Osteoarthritis and Cartilage

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The prevalence, incidence, and progression of radiographic thumb base osteoarthritis in a population-based cohort: the Rotterdam Study

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SUMMARY

Objective: To describe the prevalence, incidence, and progression of radiographic thumb carpometa-carpal (CMC-1) and trapezioscaphoid (TS) radiographic osteoarthritis (ROA) in the general Dutch population aged $\geq$55y.
Design: Data were from the first and second cohort of the Rotterdam Study (1990–2005, 4–12 years follow-up, age 55+). Participants underwent bilateral radiographs at baseline (N = 7792) and follow-up (N = 3804), read for Kellgren–Lawrence (K-L) grade. ROA was defined on the joint level as K-L grade $\geq$2. The prevalence was assessed at baseline, incidence at follow-up in those free of ROA at baseline, and progression in those with ROA. Differences based on sex and age were evaluated using logistic regression models.
Results: At baseline, 1977 (25.3%) had CMC-1 ROA and 1133 (14.5%) TS ROA. The prevalence was higher in females for CMC-1 (aOR = 1.98 95%CI [1.77–2.21]) and TS ROA (aOR = 2.00 [1.74–2.29]) and increased for every year of age (CMC-1 ROA 1.08 [1.07–1.08]) (TS ROA 1.06 [1.05–1.07]). Most (437/512; 85.4%) incident cases of CMC-1 ROA (2994 at risk) were mild (K-L = 2), whereas most (145/167; 86,8%) incident cases of TS ROA (3311 at risk) were moderate to severe (K-L = 3/4). CMC-1 ROA progression was mostly (88/100; 88.0%) seen in the K-L 2 group at baseline, whereas that was (4/17; 23.5%) for TS ROA.
Conclusion: CMC-1 ROA and TS ROA are prevalent in the general Dutch population. While incident CMC-1 ROA was primarily mild, incident TS ROA was more often moderate to severe. CMC-1 ROA was a strong predictor for incident TS ROA.

Introduction

Thumb carpometacarpal (CMC-1) osteoarthritis (OA) is a disabling and degenerative disease characterized by pain, tenderness, stiffness, reduced strength, and disability in daily living[1,2].

Radiographic CMC-1 OA (ROA) includes the presence of osteophytes, narrowing of the CMC-1 joint, osteosclerosis, and cysts[3]. Multiple cross-sectional studies have investigated the prevalence of CMC-1 radiographic osteoarthritis (ROA) in the general population. However, there is a considerable variation in the reported prevalence across different studies, ranging from 0 to 100%[4–8], and a

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meta-analysis from Van der Oest *et al.* reported significant heterogeneity between study estimates that could partly be explained by sex and age[9]. Since study populations vary greatly in age and general health, the prevalence of CMC-1 ROA within the general population is still unclear.

Little is known on the longitudinal disease course of CMC-1 ROA in the general population. Only a few large cohort studies reported data on incident or progression of hand ROA[7,10,11], though none were specifically focused on the CMC-1 joint. A recent systematic review from Shapiro *et al.* found quite a few studies with large variability in progression scores ranging from 20 to 70%[12], concluding that more studies in large cohorts are needed to understand the progression of CMC-1 ROA better.

Even less is known on the prevalence and longitudinal disease course of trapezioscaphoid (TS) ROA. This joint is affected in the most severe stage of the Eaton classification[13], which is a common scoring system for CMC-1 OA in hand surgery practice. While some studies have evaluated the correlation between CMC-1 joint ROA and distal/proximal interphalangeal ROA, this has scarcely been assessed for the TS joint.

More insight into the true prevalence and longitudinal disease course of CMC-1 and TS ROA is needed to understand this degenerative disease and improve patient education, clinical decision making, and policymaking. Therefore, this study describes the prevalence, cumulative incidence, and longitudinal disease course of CMC-1 and TS ROA in a large Dutch population-based cohort.

Methods

Study design

This study is embedded within the Rotterdam Study, which is a large ongoing prospective population-based cohort study that investigates the occurrence of chronic diseases and associated factors in the elderly. The detailed study design of the Rotterdam Study has been described previously[14]. In short, participants of the Rotterdam Study are followed in several programs for various frequent diseases in the elderly, including locomotor diseases. The main objective of the locomotor epidemiology program is to study the etiology and frequency of major musculoskeletal diseases such as osteoarthritis and osteoporosis. Therefore, X-rays of the knee, hip, and hand were taken and scored to evaluate osteoarthritic features. The Rotterdam study has an observational character; no interventions were part of the study design, and participants were not restricted in seeking healthcare.

The Rotterdam Study has been approved by the Dutch Ministry of Health, Welfare and Sport (Population Screening Act WBO, license number 1071272-159521-PG) and by the Medical Ethics Committee of the Erasmus MC (registration number MEC 02.1015). Furthermore, the Rotterdam Study is registered in the Netherlands National Trial Register (www.trialregister.nl) and into the World Health Organization International Clinical Trials Registry Platform (www.who.int/ictrp/network/primary/en/) under shared catalog identification number NTR6831. All participants of the Rotterdam Study provided written informed consent to participate in the study and to have their information obtained from treating physicians. Requests to gain access to the data set (from qualified researchers trained in human subject confidentiality protocols) may be sent to the Department of Epidemiology, Erasmus MC University Medical Center at f.vanrooij@erasmusmc.nl.

We report this study following the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) statement and Reporting of studies Conducted using Observational Routinely-collected Data (RECORD) guidelines[15,16].

Setting and participants

For this study, we used the first (RS-I) and second cohort (RS-II) of the Rotterdam Study[14]. For RS-I, all residents of the district of Ommoord in Rotterdam aged ≥55 years were invited to participate; a few years later, RS-II included participants aged ≥55 years who were not part of RS-I.

Participants were interviewed at home between 1990 and 1991 (RS-1) or between 2000 and 2001 (RS-II) by trained research assistants. Participants underwent an extensive set of examinations within 2 weeks after the home interview, including radiographs of both hands and body composition measurements. Follow-up took place between 2002 and 2003 (RS-I; 12 years later) and between 2004 and 2005 (RS-II; 4 years later) in the same research facility and included radiographs of both hands.

Radiographic assessment

Within the Rotterdam Study, standard anteroposterior radiographs of both hands were rated by a team of trained assessors, supervised by a radiologist anslud a coordinating researcher. This team of trained assessors rated both the baseline and follow-up radiographs. The assessors were blinded from the clinical and demographic data. Radiographic evaluation of the CMC-1 and TS joint was based on the Kellgren–Lawrence (K-L) classification[17,18]. The K-L classification is a five-point scale): 0 = no radiographic findings of osteoarthritis; 1 = doubtful narrowing of joint space and possible osteophytic lipping; 2 = definite osteophytes and possible narrowing of joint space; 3 = moderate multiple osteophytes, definite narrowing of joint space, small pseudocystic areas with sclerotic walls, and possible deformity of bone contour; and 4 = large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone contour. The predominance given to osteophytes in the original K-L grading system has been discussed previously[19]. Therefore, we used the modified Definition in which K-L 3 is defined as a diminution in joint space regardless of the presence of osteophytes. This adjustment tries to eliminate the predominance given to the osteophyte and thus probably provides more valid results. In a previous study on the prevalence of hand ROA in cohort RS-I, the interobserver reliability for assessing the presence of ROA as a dichotomous variable, defined as K-L ≥ 2, demonstrated a Kappa statistic of 0.74 for the CMC-1/TS joints[5]. The interobserver reliability of the scoring for RS-II is unknown. While other observers scored the radiographs as in RS-I, the instructions for scoring remained unchanged.

Definition of prevalence, cumulative incidence, and ROA progression

We defined the presence of CMC-1 ROA and TS ROA as a K-L grade ≥2. For the prevalence, we assessed all participants with available K-L scores at baseline. The cumulative incidence of CMC-1 and TS ROA was assessed in participants free of ROA (K-L ≤ 1) for that specific joint at baseline. Incident ROA was defined on a joint level as a joint with K-L≥2 during radiographic follow-up. In line with previous research, "rapid progressive disease" refers to a subgroup of participants within the incident group who had a K-L≥3 at follow-up, whereas "mild" refers to the group that had a K-L score of 2 at follow-up[20]. We defined ROA progression as a change in K-L grade ≥1 on the joint level during follow-up. Progression was

only assessed in participants with a K-L grade 2−3 at baseline; participants with K-L grades between 0 and 1 were evaluated in the incidence analysis, and participants with K-L grade 4 could not show progression (in line with Haugen *et al.*)[7]. For each participant, only the most affected side was analyzed for progression of CMC-1 and TS ROA. The right hand was evaluated in participants with equal K-L scores at baseline, which seems to be the least affected side[7]. Participants who had a lower K-L grade during follow-up than baseline were not excluded from the longitudinal analyses since this would overestimate incidence and progression rates.

Data access and cleaning methods

The authors had access to participant demographics, medical history, and body measurements (e.g., Body Mass Index). The dataset containing the results from radiographic measurements (i.e., the K-L grades from all hand joints) was provided by the data manager on request. A participants' unique identification number linked radiographic and demographic data. Participants in which the CMC-1 joints or TS joints were not scored at baseline were removed from the final dataset. Data cleaning and linkage were performed in R version 4.0.1.

Statistical analysis

Continuous data were checked for Gaussian distribution using histograms. Differences in normally distributed data were tested using the Student's *T*-test, skewed data using the Wilcoxon Singed-Rank's, and categorical data using the Chi-squared statistic. We calculated prevalence as the number of participants with K-L $\geq$ 2 divided by the total participants (in that subgroup). The prevalence of CMC-1 and TS ROA stratified by sex (males and females), side (left and right hand combined and separately), and age category (55−59, 60−64, 65−69, 70−74, 75−79, and $\geq$80). Cumulative incidence was calculated as the number of participants with K-L $\geq$ 2 divided by those at risk (in that subgroup). Cumulative incidence rates were stratified by sex. Data on prevalence and cumulative incidence are presented as a point estimate with a 95% confidence interval for binomial probabilities using Wilson's method.

Multivariable logistic regression models were used to investigate differences in prevalence and cumulative incidence based on age and sex. All analyses were performed in R version 4.0.1.

Sensitivity analysis

Age, sex, and baseline ROA were compared between participants with only radiographic data at baseline and those who also had data during follow-up. We used multiple imputations by chained reaction (MICE) to predict the missing data of CMC-1 and TS ROA at follow-up by assuming that data were as missing-at-random. Age, sex, and baseline K-L scores of the CMC-1 and TS joint of both hands were used as predictors to generate 5 imputed datasets. Estimates from the 5 datasets were pooled using a random-effects model. The double-arcsine transformation on the proportions was performed since extreme values were expected. Furthermore, a tipping-point approach was used in which the observed data at follow-up were pooled with a dataset that replaced missing values by "0" (no ROA), and a dataset replacing the missing data by "1" (ROA).

Results

Of the potentially eligible participants at baseline, 7792/10,994 (70,9%) provided X-ray data on both CMC-1 and TS joints. Demographic characteristics are shown in Table I; the median age of the study population was 65.3 (IQR: 60.2−72.5), and 56.2% of the participants were female. Follow-up radiographs were available in 2397/5562 (43.1%) RS-I participants and in 1407/2230 (63.1%) of the RS-II participants (see Fig. 1).

Prevalence

The prevalence was higher in females compared to males for CMC-1 ROA (age-adjusted OR = 1.98 95%CI [1.77−2.21]) and TS ROA (age-adjusted OR = 2.00 [1.74−2.29]) (Table II; Fig. 2). The prevalence increased with increasing age, with a sex-adjusted odds ratio of 1.08 [1.07−1.08] per year for CMC-1 ROA and 1.06 [1.05−1.07] for TS ROA, indicating that participants have 8% higher odds for developing CMC-1 ROA than the year before and 6% for TS ROA.

Characteristic	Participants at baseline (RS-I + RS-II)		Participants with 4-year follow-up (RS-II)		Participants with 12-year follow-up (RS-I)	
	Males	Females	Males	Females	Males	Females
N	3410	4382	616	791	1043	1354
Age, median (IQR)	65.1 [60.3−71.8]	65.5 [60.2−73.2]	61.3 [58.4−66.4]	61.3 [58.5−65.9]	63.1 [59.1−67.2]	63.0 [59.2−67.9]
Age category, N						
55−59	814	1058	245	316	311	415
60−64	881	1067	195	259	339	430
65−69	667	709	78	63	240	287
70−74	505	670	49	80	114	163
75−80	352	478	36	49	33	46
>80	191	400	13	24	6	13
CMC-1 ROA, N (%)	621 (18.2)	1356 (30.9)	86 (14.0)	202 (25.5)	159 (15.2)	363 (26.8)
TS ROA, N (%)	333 (9.8)	800 (18.3)	22 (3.6)	53 (6.7)	126 (12.1)	292 (21.6)

Abbreviations: RS-I: First Rotterdam Study Cohort; RS-II: Second Rotterdam Study Cohort; CMC-1: Carpometacarpal-1; TS: Trapezioscaphoid; ROA: Radiographic Osteoarthritis.

Table I   Osteoarthritis and Cartilage

Characteristics of all included participants at baseline (RS-I and RS-II) and subgroups of patients who attended follow-up clinic after 4 years (RS-II) and after 12 years (RS-I)

Fig. 1

Flowchart of the participant inclusion; CMC-1: thumb carpometacarpal; TS: trapezioscaphoid.
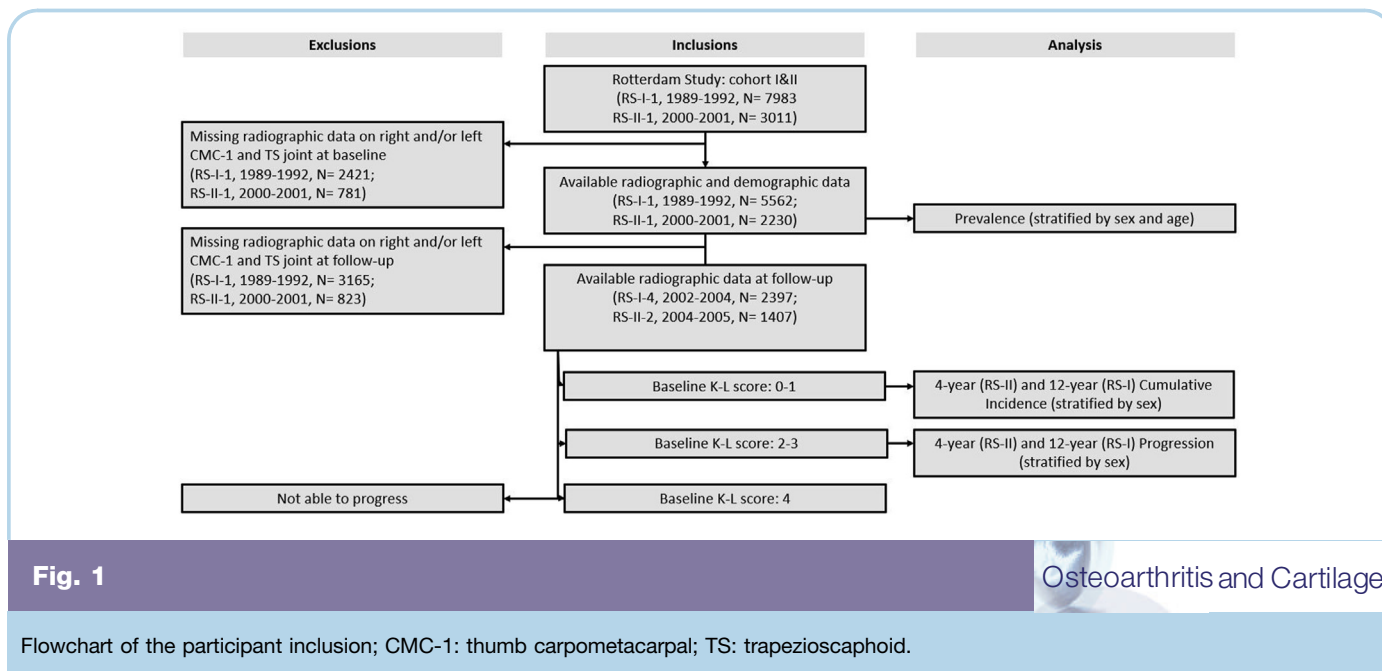
CMC-1 ROA was bilateral in 1007 of the 1977 participants with CMC-1ROA (50.9% [48.7−53.1%]), while TS ROA was bilateral in 497 of the 1133 participants with TS ROA (43,9% [41.0−46.8%]). Supplementary Figures (A, B) show that the left hand was generally more often affected than the right hand.

Cumulative incidence

The age-adjusted incidence was generally higher in females compared to males for CMC-1 ROA (4y OR = 1.59 [1.05−2.41] and 12y OR = 1.59 [1.27−2.00]) and TS ROA (4y OR = 1.76 [0.91−3.44] and 12y and OR = 2.09 [1.41−3.09]) (Table II). Higher age was associated with a higher cumulative incidence of TS ROA (4y OR = 1.05 [1.00−1.10] and 12y OR = 1.03 [1.00−1.07]; all sex adjusted), but not for CMC-1 ROA (4y OR = 1.02 [0.99−1.06] and 12y OR = 1.02 [0.99−1.04]; all sex adjusted). Most (437/512; 85.4%) incident cases of CMC-1 ROA were mild, whereas most (145/167; 86,8%) incident cases of TS ROA were moderate to severe.

Progression

We found no difference in the progression of CMC-1 ROA (4y OR = 1.11 [0.45−2.78] and 12y OR = 0.72 [0.44−1.20]) and TS ROA (4y OR = 2.29 [0.26−20.13] and 12y OR = 3.34 [0.41−27.61]) between males and females (Table II). CMC-1 ROA progression was mostly (88/100; 88.0%) seen in the K-L 2 group at baseline, whereas that was (4/17; 23.5%) for TS ROA.

Inter-relationship between CMC-1 ROA and TS ROA

The presence of CMC-1 at baseline increased the odds of having TS ROA at baseline (sex- and age-adjusted OR = 4.06 [3.54−4.66]) and vice versa. Baseline CMC-1 ROA increased the odds of incident TS ROA (4y OR = 3.822 [1.99−7.33] and 12y OR = 2.57 [1.70−3.89]; both sex- and age-adjusted). The association between TS ROA at baseline incident CMC-1 ROA was less clear (4y OR = 1.70 [0.47−6.18] and 12y OR = 2.01 [1.47−2.76]; both sex- and age-adjusted).

Sensitivity analysis

Participants without available radiographic data at follow-up were older and had a higher prevalence of CMC-1 ROA and TS ROA than participants with follow-up data (Supplementary Table (A)). The pooled cumulative incidence rates for CMC-1 ROA and TS ROA acquired using MICE were somewhat higher than the complete case estimates (Supplementary Table (B)), although 95% confidence intervals overlapped.

Discussion

This cohort study contributes insights into the prevalence and longitudinal disease course of thumb carpometacarpal radiographic osteoarthritis (CMC-1 ROA) and trapezioscaphoid (TS) ROA in the Dutch general population older than 55 years. We found a steadily increase in the prevalence of CMC-1 ROA from 7.9% in males and 15.1% in females at age 55−59−39.8% in males and 52.5% in females at age 80+, while TS ROA was present in 19.4% of the males and 30.3% of the females over 80 years. Over a 12-year follow-up, 17.6% of the males and 25.3% of the females developed CMC-1 ROA. Also, CMC-1 ROA was associated with a higher risk of having incident TS ROA at follow-up. While the incidence of TS ROA increased with age, incident CMC-1 ROA remained constant. Lastly, while incident CMC-1 ROA was mainly mild, incident TS ROA was more often moderate to severe.

Our results confirm that the prevalence of CMC-1 ROA rises with increasing age and is higher in females compared with males[5−7,9,21−23]. The meta-analysis from Van der Oest et al. reported a sex-adjusted pooled OR of 1.06 (95%CI 1.05−1.61) for every year of age, similar to our findings of 1.08 (95%CI 1.07−1.08)[9]. While they also found that CMC-1 ROA was more prevalent in females (OR 1.30; 95%CI 1.05−1.61), we found a larger difference (OR 1.98; 95%CI 1.77−2.21), which may be due to unmeasured differences in setting, race, and comorbidities. In contrast to Van Saase et al.[22], we found that the prevalence continued to rise in participants older than 80 years, which is also in line with the fitted values of the meta-analysis[9]. Dahaghin et al. hypothesized that a possible explanation

	Males N (%; 95%CI)	Females N (%; 95%CI)
Prevalence CMC-1 ROA		
55-59	64/814 (7.9; 6.2−9.9)	160/1058 (15.1; 13.1−17.4)
60-64	113/881 (12.8; 10.8−15.2)	253/1067 (23.7; 21.1−26.4)
65-69	131/667 (19.6; 16.8−22.8)	235/709 (33.1; 29.8−36.7)
70-74	135/505 (26.7; 23.1−30.8)	283/670 (42.2; 29.8−36.7)
75-79	102/352 (29.0; 24.5−33.9)	215/478 (45.0; 40.6−49.5)
80+	76/191 (39.8; 33.1−46.9)	210/400 (52.5; 47.6−57.3)
Prevalence TS ROA		
55-59	30/814 (3.69; 2.59−5.2)	88/1058 (8.3; 6.8−10.1)
60-64	54/881 (6.1; 4.7−7.9)	144/1067 (13.5; 11.6−15.7)
65-69	85/667 (12.7; 10.4−15.5)	144/709 (20.3; 17.5−23.4)
70-74	78/505 (15.4; 12.6−18.9)	169/670 (25.2; 22.1−28.6)
75-79	49/352 (13.9; 10.7−17.9)	134/478 (28.0; 24.2−32.2)
80+	37/191 (19.4; 14.4−25.6)	121/400 (30.3; 26.0−34.9)
Cumulative incidence CMC-1 ROA		
4-year overall	39/530 (7.4; 5.4−9.9)	66/589 (11.2; 8.9−14.0)
To mild	36/39	64/66
To moderate/severe	3/39	2/66
12-year overall	156/884 (17.6; 15.3−20.3)	251/991 (25.3; 22.3−28.1)
To mild	127/156	210/251
To moderate/severe	29/156	41/251
Incident TS ROA		
4-year overall	13/594 (2.18; 1.28−3.71)	28/738 (3.79; 2.64−5.4)
To mild	1/13	1/28
To moderate/severe	12/13	27/28
12-year overall	38/917 (4.1; 3.03−5.6)	88/1062 (8.3; 6.8−10.1)
To mild	8/38	12/88
To moderate/severe	30/38	76/88
Progression CMC-1 ROA		
4-year overall	7/85 (8.2; 4.0−16.0)	18/198 (9.1; 5.8−13.9)
K-L 2 at baseline	7/7	15/18
K-L 3 at baseline	0/7	3/18
12-year overall	30/134 (22.4; 16.2−30.2)	45/263 (17.1; 13.0−22.1)
K-L 2 at baseline	26/30	40/45
K-L 3 at baseline	4/30	5/45
Progression TS ROA		
4-year overall	1/13 (7.7; 0.39−33.3)	8/50 (16.0; 8.3−28.5)
K-L 2 at baseline	0/1	0/8
K-L 3 at baseline	1/1	8/8
12-year overall	1/87 (1.15; 0.06−6.23)	7/187 (3.7; 1.82−7.5)
K-L 2 at baseline	1/1	3/7
K-L 3 at baseline	0/1	4/4

Abbreviations: CMC-1: Carpometacarpal-1; TS: Trapezioscaphoid; ROA: Radiographic Osteoarthritis; K-L: Kellgren−Lawrence.

Table II

Osteoarthritis and Cartilage

Prevalence, incidence, and progression, including 95% confidence intervals (CI), of carpometacarpal-1 (CMC-1) and trapezioscahoid (TS) radiographic osteoarthritis (ROA)

for the finding of Saase *et al.* might be the selection of healthy survivors or a lower response rate of disabled persons[5].

Only a few population-based cohort studies on incident hand ROA are available. The 9-year incidence of CMC-1 ROA in the Framingham Study was 17.4% in males, and 21.1% in females, which is between our 4-year (M 7.4%; F 11.2%%) 12-year (M 15.3%; F 25.3%%) estimates. The Johnston County Osteoarthritis Project found the 12-year incidence of CMC-1 ROA to be 17.7% in males and 22.3% in females[11]. They also reported that CMC-1 ROA was more prevalent in females with an OR of 1.59 (0.96−2.64) compared to the 1.59 (1.27−2.00) that we found. Thus, the previously reported findings are in line with our results.

Few studies assessed the longitudinal progression of CMC-1 ROA[12]. Previous studies demonstrated that females had slightly more progression of CMC-1 ROA than males[7,11], while we did not observe a significant pattern on this. Similar to our results, Kallman *et al.* and Haugen *et al.* also concluded that the rate of progress slowed as the severity increased[7,23]. However, our CMC-1 ROA progression rates after 4 years (M 8.2% F 9.1%) and 12 years (M 22.4% F 17.1%) are relatively low compared to previous studies. Bijsterbosch found CMC-1 ROA progression in 22.1% of the participants after 6 years, Haugen *et al.* reported progression in 70.7% in females and 64.8% in males after 9 years, while Snyder *et al.* reported 60.6% in females and 40.7% in males after 12 years[7,10,11]. A smaller study from Harris *et al.* reported that 47−89% of the participants (included in a rheumatology outpatient clinic) with CMC-1 ROA at baseline showed progression after 10 years[24]. Shapiro *et al.* hypothesize that variability in progression rates may stem from differences in study populations, follow-up durations, scoring systems, and definitions of progression[12].
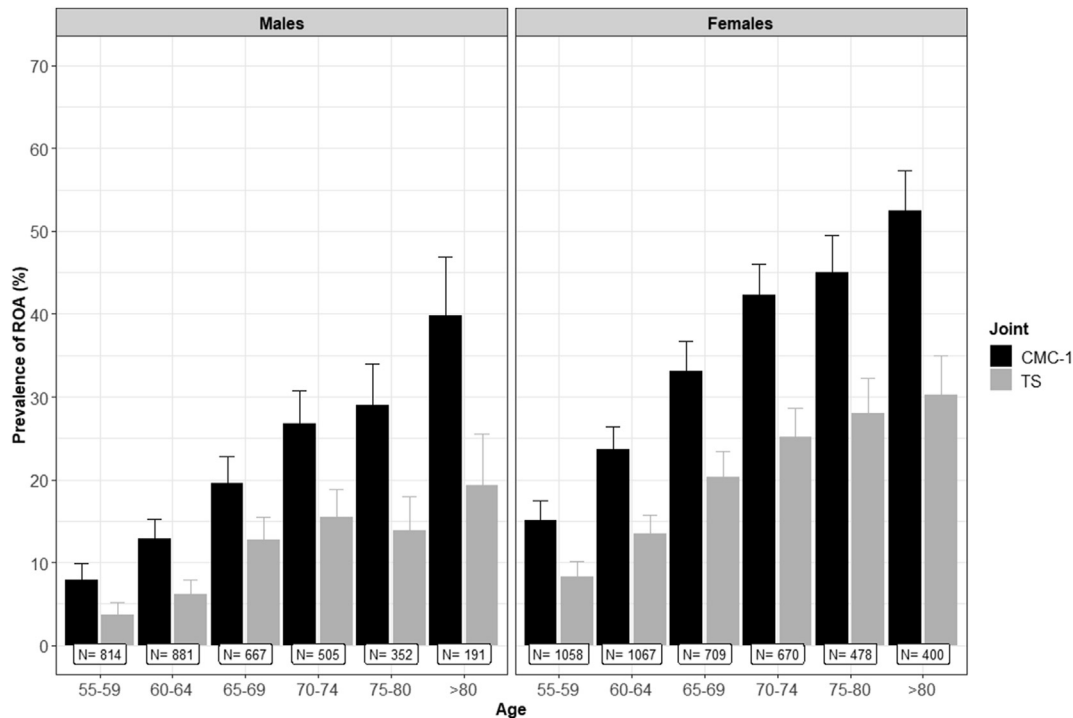
Fig. 2   Osteoarthritis and Cartilage

Age-specific prevalence of radiographic thumb carpometacarpal osteoarthritis (CMC-1 ROA; black) and trapezioscaphoid osteoarthritis (TS ROA; grey) of the left and right hand combined, in males and females. Error bars represent Wilson's binomial 95% confidence interval.

The prevalence and incidence of TS ROA are scarcely described in previous studies compared to CMC-1 ROA. One previous study reported TS ROA progression in 6.8% of the participants after 6 years, although they used another Definition of progression[10]. In agreement with the classification of Eaton-Glickel[13], in which arthritic changes in the TS joint define the most progressive stage of CMC-1 ROA, we found that TS ROA was strongly correlated with CMC-1 ROA and that CMC-1 ROA was a predictor of incident TS ROA. However, isolated TS ROA was observed as well. Future research should further investigate the clinical relevance of isolated TS ROA and the relationship between CMC-1 ROA and TS ROA.

This study has several limitations. First, the Rotterdam Study is primarily designed to study the determinants and prognosis of chronic (locomotor) diseases in the elderly, such as hand osteoarthritis, but not specifically for the thumb base. Therefore, we did not have accurate clinical data on the occurrence, cause and pain level originating from the thumb base. This information could have added the symptomatic prevalence, the symptomatic incidence, and most importantly, the symptomatic progression of CMC-1 OA within our population. Second, determining the correct K-L grade of the joints may have been challenging on plain hand radiographs. Radiographs in Bett's or Robert's view for CMC-1 OA should be preferred over AP view[25,26]. The radiographs were not graded in pairs (in the same person), resulting in cases (RS-I 1.88–2.00%; RS-II 0.57–0.64%) where the CMC-1 joint was graded as ROA at baseline, but not at follow-up (Supplementary Table 1). Comparable to other studies on ROA, we included them in our analysis to avoid inflation of incidence and progression rates[20]. Despite these limitations, our

results are comparable to the estimates from other well-known cohort studies, which gives us confidence that, in most cases, our results are reliable[5,27,28].

Third, the baseline radiographs were obtained between 1990 and 2001. In 2021, populations and diseases' characteristics (e.g., the prevalence of obesity) are likely to have changed. Therefore, the current prevalence of CMC-1 ROA and TS ROA may be different from what we found. On the other hand, we were able to report on the longitudinal disease course after a relatively long period of 12 years. In addition, estimates were derived from participants of the Rotterdam Study in Ommoord, which is predominantly an urban setting. While our findings were similar to other western cohort studies[7], estimates from this study may not be entirely generalizable to rural populations with higher loads of manual working or other ethnicities[11] Furthermore, the drop-out rates in the longitudinal analyses were 56.9% (RS-I) and 39.6% (RS-II). Our analysis showed that the participants with available data at follow-up were younger, more often females, and had less CMC-1/TS ROA at baseline than those without follow-up data. The difference in age distribution can explain the lower prevalence of ROA in participants with follow-up. While this pattern of drop-out is not uncommon in longitudinal studies on ROA[20], the incidence and progression rates may not be generalizable to the entire cohort. However, the estimates from our sensitivity analyses mostly had overlapping confidence intervals with our complete-case estimates, meaning that large overestimations or underestimations of the true incidence were unlikely.

This study also has some strengths. While an increasing number of studies have described the prevalence of CMC-1 ROA, there have

been only a few analyses on the incidence and progression of CMC-1 ROA in longitudinal cohort studies that represent the general population. Our data adds comprehensive information from a large cohort of participants (≥55) embedded into the Rotterdam Study on the longitudinal disease course of CMC-1 ROA. Furthermore, we present extensive data on TS ROA, which is an understudied site in hand ROA. Lastly, the large sample size allowed for stratification of sex and age while preserving precise estimates.

With an ageing population, the absolute number of people that develop CMC-1 ROA is expected to rise. The effect on individual and public healthcare remains unclear as there seems to be a real discrepancy in the radiological and symptomatic prevalence of CMC-1 ROA. While many people have CMC-1 ROA, only a portion seek medical treatment. Future research is needed to identify which patients progress from radiological to symptomatic disease to treat underlying causes and prevent an increase in symptomatic CMC-1 ROA.

Author contributions

All authors were involved in the conception and design of the study. JST and RMW performed the initial analysis, and all authors were helped with interpreting the data. JST and RMW wrote the first draft of the manuscript, while all other authors provided critical revisions of the article for intellectual content. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Conflict of interest

The authors declare that they did not have a conflict of interest.

Ethical approval

The Rotterdam Study has been approved by the Dutch Ministry of Health, Welfare and Sport (Population Screening Act WBO, license number 1071272-159521-PG) and by the Medical Ethics Committee of the Erasmus MC (registration number MEC 02.1015). The Rotterdam Study has also been entered into the Netherlands National Trial Register (www.trialregister.nl) and into the World Health Organization International Clinical Trials Registry Platform (www.who.int/ictrp/network/primary/en/) under shared catalog number NTR6831. All participants provided written informed consent to participate in the study and have their information obtained from treating physicians.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.joca.2022.01.003.

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