the temporomandibular region (Laskin *et al.*, 1983). These conditions are characterized by pain in the muscles of mastication, the temporomandibular joint, or both. In addition to report of ongoing pain, pain on palpation and/or pain on function may be present. Signs that frequently accompany the pain in clinic populations include joint sounds, such as clicking or crepitation, and limitations or deviation upon mandibular opening. The most common subtypes of temporomandibular disorders in clinic populations appear to be myofascial pain and arthralgia, followed by disc displacements with reduction (Truelove *et al.*, 1992). Although epidemiologic research on specific subtypes of temporomandibular disorders is in its infancy, historically these conditions were considered part of a single disease entity, and were investigated as such. Therefore, of necessity, much of this review will cover epidemiologic research that investigated temporomandibular disorders more generically. Whenever possible, an attempt will be made to "tease apart" the findings of these investigations to provide data relevant to the specific entities subsumed under the collective term.

The first section of this paper defines epidemiology and epidemiologic perspectives and describes how epidemiologic data can be used to stimulate and enhance clinical and basic science investigations, as well as societal decision-making. The next section reviews epidemiologic data on TMD pain and other signs and symptoms of temporomandibular disorders, and discusses the implications of these findings for the investigation of etiologic factors. A brief conclusion summarizes directions for future research.

(II) *Epidemiology: What is it and Why is it Relevant?*

(A) Definition and perspectives

Epidemiology is defined as the study of the distribution, determinants, and natural history of disease in populations (Lilienfeld and Lilienfeld, 1980). Within this brief definition are embedded the core perspectives of epidemiology—the population perspective, the ecological perspective, and the developmental perspective.

The basic premise of the population perspective is that diseases and disorders cannot be understood exclusively by the study of persons seeking treatment. Rather, to understand a disease, one must understand the

expression of the disease in the population as a whole. Clinic samples reflect not only the manifestations of the disease itself, but also all those biological, psychological, and social factors associated with an individual's motivation to seek care and with access to care. In addition, for conditions where different clinics espouse different treatment philosophies, samples drawn from different clinical settings may represent widely disparate groups of patients. An example of the importance of the population perspective is that only about half of the cases of temporomandibular disorder pain identified in the population have ever sought treatment, and only about one-quarter have sought treatment in the past six months (Von Korff *et al.*, 1988). Inferences about these conditions drawn exclusively from clinic populations are likely to be incomplete, at best, and possibly systematically biased.

The ecological perspective implies that the manifestations of diseases are the product of interaction of disease agents, host factors, and environmental influences. Not every individual who is exposed to a disease agent develops the disorder. The probability of disease is, rather, influenced by characteristics of the individual (*e.g.*, constitution, immune status, psychological state) as well as the physical, social, and cultural environment in which the individual lives (*e.g.*, exposure to other pathogens, dietary preferences, access to health care, social support). Although these concepts were initially found to be useful for the understanding of acute, infectious disease conditions, they apply equally well to chronic problems like diabetes, hypertension, and chronic or recurrent pain problems such as back pain and temporomandibular disorders (Dworkin *et al.*, 1992).

The developmental perspective implies the need to understand the natural history of conditions—that is, their development over time in populations, as well as their development in relation to the life span of individuals. An understanding of the natural history of a condition in a population involves understanding (1) the rate of onset (incidence) of the condition; (2) the average duration of the condition, and, more importantly, the extent to which the condition manifests itself as a single acute episode, as repeated episodes, or as a persistent or chronic problem; (3) the extent to which the problem is progressive (*i.e.*, particular states or stages following one another in predictable sequence and, possibly, with predictable timing); and (4) the extent to which the temporal pattern of disease is fixed or variable across individuals. An understanding of the development of conditions across the life span involves an understanding of increases or decreases in prevalence with age as the result of either developmental/aging processes or as a product of being an individual living at a specific historical period (cohort effects).

The population perspective, the ecological perspective, and the developmental perspective of epidemiology influence the types of research questions asked, the samples investigated, the variables and kinds of relationships considered important, and the methods used to study them. The results of epidemiologic studies thus provide a wealth of information that goes beyond the individual patient at a particular point in time to provide a more comprehensive understanding of disease processes.

(B) Uses of epidemiology

While researchers in dentistry are probably most familiar with epidemiology as a way of documenting the prevalence of conditions in the population, and hence the public health importance of the diseases we study, epidemiologic research can serve a number of different functions even more fundamental to our understanding of disease. Seven uses or aims of epidemiology have been identified (Morris, 1975): historical study, assessing community health, assessing the use and effectiveness of health services, predicting individual risk of disease, identification of syndromes, completing the clinical picture, and searching for causes of disease. A brief review of each of these uses follows, indicating where epidemiologic research on temporomandibular disorders has been conducted in support of these aims, and where information remains to be developed.

(1) Historical study

The first use of epidemiologic research is historical study. Epidemiologic data concerning the waxing and waning of specific diseases and disorders over time can not only document trends of interest in planning health services, but also can provide clues as to factors influencing prevalence (*i.e.*, risk factors) and thus improve our fundamental understanding of the nature of the disorder. Unfortunately, good historical data are lacking for temporomandibular disorders. Many who conduct research on temporomandibular disorders share the impression that temporomandibular pain occurred at a low rate in the early part of the 20th century and became more prevalent in the 1960s and that prevalence is now stable or possibly declining. However, these impressions come largely from experience with clinic populations, and could reflect nothing more than the abilities of clinicians to identify temporomandibular problems, the willingness of clinicians to treat them, changes in reimbursement for TMD treatment, or a change in the public perception of these symptoms such that they came to be viewed as a disorder that could be helped by medical or dental treatment. Given that well-designed baseline epidemiologic surveys were conducted for several Scandinavian populations in the 1970s and several North American populations in the 1980s and 1990s, we should, in the future, be better able to document historical trends in the prevalence and dis-

tributions of these conditions.

(2) Community diagnosis and community health

Perhaps the most common use of epidemiologic studies of temporomandibular disorders has been to document what Morris terms "community diagnosis and community health". The emphasis of this use is to describe and try to "diagnose" the condition of the population. Indices of illness or well-being are produced, and the character and dimension of the problem are documented. For example, epidemiologic studies documenting the prevalence of a number of specific signs and symptoms of temporomandibular disorders in the population were carried out in various areas of Scandinavia beginning in the 1970s (*e.g.*, Agerberg and Carlsson, 1972; Helkimo, 1974a). Most of these studies used self-administered questionnaires or interviews to assess symptoms of pain and jaw dysfunction. Frequently, the entire sample or a subset of respondents also underwent a clinical examination. Rather than defining cases on the basis of presence or absence of particular signs and symptoms, these studies used case definitions based on severity indices. Thus, prevalence was defined as the number of people in the population meeting certain cut-offs for severity.

The rationale for using these indices is that many of the signs thought to be characteristic of temporomandibular disorders (*e.g.*, joint clicking) are quite common in the general population, and may actually represent normal variation rather than pathology (Goyer and Rogan, 1986). Because many people are not significantly bothered by their symptoms, analyses that simply count the number of people with a particular sign or symptom may not provide a good estimate of the burden of these disorders in the population. Thus, severity indices were devised in an attempt at better documentation of the public health significance of these problems. The most widely used of these indices, the Helkimo Anamnestic (self-report) and Clinical Indices (Helkimo, 1974b), gave differential weight to various signs and symptoms, and combined a number of signs (for example, joint sounds, locking and pain on palpation) into a single index. As mentioned earlier, although this approach can document the burden of signs and symptoms in the population, organizing data in this way may not be helpful for other uses of epidemiology, such as attempts at understanding the etiology of specific TMD conditions.

After the initial studies cited above, numerous additional investigations documenting the burden of signs and symptoms of TMD in adult populations were conducted. Such investigations continue to be carried out up to the present day, primarily in Scandinavia (*e.g.*, Norheim and Dahl, 1978; Helöe and Helöe, 1979; Alanen and Kirveskari, 1982; Tervonen and Knuuttila, 1988; Agerberg and Bergenholtz, 1989; Agerberg and Inkapööl, 1990; Salonen *et al.*, 1990; Magnusson *et al.*, 1991) as well as elsewhere in Europe (*e.g.*, Szentpetery *et al.*, 1986; De Kanter *et al.*, 1992, 1993) and North America (*e.g.*, Solberg *et al.*, 1979; Locker and Slade, 1988; Von Korff *et al.*, 1988; Schiffman *et al.*, 1990; Lipton *et al.*, 1993; Goulet *et al.*, 1995). Many of these more recent studies also provided data to serve additional uses of epidemiology.

(3) Use and effectiveness of the health services

Once the prevalence of signs and symptoms of sufficient severity is identified in the community, epidemiology may be used to investigate the need and demand for treatment in the population. Epidemiology also provides tools for investigating, on a population basis, access to care, quality and costs of services provided, and other issues related to the use and effectiveness of health care. Virtually no studies of this sort have been carried out for temporomandibular disorders (Von Korff, 1995).

(4) Individual chances and risks

The fourth use of epidemiology is the application of epidemiologic data to the assessment of individual risks for disease. This use relies on data concerning the rates of onset (incidence) of a disorder in persons with various characteristics, or risk factors (*e.g.*, the risk of lung cancer in women of age 40 who smoke). Because very few prospective studies assessing onsets of temporomandibular disorders have been carried out, little is known about the risk factors associated with onset. A single study assessing the probability of onset of TMD pain over a three-year period in a defined population (Von Korff *et al.*, 1993) found the rate of onset to be significantly increased for persons who had other pain conditions at baseline. Risks of onset were highest for those aged 18-44, and were about 1.5 times higher for women than for men and for severely depressed *vs.* non-depressed individuals. However, none of these latter risk factors was statistically significant in this relatively small sample.

(5) Identification of syndromes

By assessing the clustering of particular signs and symptoms, patterns of onset, natural history, risk factors for and prognosis of such groups of signs and symptoms, epidemiologic methods have the potential for identifying specific disease entities. Because most of the epidemiologic data gathered to date in studies of temporomandibular disorders have included the presence of specific signs and symptoms, rather than simply the identification of pre-defined cases *vs.* non-cases, the potential for use of these data in identification of particular subtypes or syndromes is great. However, only a few attempts have been made to use the data on clinical signs and symptoms in this way. We have presented data (LeResche *et al.*, 1988) documenting the effects of using two different sets of diagnostic criteria to classify the same subjects, but have not yet assessed whether the

subgroups identified by either of these classifications remain cohesive over time. Recently (Rudy *et al.* 1996), statistical clustering techniques have been used to generate an empirical classification of TMD clinic patients into mutually exclusive diagnostic groups. The resulting classification corresponds rather closely to a number of entities commonly defined clinically, *i.e.*, myofascial pain, disc displacement, arthrosis, and a combination of muscle and joint pain.

In the psychosocial sphere, TMD patients, like other chronic pain patients, can be classified into empirically derived subgroups (*e.g.*, dysfunctional patients, adaptive copers) based on their self-reported pain, psychological symptoms, pain-related interference, and social support (*e.g.*, Rudy *et al.*, 1989; Turk and Rudy, 1990). Other classifications of pain-related disability have also been found to be applicable to persons in the population with TMD pain, as well as to clinic patients (Von Korff *et al.*, 1992). There is some evidence that tailoring treatments based on the classification of disability results in improved outcomes (*e.g.*, Rudy and Turk, 1995), which further validates the existence of clinical syndromes or subtypes in the psychosocial domain.

(6) Completing the clinical picture

As mentioned above, the population perspective of epidemiology is important for providing data on conditions, not only among those who seek treatment in particular settings, but also as they occur in the population as a whole. For temporomandibular disorders, it has become clear that persons seeking care differ systematically from those who do not. For example, their pain is of higher intensity and more recent origin than that of those who do not seek treatment (Von Korff *et al.*, 1991), and the gender distribution of those seeking care is disproportionately female (about 5:1 or higher) compared with the somewhat more balanced gender distribution of prevalence (about 2:1) found in the community. Thus, inferences about the severity, duration, and gender distribution of these disorders drawn exclusively from clinic populations provide an incomplete picture of the nature of these problems.

(7) In search of causes

Epidemiologic methods have the potential for identifying the causes of disease in two ways. First, certain epidemiologic study designs, such as case-control, cohort or prospective studies, described below, can identify candidate risk factors. Identification of these risk factors can provide hypotheses for basic laboratory or clinical research aimed at delineating disease mechanisms. In addition, experimental epidemiologic study designs, such as randomized clinical trials or preventive trials, can confirm the role of causal factors more definitively, often providing information on disease mechanisms in the process. It is this last use of epidemiology on which we will focus in the remainder of this article. Specifically, we will review the existing data on prevalence, distribution, and risk factors for cardinal signs and symptoms of temporomandibular disorders. The aim is to identify hypotheses concerning the etiologies of these disorders that may be tested by basic science and clinical research as well as epidemiologic methods.

(C) Epidemiologic study designs

Epidemiologists use a variety of study designs to identify the distribution, determinants, and natural history of disorders in populations. As with many sciences, descriptive, observational methods are used in the early stages of investigation, followed by experimental research as more basic knowledge is gained. For example, descriptive epidemiologic research has identified estrogen and low-fat diets as factors that may be responsible for preventing heart disease in older women. A major long-term, randomized clinical trial, the Women's Health Initiative (Rossouw *et al.*, 1995), has been designed to test experimentally the hypothesis that these factors are indeed responsible for the observed lowering of heart disease risk in certain groups of women. To cite a perhaps more familiar example, epidemiologic observations of lower risks of caries in communities with high levels of naturally occurring fluoride led to the design of the Newburgh-Kingston studies, where water fluoridation was introduced experimentally into the water of one (experimental) community, while a similar, neighboring community's water was left unfluoridated as a control (Dean *et al.*, 1942).

Observational study designs used in epidemiology include: cross-sectional studies, retrospective studies (including case-control studies), and prospective studies. These study designs and their relative advantages and disadvantages are well-described in standard epidemiologic references and books for clinicians (*e.g.*, Rothman, 1986; Riegelman and Hirsh, 1989) and will be touched on here only to provide background on the types of study designs that have been used to generate data on TMD.

Cross-sectional studies are usually designed to document the burden (*i.e.*, prevalence) of a condition in the community at a single point in time, as described above. Because they lack a temporal dimension, their utility for illuminating etiology is limited, except to the extent that results indicate that the disorder is clearly concentrated in certain geographic, age, gender, or socio-economic groups.

Retrospective studies identify persons with the disorder (cases) and persons without (controls) and attempt to identify prior exposures, environmental, or personal background factors that differ between the groups. Retrospective studies are particularly useful in studying rare conditions, where large numbers of persons would

have to be followed to identify cases prospectively, and they provide a relatively inexpensive first step in identifying risk factors for more common conditions.

Prospective studies measure host and environmental factors at baseline and follow groups of persons initially free of disease over time to identify those factors which predict onset of disorder. Prospective studies are frequently more expensive and time-consuming than retrospective studies, and thus the use of this design is generally confined to instances where at least some candidate risk factors have been initially identified.

Experimental designs used in epidemiology include randomized clinical trials, which test the utility of specific treatments for a disorder, and preventive trials, such as the Newburgh-Kingston trial mentioned above, aimed at testing the utility of preventive measures. Both of these kinds of experiments share the cardinal characteristics of all scientific experiments, whether in the biological, physical, or social sciences—that is, a single (independent) variable is manipulated, and the effects on a dependent variable, or variables, are observed. Attention is paid to standardization, replicability, and control. In addition, clinical and preventive trials are characterized by certain specific features, which are necessitated when human subjects are involved. These include: (1) the presence of control groups, which do not receive the experimental treatment or preventive measure; (2) randomization of subjects to experimental and control groups; and (3) blinding of examiners to the status of each participant as an experimental or control subject.

(III) *Epidemiologic Data on Temporomandibular Disorders*

(A) Case definition

Because there is no single agreed-upon definition for temporomandibular disorders as a global term, encompassing a variety of subtypes, the prevalence rates reported for TMD have varied widely (*e.g.*, see reviews by Helkimo, 1979; Greene and Marbach, 1982; Carlsson, 1984; Rugh and Solberg, 1985; Carlsson and LeResche, 1995). The recent introduction of Research Diagnostic Criteria for Temporomandibular Disorders (Dworkin and LeResche, 1992), which provide standardized examination methods and standardized means of gathering self-report information, as well as common operational definitions for various diagnostic entities, will allow future research to be based on common case definitions. Despite the prior absence of a common case definition, however, several research groups have focused on pain in the structures of the temporomandibular region as the defining characteristic of a temporomandibular disorder. The rationale for this case definition is that the impacts of these conditions in terms of individual suffering and interference with usual activities, and economic impacts, such as lost productivity, are largely due to pain rather than to such symptoms as joint sounds or even jaw locking. Furthermore, pain is overwhelmingly the reason that people seek health care for temporomandibular disorders (Dworkin *et al.*, 1990). Prevalence data based on this case definition are reviewed in the next section.

(B) Prevalence and distribution of temporomandibular pain in the population

(1) Age- and gender-specific prevalence rates in adults

Table 1 presents data for the prevalence of pain in the temporomandibular region, broken down by age and by gender, or by both age and gender if such data were reported. The studies shown in Table 1 represent true population-based studies, *i.e.*, either the entire population was investigated or the samples investigated are known to be representative of a specific defined population. In compiling Table 1, this author began with the comprehensive list of epidemiologic studies developed for a recent meta-analytic review (De Kanter *et al.*, 1993). Additional population-based studies conducted since 1993 were also identified from the MEDLINE database. The reports of these epidemiologic investigations were reviewed in an attempt to identify all the available studies that were both population-based and which presented prevalence rates based on report of pain in the temporomandibular region.

Three population-based studies using a case definition of pain in the temporomandibular region have been conducted in North America since the mid-1980s. In a telephone survey of adult residents of Toronto, Ontario (Locker and Slade, 1988), 9.5% of women and 5% of men reported experiencing pain in the face just in front of the ears. Prevalence rates of pain were slightly higher in those under age 45 (8.3%) than in those 45 years of age and older (7.2%).

In 1988, a survey of five common pain conditions, including pain in the temporomandibular region, was conducted among a stratified random sample of enrollees of Group Health Cooperative of Puget Sound, a health maintenance organization in Seattle, Washington (Von Korff *et al.*, 1988). The Group Health population is demographically similar to that of the region as a whole. Subjects were mailed questionnaires, and non-respondents were followed up by telephone. Subjects were asked to report the presence of pain in the temporomandibular joint or facial muscles in the prior six months; fleeting or minor pains were excluded. Eight percent of the men and 15% of the women reported such pain. Rates peaked in the 25-44-year age group, with 10%

TABLE 1

Population-based Prevalence Studies of Pain in the Temporomandibular Region

Authors/Year	Pain Definition	Study Population	Sample Size	Prevalence Rates (%) by Gender and Age
North America				
Locker and Slade, 1988	Pain in the face just in front of the ears	Persons 18 years and older, city of Toronto	677	Males, 5.0%; Females, 9.5%; < 45 yrs, 8.3%; ≥ 45, 7.2%
Von Korff *et al.*, 1988a	Pain in the muscles of the face, the joint in front of the ear, or inside the ear (not infection) in past six months; not "fleeting" or "minor" pain	HMO enrollees 18-75 years old, metropolitan Seattle, WA	1016	Males / Females 18-24: 7% / 11% 25-44: 10% / 18% 45-64: 8% / 12% ≥ 65: 0% / 2% All ages: 8% / 15%
Goulet *et al.*, 1995	Jaw pain in your jaw muscles or jaw joints often or very often	French-speakers 18 years and older, Province of Québec	897	Males / Females 18-34: 3.5% / 8.7% 35-54: 6.8% / 10.4% ≥ 55: 3.3% / 9.7% All ages: 5% / 9%
Europe				
Helkimo, 1974a	Facial and jaw pain	Persons 15-65 years old from two populations of Lapps, Northern Finland	321	Males, 10%; Females, 14% 15-24, 10%; 25-34, 2%; 35-44, 23%; 45-54, 14%; 55-65, 15%
Mohlin, 1983	TMJ or muscle pain	Women aged 20-45, County of Gothenberg and Bohus, Sweden	272	All subjects (females): 6.3%
Szentpetery *et al.*, 1986	Pain in the face, neck, or around the ears	Persons 12-85 years old, Szeged, Hungary	600	Males, 3.2%; Females, 8.3%

of the men and 18% of the women in this age group reporting pain; rates were quite low (0% for men and 2% for women) over age 65.

A recent telephone survey of the French-speaking population of the Province of Québec (Goulet *et al.*, 1995) defined temporomandibular pain as frequent episodes of pain in the jaw joint or jaw muscles. Five percent of the males and 9% of the females reported currently experiencing such pain often or very often, and 30% of the population reported having had at least one such episode at some time. Prevalence rates for temporomandibular pain report were highest among 35-54-year-olds, with 6.8% of the men and 10.4% of the women reporting frequent episodes of pain.

Although many epidemiologic studies of TMD signs and symptoms have been conducted in Europe, relatively few have inquired into the presence of pain in the temporomandibular region. These studies are also summarized in Table 1. All used similar measurement approaches, *i.e.*, in-person interviews or self-report questionnaires completed by subjects in the presence of study personnel.

In an early study of the Lapps of Northern Finland (Helkimo, 1974a), facial and/or jaw pain was found in 10% of the men and 14% of the women. Rates were highest among 35-44-year-olds, with 23% of subjects in this age group reporting pain.

Temporomandibular joint or facial muscle pain was reported by 6.3% of a sample of young adult women in Sweden (Mohlin, 1983) and by 8% of the women and 3% of the men in a population-based study in Hungary (Szentpetery *et al.*, 1986). Age-specific prevalence rates were not reported for these two studies.

The studies summarized in Table 1 are relatively consistent in terms of prevalence rates and gender and age patterns for the presence of TMD pain. The range of prevalence rates is remarkably narrow, given the variability in the populations studied and the definitions of pain used. Questions worded "Do you have...pain?", defined as pain in the temporomandibular region, or pain in the jaw joint and/or muscles of mastication, produced prevalence estimates for men ranging from 3.2% to 10% and for women ranging from 6.3% to 15%, whether the time frame was specified as six months (Von Korff *et al.*, 1988) or was left unspecified (Locker and Slade, 1988; Goulet *et al.*, 1995; Helkimo, 1974a; Mohlin, 1983; Szentpetery *et al.*, 1986).

Pain in the temporomandibular region was also universally found to be more prevalent in women than in men. The ratio of female:male prevalence rates in the three North American studies was virtually identical (1.8:1 or 1.9:1). The lowest ratio (1.4:1) was in the study of the Lapps (Helkimo, 1974a), and the highest (2.6:1) in the Hungarian study (Szentpetery *et al.*, 1986).

Finally, all those studies that assessed age-specific prevalence rates for pain in the temporomandibular region found that this type of pain declines in frequency after about age 45-50 years. Only two studies reported age- by sex-specific rates, and these used slightly different age groupings. However, both found the highest prevalence of pain in the temporomandibular region to be in young and middle-aged women—25-44-year-olds in one study (Von Korff *et al.*, 1988) and 35-54-year-olds in the other (Goulet *et al.*, 1995).

From these studies, we may thus conclude that pain in the temporomandibular region is a relatively common pain condition for adults, that occurs about twice as frequently in women as in men. This type of pain is most prevalent in young and middle-aged adults, and declines in frequency among the elderly.

(2) Prevalence of temporomandibular pain in children

To complete the epidemiologic picture of pain in the temporomandibular region across the life cycle requires information on the patterns of such pain in children. A recent review of research on temporomandibular disorders in children (Nydell *et al.*, 1994) identified 11 studies that had investigated the prevalence of pain in the face or jaws in children, adolescents, and young adults. Prevalence rates of pain in the temporomandibular region found in these investigations ranged from 0-18%, with a median value of 3%. However, many of the studies reviewed were not population-based. Only four population-based random sample studies that have examined the prevalence of ongoing pain in the temporomandibular region among children or adolescents could be identified. All were conducted outside North America and all reported low prevalence rates.

A sample of 2198 children was randomly selected from several schools in Kagoshima, Japan (Ogura *et al.*, 1985). The children ranged from 10 to 18 years of age. Prevalence of pain in the temporomandibuar region was 1.7% overall, with no significant differences between boys and girls. Pain prevalence increased slightly with age, with rates of 0.7% in the 10-12-year-olds, 1.5% in the 12-15-year-olds, and 2.0% in the 15-18-year-olds.

Two studies were conducted on random samples of children attending two school dental clinics in Malmö, Sweden. The first (Nilner and Lassing, 1981) investigated 440 children aged 7-14. The second (Nilner, 1981) utilized a similar design to investigate TMD pain in a sample of 309 15-18-year-olds. Temporal headaches were relatively common, occurring in approximately 10% of children in both samples. However, pain elsewhere in the temporomandibular region occurred in only 3% of the younger children and 4% of the older group.

Finally, the prevalence of facial pain was investigated in a population of 285 17-year-olds in the municipality of Skellefteå in northern Sweden (Wänman and Agerberg, 1986). Pain in the face or jaws was reported by 2.7% of the males and 2.5% of the females.

These four studies would suggest that pain in the temporomandibular region is relatively uncommon in children aged 7-17. However, it appears that pain report may increase somewhat with age in this group. The gender differences in prevalence seen in adults are not apparent in children; rates of pain in the temporomandibular region appear to be similar for girls and boys.

(C) Prevalence rates of specific signs and symptoms diagnostic for particular subtypes of TMD

We turn now from reviewing the epidemiology of temporomandibular pain, as globally defined, to a more specific examination of the prevalence patterns of signs and symptoms related to particular subtypes of these conditions.

(1) Pain in the temporomandibular joint

According to the Research Diagnostic Criteria for Temporomandibular Disorders (Dworkin and LeResche, 1992), a diagnosis of either simple arthralgia or osteoarthritis of the temporomandibular joint requires the presence of pain on palpation of the joint, as well as a report of either ongoing pain in the temporomandibular joint, or pain in response to certain clinical range-of-motion tests. (A diagnosis of osteoarthritis also requires the presence of coarse crepitus.) Data from population-based studies on the combination of these symptoms (*i.e.*, the prevalence of persons meeting the full diagnostic criteria) are currently lacking. However, some data are available concerning one component of the diagnostic

TABLE 2

Population-based Prevalence Studies of Temporomandibular Joint Pain in Adults

Authors/Year	Pain Definition	Study Population	Sample Size	Prevalence Rates (%) by Gender and Age
Lipton *et al.*, 1993	During the past six months, "more than once": ... pain in the jaw joint or in front of the ear	US civilian population 18 years or older	42,370	Males, 3.5%; Females, 6.9% 18-34, 6.5%; 35-54, 5.0%; 55-74, 4.0%; ≥75, 3.9%
Agerberg and Bergenholtz, 1989	"Headaches" in or near the ear	25-, 35-, 50-, and 65-year-old residents of West Bothnia, Sweden	1578	Males / Females 25: 0.5% / 4.5% 35: 1.5% / 3.4% 50: 2.6% / 3.5% 65: 5.4% / 7.9% All ages: 2.5% / 4.9%

criteria: ongoing pain in the temporomandibular joint.

Two population-based studies of adults have attempted to differentiate temporomandibular joint pain from pain in the muscles of mastication. Data concerning joint pain gathered in these studies are shown in Table 2. (Because the questions on muscle pain used in these investigations focused exclusively on the cheek area, and did not include temporalis pain or pain in the submandibular or posterior mandibular region, they provide little insight concerning the prevalence of myofascial pain.)

Data on temporomandibular joint pain, as distinct from muscle pain, were gathered as part of the 1989 National Health Interview Survey, which was administered by telephone to a large, representative sample of the US population (Lipton *et al.*, 1993). Data from respondents were weighted to produce the national prevalence estimates shown in Table 2. Pain "in the jaw joint or in front of the ear" (a definition that could include some muscle pain, as well as joint pain) during the prior six months was reported by about 7% of woman and 3.5% of men. The highest rates were found in 18-34-year-olds, and rates declined with age.

In the second study, a randomly selected sample of persons in each of four age cohorts (25-year-olds, 35-year-olds, 50-year-olds, and 65-year-olds) residing in a county of Sweden was surveyed concerning the presence of various kinds of "headaches" (Agerberg and Bergenholtz, 1989). As shown in Table 2, age- and gender-specific prevalence rates of pain "in or near the ear" (which, in the context of the other questions, was presumably interpreted primarily as joint pain) ranged from 0.5% to 7.9%, with an overall rate of 2.5% for men and 4.9% for women. These gender-specific rates are fairly similar to those reported for the US study (Lipton *et al.*, 1993). However, in the Swedish study, unlike the US National Health Survey, the highest rates of joint pain were found in the oldest age group.

Given the very small number of studies that have explored pain in the joint, any conclusions should be drawn with extreme caution. The gender differential for pain in the temporomandibular joint found in these studies appears to be similar in pattern to that for pain in the temporomandibular region in general, although overall rates for joint-specific pain are lower. However, the prevalence pattern for this symptom by age is not clear. Further research is needed to clarify the rates of this symptom, and of the specific diagnostic entities with which it is associated (*i.e.*, arthralgia and osteoarthritis) in the general population.

(2) Joint sounds

Table 3 presents data on the prevalence of joint sounds. In the Research Diagnostic Criteria for TMD (Dworkin and LeResche, 1992), clicking sounds that are reproducible on repeated openings and occur in a reciprocal pattern, or on excursive as well as vertical range of motion, are considered to be indicative of disc displacement with reduction. Because the studies listed in Table 3 did not utilize these specific criteria (although reproducibility was generally required), the prevalence rates given probably represent an upper limit on the prevalence of this diagnosis in the general population. It should be noted that although painless clicking is considered a TMD "diagnosis", this is a very common condition in the general population that rarely progresses to more serious problems (Okeson, 1995).

According to the Research Diagnostic Criteria for TMD (Dworkin and LeResche, 1992), hard grating or crepitation is required for a joint to meet diagnostic cri-

TABLE 3

Population-based Prevalence Studies of Temporomandibular Joint Sounds in Adults: Measured upon Examination

Authors/Year	Assessment Approach	Study Population	Sample Size	Prevalence Rates (%) by Gender and Age
Mohlin, 1983	Palpation or audible	Women aged 20-45, County of Gothenberg and Bohus, Sweden	272	Clicks 26.8% Crepitus 2.9% (women only)
Szentpetery *et al.*, 1986	Stethoscope	Persons 12-85 years old, Szeged, Hungary	600	Males Females Clicks 17.2% 26.3% Crepitus 20.7% 36.8%
Agerberg and Inkapööl, 1990	Stethoscope	Persons 18-65, County of Stockholm, Sweden (sample weighted with those most likely in need of health services)	637	Males Females Clicks 21% 28% Crepitus 26% 40%
Agerberg and Bergenholtz, 1989	Palpation or audible	25-, 35-, 50-, and 65-year-old residents of West Bothnia, Sweden	1578	Clicks: Males Females 25 12% 21% 35 15% 31% 50 19% 25% 65 22% 25% All ages 17% 27% Crepitus: Males Females 25 1% 5% 35 3% 5% 50 1% 3% 65 4% 10% All ages 7% 3%

teria for osteoarthritis or osteoarthrosis. Although additional criteria are required to differentiate between these two conditions, the prevalence of reproducible hard crepitus found in the studies described below may give some indication of the population prevalence of these two conditions combined.

All the studies listed in Table 3 were population-based and used examination methods, rather than self-report, to gather data on sounds. Two different approaches to examination were used: Either (1) joints were palpated digitally to detect abnormal movement, and sounds were counted as present if they were either audible or palpable (Mohlin, 1983; Agerberg and Bergenholtz, 1989); or (2) sounds were assessed with a stethoscope (Szentpetery *et al.*, 1986; Agerberg and Inkapööl, 1990). When examiners are trained and calibrated, the inter-examiner reliability of both these assessment methods has been found to be acceptable (Dworkin *et al.*, 1988), although not excellent.

In the study of a Swedish female population, described above (Mohlin, 1983), palpable (or audible) clicks were detected in 27% and palpable crepitus in 3% of the 272 women examined. Joint palpation for sounds was also used as the detection method in a survey of adults in West Bothnia (Agerberg and Bergenholtz, 1989). This investigation found that the overall prevalence of clicking detected by examination was 17% in men and 27% in women. Rates for men increased with age, from 12% in the youngest age group to 22% in those aged 65 (Table 3). For women, rates were highest for the 35-year-olds and somewhat lower in older women. Crepitus was about twice as prevalent in women as in men (7% vs. 3%), and increased from 3% in the youngest age group to 7% in those aged 65. However, the age-related increase was not linear.

Studies using a stethoscope included a survey of persons aged 12-85 in Szeged, Hungary, described earlier (Szentpetery *et al.*, 1986) and an investigation of persons aged 18-65 in the County of Stockholm, Sweden (Agerberg and Inkapööl, 1990). The Hungarian study found clicks to be present in 17% of the males and 26% of the females. The comparable rates for the Swedish sample were 21% for men and 28% for women. Crepitus was found to be more prevalent in these studies than in

those evaluating sounds by digital palpation, probably because the stethoscope is capable of picking up "soft" crepitus, as well as the coarse crepitus diagnostic of osteoarthritis of the joint. About 21% of the men and 37% of the women were found to have crepitus in one or both joints in the Hungarian sample, whereas the Swedish study detected these sounds in 26% of the men and 40% of the women.

Previous reviews have reported wide variability—for example, from 6% to 50% (Carlsson and LeResche, 1995)—in prevalence rates for temporomandibular joint sounds across studies. These reviews have tended to add prevalence rates for clicking and crepitus (if these were initially differentiated) in order to compare studies assessing these specific sounds with those that reported only on the presence of "joint sounds" without differentiating between the types of sounds; also, studies that were not truly population-based were reviewed (*e.g.*, studies of dental patients). Finally, the effect of assessment technique on prevalence rates has typically not been considered.

In contrast to this impression of highly variable prevalence across studies, the rates shown in Table 3 are fairly similar, if one compares studies using similar detection methods. In the small sample of population-based studies reviewed here, rates of clicking ranged from 17%-21% for men and from 26%-28% for women, regardless of detection method. Rates of detected crepitus were low in the studies using digital palpation, 3% (Mohlin, 1983) and 7% (Agerberg and Bergenholtz, 1989) for women and 3% for men in the single study that used this method to examine male subjects (Agerberg and Bergenholtz, 1989). Use of a stethoscope to examine for crepitus resulted in substantially higher rates (21% and 26% for men; 37% and 40% for women), but again the sex-specific prevalence of sounds is similar for the two studies that used this examination method. In all studies that examined both sexes, regardless of the detection method used, women showed a slightly higher prevalence of clicks than men, and their rates of crepitus were 1.5 to 2.3 times those of men.

Although one may argue whether joint clicking represents a pathologic condition or simply a normal variation in the population (Goyer and Rogan, 1986), it appears that the prevalence rates for clicking are slightly higher in women than in men. Whether this differential is related to the presence of pain or to some other characteristic that is more prevalent in women, such as joint laxity (Westling, 1992), has not been investigated.

The high rates of crepitus detected with the use of a stethoscope probably include some sounds that are clinically significant and some that are not. However, even in studies using digital palpation, the rates of crepitus appear to be higher in women than in men. This may again be related to the presence of pain, or it may be a reflection of the higher prevalence of certain systemic arthritic conditions in women (Wolfe, 1994). Unfortunately, only one population-based study (Agerberg and Bergenholtz, 1989) appears to be available on the prevalence of joint sounds by age, so no inferences can be drawn regarding possible age influences on these signs of joint disorders.

(D) Implications for investigation of etiologic factors

(1) General considerations

How does an understanding of the prevalence patterns of temporomandibular pain aid us in the search for causes of these conditions? First of all, the low prevalence rates in children would suggest that either risk factors do not begin to operate until after puberty, or, alternatively, risk factors may be present in children, but a period of exposure to these risk factors may be necessary before the pain condition develops. A third possibility is that the same risk factors may operate for children as for adults, but that children's tissues have greater potential for healing and adaptation, so that ongoing pain does not develop. The decline in prevalence rates after middle age would indicate that persons who experience pain earlier in their lives cease to experience this symptom at some point (*i.e.*, large numbers of persons experiencing temporomandibular pain do not accumulate in the population). This may be because adaptive remodeling of the tissues takes place. In addition, risk factors for the onset of pain may be less prevalent in older persons, or the pool of susceptible hosts may be exhausted, so that fewer people are at risk. Finally, the higher prevalence rates for adult women than for adult men would indicate that biologic, behavioral, psychologic, and/or social factors associated with female gender increase the risk of experiencing pain in the temporomandibular region. Whatever these factors might be, they do not appear to be operating prior to puberty, since sex differences in prevalence are not observed among children.

(2) Psychosocial considerations

In the psychosocial domain, life stress, depression, and the presence of multiple somatic symptoms have often been proposed as possible risk factors for temporomandibular pain (Rugh and Solberg, 1976; Greene *et al.*, 1982; Eversole *et al.*, 1985; Lundeen *et al.*, 1987; Dworkin *et al.*, 1994). It is logical to investigate these conditions as possible risk factors, since they tend to be reported more frequently by women (*e.g.*, Weissman and Olfson, 1995) and to have higher prevalence among adults than children. Whether prevalence rates decline after middle age is, however, less clear (Simon and Von Korff, 1995). In addition, the examination of psychological factors as

possible risk factors for TMD appears sensible, in that plausible peripheral and central mechanisms through which psychological factors might operate to increase the probability of TMD pain have been postulated. For example, stress has been shown to increase masseter muscle tension in myofascial pain patients (Flor *et al.*, 1991), and certain neurotransmitters (*e.g.*, norepinephrine and serotonin) are implicated in both pain and depression (Fields, 1987). Unfortunately, the results of studies that have examined these factors using a case-control design are difficult to interpret, since any observed differences might be attributed to the effects of having a chronic pain condition, as well as to between-group differences that were present prior to pain onset.

The single prospective study of the incidence of temporomandibular pain, cited earlier (Von Korff *et al.*, 1993), found the presence of pains in other body sites at baseline to be a significant predictor of onset of TMD pain within the ensuing three years. Rates of onset were also somewhat higher among the severely depressed and among women, as opposed to men, but these relationships were not statistically significant. Clearly, more research using prospective designs is needed to clarify the possible roles of stress, depression, and somatic distress in the onset of TMD pain.

(3) Biologic considerations

In the biologic domain, structural factors, including class of occlusion and specific occlusal relationships, have long been postulated as risk factors for various types of temporomandibular disorders (although not specifically for TMD pain). A review of this literature is beyond the scope of this article. However, others have concluded that few of the predicated relationships appear to be supported by rigorously controlled studies (Seligman and Pullinger, 1991a,b). From an epidemiologic perspective, one might inquire as to whether a specific occlusal factor could be identified that might explain the age and sex prevalence patterns observed for TMD pain.

In terms of other biological variables, the age-sex prevalence patterns of temporomandibular pain described above (*i.e.*, rise in prevalence after puberty, higher prevalence in women than in men, and lower prevalence for women in the post-menopausal years) are all consistent with a possible etiologic role for female reproductive hormones in these pain conditions. The prevalence pattern for TMD pain is similar to that of migraine headache, where hormonal factors have long been thought to play a part, at least for a subset of cases. The increased rates of occurrence of migraine headaches during specific phases of the menstrual cycle and the adverse effects of oral contraceptives on migraine are well-documented in clinical studies (Schipper, 1986; Silberstein and Merriam, 1991; Marcus, 1995). However, only a few studies have assessed the possible effects of reproductive hormones on facial pain.

Specifically, these studies have examined the use of exogenous reproductive hormones (*e.g.*, oral contraceptives, post-menopausal hormone replacement therapies) as possible risk factors for temporomandibular pain. One study compared the oral contraceptive histories of 50 treated female cases of TMD with those of asymptomatic controls of similar age (Abubaker *et al.*, 1992); treated cases reported significantly more hormone use than controls. In contrast, another study (Marbach *et al.*, 1988) found lower rates of oral contraceptive use among a sample of 88 female TMD patients than among 111 age-matched controls. The contradictory findings of these two studies may be attributable to the relatively small sample sizes examined, or to the fact that the case groups were selected based on different criteria. In addition, investigating the relationship of oral contraceptive use to TMD in women of reproductive age may not provide the most powerful test of the relationship of reproductive hormones to TMD pain, since both cases and controls are likely to have circulating levels of estrogen and progesterone within the biologically active range.

In an attempt to compare risk of temporomandibular pain in women having relatively low hormone levels with that of women with appreciable amounts of hormones, we examined the possible relationship of use of post-menopausal hormone replacements to temporomandibular pain (LeResche *et al.*, 1997). Data from automated pharmacy records of women enrolled in a large health maintenance organization were used to identify prescriptions filled for post-menopausal hormone replacement therapies. Use of estrogen and progestins was compared for 1291 women over age 40 referred for TMD treatment over a ten-year period and 5164 age-matched women who were not referred for treatment at any time during the ten-year period (controls). In analyses controlled for health services use, the odds of being a TMD case were approximately 30% higher among those receiving estrogen compared with those not exposed; a clear dose-response relationship was evident. The relationship of progestin use to TMD was not statistically significant.

Several peripheral and central mechanisms through which estrogen could operate to increase pain have been postulated for TMD or other painful conditions. These include increased joint laxity (Westling, 1992), enhanced inflammatory responses in the joint (Haskin *et al.*, 1995; Milam, 1995), and action on prostaglandin release or serotonin receptors (Silberstein and Merriam, 1991). In some species, there also appear to be sex differences in pain modulation systems (Bodnar *et al.*, 1988), some of which may be estrogen-based (Mogil *et al.* 1993; Sternberg *et al.*, 1995). Thus, it appears that the relationship of female reproductive hormones to temporomandibular pain is an issue worthy of further investigation.

While the factors mentioned here do not constitute an exhaustive list of potential risk factors for temporomandibular pain, they are illustrative of how epidemiology may be used to identify candidate risk factors and follow up on possible causal relationships.

(E) Directions for Future Research

Although several different populations have been investigated and a number of different epidemiologic study designs used, several consistencies are apparent in the epidemiologic literature on temporomandibular pain and related signs and symptoms. Pain in the temporomandibular region appears to be a relatively common pain problem, occurring in approximately 10% of the population over age 18; it is primarily a condition of young and middle-aged adults, rather than of children or the elderly, and is approximately twice as common in women as in men. This prevalence pattern suggests that etiologic investigations should be directed at biologic and psychosocial factors that are more common in women than in men, and which diminish in older age groups.

In the psychosocial sphere, potential risk factors that meet these criteria included stress, depression, and somatic distress. Prospective studies are needed to clarify the possible role of these factors in the onset and/or maintenance of TMD pain problems.

In the biologic arena, research on hormonal factors appears particularly promising. Clinical and epidemiologic studies investigating variations in TMD pain with variations in hormone levels are needed. An example of such research would be investigation of TMD pain levels across the menstrual cycle (*e.g.*, Dao *et al.*, 1996). Basic research examining the effects of reproductive hormones on tissues of the temporomandibular joint (*e.g.*, Kapila *et al.*, 1996) and masticatory muscles, as well as on the possible role of hormones in central pain processing, also appears timely.

These are just some of the potential areas of research suggested by the epidemiologic data. Creative clinical and basic scientists viewing the epidemiologic data from the perspective of their own particular areas of expertise may generate additional important hypotheses.

To summarize the findings on signs and symptoms associated with particular temporomandibular disorders: Some of these signs and symptoms—specifically, pain in the temporomandibular joint and crepitus in the joint—also appear about twice as frequently in women as in men, although they occur less frequently than reported pain in the temporomandibular region. Clicking in the joint is a phenomenon found in about one-fifth to one-quarter of the adult population; it appears to be slightly more common in women than in men. Information on age patterns of these signs and symptoms is insufficient for conclusions about age-related factors to be drawn. The available data highlight the need for further research on etiologic factors associated with these signs and symptoms, or, more appropriately, with specific diagnostic subtypes of temporomandibular disorders.

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