

INFLUENCE OF REPETITIVE MICRO-TRAUMA ON PATHOGENESIS AND PROGRESSION OF HAND AND NECK OSTEOARTHRISIS

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Summary. Repetitive micro-trauma is one of the causes of osteoarthritis. The aim of our study was to determine if repetitive micro-trauma caused by prolonged use of a keyboard or a mechanical typewriter is associated with the increase in degenerative changes in the hand and cervical joints. We studied a sample of people of over 40 years of age, who have been working on a keyboard or a mechanical typewriter for at least 10 years. A clinical and radiological evaluation of the degree of osteoarthritis of the hands and the neck spine was done according to the Kellgren-Lawrence grade; CRP and ESR were used as laboratory markers of secondary inflammation in osteoarthritis. We also used some demographic and epidemiological data. We did a prospective study with 30 examinees, average age 47 years (SD 4.77), average effective working hours 8.88 (SD 6.59). The average usage of the keyboard was 18.71 years (SD 6.59). We found that the clinical degree of osteoarthritis on distal interphalangeal joints (DIP) is in correlation with age ($r = 0.516$, $p = 0.05$) and years of working ($r = 0.459$, $p = 0.05$). The radiological grade of osteoarthritis on DIP and proximal interphalangeal joints (PIP) are associated ($r = 0.835$, $p = 0.01$). We found no significant association with effective day working hours and the clinical and radiological grade of osteoarthritis of DIP and PIP hand joints. The radiologically determined cervical osteoarthritis grade is significantly higher than that of DIP ($p = 0.004$) and PIP ($p = 0.035$) joints of the hands.

Key words: Osteoarthritis, hands, keyboard, cervical spine

Introduction

Osteoarthritis or osteoosteoarthritis (OA) is a degenerative process the evolution of which comes with age. Women suffer more frequently than man, especially after menopause (1,2). The anatomic substrate of osteoarthritis is progressive degeneration and loss of joint cartilage, reactive changes on bone ends and the subchondral bone, as well as in the synovial membrane (3). The clinical manifestations of osteoosteoarthritis include: progressive joint pain, rigor, swelling of the joint, restrictive movements (1,3). Joint pain is the dominant symptom of OA. The association between joint pain and the radiographic features of OA is not constant. In studies performed during the 1950s in the north of England, the relationship between pain and the radiographic evidence of OA was considerably stronger for the hip than for the knee or distal interphalangeal joint (4).

There are many factors that have its influence on the pathogenesis and evolution of osteoarthritis: genetics, mechanical and biochemical factors, and immunology (1,5). Research has been done on risk factors for hand OA among Chinese residents (age 60-95, lower levels of education, higher bone mineral index and bone mineral density) that has shown an increase in hand OA prevalence in men, but not in women. While older age and menarche are associated with increased OA prevalence, no such relation

has been observed for age at menopause (6). Among women with hand OA, stronger pain is significantly associated with days of rising barometric pressure ($P < 0.001$). These findings have been obtained for the population 49 years of age and older (7).

Mechanical factors are risk factors for OA and they include: trauma, joint shape and repetitive use- occupational and leisure (4). The most acceptable theory of the pathogenesis of osteoarthritis is a repetitive micro trauma (1,5,8). A repetitive micro trauma provokes the release of fibrinolytic factors that damage the joint cartilage (9). The repetitive micro trauma of hands is common in data input personnel, secretaries, and dentists (10). In Serbia, there are still workplaces where people use mechanical typewriters. Distal (DIP) and proximal (PIP) interphalangeal joints are exposed to stronger mechanical force in mechanical typewriter use than in keyboard usage. This will speed up the arthritic process. We hypothesized that in the population at risk, the repetitive micro trauma which lasts for many years will contribute to a more progressive arthrotic process, compared to people without professional risk, and that the years of exposition are in a positive correlation with the degree of osteoarthritis.

Hours of working in a non-physiological neck position cause neck pain and difficulties in neck motion; after many years, arthrotic changes on the neck spine

and problems connected with irregular blood flow through vertebral arteries occur. There is a significant interference of pain with the quality of life and activity of patients. The major diagnostics associated with pain are osteoarthritis and tehosynovitis/bursitis. Women have a mean rate of pain intensity significantly superior compared to male patients (11). OA is the cause of disability in older adults. "The association between participation restriction and selected patient characteristics in community-dwelling older adults aged 50 years and over (the age at which OA emerges as the leading cause of disability and specifically the contribution of peripheral joint pain) was investigated in cross-sectional postal survey of population sample of 11,309 subjects in USA. Participation restriction is common in community-dwelling adults age of 50 years and over and is associated with a range of health conditions, impairments and activity limitation" (12). We believe that OA can appear in population at risk before 50 years of age.

The subject of our interest was the influence of prolonged exposure to mechanical force that causes a repetitive micro trauma (its intensity and time of exposure) in the pathogenesis and progression of osteoarthritis. We wanted to compare the degree of osteoarthritis of the hands and the neck in the population at risk.

We expect that long utilization of a keyboard and/or a mechanical typewriter have an influence on the clinical manifestations and a higher radiological degree of osteoarthritis of the hands and the neck. We presume a higher radiological degree of osteoarthritis on DIP and PIP hands joints than the degree of neck osteoarthritis.

Patients and Method

We studied a sample of 30 people over 40 years of age (min 39, max 57 years of age) who have been working on a keyboard or a mechanical typewriter for at least 10 years. A clinical and radiological evaluation of the degree of osteoarthritis of the hands and the neck spine was done according to the Kellgren-Lawrence grade scale. CRP and ESR were used as laboratory markers of secondary inflammation in osteoarthritis. We also used some demographic and epidemiological data (age, profession, average years of working, average effective daily working hours, clinical manifestations). To obtain these data we used a questionnaire especially made for this purpose.

The examinees were data input personnel, typists, accountants, bank employees, and university teaching assistants.

The study was done at the Institute for Prevention, Treatment and Rehabilitation of Rheumatic and Cardiovascular Diseases in Niska Banja during 2004. For data processing, we used descriptive statistics, nonparametric tests, and correlations. We noted the most frequent clinical symptoms of hand and neck osteoarthritis. A correlation between the clinical stage on PIP and DIP hand joints and age and working years was determined. We correlated the clinical and

radiological degree on DIP and PIP hand joints. We correlated the radiological degree of osteoarthritis on DIP and PIP hand joints and neck spine.

Results

We did a prospective study with 30 examinees (28 females, 2 males), average age 47 years (min 39, max 57), SD 4.77, and average effective working hours 8.88 (SD 6.59). The average usage of the keyboard was 18.71 years. (SD 6.59)

Of all examinees, 66.6% had nodules on PIP and DIP hand joints. The clinical degree I on DIP hand joints was observed in 46.7% subjects, degree II in 13.3%, and degree III in 10%. Nine examinees (30%) had no clinical manifestations on DIP hand joints.

The clinical degree I on PIP hand joints was registered in 30% examinees, degree II in 30%, and degree III in 10%, while 9 examinees (30%) had no clinical manifestations. 68% had a simultaneous pain in the neck and hands.

We found statistically significant correlations between the clinical and radiological degree on DIP hand joints (Spearman = 0.631, $p = 0.01$); clinical degree and age (Spearman = 0.516, $p = 0.05$); and clinical degree and years of working (Spearman = 0.459, $p = 0.05$).

Our study showed that there is a negative correlation between the clinical degree of DIP hand joints and the radiological degree of the neck spine (Spearman = 0.486, $p = 0.05$).

We determined a correlation between the clinical (Spearman = 0.491, $p = 0.05$) and radiological (Spearman = 0.835, $p = 0.01$) degree on PIP and DIP hand joints.

The radiological degree on DIP hand joints correlates with years of working (Spearman = 0.382, $p = 0.05$) and age (Spearman = 0.441, $p = 0.05$). The correlation between the clinical degree on DIP hand joints and age (Spearman = 0.516, $p = 0.01$), as well as with working years (Spearman = 0.459, $p = 0.05$) was a little bit higher. Frequencies of the radiological degree on DIP and PIP hand joints are shown in Tables 1 and 2.

Table 1. Radiological degree of osteoarthritis on DIP hand joints in at-risk examinees

Rö degree	n	%
I	9	30.0
II	14	46.7
III	5	16.7
Missing	2	6.7
Total	30	100.0

Table 2. Radiological degree of osteoarthritis on PIP hand joints in at-risk examinees

Rö degree	n	%
I	12	40.0
II	12	40.0
III	5	16.7
Missing	1	3.3
Total	30	100.0

Of all examinees, 96.4% had neck pain. Frequencies of the radiological degree on the neck spine are shown in Table 3. There is a negative correlation between neck pain and the radiological degree on PIP hand joints (Spearman = -0.645, $p = 0.05$). The examinees with neck pain usually complain of headache only (16.7%), vertigo (12.5%), headache and difficulties in neck movements (8.3%) and syncope (8.3%). We determined that neck pain is in a positive correlation with effective day working hours ($r = 0.412$, $p = 0.05$).

Table 3. Radiological degree of neck spine osteoarthritis

Rö degree	n	%
I	5	16.7
II	11	36.7
III	12	40.0
IV	1	3.3
Missing	1	3.3
Total	30	100.0

Swelling of hands as a clinical manifestation of osteoarthritis was absent in 63.4% examinees. Only 10% had swelling on PIP hand joints, 10% on DIP and 16.6% had diffuse hand swelling.

We did not find statistically significant correlations between the average workday duration and: the clinical and radiological degree of arthritis on PIP and DIP hand joints and neck spine. Our results show a higher radiological degree of neck spine osteoarthritis compared to the radiological degree of osteoarthritis on PIP ($p=0.035$) and DIP ($p=0.004$) hand joints, but not always at the same time in the same examinee. The results are shown in Tables 4 and 5.

Table 4. Correlations between the radiological degree of hand and neck osteoarthritis in at-risk examinees

Radiological changes	N	r	p
DIP & PIP	27	0.864	0.000
PIP & neck spine	27	-0.114	0.572
DIP & neck spine	28	0.095	0.631

Table 5. Comparison between the radiological degree of osteoarthritis on DIP and PIP hand joints and neck spine in at-risk examinees

	N		Mean	Difference of means	Standard deviation	t	p
PIP-neck spine	28	Neck spine	2.2321	-.6071	1.0306	-3.117	.004
		PIP	1.7500				
IP-neck spine	27	Neck spine	2.2222	-.4815	1.1222	-2.229	.035
		DIP	1.8519				

All examinees had normal CRP levels and ESR.

Discussion

Generally speaking, OA is a normal process which does not appear before the fifth decade of life (1). "OA is undoubtedly an ageing-related disorder since it hardly ever occurs before the age of 30 and rarely occurs in

subjects under 50 years of age. According to French data, OA rarely occurs before the age of 40-45 (2-3%) but affects almost one-third of subjects between the ages of 45 and 64 and between 60-70% of over 65-year-olds" (13).

"OA is the most common joint disorder to affect Western populations, and the hand is the most frequent site of involvement" (Felson, 1988 by 14). "Significant independent predictors of total patient expenditures related to OA are being female and having joint stiffness" (15). In Brazil, the prevalence of OA is 4.14%. The data were obtained by the COPCORD questionnaire. In this study, OA was the most prevalent disease. The screening strategy used only symptomatic patients. The mean age for OA was 56 years (SD 12.7) (16).

OA of the hands, as well as the spine is less frequent in Morocco than in Europe and America (17). The prevalence of DIP joints OA in the urban population of Antalia, Turkey, aged 50 or over, was 26.3% and 3.8% in women and men, respectively (18).

In the first detailed study on the pattern of involvement of OA of the hand, which involved hospital outpatients, Kellgren and Moore reported a predilection for the disorder of DIP joint, thumb base, and PIP joint (Kellgren and Moore 1952 by 14).

According to a study done in Great Britain on 1,467 man and 1,519 women, aged 53 years, the pattern of hand joint involvement was almost identical between men and women. Both sexes had ≥ 4 joints involved. The sample chosen for follow-up comprised subjects born to non-manual (excluding the self-employed) and agricultural workers, as well as 1 in 4 subjects born to manual workers or self-employed. The most frequently involved site in both sexes was DIP joint (prevalence was higher in women than in men). This was followed in frequency by PIP joint and thumb base.

Moderate or severe radiographic OA has been found to have a predilection for DIP joints and thumb base, with the frequency of DIP involvement being greatest in the second finger, followed by the third and fifth fingers. This was found in O'Brien's *et al.* research on

1,334 men and women, aged 21 years and older (O'Brien *et al.*, 1966 by 14). Some investigators documented the predilection for right-handed involvement among right-handed individuals for right-sided DIP joints with left side thumb base involvement. Some researchers failed to show a clear difference between the distribution of OA in the right and left hands (Lane *et al.* by 14). These authors found that in women aged

between 45-64 years symmetric involvement of hand joints is a predominant characteristic and observed a statistically significant grouping by row and ray (clustering by row- DIP, PIP or carpometacarpal joints; ray - PIP and DIP) (14)

The evolution of osteoarthritis comes with age but not equally on all joints. The progression is faster on joints which are more and frequently exposed to a micro-trauma (10,19). DIP hand joints in dentists are more frequent and earlier attacked (before the age of 50), compared to the population at no risk (10). To investigate the effect of mechanical stress on finger OA by comparing women from two occupations with different hand load but the same socio-economic grade, and to investigate whether hand load may affect the pattern of joint involvement in OA, radiographs of both hands of 295 dentists and 248 teachers were examined by Finnish researches. Each interphalangeal (distal, proximal and thumb interphalangeal) and metacarpophalangeal joints were graded separately by using reference images. The non-dominant hand was more frequently affected by OA of grade 2 or higher than the dominant hand. The prevalence of OA of grade 2 or higher in any finger joint, as well as in any distal interphalangeal joint, was higher among teachers than dentists (59 vs. 48%, $P = 0.020$ and 58 vs. 47%, $P < 0.010$, respectively). Finger OA showed more clustering in the ring and little fingers and more row clustering and symmetry in teachers than in dentists. The age-adjusted odds ratio of a more severe OA (grade 3 or more) in the right-hand thumb and the index and middle fingers was significantly elevated among dentists compared to teachers. These findings indicate that finger OA in middle-aged women is highly prevalent and often polyarticular. These authors suggest that hand use may have a protective effect on finger joint OA, whereas continuing joint overload may lead to joint impairment (20)

Bad working conditions such as huge temperature differences and hard physical strain (agriculture) contribute to a faster progression of osteoarthritis in affected joints (21). Our results showed a higher damage to DIP compared to damage to PIP hand joints but the difference is not statistically significant (the average radiological degree of osteoarthritis on DIP hand joints is 1.8519, and on PIP 1.7778, $p = 0.327$).

"OA is significantly associated with decreased hand strength. Among individuals with OA increasing radiographic severity (PIP < MCP and CMC hand joints) is associated with reduction in grip and pinch strength, even when controlling for self-reported pain" (22).

A micro-trauma with the pinching mechanism is a responsible pathogenetic factor for osteoarthritis on DIP and PIP hand joints and its progression. A further factor is duration of exposure to bad environmental conditions (1), which has also been shown in our study. The radiological degree on DIP hand joints correlates with years of working (Spearman = 0.382, $p = 0.05$) and age (Spearman = 0.441, $p = 0.05$). Structural damage to joints appears much earlier than clinical manifestations. "Radio-clinical disparity is indisputable. It is an ever-

present phenomenon, which has been highlighted in all recent epidemiological studies" (23). In a study done among Caucasian subjects over 55 years of age with no clinical evidence or history of joint disease, as well as no family history of joint placement for OA, it was found that among subjects who were negative for radiological OA of hips, knees and lower lumbar spine, 44% had unilateral hand radiological OA (classified according to the Kellgren- Lawrence grade) and 27% bilateral hand radiological OA; 81% were positive for radiographic cervical spine OA (24). "In most instances OA occurs without symptoms or disability. Furthermore, symptoms relating to OA are predominantly phasic, and are often associated with a good prognosis. Disconcordance between symptoms and structural change, biosynthetic activity, and general good outcome, suggest that OA reflects the inherent repair process of synovial joints" (25)

In our sample, 30% of examinees did not have clinical manifestations of osteoarthritis on PIP and DIP hand joints while radiological manifestations were notable.

People with hand osteoarthritis do not always experience reduced strength of hand muscles or other functions of the hand such as grip and pinch strength (1,26). This is often the reason for not visiting the doctor. They usually come to the doctor's too late, when deformations on the joints are evident. It is usually women, frequently after menopause and sometimes only for esthetic reasons, (1) who ask for medical help. A majority of our examinees have the first and second clinical degree of osteoarthritis on PIP and the first degree on DIP hand joints.

Chinese older people (60 years and over) had a much lower prevalence of OA in DIP and PIP joints but a similar prevalence in metacarpophalangeal (MCP) joints compared to Caucasians in the U.S.A. These results were obtained on a random sample of 1,843 Chinese older people (subjects completed a home interview and AP knee x-ray and PA x-ray of both hands were done). Some previous studies reported that repeated forceful gripping increases the risk of OA in MCP joints and thumb base but not in other hand joints in part because the large lever arms in the proximal joints increase loading in these joints during grip. In this study, OA of PIP joints in men had a higher prevalence of knee OA but no such results were found in women. A statistically significant association was noticed between OA on DIP joints and knee OA in women (27).

As regards occupational factors, posture and gesture predominate over workload itself (23).

It seems that the immense problem for the patient's life quality is neck pain, reduction of amplitude of neck movements and rigor. All this appears after long hours of working, sitting, and holding the neck in a non-physiological position (complete flexion of the neck during typing on a mechanical typewriter machine and lateroflexion during typing on a keyboard). A number of studies confirm the existence of positive correlations between neck pain and risk factors at work such as: poor ergonomic design of the workplace and task including

work organization, poor working posture (keeping neck in the anteroflexion, position of the hands during typing), lack of task variation, and insufficient breaks for rest (28,29). All our examinees complained about neck pain. Neck and shoulder pain are major problems in modern society. With the increased use of computers and stationary-designed workplaces, ever younger and younger people are faced with musculoskeletal disorders of the neck and shoulders. Positive relationships between neck and shoulder pain and the following work-related risk factors have been found in several studies: occupational repetitiveness, arm force, arm posture, hand/arm vibration, neck flexion, static or sedentary postures, duration of sitting, twisting or bending of the trunk, workplace design (28,29). "Prolonged gripping, prolonged bending of the neck forwards, working with arms at/above shoulder height, low job control, many changes in tasks and low job support were independently associated with hand paraesthesia. Among responders also reporting presence of neck and upper limb pain, working with arms at/above shoulder height and many changes in tasks were independently associated with hand paraesthesia; prolonged gripping was linked to hand paraesthesia in the absence of neck and upper limb pain. "Hand paraesthesia is associated with physical and psychosocial workplace factors, although different work-related factors were associated with hand paraesthesia according to the concurrent presence of neck and upper limb pain, suggesting that these symptoms may not always be mediated in the same way" (30). Neck pain often begins gradually as a result of fixed staring at a small area or glancing repeatedly from one area to another (from the screen to a document on the desk). If the head is held at an angle greater than 15 degrees (for example, holding the phone between the neck and the shoulder, or looking down at the keyboard), this will cause greater muscular fatigue and pain will become apparent more rapidly (31). Our examinees had headaches (16.7%), vertigo (12.5%), headache and rigor (8.3%), and syncope (8.3%). Our research data confirm that neck pain is related to effective workday duration ($r = 0.412$, $p = 0.05$).

We can explain the negative correlation between neck pain and radiological degree on PIP hand joints (Spearman = -0.645 , $p = 0.05$) by individual working styles - style of sitting, position of the neck and hands during work. We hypothesize that those people who use PIP hand joints less frequently tend to keep the neck in poor positions longer. We did hypothesize that the radiological degree of osteoarthritis on DIP and PIP hand joints is higher than the degree of neck osteoarthritis,

but we obtained the opposite results. The higher radiological degree of neck spine osteoarthritis in comparison to the radiological degree of osteoarthritis on PIP ($p = 0.004$) and DIP ($p = 0.035$) hand joints, but not always at the same time and in the same examinee, can be accounted for by an individual keyboard working style.

According to our study, there is no statistically significant correlation between effective workday duration and the clinical and radiological degree of osteoarthritis on PIP and DIP hand joints. Our study confirmed that age and mechanical stress correlate with higher joint damage.

Conclusion

A total of 30 examinees exposed to professional risk for hand osteoarthritis, average age 47 years, were examined. Their average workday lasted for 8.88 hours and the average usage of the keyboard was 18.71 years. We draw the following conclusions:

1. There is no statistically significant correlation between average workday duration and the radiological and clinical degree on PIP and DIP hand joints and neck spine
2. The radiological degree of neck spine osteoarthritis, when compared to the radiological degree of osteoarthritis on PIP and DIP hand joints, is statistically significantly higher
3. The longer workday duration, the more frequent neck pain.
4. The radiological and clinical degree of osteoarthritis on DIP hand joints are connected with age and working years.

Suggestions

In order to preserve health and achieve a better life quality among people who professionally use keyboards we recommend:

1. Exclusive usage of ergonomic keyboards (with palm rest)
2. Individual adjustment of the desk and position of the monitor
3. Avoiding long lasting poor neck positions
4. More frequent rest breaks: every 1.5 hours of continuous work, do hand and neck gymnastics for 10-15 minutes, and every 30 minutes of continuous work, take a 5-minute break.
5. It is recommendable to listen to relaxing music during breaks. It increases the relaxation effect.

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UTICAJ PONOVLJENE MIKROTREUME NA NASTANAK I PROGRESIJU OSTEOARTROZE ŠAKA I VRATNE KIČME

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Kratak sadržaj: Jedan od uzročnih faktora artroze je ponovljena mikrotrauma. Cilj našeg rada bio je da se utvrdi povezanost ponovljene mikrotraume kod višestruke, višegodišnje upotrebe tastature računara i/ili mehaničke mašine za kucanje sa stepenom artroze na proksimalnim interfalangealnim (PIP) i distalnim interfalangealnim (DIP) zglobovima šaka i cervikalnoj kičmi.

Kriterijumi za izbor ispitanika bili su uzrast preko 40 godina i upotrebe tastature mašine za kucanje i/ili računara najmanje 10 god. Vršena je klinička i radiološka procena stadijuma artroze šaka po Kelgren-u i Lawrenc-u, kao i klinička i radiološka zahvaćenost vratne kičme. CRP i SE su korišćeni kao laboratorijski markeri sekundarne inflamacije u artrozi. Ostali demografski i epidemiološki podaci dobijeni su putem upitnika posebno sačinjenim za ovu priliku.

Ispitano je 30 ispitanika prosečne starosti 47 (SD 4,77) god, prosečnog broja dnevnih efektivnih radnih sati 8,88 (SD 6,59). Ispitanici u proseku koriste tastaturu 18,71 (SD 6,59) god.

Ispitivanjem smo ustanovili da klinički stadijum na DIP zglobovima korelira sa godinama starosti ($r=0.516$, $p=0.05$) i dužinom radnog staža ($r=0.459$, $p=0.5$). Postoji korelacija između radiološkog stadijuma na PIP i DIP zglobovima šaka ($r=0.835$, $p=0.01$). Ne postoji statistički značajna korelacija između prosečnih dnevnih efektivnih radnih sati i kliničkog i radiološkog stepena artroze na PIP i DIP zglobovima šaka. Radiološki stadijum artroze vratne kičme je statistički značajno veći od radiološkog stepena artroze na DIP ($p=0.004$) i PIP ($p=0.035$) zglobovima šaka.

Naša ispitivanja pokazala su veći radiološki stepen artroze vratne kičme u odnosu na stepena artroze šaka kod ispitanika koji više godina koriste tastaturu.

Ključne reči: Artroza, šake, tastatura, vratna kičma