ORIGINAL ARTICLE

Potential of ultrasonography for epidemiological study of work-related wrist tenosynovitis

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Objective: To explore the possible role of ultrasonography in case definitions for epidemiological studies of work-related wrist tenosynovitis.

Methods: Clinical and ultrasonography (7.5 MHz linear probe) data systematically collected from meat workers (n = 128) with biomechanical exposure characterisation were analysed. The diagnostic accuracy of different combinations of potentially relevant ultrasonography findings (nonhomogeneity, thickening and anechoic halo) was evaluated using symptomatology as a reference standard. The concordance between ultrasonography findings and symptoms was then analysed.

Results: Analysis of wrist biomechanical exposure was suggestive of increased prevalence of musculoskeletal disorders. Using symptoms as a reference standard, each of the three ultrasonography findings (and their combinations) showed good specificity ($\geq 85\%$) accompanied by low sensitivity ($< 60\%$); the positive likelihood ratio for at least two findings was 4.1. κ Values (95% confidence intervals) between symptoms and different sets of ultrasonography findings were as follows: for non-homogeneity, $\kappa = 0.31$ (0.19 to 0.43); at least one finding, $\kappa = 0.28$ (0.16 to 0.40); at least two findings, $\kappa = 0.32$ (0.20 to 0.44); all $p < 0.01$.

Conclusion: The use of ultrasonography in symptomatic subjects could contribute to a more specific epidemiological case definition of wrist tenosynovitis. The results of this study could help orient future research in this direction.

Tenosynovitis of the wrist (also known as wrist tendinopathy or wrist tendinitis) commonly accompanies forceful and repetitive wrist–hand activities, especially when associated with awkward wrist posture. Epidemiological studies of wrist tenosynovitis commonly use clinical case definitions based on symptoms, sometimes in conjunction with physical signs and clinical history.^{1–9} Results can be affected by the choice of case definition and the validity of the diagnostic techniques.¹⁰ However, the symptoms and physical signs associated with the wrist are not specific, and further investigation is needed to form a reliable case definition for epidemiological studies.^{11–15}

Portable high-resolution (7–15 MHz) ultrasound transducers allow dynamic examination of tendons and can provide a rapid, relatively inexpensive non-invasive imaging tool suitable for epidemiological studies. Ultrasonography is now an elective means to study tendons, sheaths and many of their pathological changes (infective, rheumatic or traumatic inflammation; partial or entire ruptures; effects of diabetes and other degenerative disorders).^{16–18} However, the role of ultrasonography in the epidemiological classification of overuse tenosynovitis, including acute and degenerative changes, is yet to be clearly defined.

To investigate the possible role of high-resolution ultrasonography in case definitions for epidemiological studies of wrist tenosynovitis, we analysed data collected for this purpose from a population of meat workers highly exposed to biomechanical risk factors. We first used the presence of symptoms as a reference standard for assessing the diagnostic accuracy of selected ultrasonography findings. As symptomatology cannot be considered a diagnostic gold standard, we also analysed the concordance of ultrasonography findings with symptoms.

SUBJECTS AND METHODS

Subjects and setting

The setting was a meat processing plant employing 160 production workers, involved in 42 job tasks; instrumental/

clinical data regarding diagnosis of wrist tenosynovitis and carpal tunnel syndrome were systematically collected onsite in 1998.¹⁹ For our exploration of the role of ultrasonography in epidemiological case definitions of wrist tenosynovitis, we considered the 128 workers (106 men) employed for at least 6 months who were available for data collection (ie, not on vacation or sickness/maternity leave). Mean (standard deviation (SD)) age was 38 (10) years (range 22–61). Mean (SD) duration of employment in the plant was 8 (6) (range 1–23) years. Mean (SD) body mass index (BMI; weight (kg)/height²(m²)) was 26 (3) (range 18–42) kg/m² for men and 25 (3) (range 21–33) kg/m² for women. All participants provided informed consent to the study protocol. In the absence of invasive procedures, approval from the local ethical committee would have been inappropriate in our country.

Characterisation of biomechanical exposure

To characterise wrist biomechanical exposure in the study setting, videotapes of each task were independently reviewed by two trained technicians (FG and CF) to calculate hand activity level and estimate peak finger force, according to American Conference of Governmental Industrial Hygienists (ACGIH) criteria for applying threshold limit values in monotask handwork (<http://umrerc.engin.umich.edu/jobdatabase/RERC2/HAL/ACGIHTLV.htm>).

Clinical examinations

Clinical examinations were performed by a specialist occupational physician trained in the detection of musculoskeletal disorders (LI), who was blinded to ultrasonography findings. Typical symptoms of flexor digitorum tenosynovitis were defined according to the Birmingham consensus criteria²⁰ (focusing on the volar aspect of the wrist). Thus, in each wrist, symptoms were assessed in terms of volar pain involving the

Abbreviation: BMI, body mass index

hand, wrist or forearm during active movement of the tendon against resistance, including pinching and grasping. Participants were also asked whether they had received treatment for wrist tenosynovitis in the past 12 months.

Ultrasonography

Ultrasonography evaluations were performed onsite by an occupational physician with a high level of professional training and 4 years' regular experience in musculoskeletal ultrasonography (AC) blinded to clinical findings, using a transportable Hitachi EUB 405 device fitted with a 7.5 MHz linear probe (Hitachi Medical Corporation, Tokyo, Japan). Tendons of the flexor digitorum (profundus and superficialis) muscle were examined at the palmar compartment of the wrist, with the probe placed parallel and proximal to the distal crest in the transverse scan, and parallel to the palmaris longus tendon in the longitudinal scan.

For each hand, wrist tendons were examined in transverse and longitudinal orientations, both at rest and dynamically. To take into account both acute and degenerative tendon changes, the following ultrasonography findings were recorded: (1) non-homogeneity of tendinous bundle echotexture; (2) thickening of the tendinous bundle; and (3) anechoic halo around at least one tendon.

Data analysis

On the basis of the characteristics of the manual work, analyses were conducted per hand (prevalence data are described per hand and per person). Differences between ultrasonography parameter findings and recorded symptoms were assessed using Pearson's χ^2 test, and observed and expected agreements were calculated. The κ coefficient was used to assess agreement levels between symptoms and ultrasonography parameters; the χ^2 test being used to assess its significance. κ values were graded as very good (1–0.81), good (0.80–0.61), moderate (0.60–0.41), fair (0.40–0.21) and poor (<0.20).²¹

A logistic regression model was built to assess the contributions of individual factors to agreement between symptoms and ultrasonography in dominant hands (choosing the ultrasonography outcome measure showing the highest κ value). STATA V.8 software was used for all analysis, with significance set to $p < 0.05$.

RESULTS

Biomechanical exposure characteristics of the study population

Analysis of repetitiveness showed a mean rate of 30 actions/min, corresponding to an action frequency of 0.5 actions/s. Each participant was required to work 8 h/day and had breaks

for about 95 min (corresponding to a duty cycle of about 80%). Activity was judged to be similar in either hand. Hand activity level values ranged from 5 to 6 (average 5.2). Peak finger force was judged medium to high, ranging from 4 to 8 (average 6). Applying ACGIH criteria for assessment of monotask hand-work, the intersection between peak finger force and hand – activity level values fell within the area above the threshold limit value line associated with markedly increased prevalence of musculoskeletal disorders.²²

Clinical characteristics and symptoms

Among 126 participants who provided information on hand dominance, 116 were right handed (92%) and 10 left handed (8%). In the 12 months before the interview, 13 of 128 (10%) workers had undergone medical treatment for wrist tenosynovitis (6 on the dominant and 2 on the non-dominant hand, 5 bilaterally); no surgery had been performed. Current typical symptoms of tenosynovitis in the hand and forearm were reported by 42 of 128 (33%) interviewed workers. A total of 18 (43%) of these instances were bilateral, 19 (45%) were limited to the right side and 5 (12%) to the left side. Thus, 60 of 256 (about 24%) hands were currently symptomatic.

Ultrasonography findings

Table 1 reports the hand and worker prevalence of symptoms and different ultrasonography findings (and numbers of findings).

Table 2 shows the hand prevalence of different (numbers of) ultrasonography findings per hand, also their sensitivity, specificity, likelihood ratios and predictive values using symptomatology as a reference standard. Each of the three ultrasonography findings (and their combinations) showed good specificity ($\geq 85\%$) accompanied by low sensitivity ($< 60\%$).

Table 3 reports observed and expected values of agreement between the presence of symptoms and different ultrasonography outcomes, together with the relevant κ coefficients and associated 95% CI (and p values). Results of the χ^2 analysis were highly significant for each set of ultrasonography outcomes. With the κ values of non-homogeneity, at least one finding and at least two findings indicated fair concordance (0.21–0.40). Thickening anechoic halo and all three findings showed only slight concordance ($\kappa < 0.20$).

Logistic regression analysis was performed to assess contributions of individual factors (sex and, as continuous variables, age, BMI and height) to agreement between symptoms and ultrasonography (at least two findings, selected because of the most favourable κ value). Sex, age and BMI were entered into the model. For men, the odds ratio (OR) for agreement between symptoms and ≥ 2 ultrasonography findings was 5.5 (95% CI, 1.05 to 28.87). Neither BMI (OR for each kg/m^2 , 0.5; 95% CI, 0.20 to 1.26) nor age (OR for each year, 1.02; 95% CI, 0.98 to 1.06) reached significance.

DISCUSSION

Few data are available regarding the role of ultrasonography in epidemiological studies of wrist tenosynovitis. To contribute to a more specific epidemiological case definition, we examined relationships between symptoms and sonographic signs in a representative population of workers at high risk of cumulative trauma disorders. The results could help orient future research into how this flexible imaging tool might be incorporated into a more specific epidemiological case definition of wrist tenosynovitis.

Analysis of biomechanical exposure showed characteristics commonly associated with significantly increased prevalence of musculoskeletal disorders.²² Furthermore, the prevalence (by

Table 1 Hand and worker prevalence of symptoms and different ultrasonography findings

Case definition	Prevalence, % (n)	
	Workers (n = 128)	Hands (n = 256)
Symptoms	32.8 (42)	23.4 (60)
Symptoms with non-homogeneity	12.5 (16)	9.4 (24)
Symptoms with thickening	11.7 (15)	6.6 (17)
Symptoms with anechoic halo	7.8 (10)	7.8 (20)
Symptoms with at least one ultrasonography finding	21.9 (28)	13.7 (35)
Symptoms with at least two ultrasonography findings	15.6 (20)	8.6 (22)
Symptoms with all three ultrasonography findings	3.1 (4)	1.6 (4)

Table 2 Diagnostic measures of different ultrasonography findings (and combinations of findings) in hands, using symptomatology as a reference standard (total 256 hands)

Ultrasound findings	Symptoms, n (%)		Prevalence (%)	Sensitivity (%)	Specificity %	LR for a positive test	LR for a negative test	PPV	NPV
	+	–							
Non-homogeneity	+ 24 (9.4)	22 (8.6)	18	40.0	88.8	3.60	0.67	0.52	0.83
	– 36 (14.1)	174 (67.9)	82						
Thickening	+ 17 (6.6)	24 (9.4)	16	28.3	87.7	2.30	0.82	0.41	0.80
	– 43 (16.8)	172 (67.2)	84						
Anechoic halo	+ 20 (7.8)	29 (11.3)	19	33.3	85.2	2.20	0.79	0.41	0.81
	– 40 (15.6)	167 (65.2)	81						
At least one finding	+ 35 (13.7)	51 (19.9)	33.6	58.3	73.9	2.20	0.57	0.41	0.85
	– 25 (9.8)	145 (56.6)	66.4						
At least two findings	+ 22 (8.6)	17 (6.6)	15.2	36.7	91.3	4.10	0.69	0.56	0.82
	– 38 (14.8)	179 (69.9)	84.8						
All three findings	+ 4 (1.5)	7 (2.7)	4.3	6.7	96.4	1.75	0.97	0.36	0.77
	– 56 (21.9)	189 (73.8)	95.7						
Overall (n=256)	60 (23.4)	196 (76.6)							

LR, likelihood ratio; NPV, negative predictive values; PPV, positive predictive values.

subject) of wrist tenosynovitis judged by clinical symptoms alone (about 33%) was similar to that reported in other working populations exposed to repetitive or forceful hand movements.^{1 23–25} However, such estimates will presumably include many false positives (owing to symptoms not arising from wrist tenosynovitis or to over-reporting) and will miss latent (asymptomatic and under-reported symptomatic) cases.

The three sonographic parameters considered in the study are commonly considered pathognomonic of acute or degenerative tendon pathology: an anechoic halo around the tendon (representing fluid or thickening of the distended synovial membrane) is considered the hallmark of tenosynovitis,²⁶ whereas thickening or non-homogeneity of the tendineous bundle echotexture can be signs of wrist tendon trauma and repair processes.^{27 28} On the basis of the current understanding of the pathophysiology of acute and degenerative tendon pathology in the context of repetitive, forceful hand movements, it was reasonable to expect that at least one of these sonographic signs would present in most of the symptomatic hands. The finding that only 14% of symptomatic hands (and 22% of symptomatic workers) showed any of these signs supports the concept that the use of symptom-based case definitions is likely to overestimate the frequency of wrist tenosynovitis.¹¹

Considering the presence of symptoms as a surrogate gold standard, ultrasonography seemed to have poor sensitivity (range about 7–58% depending on the sonographic definition used), but good specificity (range about 74–96%). In the study population, hypothetical case definitions incorporating the sonographic signs cut the prevalence (by subject) of wrist tenosynovitis from about 33% for all symptomatic workers to about 22% for at least one sign to as little as about 3% for all three signs, with at least two signs providing a midway value of about 16% (table 1). In the absence of a true gold standard for

diagnosing of tenosynovitis in large groups of subjects, it is difficult to determine which of these combinations most closely reflects the pathophysiological situation. To gain some clues, we analysed the agreement with symptoms.

Of the single sonographic findings, “non-homogeneity of tendineous bundle echotexture” showed the best (fair) agreement with symptoms. This might seem surprising, given the putative correspondence of this sonographic sign with fibrosis and healing processes, which are not thought to be particularly painful. However, the low concordance between anechoic halo and symptoms in our population could be attributed to the disabling nature of the pain that accompanies tenosynovitis, which is scarcely compatible with the meat workers’ job tasks. More generally, the poor concordance between ultrasonography findings and symptoms further supports the concept that pain is not specific for wrist tenosynovitis. Limitations of symptom-based case definitions may stem from different sources of pain (synovial, joint, retinacular, etc) and psychosocial factors leading to various reporting confounders.¹⁰ Notably, the finding (at logistic regression analysis) that men were more likely to show agreement between self-reported symptoms and ultrasonography could be at least partially explained by the influence of sex role models (as well as different perceptions of pain in men and women).^{29 30}

Which combinations of ultrasonography findings could deserve consideration for inclusion in a working case definition for epidemiological research? This study can provide some hints for further research. “At least one finding” provided the best (albeit low) sensitivity and acceptable specificity (using the “surrogate” reference standard of symptoms). However, “at least two findings”, provided very good specificity, the highest accuracy (79%) and the best concordance with symptoms. Moreover, the positive likelihood ratio (of about 4) suggests that the presence of at least two findings in a symptomatic

Table 3 Analysis of observed and expected agreements for hands between presence of symptoms and different (combinations of) ultrasound findings

Ultrasonography parameters	Observed agreement (%)	Expected agreement (%)	κ coefficient	95% CI for $\kappa = \kappa \pm 1.96 (SE_{\kappa})$	p Value of χ^2 for κ coefficient
Non-homogeneity	77.3	67.0	0.31	0.19 to 0.43	<0.001
Thickening	73.8	68.0	0.18	0.06 to 0.30	0.001
Anechoic halo	73.1	66.4	0.20	0.08 to 0.32	<0.001
At least one finding	70.3	58.7	0.28	0.16 to 0.40	<0.001
At least two findings	78.5	68.5	0.32	0.20 to 0.44	<0.001
All three findings	75.4	74.3	0.04	–0.08 to 0.16	<0.01

Main message

- As symptoms for wrist tenosynovitis are sensitive but not specific, the use of ultrasonography in symptomatic subjects could contribute to the development of a more refined epidemiological case definition (as a premise for reliable epidemiological research aimed at defining of valid strategies for prevention and management of this cumulative trauma disorder).

subject would reinforce a field diagnosis of wrist tenosynovitis. Thus, we think that this criterion could be a promising candidate.

It is interesting to compare the findings of this study with those of a concurrent investigation into the role of nerve conduction study parameters in carpal tunnel syndrome in the same population of meat workers.³¹ Remarkably, the concordance with symptomatology recorded in this study for at least two ultrasonography findings was not inferior to analogous levels of agreement found in the same workers for nerve conduction studies, which are considered important (together with symptom characteristics) in the consensus criteria for classification of carpal tunnel syndrome in epidemiological studies.³² This observation seems to support the concept that ultrasonography (which has the advantage over electromyography of being a much more acceptable examination) could play a useful part in epidemiological case definitions of wrist tenosynovitis. In particular, we think that sonography could allow a more specific epidemiological classification of those subjects who report symptoms in an initial screening questionnaire.

It should be underlined that the ultrasonography data under analysis were obtained using a 7.5 MHz linear probe (a reasonable choice at the time of data collection). The better definition of small, superficial tendons provided by a 10 MHz linear probe could be more informative. Further, the use of power Doppler technology to distinguish between hypochoic fluid (serous tenosynovitis) and synovium (hypertrophic tenosynovitis) could provide another potentially relevant ultrasonography finding for future investigations. More generally, standardisation of techniques, hardware/software and operator training are important issues that need to be considered.³³ Sonography is reliable in experienced hands,^{34, 35} and, if used as a second-line classification technique for subjects who report symptoms in epidemiological research studies, recourse to an experienced rater is likely to be feasible.

The development of classification criteria for epidemiological case definitions is an important step to allow reliable epidemiological research into cumulative trauma disorders such as wrist tenosynovitis aimed at definition of valid strategies for prevention and management.^{11, 12} The results of this study suggest that the use of ultrasonography in symptomatic subjects could contribute to a more specific epidemiological case definition of wrist tenosynovitis and could help orient future research in this direction.

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ECHO.....

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Well water may explain excess bladder cancer mortality in New England

Drinking from private wells across the United States may have to cease if findings of a study linking it to a long recognised excess mortality from bladder cancer in New England are confirmed.

The link between residual bladder cancer mortality and use of private wells was found in white men (Pearson's correlation coefficient $r = 0.42$) and women ($r = 0.48$) in New England and New York and New Jersey ($r = 0.49, 0.62$, respectively) after adjusting for population density, which is positively associated with bladder cancer in the United States. Thus it seems possible that greater exposure to carcinogens in well water or some other close marker causes bladder cancer, though this needs to be clarified by non-ecological studies.

The study compared age adjusted bladder cancer mortality in white men and women during 1985–99 and the proportion of people obtaining drinking water from private wells in New England and some other states, as calculated from data on water use in 1970. This was the first year that national data on water use included private wells and provides a 15 year minimum interval with the mortality data.

Excess bladder cancer mortality has been known in New England since the 1950s, though its exact cause is unknown. Use of private wells here is prevalent. Water from them does not have to meet federal standards for drinking water, and the common practice in New England of drilling the wells into fractured crystalline bedrock aquifers increases the chances of natural contaminants such as arsenic gaining access. Arsenic in drinking water has been linked to bladder cancers elsewhere in the world.

▲ Ayotte JD, *et al*. *Journal of Epidemiology and Community Health* 2006; **60**:168–172.