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Musculoskeletal complaints in individuals with finger or partial hand amputations in the Netherlands: a cross-sectional study

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ABSTRACT

Purpose: To compare the prevalence of musculoskeletal complaints (MSCs) in individuals with finger or partial hand amputations (FPHAs) with a control group and to explore the effect and predictors of MSCs in individuals with FPHAs.

Method: A questionnaire-based cross-sectional study was conducted. The primary outcome measures were: prevalence of MSCs, health status, pain-related disability, physical work demands, work productivity, and hand function.

Results: The response rate was 61%. A comparable proportion of individuals with FPHAs ($n = 99$) and controls ($n = 102$) reported MSCs in the preceding 4 weeks (33% vs. 28%, respectively) or in the preceding year (37% vs. 33%, respectively). Individuals with FPHAs with MSCs experienced more pain than controls with MSCs. Regular occurrence of stump sensations and self-reported limited range of motion (ROM) of the wrist of the affected limb were predictors for MSCs in individuals with FPHAs.

Conclusions: The prevalence of MSCs was comparable in individuals with FPHAs and controls. However, clinicians should pay special attention to the risk of developing MSCs in patients with stump sensations and limited ROM of the wrist of the affected limb. Future research should focus on the role of wrist movements and compensatory movements in the development of MSCs in individuals with FPHAs.

ARTICLE HISTORY

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Amputation; upper extremity; cumulative trauma disorders; pain; rehabilitation

► IMPLICATIONS FOR REHABILITATION

- The prevalence of musculoskeletal complaints (MSCs) in individuals with finger or partial hand amputations (FPHAs) and control subjects was similar.
- Regular occurrence of stump sensations and limited range of motion of the wrist of the affected limb were predictors of developing MSCs in individuals with FPHAs.
- Clinicians should pay special attention to individuals with FPHAs with the presence of these predictors of developing MSCs.
- For a better understanding of the development of and treatment options for MSCs, future research focusing on the role of wrist function in the development of MSCs in individuals with FPHAs is necessary.



Introduction

The loss of a finger or part of the hand can have both functional and psychological consequences [1–4]. Among upper extremity amputation and devascularisation injuries, finger amputations are the most common type of injury [5]. The largest incidence of upper extremity injuries is found in males in the 45–54 years age group. Amputations of the upper limb usually occur at a relatively young age and are mainly caused by trauma [6–8]. Therefore, individuals with an amputation of their upper limb are likely to live and work with the amputation for a long portion of their life [9].

In individuals with upper limb absence (ULA), congenital or acquired, the prevalence of musculoskeletal complaints (MSCs) of their residual limb, non-affected limb, neck, or back ranges from 20% to 64%, depending on the location of MSCs [1,6,9–12]. A prevalence of MSCs in the preceding year in individuals with

major ULA (wrist disarticulation or more proximal amputation levels) of 65%, versus a year prevalence of 34% in the control group, was found recently [13]. However, there is inconclusive evidence regarding the factors that may contribute to the development of MSCs, such as level of amputation and time since amputation [10–12].

Grip strength and hand function may be diminished in individuals with finger or partial hand amputations (FPHAs), especially in those with multiple digit amputations [14–16]. Studies focusing on MSCs in individuals with FPHAs are, however, sparse. One study on MSCs in individuals with ULA included nine patients with a partial hand amputation, of which one patient reported pain in the contralateral arm [10]. As the presence of MSCs can cause various limitations in work and daily life [17,18], better insight into the prevalence and effect of MSCs on individuals with FPHAs is required.

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The aims of this study were: (1) to compare the prevalence of MSCs in individuals with FPHAs in the Netherlands with that in a control group; (2) to evaluate the effect of MSCs on health and work in individuals with FPHAs; and (3) to analyse predictors of MSCs in individuals with FPHAs, including demographic features, amputation-related features, stump and phantom limb complaints, health and work outcomes and hand function. We hypothesised an increased prevalence of MSCs compared to control subjects, depending on the level of amputation and number of digits involved.

Methods

Participants and procedure

A questionnaire-based cross-sectional study was conducted. Patients with FPHAs, who had visited the Department of Rehabilitation Medicine of the University Medical Center Groningen (UMCG) since 2002, were eligible if they were 18 years or older, had a good knowledge of the Dutch language, and if the time since amputation was at least 1 year. Patients were excluded if the amputation level was at wrist disarticulation or a more proximal level. A control group, matching in gender and age with the FPHAs group, was assembled using data from Postema et al. [13], added with data from newly recruited controls who were acquaintances of the researchers.

In March 2015, data retrieval was performed using the database of the Department of Rehabilitation Medicine of the UMCG. All eligible participants were sent a questionnaire in August 2015. Fifteen days later, a reminder was sent to the participants who had not yet responded. A gift voucher of €10 was sent to all participants who completed the questionnaire. In cases of missing answers, the relevant questions were returned to the participant, with the request to answer these questions.

The local medical ethics committee decided that no formal ethical approval was necessary for this study (2015/253).

Questionnaire

A modified version of the questionnaire developed by Postema et al. was used [13]. The questionnaire consists of nine sections, including:

1. Participant characteristics;
2. Amputation-specific characteristics, including level, cause, and date of amputation. Amputations proximal to the metacarpophalangeal joints level were classified as partial hand amputations. Finger amputations (both total and partial amputations) were classified into the following categories according to the affected finger(s): thumb (with or without other fingers); digit 2–5 (one finger); digit 2–5 (multiple fingers). In addition, participants were asked about their hand dominance before the amputation, whether they had undergone hand surgery after the amputation, stump pain, stump sensations (e.g., tingling, stiffness, sensation of tightness, itching), phantom limb pain, and phantom limb sensations. Sensations were classified into three categories: sensations related only to bumping or weather; other sensations; and no sensations.
3. Prosthesis use and, if so, what type of prosthesis and wearing hours on a working day and a resting day. In addition, use of adaptive devices in housekeeping, for hobbies, or at work.
4. Employment status and, if employed, participants were asked to evaluate their work quantity and work quality in the past 4 weeks on a 0–10 scale (with 10 indicating normal

performance). Work productivity was assessed using the Quality-Quantity method, which was developed to measure productivity losses without absence [19], and calculated as follows: $(\text{work quantity score}/10) \times (\text{work quality score}/10) \times 100\%$. The construct validity of this method varies from moderate to very strong, depending on the kind of production output [20]. Furthermore, physical work demands were assessed using the Upper Extremity Work Demands (UEWD) score [21], which was found to have good reliability, but moderate criterion validity [22]. The UEWD consists of seven items, each with four answer possibilities, which are summed to create a total score, ranging from 7 (lowest UEWDs) to 28 (highest UEWDs).

5. Health status, using three subscales of the 36-item Short Form Health Survey (SF-36): Bodily Pain, General Health, and Mental Health [23]. The SF-36 is validated in both the general population and in chronic disease populations in the Netherlands [24]. Item scores were transformed to a 0–100 scale, with a higher score indicating better perceived health or less pain.
6. MSCs, defined as complaints such as pain, stiffness, and tingling of the muscles, ligaments, bones, nerves, and/or joints. The question was formulated in such a way that MSCs were clearly distinguished from complaints as a result of an accident, infection, sports injury, joint disease, stump pain, or phantom limb pain. Point prevalence of MSCs was defined as the proportion of participants with MSCs in the past 4 weeks, and year prevalence of MSCs as the proportion of participants with MSCs in the past year (during a period of at least four consecutive weeks). If participants had experienced MSCs, they were asked to answer additional questions about the characteristics and treatment of their MSCs. The classification of the location of MSCs, which was partially based on the Dutch Musculoskeletal Questionnaire [25], is shown in Figure 1.
7. Pain-related disability. All participants who experienced pain because of MSCs, stump pain, or phantom limb pain were asked to answer the Pain Disability Index (PDI). The PDI is a seven-item questionnaire that was shown to be a valid measure of the average effect of pain on seven domains of activities of daily living (ADL: family and household, recreation, social activities, work, sexuality, self-care, and basic needs) [26–28]. Scores on the seven items are summed and range from 0 to 70, with a higher score indicating greater disability.
8. Hand function. To assess hand function, participants were asked if they could perform nine functional hand grips [opposition grip, lateral pinch, tip pinch, cylindrical grip, side-to-side grip (with and without use of the thumb), tripod pinch, hook grip, and spherical grip] (Figure 2). Each question had three answer possibilities: yes, without any problems (one point); yes, with difficulty or reduced strength (two points); no, cannot perform the hand grip (three points). For each hand separately, a total score was calculated ranging from 9 to 27, with a lower score indicating better hand function. This total score was converted to a percentage of the maximal possible score as follows: $100 - (((\text{total score} - 9)/18) \times 100\%)$. In addition, a total score for both hands combined was calculated, ranging from 18 to 54, and converted to a percentage of the maximal possible score: $100 - (((\text{total score} - 18)/36) \times 100\%)$. Furthermore, participants were asked if they had limited range of motion (ROM) of their wrists in flexion/extension and ulnar/radial abduction, based on images showing these four different movement directions. In addition, participants were asked to answer the Orthotics and Prosthetics Users' Survey (OPUS), a validated instrument

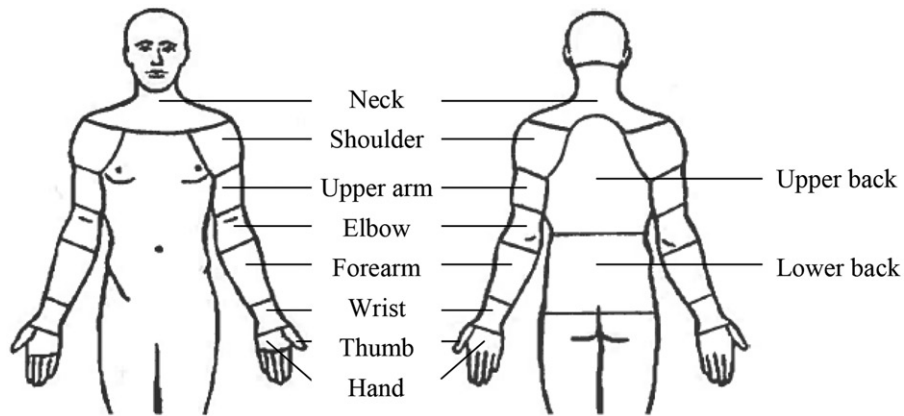


Figure 1. Classification of the location of MSCs.

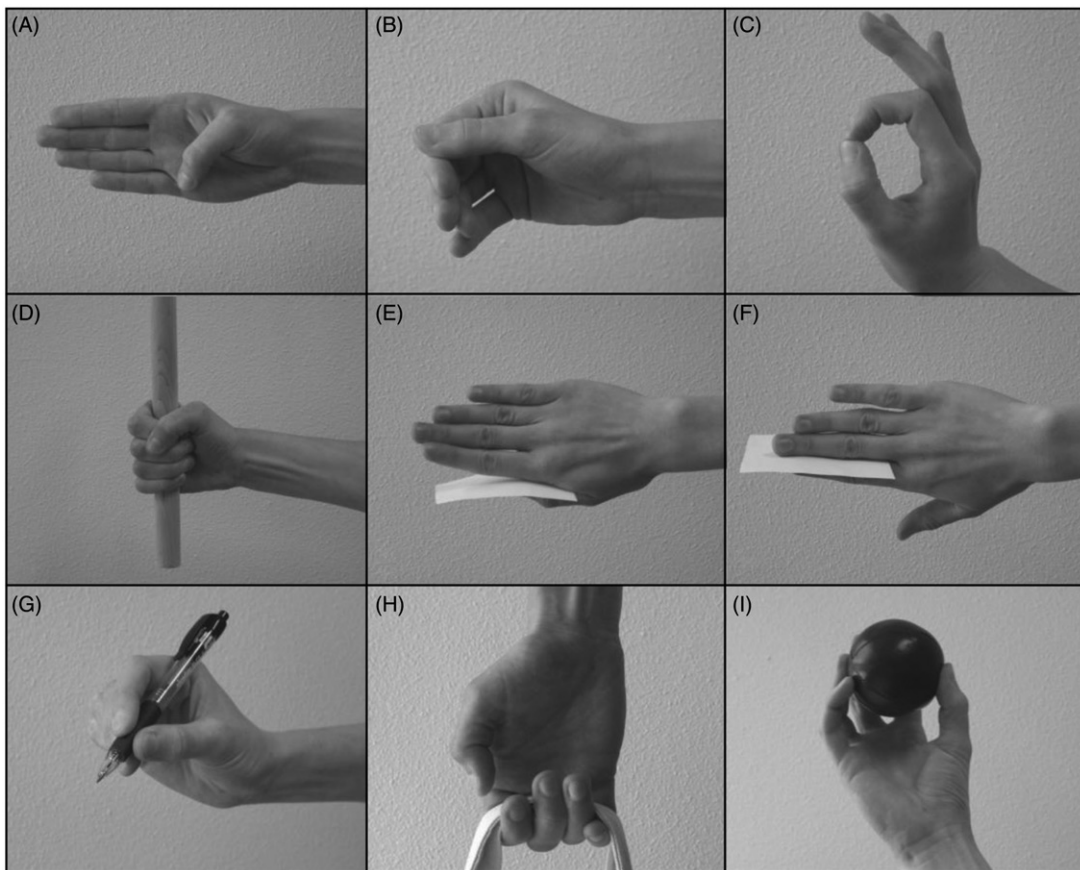


Figure 2. Hand grips. (A) Opposition grip. (B) Lateral pinch. (C) Tip pinch. (D) Cylindrical grip. (E) Side-to-side grip (with use of the thumb). (F) Side-to-side grip (without use of the thumb). (G) Tripod pinch. (H) Hook grip. (I) Spherical grip.

to measure manual functioning after unilateral upper limb amputation [29]. They were asked to evaluate the ease of performing 18 ADL tasks, each with four answer possibilities, ranging from 0 to 3 (a higher score indicates easier performance of the activity). Scores on all items were summed, and they ranged from 0 to 54. A maximum number of three missing answers was allowed. This total score was then converted to a percentage of the maximal possible score as follows: $(\text{total score}/(\text{number of completed activities} \times 3)) \times 100\%$, with a higher score indicating easier performance of activities.

9. Appearance of the hand(s). Participants were asked how often they were disturbed by the appearance of their hand(s) on a six-point Likert scale.

The control group answered a similar questionnaire, without questions regarding amputation, prosthesis use, and hand function [13].

Statistical analysis

Data were analysed using IBM SPSS Statistics 22.0 (IBM Corp., Armonk, NY). The significance level was set at $\alpha = 0.05$.

All data were checked for a normal distribution before analyses using Q-Q plots. Normally distributed data are presented as mean \pm standard deviation (SD); non-normally distributed data are presented as median [interquartile range (IQR)]. Categorical data were analysed using the Chi-square test or Fisher's exact test.

In cases of paired proportions, McNemar's test was used. Continuous data were analysed using the independent *t*-test or the Mann–Whitney test as a non-parametric alternative. For comparisons between more than two groups, continuous data were analysed using the one-way ANOVA or the Kruskal–Wallis test as a non-parametric alternative. Post hoc comparison was then performed with the Mann–Whitney test.

To determine the effect of limitations in performing the nine hand grips with the affected hand on the point prevalence of MSCs, univariate associations were calculated using the Chi-square test. For each hand grip, a dichotomous variable was created (limitation vs. no limitation). A logistic regression analysis was performed to determine the effect of the independent variables on the point prevalence of MSCs. First, the following variables were analysed univariately: civil status, side, level, and cause of FPHAs (trauma/other), time since amputation, number of amputated fingers (one/multiple), use of prosthesis, use of adaptive equipment, performance of hand surgery after the amputation, presence of stump pain and stump sensations, presence of phantom limb pain and phantom limb sensations, employment status, UEWD score, presence of comorbidity, general health, mental health, total hand function, self-reported limited ROM of the affected and non-affected wrist, and disturbance by appearance of the hand(s). Second, all variables associated with the presence of MSCs ($p < 0.05$) were entered in a multivariate logistic regression in one step, in combination with the following variables: gender, age, and level of education.

Results

Response rate

Data retrieval showed that 293 patients were registered with the diagnosis of FPHAs. One hundred and four patients were excluded because they did not meet the inclusion criteria, were deceased, could not be contacted, or were living abroad. Of the remaining 189 eligible participants, 104 patients were included in the study, nine patients declined to participate, one questionnaire was omitted because of insufficient answering, and one because of insufficient understanding of the Dutch language, and 74 patients did not respond at all. The response rate was calculated as follows: $(104 + 9 + 1 + 1)/189 = 61\%$. The five participants with bilateral amputations were excluded from the analyses, since this group appeared to be too small.

Baseline characteristics

The patient group differed from the control group with regard to level of education, employment status, and the presence of a comorbidity (Table 1). Mean age at amputation in the patient group was 45.5 years (SD: 15.9). Median time since amputation was 4.9 years (IQR: 2.3; 8.8). Thirty-five participants (35%) had undergone hand surgery after the amputation. A minority of the participants were currently using a prosthesis ($n = 7$, 7%) or adaptive equipment ($n = 9$, 9%). Five participants were using a cosmetic prosthesis; the other two participants used a prosthesis for work and a prosthesis for keyboarding. Median wearing hours of the prosthesis on a working day were 8.0 (IQR: 3.0; 14.0), and on a resting day 8.0 (IQR: 4.0; 12.0).

Prevalence of MSCs

Point and year prevalence of MSCs did not differ significantly between individuals with FPHAs and controls (Table 2).

Table 1. Baseline characteristics of the study population.

	FPHAs (<i>n</i> = 99)	Controls (<i>n</i> = 102)	<i>p</i> Values
Gender: male	82 (82.8)	84 (82.4)	0.929
Age (mean ± SD)	52.1 ± 14.8	50.4 ± 14.9	0.411
Civil status			0.324
Single	16 (16.2)	10 (9.8)	
Living together or married	78 (78.8)	84 (82.4)	
Divorced or widow(er)	5 (5.1)	8 (7.8)	
Educational level			<0.001 ^c
None or low	46 (46.9)	12 (11.9)	
Medium	39 (39.8)	25 (24.8)	
High	13 (13.3)	64 (63.4)	
Employed	53 (53.5)	73 (71.6)	0.008 ^c
Presence of comorbidity	50 (50.5)	21 (20.6)	<0.001 ^c
Side of amputation		N/A	
Left	56 (56.5)		
Right	43 (43.4)		
Amputation of dominant side ^a	46 (46.5)	N/A	
Cause of amputation		N/A	
Cancer	4 (4.0)		
Trauma	87 (87.9)		
Vascular disease	1 (1.0)		
Infection	3 (3.0)		
Other	4 (4.0)		
Level of amputation ^b		N/A	
Thumb (with or without other fingers)	11 (11.1)		
Digit 2–5 (one finger)	52 (52.5)		
Digit 2–5 (multiple fingers)	22 (22.2)		
Partial hand amputation	14 (14.1)		
Regular occurrence of stump complaints		N/A	
Stump pain	10 (10.1)		
Stump sensations, only related to weather and/or bumping	11 (11.1)		
Stump sensations, other	30 (30.3)		
Regular occurrence of phantom limb complaints		N/A	
Phantom limb pain	11 (11.1)		
Phantom limb sensations, other	27 (27.3)		
Disturbed by appearance of hand(s)		N/A	
Never or rarely	63 (63.6)		
Sometimes	20 (20.2)		
Often, mostly or continuously	16 (16.2)		

Due to missing values, not all data add up to the group totals. Missing values never exceeded the level of 1.0% for any variable. N/A: not applicable. All data are shown as *n* (%), unless stated otherwise.

^aNot applicable for bilateral amputations ($n = 5$) and in case of ambidexterity ($n = 6$).

^bOnly individuals with unilateral FPHAs are mentioned ($n = 99$). Finger amputations also include partial finger amputations.

^cStatistically significant at $p \leq 0.05$.

In individuals with FPHAs, MSCs were mainly located in the affected limb and less often in the non-affected limb (year prevalence: 28% and 13%, respectively, Table 3).

Characteristics of MSCs

Pain was the most frequently experienced type of complaint in both groups. Individuals with FPHAs experienced tingling and muscle weakness more often, their MSCs more often lasted at least 1 year, and they visited a healthcare professional more often in the past year, compared to controls.

Most individuals with FPHAs who experienced MSCs during the past year had complaints that were present at various moments during the day, regardless of activities ($n = 30$, 81%). A minority experienced MSCs only during specific activities ($n = 2$, 5%), or during and directly after specific activities ($n = 5$, 14%). In most cases, MSCs were not present before the amputation ($n = 32$, 89%).

Most individuals with FPHAs who experienced MSCs during the past year took measures to diminish their complaints ($n = 30$,

Table 2. Prevalence and characteristics of MSCs in individuals with FPHAs and controls.

	FPHAs (n = 99)	Controls (n = 102)	p Values
Point prevalence MSCs	33 (33.3)	28 (27.5)	0.364
Year prevalence MSCs	37 (37.4)	34 (33.3)	0.549
High back and/or neck	12 (12.1)	18 (17.6)	0.272
Low back	5 (5.1)	11 (10.8)	0.133
Upper extremities ^a	32 (32.3)	24 (23.8)	0.178
Total sites of complaints (median (IQR)) ^b	2.0 (1.0; 4.0)	2.0 (1.0; 3.0)	0.125
Type of complaints ^b			
Pain	26 (70.3)	29 (85.3)	0.130
Stiffness	20 (54.1)	21 (61.8)	0.511
Tingling	19 (51.4)	5 (14.7)	0.001 ^d
Muscle weakness	15 (40.5)	6 (17.6)	0.035 ^d
Duration of complaints ^b			0.023 ^d
<3 months	5 (13.5)	12 (35.3)	–
3–12 months	5 (13.5)	8 (23.5)	–
>1 year	27 (73.0)	14 (41.2)	–
Healthcare use ^{b,c}	17 (45.9)	8 (23.5)	0.048 ^d

All data are shown as *n* (%), unless stated otherwise.

^aNumber of individuals with MSCs in one or both of their upper extremities.

^bOne missing value in the control group (1.0%).

^cOnly calculated for individuals with MSCs in the past year (FPHAs: *n* = 37, controls: *n* = 34). One missing value for total sites of complaints in the control group.

^dVisiting a healthcare professional in the past year because of MSCs.

^eStatistically significant at *p* < 0.05.

Table 3. Year prevalence of the different locations of MSCs of the affected and non-affected limbs in individuals with FPHAs (*n* = 99).

Location of MSCs	Year prevalence affected limb	Year prevalence non-affected limb	p Values ^a
Shoulder	13 (13.1)	10 (10.1)	0.581
Upper arm	4 (4.0)	1 (1.0)	0.375
Elbow	8 (8.1)	5 (5.1)	0.453
Forearm	8 (8.1)	2 (2.0)	0.109
Wrist	9 (9.1)	3 (3.0)	0.070
Hand	19 (19.2)	1 (1.0)	<0.001 ^c
Thumb ^b	3 (3.5)	0 (0.0)	–

All data are shown as *n* (%).

^aResults of McNemar's test.

^bIndividuals with a partial or total amputation of the thumb were excluded in this analysis (*n* = 13). No *p* values could be calculated since one of the cell frequencies was zero.

^cStatistically significant at *p* < 0.05.

81%). Several individuals took more than one measure (*n* = 10, 27%). Measures taken most often were the use of pain medication or any other pain treatment (*n* = 15, 41%) and consultation of a physiotherapist, hand therapist, or occupational therapist (*n* = 14, 38%).

Health and work outcomes

Individuals with FPHAs who experienced MSCs during the past 4 weeks had more pain, gave their pain a higher rating, and had a higher PDI-score than controls (Table 4). In addition, there was a difference in UEWD scores between the three groups. Post hoc comparison showed that both groups of individuals with FPHAs (those with and without MSCs during the past 4 weeks) had higher UEWD scores than did control subjects.

Hand and wrist function

No significant associations were found between limitations in the performance of the nine hand grips and the point prevalence of MSCs (Table 5). Furthermore, hand function scores and OPUS

performance scores did not differ between individuals with and without MSCs in the past 4 weeks. Several individuals with FPHAs reported limited ROM of the wrist of the affected limb (*n* = 16) and the wrist of the non-affected limb (*n* = 7). All individuals reported limited flexion/extension, and a majority (*n* = 18) also reported limited ulnar/radial abduction.

Predictors of MSCs

Multivariate logistic regression showed that there were two statistically significant predictors of presence of MSCs in individuals with FPHAs: regular occurrence of stump sensations and self-reported limited ROM of the wrist of the affected limb (Table 6).

Discussion

Main findings

The point and year prevalence of MSCs did not differ between individuals with FPHAs and controls. Year prevalence of MSCs in individuals with FPHAs was almost equal to the year prevalence of complaints of the arms, neck, and/or shoulders (CANS) in the general population of the Netherlands (37%) [30], and thus substantially lower than the year prevalence of MSCs in individuals with ULA in the Netherlands (65%) [13]. When MSCs were present, individuals with FPHAs experienced more pain than controls. Furthermore, we found two clinically relevant predictors of the presence of MSCs in individuals with FPHAs: regular occurrence of stump sensations and self-reported limited ROM of the wrist of the affected limb.

Prevalence of MSCs

We hypothesised that an increased prevalence of MSCs in individuals with FPHAs could be expected, depending on the level of amputation and number of digits involved, which was, however, not supported by our results. MSCs are an umbrella term for various disorders that develop because of repetitive movements, awkward postures, sustained force, and other risk factors [31,32]. A possible explanation for the development of MSCs in individuals with ULA is the increased workload for the non-affected limb [10] and the presence of compensatory movements in the trunk and proximal upper limb [33–35]. Our results suggest that the physical defect due to FPHAs is not of such extent that the amputee has an increased risk of developing MSCs.

The major anatomical difference between individuals with FPHAs and ULA is the presence of the wrist joint. The comparison of year prevalence of MSCs in individuals with FPHAs (37%) and ULA (65%) with the year prevalence in controls (33%) suggests that there is no increased risk of developing MSCs in the presence of a functional wrist joint. This is supported by our finding that patient-reported limited ROM of the wrist of the affected limb is a predictor for the presence of MSCs in individuals with FPHAs.

Individuals with ULA who use a prosthesis show compensatory movements of the trunk and proximal upper limb to overcome deficits in degrees of freedom due to stiffness of the prosthetic wrist [33,34]. When integrating wrist flexion in a prosthetic arm, compensatory movements reduced in most of the cases [36]. Although studies varied in this finding [37], a stiff wrist seems to be associated with the presence of compensatory movements, and therefore possibly with the development of MSCs. To test the hypothesis that the presence of a functional wrist joint is essential for preventing MSCs, future research in which the presence of

Table 4. Health and work outcomes in individuals with FPHAs, with and without MSCs during the past four weeks, and controls.

	FPHAs, with MSCs (n = 33)	FPHAs, without MSCs (n = 66)	Controls (n = 102)	p Values
Health outcomes				
General health (SF36)	67.0 (51.0; 87.0)	79.5 (57.0; 92.0)	76.0 (70.0; 87.8)	0.201 ^d
Mental health (SF36)	80.0 (62.0; 85.0)	84.0 (64.0; 92.0)	84.0 (72.0; 88.0)	0.132 ^d
Bodily pain (SF36) ^a	41.0 (32.0; 62.0)	N/A	67.3 (57.1; 69.4)	0.003 ^{e,g}
Pain grade (SF36) ^a	6.0 (3.0; 7.0)	N/A	3.0 (2.0; 4.0)	0.006 ^{e,g}
PDI ^a	22.0 (5.0; 37.0)	N/A	12.0 (5.0; 15.0)	0.043 ^{e,g}
Work outcomes				
UEWD ^b	19.5 (14.5; 23.0)	17.0 (14.0; 19.0)	11.0 (9.0; 15.0)	<0.001 ^{d,f,g}
Work productivity ^c	100 (68; 100)	100 (80; 100)	100 (83.3; 100)	0.465 ^d

N/A: not applicable; SF36: 36-item Short Form Health Survey. All data are presented as median (IQR).

^aOnly individuals with MSCs type "pain" during the past four weeks were included (FPHAs with MSCs: n = 23, controls: n = 23).

^bCalculated only for employed individuals (FPHAs with MSCs: n = 17, FPHAs without MSCs: n = 36, controls: n = 73). One missing value in the group FPHAs without MSCs.

^cCalculated only for employed individuals without sick leave in the past four weeks (FPHAs with MSCs: n = 14, FPHAs without MSCs: n = 33, controls: n = 68).

^dResult of the Kruskal–Wallis test.

^eResult of the Mann–Whitney test.

^fPost hoc comparison using the Mann–Whitney test showed the following results: FPHAs with MSCs vs. FPHAs without MSCs: p = 0.143; FPHAs with MSCs vs. controls: p < 0.001; FPHAs without MSCs vs. controls: p < 0.001.

^gStatistically significant at p ≤ 0.05.

Table 5. Characteristics of hand and wrist function in individuals with FPHAs, with and without MSCs in the past four weeks.

	FPHAs with MSCs (n = 33)	FPHAs without MSCs (n = 66)	p Values
Limitation in performance (n (%))^a			
Opposition grip	14 (42.4)	18 (27.3)	0.129
Lateral pinch	9 (27.3)	15 (22.7)	0.619
Tip pinch	9 (27.3)	12 (18.2)	0.297
Cylindrical grip	14 (42.4)	31 (47.0)	0.669
Side-to-side grip (with use of the thumb)	7 (21.2)	21 (31.8)	0.269
Side-to-side grip (without use of the thumb)	13 (39.4)	23 (34.8)	0.658
Tripod pinch	17 (51.5)	37 (56.1)	0.669
Hook grip	22 (66.7)	34 (51.5)	0.152
Spherical grip	16 (48.5)	29 (43.9)	0.669
Total hand function ^b	88.9 (76.4; 94.4)	88.9 (78.5; 97.2)	0.665
Affected hand function ^b	77.8 (55.6; 88.9)	77.8 (59.7; 94.4)	0.606
Non-affected hand function ^b	100 (100; 100)	100 (100; 100)	0.784
OPUS performance score ^b	69.6 (57.4; 94.0)	90.7 (65.0; 97.7)	0.070

Data are presented as median (IQR), unless otherwise stated. Missing values never exceeded the level of 3.0% for any variable.

^aLimitation in the performance of the hand grip with the affected hand.

^bThese data are shown as a percentage of the maximal possible score.

compensatory movements in individuals with and without limited wrist motion is compared with respect to MSCs is necessary.

A possible explanation for the presence of MSCs in individuals with stump sensations is that patients avoid using the affected arm due to these sensations. Consequently, the non-affected arm may have an increased risk of developing MSCs. However, further research is needed to confirm this hypothesis.

Effect of MSCs on health and work

A few possible explanations for the difference in pain scores between individuals with FPHAs and controls can be mentioned. First, the sequence of questions was slightly changed in our questionnaire for the individuals with FPHAs compared to the questionnaire for controls. In the latter, participants were instructed to answer these questions with respect to pain due to MSCs. In our questionnaire, participants answered the questions with respect to all bodily pain (corresponding to the original objective of the SF-36). However, since the bodily pain score for individuals with FPHAs was also lower (indicating more pain) than the normative data for the Dutch population [24], the sequence of questions may not fully account for this difference. Furthermore, recall bias may have occurred. It is possible that individuals with FPHAs are more focused on pain and other complaints than are control subjects.

Individuals with FPHAs had higher perceived physical work demands (UEWD score) than did controls. Further research should clarify if this difference is due to awareness of physical demands because of the amputation or if there is an actual difference in work demands or occupations between these populations.

Strengths and limitations

To our knowledge, this is the first study focusing on MSCs in individuals with FPHAs. The response rate was high compared to previous studies on MSCs in individuals with ULA [1,9,13].

When interpreting our results, several factors that could have influenced our findings on the prevalence of MSCs in individuals with FPHAs should be considered. The time since amputation was relatively short, since we could only invite patients who were registered with the diagnosis of FPHAs since 2002. However, in previous studies, there was inconclusive evidence regarding the influence of the time since amputation on the development of MSCs [11,12]. Furthermore, the heterogeneity of the amputation levels, especially the partial hand amputations, complicates generalisability of the results to the general FPHAs population. This heterogeneity could also explain why we did not find an association between the prevalence of MSCs and amputation levels.

Another limitation is that the questionnaire used is a self-reported questionnaire, consisting of several non-validated parts

Table 6. Logistic regression of presence of MSCs in the past four weeks in individuals with FPHAs ($n = 96$).

	<i>B</i>	S.E.	Sig.	OR	95% C.I. for OR		<i>R</i> ²
					Lower	Upper	
Participant predictors							
Gender	0.168	0.670	0.802	1.183	0.318	4.399	0.045
Age			0.841				
45–64	0.050	0.603	0.933	1.052	0.323	3.428	
65+	–0.371	0.823	0.653	0.690	0.138	3.464	
Educational level							
Medium	0.423	0.572	0.460	1.527	0.497	4.688	
High	0.340	0.770	0.659	1.405	0.310	6.361	
FPHAs-related predictors							
Regular occurrence of stump pain	1.394	0.856	0.103	4.032	0.754	21.571	0.168
Regular occurrence of stump sensations			0.033 ^a				
Stump sensations, only related to weather and/or bumping	–0.552	0.911	0.544	0.576	0.097	3.431	
Stump sensations, other sensations	1.246	0.539	0.021 ^a	3.477	1.209	9.998	
Other predictors							
Self-reported limited ROM of wrist of affected limb	1.509	0.684	0.027 ^a	4.521	1.183	17.281	0.060
Constant	–1.644	0.648	0.011 ^a	0.193	–	–	

B: regression coefficient; S.E.: standard error; Sig: *p* values; OR: odds ratio; C.I.: confidence interval.

*R*² is presented as Nagelkerke *R*². Total *R*²: 0.273. Constant for “MSCs during the last four weeks” is an individual with the following characteristics: male, aged 18–44, educational level none or low, no regular occurrence of stump pain, no regular occurrence of stump sensations and no self-reported limited ROM of the wrist of the affected limb.

^aStatistically significant at $p \leq 0.05$.

(e.g., the questions about the performance of the nine hand grips). To determine the influence of the hand grips and the ROM of the wrist on the presence of MSCs, it is recommended to measure these with an objective, standardised method. Furthermore, the control data of this study have been partially used in two earlier studies [13,38]. However, this control group seems to be a good representation of the prevalence of MSCs in the general population of the Netherlands [30].

Clinical implications

Clinicians do not need to give special attention to the prevention of MSCs in individuals with FPHAs, since there was no difference in prevalence rates of MSCs between these individuals and controls. However, clinicians should explore ROM of the wrist of the affected limb and regular occurrence of stump complaints to advise patients who may be at risk for MSCs, so that they can take precautionary measures in daily life and work. Therefore, it is important to pay attention to these factors during every patient’s clinical visit. As individuals with FPHAs experienced more pain than controls when MSCs were present, there should be special attention for pain treatment in this population. Future research could focus on objectifying the ROM of the wrist of the affected limb in individuals with FPHAs and the relationship between limited ROM and the presence of compensatory movements and MSCs. Furthermore, it would be interesting to investigate whether this relationship is different for the various amputation levels of FPHAs.

Conclusions

No significant difference was found in point and year prevalence of MSCs between individuals with FPHAs and controls. Higher pain scores were found for individuals with FPHAs who experienced MSCs compared to controls. Two clinically relevant predictors of the presence of MSCs were identified: regular occurrence of stump sensations and self-reported limited ROM of the wrist of the affected limb. For a better understanding of the aetiology of MSCs in individuals with upper extremity amputations, future

research focusing on the role of the ROM of the wrist and compensatory movements in the development of MSCs is warranted.

Disclosure statement

The authors report no conflicts of interest.

References

- [1] Ostlie K, Franklin RJ, Skjeldal OH, et al. Musculoskeletal pain and overuse syndromes in adult acquired major upper-limb amputees. *Arch Phys Med Rehabil.* 2011;92:1967–1973.e1.
- [2] Ostlie K, Magnus P, Skjeldal OH, et al. Mental health and satisfaction with life among upper limb amputees: a Norwegian population-based survey comparing adult acquired major upper limb amputees with a control group. *Disabil Rehabil.* 2011;33:1594–1607.
- [3] Pereira BP, Kour AK, Leow EL, et al. Benefits and use of digital prostheses. *J Hand Surg Am.* 1996;21:222–228.
- [4] Lifchez SD, Marchant-Hanson J, Matloub HS, et al. Functional improvement with digital prosthesis use after multiple digit amputations. *J Hand Surg Am.* 2005;30:790–794.
- [5] Atroshi I, Rosberg HE. Epidemiology of amputations and severe injuries of the hand. *Hand Clin.* 2001;17:343–350.
- [6] Datta D, Selvarajah K, Davey N. Functional outcome of patients with proximal upper limb deficiency-acquired and congenital. *Clin Rehabil.* 2004;18:172–177.
- [7] van der Sluis CK, Brouwers MAH. Een armamputatie of een transversaal congenitaal reductiedefect (an arm amputation or a transversal congenital reduction deficiency). In: Geertzen JHB, Rietman JS, Vanderstraeten GG, editors. *Revalidatie voor volwassenen (rehabilitation for adults)*. 1st ed. Assen: Koninklijke Van Gorcum; 2014. p. 199–221.
- [8] Bender LF, Koch RD. Meeting the challenge of partial hand amputations. *Orthotics Prosthet.* 1976;30:3–11.
- [9] Hanley MA, Ehde DM, Jensen M, et al. Chronic pain associated with upper-limb loss. *Am J Phys Med Rehabil.* 2009;88:742–751.

- [10] Jones LE, Davidson JH. Save that arm: a study of problems in the remaining arm of unilateral upper limb amputees. *Prosthet Orthot Int.* 1999;23:55–58.
- [11] Ephraim PL, Wegener ST, MacKenzie EJ, et al. Phantom pain, residual limb pain, and back pain in amputees: results of a national survey. *Arch Phys Med Rehabil.* 2005;86:1910–1919.
- [12] Burger H, Vidmar G. A survey of overuse problems in patients with acquired or congenital upper limb deficiency. *Prosthet Orthot Int.* 2016;40:497–502.
- [13] Postema SG, Bongers RM, Brouwers MA, et al. Musculoskeletal complaints in transverse upper limb reduction deficiency and amputation in the Netherlands: prevalence, predictors, and effect on health. *Arch Phys Med Rehabil.* 2016;97:1137–1145.
- [14] Chow SP, Ng C. Hand function after digital amputation. *J Hand Surg Br.* 1993;18:125–128.
- [15] Sagiv P, Shabat S, Mann M, et al. Rehabilitation process and functional results of patients with amputated fingers. *Plast Reconstr Surg.* 2002;110:497–503.
- [16] Kuret Z, Burger H, Vidmar G. Influence of finger amputation on grip strength and objectively measured hand function: a descriptive cross-sectional study. *Int J Rehabil Res.* 2015;38:181–188.
- [17] Bongers PM, de Vet HC, Blatter BM. Repetitive strain injury (RSI): occurrence, etiology, therapy and prevention. *Ned Tijdschr Geneesk.* 2002;146:1971–1976.
- [18] Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMCC(3)-study. *Pain.* 2003;102:167–178.
- [19] Brouwer WB, Koopmanschap MA, Rutten FF. Productivity losses without absence: measurement validation and empirical evidence. *Health Policy.* 1999;48:13–27.
- [20] Tang K. Estimating productivity costs in health economic evaluations: a review of instruments and psychometric evidence. *Pharmacoeconomics.* 2015;33:31–48.
- [21] Opsteegh L, Soer R, Reinders-Messelink HA, et al. Validity of the dictionary of occupational titles for assessing upper extremity work demands. *PLoS ONE.* 2010;5:e15158.
- [22] Jacobs NW, Berduszek RJ, Dijkstra PU, et al. Validity and reliability of the upper extremity work demands scale. *J Occup Rehabil.* 2016. doi: 10.1007/s10926-016-9683-9
- [23] Ware JE, Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care.* 1992;30:473–483.
- [24] Aaronson NK, Muller M, Cohen PD, et al. Translation, validation, and norming of the Dutch language version of the SF-36 health survey in community and chronic disease populations. *J Clin Epidemiol.* 1998;51:1055–1068.
- [25] Hildebrandt VH, Bongers PM, van Dijk FJ, et al. Dutch musculoskeletal questionnaire: description and basic qualities. *Ergonomics.* 2001;44:1038–1055.
- [26] Tait RC, Pollard CA, Margolis RB, et al. The pain disability index: psychometric and validity data. *Arch Phys Med Rehabil.* 1987;68:438–441.
- [27] Tait RC, Chibnall JT, Krause S. The pain disability index: psychometric properties. *Pain.* 1990;40:171–182.
- [28] Soer R, Koke AJ, Vroomen PC, et al. Extensive validation of the pain disability index in 3 groups of patients with musculoskeletal pain. *Spine.* 2013;38:E562–E568.
- [29] Burger H, Franchignoni F, Heinemann AW, et al. Validation of the orthotics and prosthetics user survey upper extremity functional status module in people with unilateral upper limb amputation. *J Rehabil Med.* 2008;40:393–399.
- [30] Huisstede BM, Wijnhoven HA, Bierma-Zeinstra SM, et al. Prevalence and characteristics of complaints of the arm, neck, and/or shoulder (CANS) in the open population. *Clin J Pain.* 2008;24:253–259.
- [31] Yassi A. Repetitive strain injuries. *Lancet.* 1997;349:943–947.
- [32] van Tulder M, Malmivaara A, Koes B. Repetitive strain injury. *Lancet.* 2007;369:1815–1822.
- [33] Carey SL, Jason Highsmith M, Maitland ME, et al. Compensatory movements of transradial prosthesis users during common tasks. *Clin Biomech.* 2008;23:1128–1135.
- [34] Metzger AJ, Dromerick AW, Holley RJ, et al. Characterization of compensatory trunk movements during prosthetic upper limb reaching tasks. *Arch Phys Med Rehabil.* 2012;93:2029–2034.
- [35] Major MJ, Stine RL, Heckathorne CW, et al. Comparison of range-of-motion and variability in upper body movements between transradial prosthesis users and able-bodied controls when executing goal-oriented tasks. *J NeuroEng Rehabil.* 2014;11:132.
- [36] Bertels T, Schmalz T, Ludwigs E. Objectifying the functional advantages of prosthetic wrist flexion. *J Prosthet Orthot.* 2009;21:74–78.
- [37] Deijs M, Bongers RM, Ringeling-van Leusen ND, et al. Flexible and static wrist units in upper limb prosthesis users: functionality scores, user satisfaction and compensatory movements. *J NeuroEng Rehabil.* 2016;13:26.
- [38] Postema SG, Bongers RM, Brouwers MA, et al. Upper limb absence: predictors of work participation and work productivity. *Arch Phys Med Rehabil.* 2016;97:892–899.