Autofeedback from Ultrasound Images Provides Rapid Improvement in Palpation Skills for Identifying Joint Swelling in Rheumatoid Arthritis

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ABSTRACT. ***Objective.*** Joint swelling, an important factor in the classification criteria and disease activity assessment in rheumatoid arthritis (RA), renders joint palpation a necessary skill for physicians. Ultrasound (US) examination that visualizes soft tissue abnormalities is now used to assess musculoskeletal disease. We assessed the usefulness of US assessments in enhancing physical joint examination skills.

Methods. We examined 1944 joints (bilateral shoulder, elbow, wrist, metacarpophalangeal joints 1–5, and knee joints) in 108 patients with RA during April-July 2011. We first physically examined and confirmed joint swelling; subsequently, the same rheumatologist conducted US examinations and multiple assessors graded the joint swelling. When the 2 results differed, we received autofeedback from the US results to improve the physical examination skills.

Results. The sensitivities and specificities of physical examination for US-detected swollen joint, the correlation coefficient (CC) of the swollen joint counts, and the concordance rate in each patient for joint swelling sites and power Doppler (PD)-positive sites with the κ coefficients between the physical and US examinations were compared over time. We found that the sensitivity of physical examination increased by 42 percentage points (pp), while the specificity decreased by 18 pp. The average CC in June-July was greater than that in April-May. The percentage of κ coefficients > 0.8 increased from 8.8% to 17% for joint swelling and from 8.3% to 14% for PD-positive sites.

Conclusion. Our results suggest that autofeedback from US assessment provides quick improvement in palpation skills for identifying joint swelling in patients with RA. (J Rheumatol First Release May 15 2012; doi:10.3899/jrheum.111433)

Key Indexing Terms:
RHEUMATOID ARTHRITIS ULTRASOUND JOINT SWELLING JOINT PALPATION

Physical joint examination and assessment of swollen joint counts (SJC) in musculoskeletal diseases, particularly in rheumatoid arthritis (RA), are critical for early diagnosis and accurate assessment of disease activity[1,2,3,4,5]. In patients with inflammatory arthritis, unskilled joint palpation and inaccurate SJC can lead to delayed or wrong diagnosis and treatment, resulting in disease progression. Despite the importance of physical joint examination, the judgment of joint swelling might depend on the individual physician's skill, which is related to duration of clinical experience; therefore, a low concordance rate has been observed among physicians in this regard[6].

Ultrasound (US) examination is recognized to be more sensitive for identifying soft tissue abnormalities, such as fluid in joints, synovitis, enthesitis, and bone erosions, as compared to physical examination. It is therefore used as a supporting tool for the early diagnosis of RA[7,8,9], polymyalgia rheumatica[10], psoriatic arthritis[11], and other musculoskeletal diseases, and also for evaluating the progression of these diseases[12,13,14]. By performing US examination simultaneously with physical examination, improved sensitivity and/or correction of the variable sensitivity among physicians for identifying joint swelling may be achieved. Moreover, the accuracy of physical findings can be confirmed using US imaging. However, this does not decrease the importance of physical

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joint examination and the skills it requires; this continues to be an important skill of rheumatologists[1,2,3,4,5].

We conducted US examination and provided autofeedback using US images following physical joint examination; then we assessed the effects of this feedback on physical examination skills.

MATERIALS AND METHODS

We performed physical examination for judgment of joint swelling followed by US examination (ProSound Alpha7 with UST-5411 transducer; Hitachi Aloka Medical, Ltd., Tokyo, Japan) for confirmation and grading[15,16,17,18] of 1944 joints [bilateral shoulder, elbow, wrist, metacarpophalangeal (MCP) joints 1–5, and knee joints; Figure 1]. The study subjects were 108 patients with RA (92 women, 16 men) who presented at Juntendo University Hospital between April and July 2011 and were diagnosed with RA based on the 1987 RA criteria[1]. The mean age of patients was 49.6 ± SD 13.1 years (range 23–73 yrs) and the disease duration was 126.2 ± 103.8 months (range 6–624 mo). Joint swelling detected by US (US-SJ), defined as synovial hypertrophy and/or effusion, was identified as abnormal hypoechoic material within joint recesses, tendon sheaths, or bursae and graded on a semiquantitative grayscale (GS) from 0 to 3 (where 0 = absence, 1 = mild, 2 = moderate, and 3 = marked)[15,16,17,18]. Synovial blood flow was evaluated by power Doppler (PD) observation in each of the intraarticular and periarticular synovial sites. PD variables were adjusted at the lowest permissible pulse repetition frequency to maximize sensitivity. Color gain was set just below the level at which color noise appeared underlying bone. Intraarticular PD signals were graded on a semiquantitative scale from 0 to 3 (where 0 = absence, no synovial flow; 1 = mild, ≤ 3 isolated signals; 2 = moderate, > 3 isolated signals or confluent signal in less than half the synovial area; and 3 = marked, signals in more than half the synovial area)[15,16,17,18].

Physical joint examination was performed by an expert rheumatologist (MO) with more than 15 years of clinical experience in rheumatology; US examination was also conducted by the same rheumatologist. Multiple assessors judged the US assessment and graded the GS and PD findings. When the results of the US examination differed from those of the physical examination, we received autofeedback of the results of the US examination to improve the physical examination skills (Figure 1). To confirm the rapid improvement rendered by the US examination in the physical examination skills, we calculated the following values in each half of the study period (first half: April-May 2011; second half: June-July 2011) and compared those values between the 2 study periods.

(1) Sensitivities and specificities of physical examination for US-SJ. Improvement factors in the percentages, sensitivities, and specificities between the 2 study periods were calculated as percentage points (pp).

(2) Correlation coefficients (CC) for the swollen joint counts between those assessed by physical examination (CLI-SJC) and by US examination (US-SJC) were compared with Spearman's test.

(3) Joint swelling sites were compared between those detected by the physical and by US examinations, and the concordance rate was calculated in each patient using kappa coefficients (poor concordance: greater than 0 and ≤ 0.4; good: > 0.4 and ≤ 0.6; moderate: > 0.6 and ≤ 0.8; excellent: > 0.8 and ≤ 1.0).

(4) Joint swelling sites detected by the physical examination were compared with the joint sites with PD signal (≥ 2) and the concordance rate in each patient was calculated using kappa coefficients.

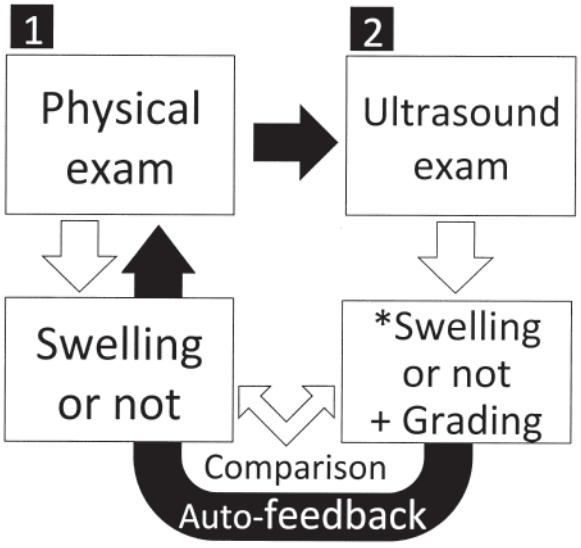

Figure 1. The process of the study; 1: first half of the study period; 2: second half. *Swelling confirmed by multiple assessors.

RESULTS

Joint swelling was frequently observed in small joints using US, particularly in the wrist (154/216 joint sites, 71.3%), 2nd MCP (125/216 joint sites, 57.9%), and 3rd MCP (125/216 joint sites, 57.9%). The frequency of large joint swelling at the shoulder (30/216 joint sites, 13.9%) and elbow joints (42/216 joint sites, 19.4%) was lower than that in the small joints (Table 1, Figure 2A).

The average sensitivity of the clinical examination for US-SJ was 43% when joint swelling was defined as GS ≥ 1, 58% when GS ≥ 2, and 56% when GS ≥ 3 in the first half of the study period (Table 2, Figure 2B). In the second half, sensitivity improved to 53% (+10 pp) when GS ≥ 1, 68% (+10 pp) when GS ≥ 2, and 78% (+22 pp) when GS ≥ 3. Sensitivity was highest when GS ≥ 3 in the latter half of the study, June-July 2011.

The average specificity of the physical examination was 88% when joint swelling was defined as GS ≥ 1, 87% when GS ≥ 2, and 81% when GS ≥ 3 in the first half of the study. In the second half, specificity decreased to 84% (–4 pp) when GS ≥ 1, 79% (–8 pp) when GS ≥ 2, and 75% (–6 pp) when GS ≥ 3. However, as the increase in pp for sensitivity (total 42 pp) was greater than the decrease in pp for specificity (total 18 pp; Figure 3), physical examination skills for identifying joint swelling were considered to have improved substantially in the latter half of the study period.

The CC between CLI-SJC and US-SJC was 0.426 ($p = 0.003$) when GS ≥ 1, 0.675 ($p < 0.0001$) when GS ≥ 2, and 0.521 ($p = 0.0002$) when GS ≥ 3 in the first half; while in the second half, it was 0.548 ($p < 0.0001$) when GS ≥ 1, 0.677 ($p < 0.0001$) when GS ≥ 2, and 0.602 ($p < 0.0001$) when GS ≥ 3 (Figure 4A, 4B; Table 3). Thus, CC values in the second half (average CC = 0.609) were greater than those in first half (average CC = 0.541), in particular when GS ≥ 2.

The concordance rate of joint swelling sites between those detected by the physical and by US examinations was calculated using kappa coefficients and compared between the 2 study periods (Figure 5A). The percentage of physical examination with excellent concordance rate (kappa > 0.8) increased from 8.8% in the first half to 17% in the second half. Moreover, the percentage of physical examination with excellent concordance rate with PD signal-positive (≥ 2) sites also

Table 1. Frequency of swollen joints detected by ultrasound (ultrasound-SJ) in each joint site.

Joint	GS ≥ 1 No. (%) ultrasound-SJ	GS ≥ 2 No. (%) ultrasound-SJ	GS ≥ 3 No. (%) ultrasound-SJ
Shoulder	30 (13.9)	10 (4.6)	6 (2.8)
Elbow	42 (19.4)	24 (11.1)	20 (9.3)
Wrist	154 (71.3)	124 (57.4)	62 (28.7)
1MCP	91 (42.1)	64 (29.6)	48 (22.2)
2MCP	125 (57.9)	89 (41.2)	76 (35.2)
3MCP	125 (57.9)	75 (34.7)	63 (29.2)
4MCP	109 (50.5)	75 (34.7)	49 (22.7)
5MCP	103 (47.7)	69 (31.9)	51 (23.6)
Knee	54 (25.0)	26 (12.0)	16 (7.4)

GS: grayscale; MCP: metacarpophalangeal.

increased from 8.3% in the first half to 14% in the second half (Figure 5B).

The results thus indicated clear improvements in the sensitivity of physical examination, higher correlation coefficients between CLI-SJC and US-SJC, and an improved concordance rate in identifying joint swelling sites and PD signal-positive sites. The physical examination skills in detecting joint swellings with PD signal were considered to have improved rapidly and significantly in a short duration of 4 months following the autofeedback received from US examination.

DISCUSSION

According to the 2010 American College of Rheumatology/European League Against Rheumatism classification criteria for RA[1], scoring with serology, acute-phase reactants, and the duration of symptoms categories were the same among different physicians for the same arthritis patient. However, as the score for the joint involvement category depends to a high degree on the palpation skills and judgment of joint swelling of the physician, the SJC could vary among physicians, resulting in differing diagnoses. In patients with active polyarthritis with negative serology, we cannot obtain a score of 3 from the serology category; therefore, more sensitive and skilled joint palpation is needed to identify joint swelling in order to obtain a total score ≥ 6 that is required for classifying RA and initiating treatment. An unskilled palpation technique with low sensitivity for joint swelling might lead to oversight in classification of RA, particularly in the presence of negative serology, eventually leading to delayed treatment. Although joint involvement refers to any swollen or tender joint that on examination may be confirmed by imaging evidence of synovitis[1], the new criteria depend on analyses of multiple variable based on physical examination. Therefore US examination, which is more sensitive than physical examination, may possibly identify a higher number of false-positive patients, resulting in decreased specificity. Moreover, when the new RA criteria were described, application of US was still not determined and was not described in detail; hence, it was not clear if the US definition[19] could be used in the criteria without modification. Thus, different US swelling definitions among physicians may lead to different sensitivity and specificity in those criteria.

Moreover, in any composite score, such as the Disease Activity Score, Simplified Disease Activity Index, or Clinical Disease Activity Index, or Boolean remission criteria[1,2,3,4,5,20], joint swelling counts by physical examination are considered an important assessment factor. Therefore, maintenance and enhancement of the quality of and decreased variability of physical examination skills among physicians are still important. In our study, US was found to be helpful to achieve such purposes even in very experienced rheumatologists, and it is expected to improve the accuracy of early diagnosis and the evaluation of disease activity with accurately assessed swollen joint counts.

Although the sensitivity of physical examination increased in most joints, it decreased in some joints, and the specificity decreased slightly, after autofeedback. This might be due to limitations of ability in the physical joint examination. Therefore, it is considered that US examination should be used as a complement to physical examination on the basis of improved palpation skills.

In our study, physical joint examination and subsequent US examination were conducted by the same experienced rheumatologist. Then the US images were used for improving the physician's palpation skills using an autofeedback mechanism. The rationale for this design was that we considered it important to confirm the effectiveness of US assessment compared to palpation skills, particularly in the same clinical situation using actual clinical examination sites. By conducting US after physical examination, it can be confirmed immediately whether the diagnosis was correct, and the palpation physical examination skills can be corrected. The bias caused by the results of the physical examination may have affected the results of the US assessment, but the probability of this was extremely low because the US results were confirmed and graded by multiple assessors. There are several reports describing higher sensitivity of US examination than physical examination in investigations for joint disease[8,21,22,23]; however, there have been no reports describing improvements in palpation skills through use of US as shown in our study.

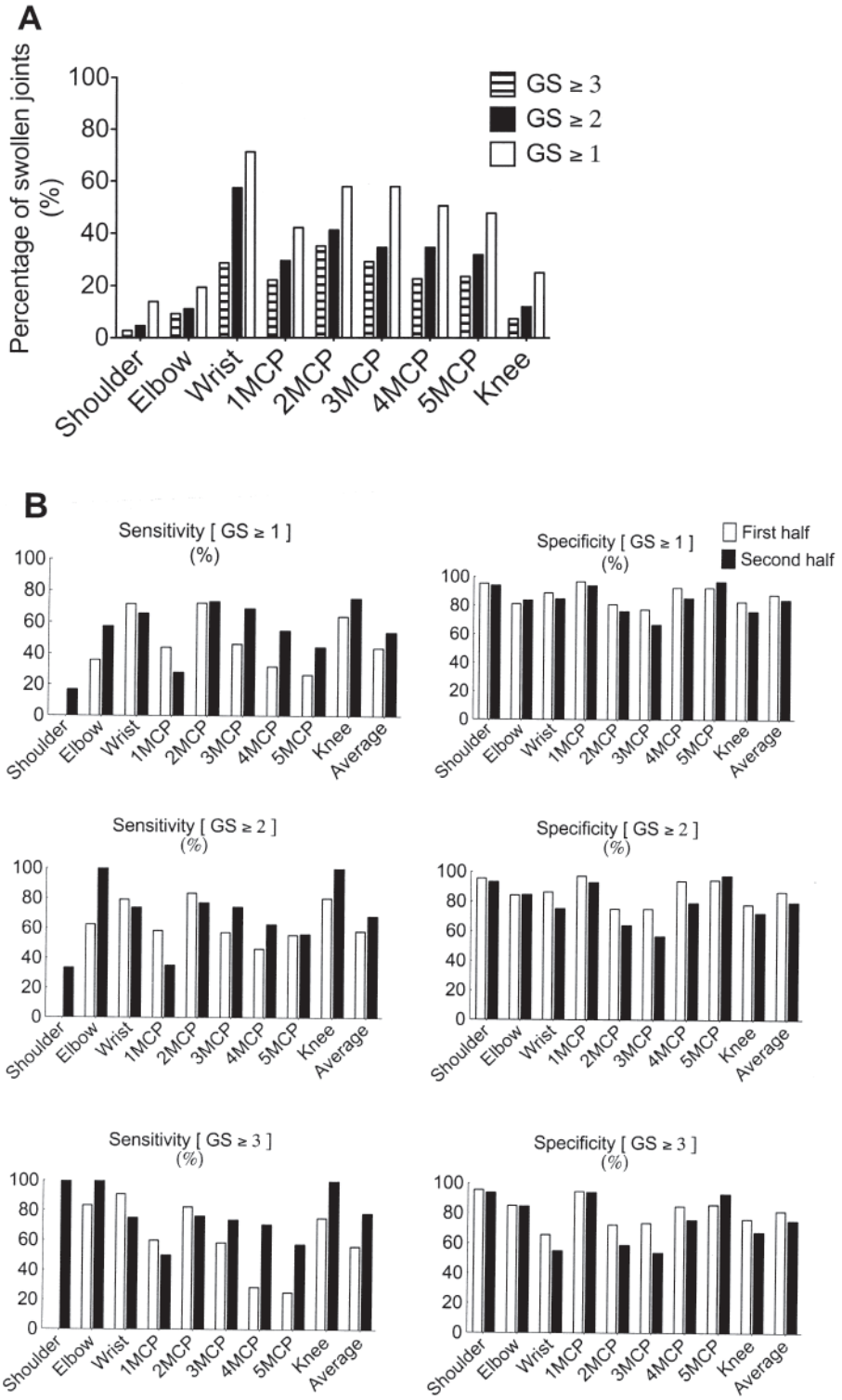

Figure 2. A. Distribution of swollen joints. Frequency of swollen joints detected by ultrasound (US-SJ) at each joint site. US-SJ was graded on a semiquantitative grayscale (GS) from 0 to 3 as described in Materials and Methods. B. Sensitivity and specificity of physical joint examinations for ultrasound-swollen joints were calculated in each half of the study period (first half: April-May 2011, white bars; second half: June-July 2011, black bars). MCP: metacarpophalangeal.

Table 2. Sensitivity and specificity of physical joint examination for swollen joints detected by ultrasound (ultrasound-SJ).

Joint	Sensitivity	Specificity	Positive LR	Negative LR	Sensitivity	Specificity	Positive LR	Negative LR
				Ultrasound-SJ: GS ≥ 1				
	First half				Second half			
Shoulder	0.00	0.95	0.00	1.05	0.17	0.94	2.78	0.89
Elbow	0.36	0.81	1.90	0.79	0.57	0.84	3.49	0.51
Wrist	0.71	0.89	6.43	0.32	0.65	0.85	4.24	0.41
1MCP	0.44	0.97	13.13	0.58	0.28	0.94	4.55	0.77
2MCP	0.72	0.81	3.78	0.35	0.73	0.76	3.04	0.36
3MCP	0.46	0.77	2.02	0.70	0.68	0.67	2.05	0.47
4MCP	0.32	0.93	4.26	0.74	0.54	0.85	3.66	0.54
5MCP	0.26	0.93	3.55	0.80	0.44	0.97	13.13	0.58
Knee	0.64	0.83	3.71	0.44	0.75	0.76	3.14	0.33
Average	0.43	0.88	3.50	0.65	0.53	0.84	3.36	0.55
				Ultrasound-SJ: GS ≥ 2				
	First half				Second half			
Shoulder	0.00	0.95	0.00	1.05	0.33	0.93	4.92	0.72
Elbow	0.63	0.84	3.96	0.45	1.00	0.84	6.44	0.00
Wrist	0.79	0.86	5.81	0.24	0.74	0.75	2.95	0.35
1MCP	0.58	0.97	19.83	0.43	0.35	0.93	4.90	0.70
2MCP	0.83	0.75	3.33	0.22	0.77	0.64	2.13	0.36
3MCP	0.57	0.75	2.29	0.57	0.74	0.56	1.70	0.46
4MCP	0.46	0.94	7.62	0.57	0.63	0.79	2.97	0.48
5MCP	0.56	0.95	10.28	0.47	0.56	0.97	20.72	0.45
Knee	0.80	0.78	3.64	0.26	1.00	0.72	3.60	0.00
Average	0.58	0.87	4.34	0.48	0.68	0.79	3.29	0.40
				Ultrasound-SJ: GS ≥ 3				
	First half				Second half			
Shoulder	0.00	0.95	0.00	1.05	1.00	0.93	15.25	0.00
Elbow	0.83	0.85	5.56	0.20	1.00	0.84	6.44	0.00
Wrist	0.91	0.66	2.65	0.14	0.75	0.55	1.66	0.46
1MCP	0.60	0.94	10.80	0.42	0.50	0.94	8.00	0.53
2MCP	0.82	0.72	2.99	0.24	0.76	0.59	1.84	0.41
3MCP	0.58	0.74	2.20	0.57	0.74	0.53	1.58	0.49
4MCP	0.29	0.85	1.86	0.84	0.71	0.76	2.89	0.39
5MCP	0.25	0.86	1.75	0.88	0.57	0.93	7.81	0.46
Knee	0.75	0.76	3.15	0.33	1.00	0.67	3.05	0.00
Average	0.56	0.81	3.02	0.54	0.78	0.75	3.11	0.29

GS: grayscale; LR: likelihood ratio; MCP: metacarpophalangeal.

This is the first report showing the usefulness of receiving autofeedback from US examination results for improving physicians' joint palpation skills. US examination is thus valuable not only for detailed examination in musculoskeletal diseases but also as an educational tool for improving joint palpation skills in physical joint examination.

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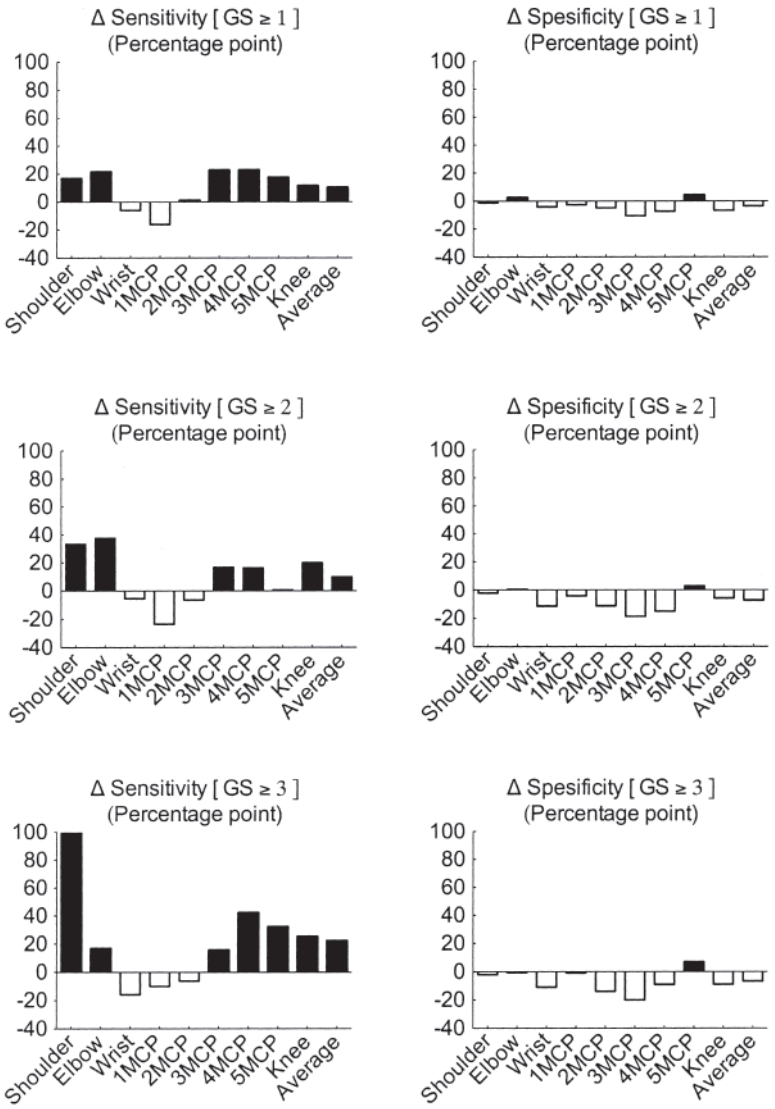

Figure 3. Changes of sensitivities and specificities between the 2 study periods. Differences were calculated as percentage points (pp). Black bars indicate positive pp, i.e., elevated sensitivity or specificity; white bars indicate negative pp, i.e., decreased sensitivity or specificity in the second half of the study. GS: grayscale; MCP: metacarpophalangeal.

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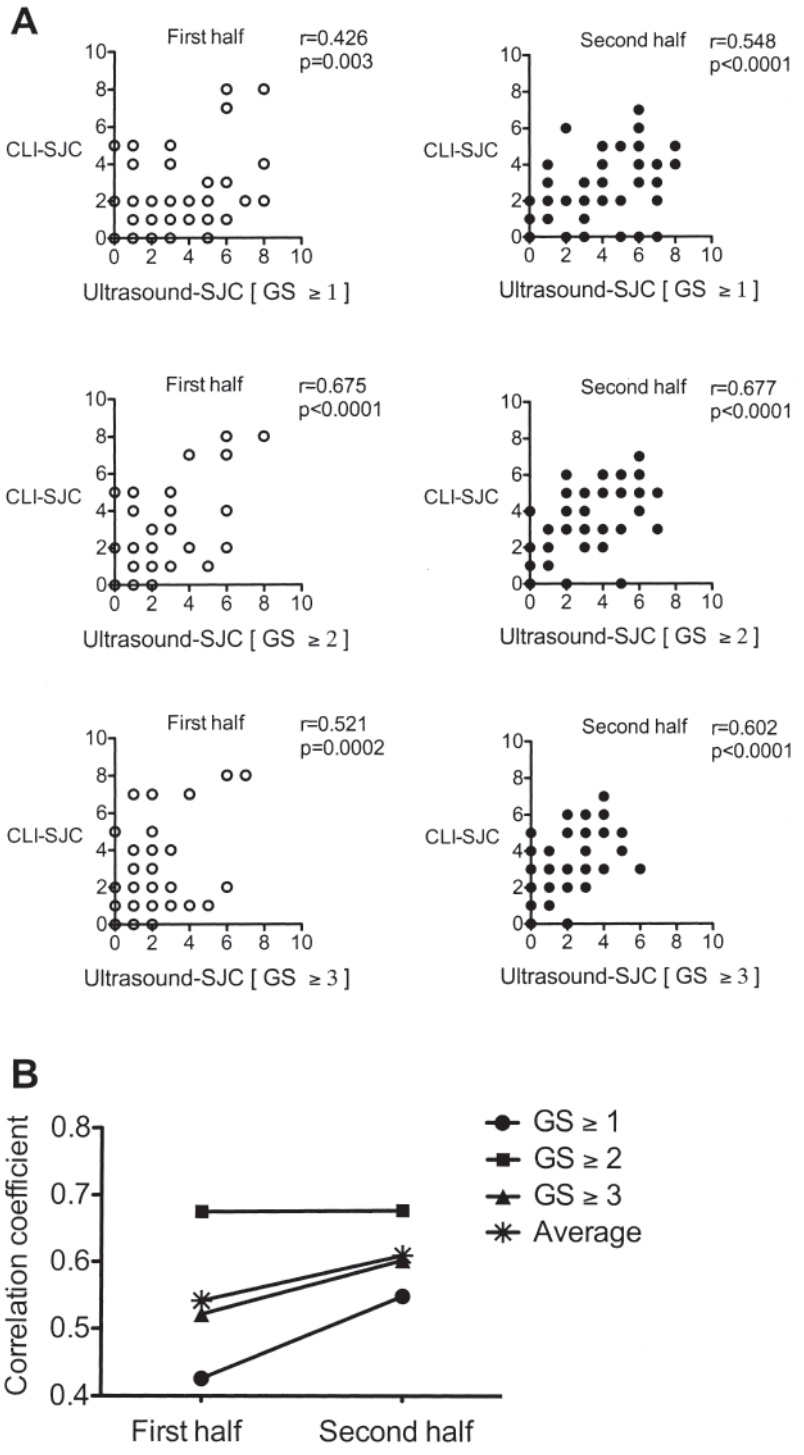

Figure 4. A. Correlations between swollen joint counts assessed by physical examination (CLI-SJC) and by ultrasound (ultrasound-SJ) in the 2 study periods (Spearman's test). B. Change of correlation coefficients between the first half and the second half of the study. GS: semiquantitative grayscale.

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Table 3. Correlation between CLI-SJC and ultrasound-SJC.

Grayscale	First Half		Second Half	
	Correlation Coefficient	p	Correlation Coefficient	p
GS ≥ 1	0.426	0.003	0.548	< 0.0001
GS ≥ 2	0.675	< 0.0001	0.677	< 0.0001
GS ≥ 3	0.521	0.0002	0.602	< 0.0001

CLI-SJC: swollen joint counts assessed by physical examination. Ultrasound-SJC: swollen joint counts assessed by ultrasound examination.

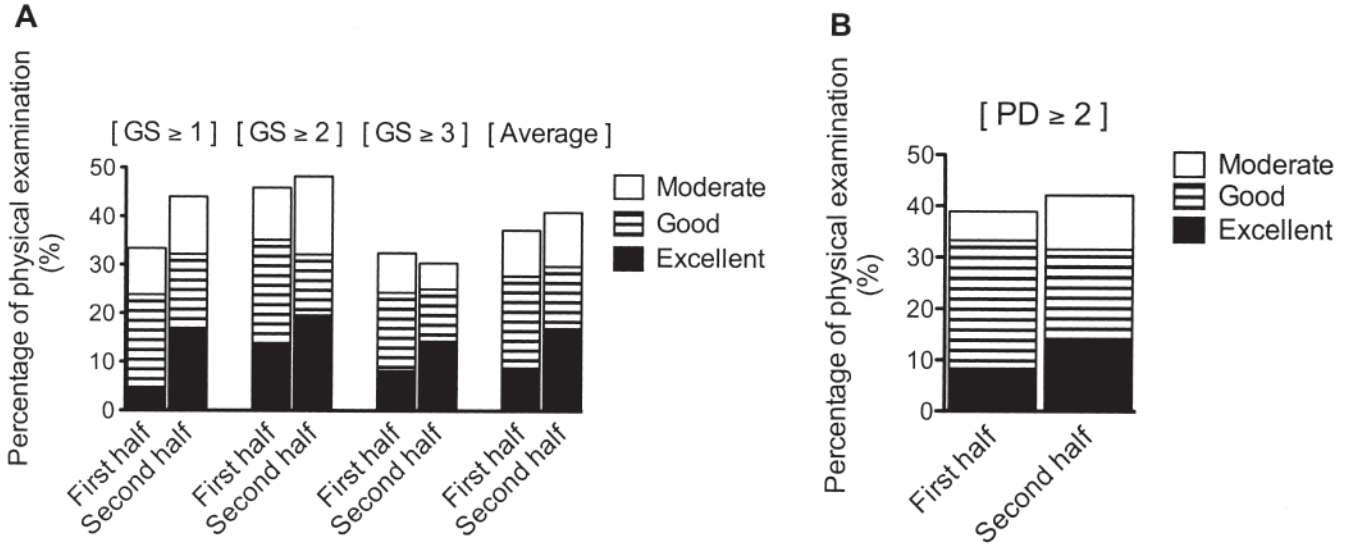

Figure 5. Changes of concordance rates. A. Concordance rate of swollen joint sites in each patient with kappa coefficients between those detected by physical and by ultrasound examination for each study period. Kappa coefficients: (poor concordance: > 0 and ≤ 0.4; good: > 0.4 and ≤ 0.6; moderate: > 0.6 and ≤ 0.8; excellent: > 0.8 and ≤ 1.0). GS: semiquantitative grayscale. B. Concordance rate in each patient between swollen joint sites and power Doppler (PD)-positive (≥ 2) joint sites for each study period.

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Ogasawara M, Murayama G, Yamada Y, Nemoto T, Kageyama M, Toyama S, et al. Autofeedback from ultrasound images provides rapid improvement in palpation skills for identifying joint swelling in rheumatoid arthritis. J Rheumatol 2012;39:1207-14. The legend of Figure 1 should read: "*Figure 1*. The process of the study. *Swelling confirmed by multiple assessors." We regret the error.
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