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Research

Adding mobilisation with movement to exercise and advice hastens the improvement in range, pain and function after non-operative cast immobilisation for distal radius fracture: a multicentre, randomised trial

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K E Y W O R D S

Distal radius fracture
Rehabilitation
Mobilisation
Physical therapy
Exercise

A B S T R A C T

Question: Does adding mobilisation with movement (MWM) to usual care (ie, exercises plus advice) improve outcomes after immobilisation for a distal radius fracture? **Design**: A prospective, multicentre, randomised, clinical trial with concealed allocation, blinding and intention-to-treat analysis. **Participants**: Sixty-seven adults (76% female, mean age 60 years) treated with casting after distal radius fracture. **Intervention**: The control group received exercises and advice. The experimental group received the same exercises and advice, plus supination and wrist extension MWM. **Outcome measures**: The primary outcome was forearm supination at 4 weeks (immediately post-intervention). Secondary outcomes included wrist extension, flexion, pronation, grip strength, QuickDASH (Disabilities of Arm, Shoulder and Hand), Patient-Rated Wrist Evaluation (PRWE) and global rating of change. Follow-up time points were 4 and 12 weeks, with patient-rated measures at 26 and 52 weeks. **Results**: Compared with the control group, supination was greater in the experimental group by 12 deg (95% CI 5 to 20) at 4 weeks and 8 deg (95% CI 1 to 15) at 12 weeks. Various secondary outcomes were better in the experimental group at 4 weeks: extension (14 deg, 95% CI 7 to 20), flexion (9 deg, 95% CI 4 to 15), QuickDASH (−11, 95% CI −18 to −3) and PRWE (−13, 95% CI −23 to −4). Benefits were still evident at 12 weeks for supination, extension, flexion and QuickDASH. The experimental group were more likely to rate their global change as 'improved' (risk difference 22%, 95% CI 5 to 39). There were no clear benefits in any of the participant-rated measures at 26 and 52 weeks, and no adverse effects. **Conclusion**: Adding MWM to exercise and advice gives a faster and greater improvement in motion impairments for non-operative management of distal radius fracture. **Registration**: ACTRN12615001330538. **[Reid SA, Andersen JM, Vicenzino B (2020) Adding mobilisation with movement to exercise and advice hastens the improvement in range, pain and function after non-operative cast immobilisation for distal radius fracture: a multicentre, randomised trial. *Journal of Physiotherapy* 66:105–112]**

Introduction

Distal radius fractures account for about 20% of all fractures treated in emergency departments, making them the most common. Compared to 2018 there is a predicted increase in the annual number of distal radius fractures in Australia in people aged $\geq$ 35 years of 20% by 2028 and 60% by 2051.[1,2] With the predicted increase in incidence there is an anticipated 27% increase in costs from 2017 to 2030.[3–5]

The increase in incidence and subsequent costs of distal radius fractures is especially concerning because there are no evidence-based rehabilitation interventions. A rigorous systematic review of 26 (quasi-)randomised controlled trials evaluating rehabilitation of radius fractures concluded that there was insufficient evidence to establish what rehabilitation intervention should be provided, by whom it should be provided (ie, which rehabilitation clinician) and for how long.[6] Medical management is usually conservative casting, which immobilises the wrist in a flexed, pronated and ulnar deviated position for up to 6 weeks; this often results in wrist pain and stiffness, especially into supination and extension.[5] Exercise is prescribed for at least 90% of patients after a distal radius fracture.[7]

A systematic review of studies of clinician-applied passive joint mobilisation to improve clinical outcomes following immobilisation for this fracture identified three randomised trials,[5,8,9] which provided limited evidence in the short term for the addition of passive joint mobilisations to advice and exercise.[10] These passive mobilisations all rely on a trained clinician to deliver them, which has a tendency towards reliance on a clinician instead of the patient exercising or self-treating. Mobilisation with movement (MWM) is a manual therapy technique that can be self-applied, thereby engaging the patient in recovering wrist and hand function. This technique has been used for conditions such as adhesive capsulitis at the shoulder[11] and lateral epicondylalgia at the elbow,[12] with a recent systematic

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review showing that this technique can reduce pain and disability in peripheral joints.[13] Self-applied MWM has not been studied in the rehabilitation of non-operatively managed distal radius fracture.[13]

The aim of this study was to determine the effect of adding wrist extension and forearm supination MWM to exercises and advice when treating impairments after immobilisation for a distal radius fracture. It was hypothesised that the addition of MWM would result in superior restoration of range of motion, pain and function when compared with exercises and advice alone.

Therefore, the research question for this prospective, multicentre, randomised, clinical trial was:

> Does adding mobilisation with movement to usual care (ie, exercises plus advice) improve outcomes after immobilisation for a distal radius fracture?

Method

Design

A prospective, parallel, two-group, randomised trial was conducted with concealed allocation, blinding and intention-to-treat analysis. Participants were recruited at seven physiotherapy practices in Sydney between February 2016 and December 2017, with a 12-month follow-up concluding in December 2018. Potential participants were screened over the phone and sent information about the study. Eligible individuals were then assessed at baseline by research assistants (registered physiotherapists experienced in managing musculoskeletal conditions) who were blind to treatment assignment. After baseline assessment, participants were randomly allocated to either an experimental group (who received MWM in addition to usual care, which was exercises and advice) or a control group (who received the same usual care but no MWM). To ensure concealed allocation, an independent statistician produced a computer-generated randomisation sequence, which was placed in sequentially numbered, opaque, sealed envelopes that were kept in a locked location. The recruiters therefore remained blind to allocation sequence. Participants were unaware of the hypothesis being tested and every effort was made to conceal the hypothesis from them. The interventions were delivered over 4 weeks and outcomes were assessed up to 12 months. The trial was reported according to the CONSORT guidelines.[14]

Participants

Adults aged ≥ 18 years were recruited if they had sustained a distal radius fracture and were being managed non-surgically in a cast. They were recruited via advertisements online in social media (such as Facebook) and printed material (posters and fliers) in hospitals, medical waiting rooms and physiotherapy clinics in Sydney. People could also be referred to the study from hospitals, medical centres and physiotherapy clinics in Sydney. The exclusion criteria were: a previous fracture to the same wrist within the last 20 years, another concurrent upper limb fracture on the same limb, pre-existing inflammatory joint conditions, pre-existing complex regional pain syndrome and inability to understand written or spoken English.

Interventions

All participants in both intervention groups received four physiotherapy consultations (20 to 30 minutes each) over 4 weeks. The aim was to have two intervention sessions within the first week, the third session 1 week later and the fourth session 2 weeks later. All participants performed upper limb range of motion exercises twice daily (see Appendix 1 on the eAddenda for details) and were provided advice about swelling control, skin care and gradually using the upper limb more during activities of daily living. All participants were given this program in a written handout by a physiotherapist. The control group received no other treatment.

The experimental group also received a MWM to improve supination and another MWM to improve extension at the wrist, as these movements are usually the most affected. The physiotherapist applied six repetitions at the first session and also instructed the participant to self-administer the MWM into supination and wrist extension (Figure 1) six times, twice daily. Participants also received an exercise sheet or video describing how to perform the self-MWM, which is presented in Appendix 2 on the eAddenda. At the three follow-up treatment sessions, the physiotherapist: administered one to three sets of 10 repetitions of the MWM based on Mulligan's recommendation that the patient should not experience any pain; and reviewed, facilitated and guided the participant's self-MWM. The location and direction of the glide could be modified so that the MWM was pain free, as advocated in the Mulligan concept.[15]

Both intervention groups were treated by physiotherapists in their place of regular musculoskeletal practice. All physiotherapists received a half-day workshop conducted by an author (SR) and Brian Mulligan at a university in Sydney. This session included information about the study, the study protocol that was to be adhered to and what assessments would take place. The therapists were taught how to: perform the intervention exercises; give general advice after cast removal, including return to activity; apply the MWM into supination and extension; teach the self-MWM into supination and extension; and teach the home exercises that both groups were to perform.

The seven physiotherapy centres in Sydney, Australia, where the trial was conducted were the private physiotherapy practices where the seven musculoskeletal physiotherapists who were responsible for delivering all treatments worked. Patients attended the practice that was located conveniently for them.

Outcome measures

Physical measures and participant ratings of pain and disability (wrist-related activity limitations) were assessed at baseline, Week 4 (immediately after the course of treatment) and Week 12. Participant-rated outcomes were also recorded at Weeks 26 and 52 either by post or via a link to an online survey[a]. The global rating of change scale was used at all follow-up times: Weeks 4, 12, 26 and 52. Physical measures were made by research assistants (registered physiotherapists with experience in musculoskeletal conditions) who were blind to each participant's allocated group. Participant-rated outcomes were completed by participants who were unaware that a specific MWM rehabilitation approach was being tested.

Primary outcome

The primary outcome measure was combined forearm and intercarpal supination at Week 4 (immediately after the intervention period), which was measured by a universal goniometer using the hand-held pencil method, as prescribed by the American Society of Hand Therapists.[16,17] It has clinical utility because it has been widely adopted across clinical settings, in previous research and practice guidelines.[16,18–20] The hand-held pencil method is reliable and valid for supination: inter-rater ICC 0.96, inter-rater SEM 3 deg, intra-rater ICC 0.94 to 0.98 and intra-rater SEM 2 to 3.5 deg.[20,21] While meaningful clinical change has not been reported for the hand-held pencil method, it has been reported to be > 8 deg for supination using the universal goniometer.[19]

Five certified hand therapists were asked to decide on the primary outcome measure and they determined that supination was the most functional measure. Supination was considered important as it is often most limited after cast removal and affects many activities of daily living such as eating, drinking, dressing, driving and personal care.[22]

Secondary outcomes

The secondary outcomes included physical measures of wrist extension range, wrist flexion range, forearm pronation range, grip strength and a functional pouring task. The participant-rated

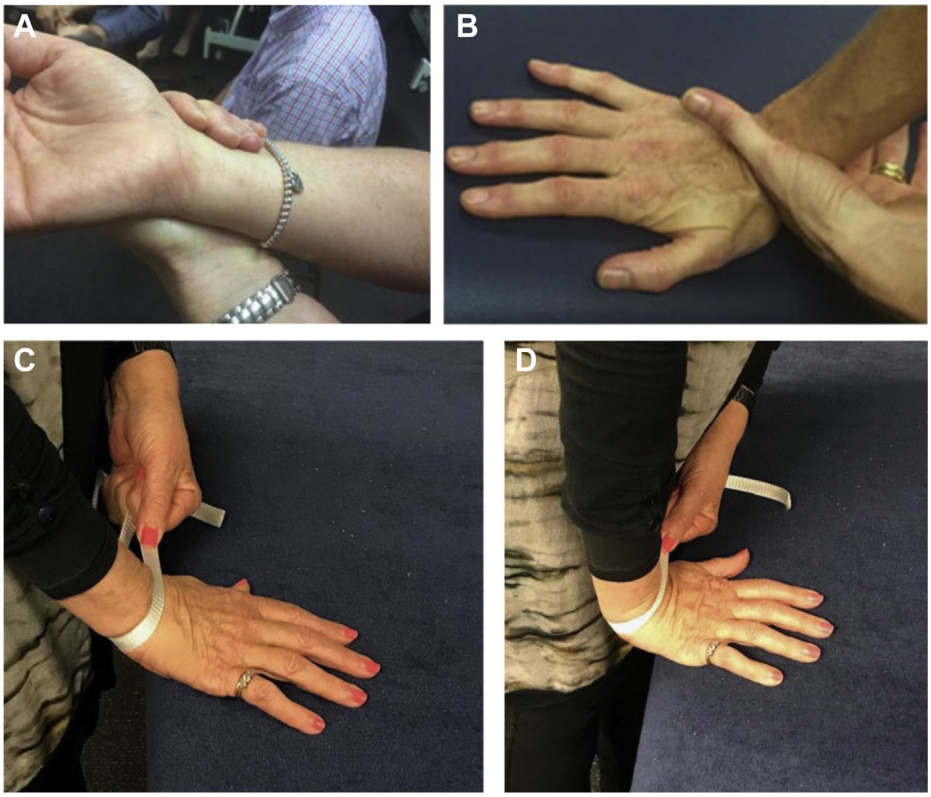

Figure 1. Mobilisation with movement for supination and extension.
A. For supination, the participant glided the radius on the ulna, then while sustaining the glide, actively supinated the forearm. B. For wrist extension, the participant was instructed to lightly place their relaxed fingertips onto a table. They performed a glide of the distal radius towards the little finger using the webspace of the unaffected hand. C. Alternately they could glide the proximal row of carpal bones towards the thumb using a thin strap. D. While sustaining the glide in 1B or 1C, the participant then performed wrist extension by leaning forward over the hand.

questionnaires that were used were: the Patient-Rated Wrist Evaluation (PRWE) and the Disabilities of the Arm, Shoulder and Hand (QuickDASH) to measure subjective wrist pain and function; the QoL Short-Form 8 (SF-8) to measure quality of life; and a global rating of change scale. Information was also collected on adherence to the exercise program and adverse events through participant diaries and physiotherapist records. The secondary measures are described in greater detail in Appendix 3 on the eAddenda.

Data analysis

A sample size of 33 participants in each group was determined based on previous research[23,24] that used supination as an outcome measure. This was based on a difference in supination of 14 deg, with a standard deviation of 20, statistical power of 80% and an alpha level of 5%.

An independent statistician who was blind to group allocation performed the analyses. An intention-to-treat analysis was performed using commercial software[b]. Interval data were normally distributed, so parametric measures were used. For interval data, an analysis of covariance (ANCOVA) was used to determine the differences between groups, with the baseline score included as a covariate. Means (SD) and frequency counts (%) were reported for interval and categorical data, respectively. Global rating of change was reported as the percentage of participants in each group that reported a change $\geq +3$ at follow-up and were thereby classified as 'improved'. For the functional task, the percentage of participants who had 'no difficulty' was reported. The point estimates of effect were reported as mean difference (95% CI) between groups for interval data and as risk difference (95% CI) for binary data. Standardised mean differences (SMD) were calculated and SMDs of 0.2 were deemed to be small, 0.6 moderate, 1.2 large and 2.0 very large.[25] The level for significance was set at < 0.05. Adherence to home exercise was calculated as a percentage of how many sessions were completed out of the number of sessions prescribed by the physiotherapist.

Results

Compliance with the study protocol

The time from cast removal to starting the intervention was registered as 'within a week'. In the trial, this increased to a mean of 9 days (Table 1), due to the logistics of aligning patient and clinician diaries.

Flow of participants through the study

Thirty-three participants (23 female, 70%) with a mean age of 56 years (range 24 to 79) were allocated to the experimental group and 34 (28 female, 82%) with a mean age of 63 years (range 23 to 92) to the control group (Table 1). At the 12-month follow-up, 33

Table 1
Characteristics of participants.

Characteristic	Exp (n = 33)	Con (n = 34)	Total (n = 67)
Age *(yr)*, mean (SD)	56 (16)	63 (16)	60 (16)
Gender, n female (%)	23 (70)	28 (82)	51 (76)
Wrist injured, n right (%)	16 (48)	17 (50)	33 (49)
Wrist injured, n dominant hand (%)	11 (33)	16 (47)	27 (40)
Employed before accident, n (%)	19 (58)	13 (38)	32 (48)
Duration of cast immobilisation *(d)*, mean (SD)	40 (5)	43 (12)	41 (9)
Time from cast removal to starting intervention *(d)*, mean (SD)	9 (11)	10 (12)	9 (12)

Con = control group, Exp = experimental group, MWM = mobilisation with movement.

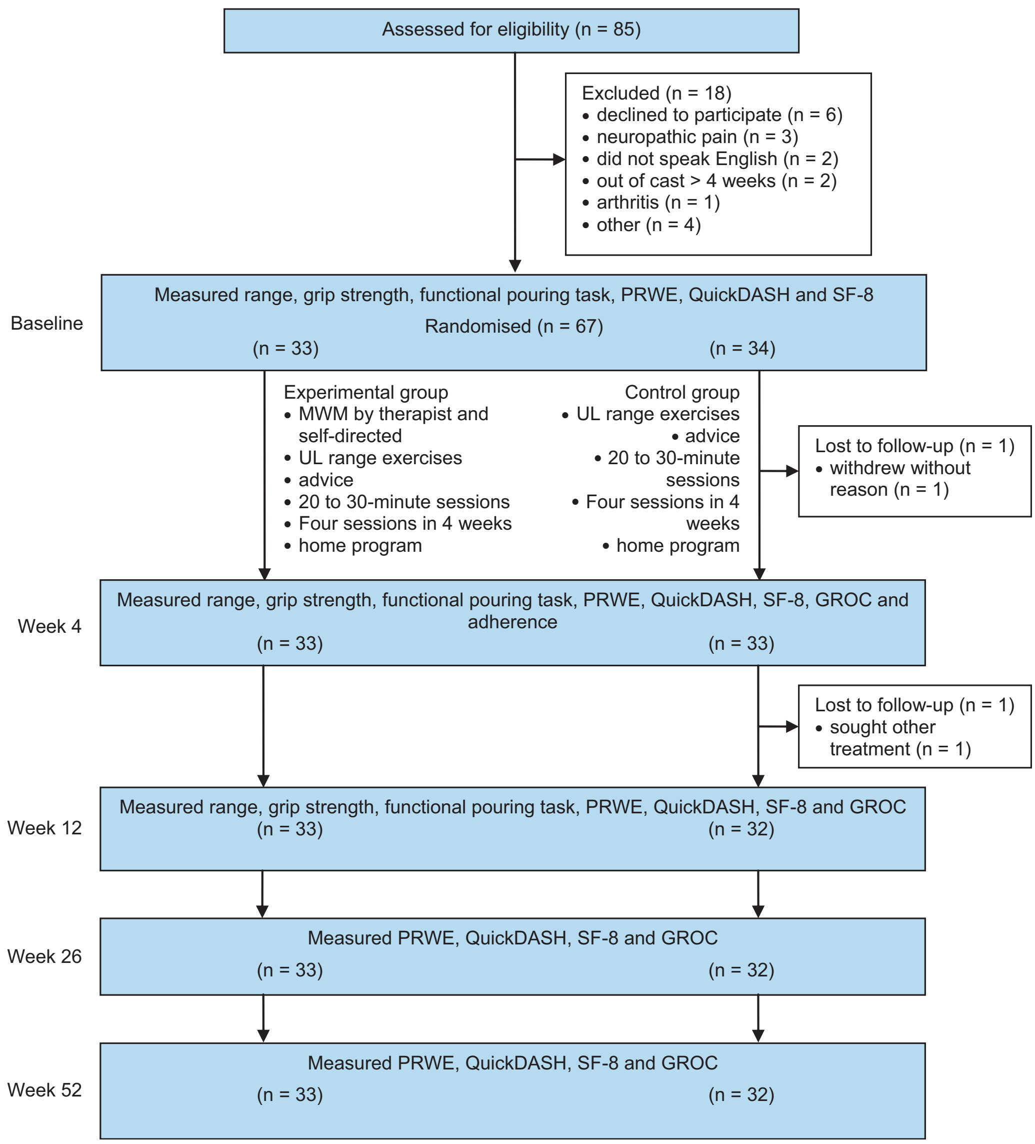

Figure 2. Design and flow of participants through the trial.
GROC = global rating of change, PRWE = Patient-Rated Wrist Evaluation, QuickDASH = Quick Disabilities of the Arm, Shoulder and Hand questionnaire, SF-8 = Short Form-8 questionnaire, UL = upper limb.

participants in the experimental group and 32 in the control group were still in the study (Figure 2).

The groups were similar at baseline, except for pronation range of motion, grip strength and employment prior to injury. While mean grip strength at baseline was 12 kg in the experimental group and 6 kg in the control group, this difference was less than the reported minimum clinically important difference (MCID) of 6.5 kg. While we attempted to characterise the fracture's severity by recording whether it was extra-articular versus intra-articular, this information was only available for 48 participants (72%). For the experimental group there were 18 extra-articular fractures, five intra-articular and 10 unknown. For the control group there were 19 extra-articular fractures, six intra-articular and nine unknown.

Effect of the intervention

Primary outcome

The experimental group had greater supination than the control group at 4 weeks, with a mean between-group difference of 12 deg (95% CI 5 to 20) (Table 2). When calculated as a SMD (0.8), it was categorised as a moderate effect.

Secondary outcomes

Supination was still greater for the experimental group at 12 weeks, with a mean difference of 8 deg (95% CI 1 to 15) between groups (Table 2). When calculated as an SMD (0.6), it was categorised as a moderate effect.

The experimental group had greater wrist extension than the control group at 4 weeks, with a mean between-group difference of 14 deg (95% CI 7 to 20). This benefit was still evident at 12 weeks: 14 deg (95% CI 6 to 21). The experimental intervention was also estimated to improve wrist flexion by 14 deg at both time points, as shown in Table 2.

The experimental intervention was also estimated to improve all aspects of the PRWE and the QuickDASH at 4 weeks, although the effect was no longer clear at 12 weeks, as shown in Table 2.

The experimental intervention was estimated to increase the likelihood of being able to pour into supination and pour into pronation at both 4 and 12 weeks, as shown in Table 3. Participants were also more likely to report a GROC in the 'improved' range at 4 weeks, as also shown in Table 3.

The participant-rated measures showed similar outcomes between the two groups at 26 and 52 weeks, as shown in Table 4 and Table 5 on the eAddenda. Individual participant data are presented in Table 6 on the eAddenda.

Table 2
Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups at 4 and 12 weeks, for continuous outcomes.

Outcome	Groups						Difference within groups				Difference between groups	
	Week 0		Week 4		Week 12		Week 4 minus Week 0		Week 12 minus Week 0		Week 4 minus Week 0	Week 12 minus Week 0
	Exp (n = 33)	Con (n = 34)	Exp (n = 32)	Con (n = 32)	Exp (n = 32)	Con (n = 31)	Exp	Con	Exp	Con	Exp – Con	Exp – Con
Supination *(deg)*, mean (SD)	78 (17)	75 (23)	95 (15)	83 (15)	96 (14)	88 (14)	18 (15)	8 (20)	19 (18)	14 (22)	12 (5 to 20)	8 (1 to 15)
Pronation *(deg)*, mean (SD)	76 (15)	63 (24)	84 (13)	79 (13)	88 (12)	83 (12)	11 (13)	14 (20)	15 (15)	16 (15)	5 (−2 to 12)	5 (−1 to 11)
Extension *(deg)*, mean (SD)	40 (13)	34 (15)	58 (13)	44 (13)	62 (14)	48 (14)	19 (16)	10 (13)	28 (18)	14 (14)	14 (7 to 20)	14 (6 to 21)
Flexion *(deg)*, mean (SD)	32 (13)	30 (12)	50 (12)	41 (12)	54 (10)	45 (10)	19 (12)	10 (13)	22 (12)	13 (12)	9 (4 to 15)	9 (4 to 14)
Grip strength *(kg)*, mean (SD)	12 (11)	6 (7)	16 (8)	15 (8)	20 (7)	19 (7)	6 (6)	7 (9)	10 (6)	10 (7)	0 (−4 to 4)	1 (−2 to 5)
PRWE pain *(0 to 50)*, mean (SD)	26 (11)	30 (12)	13 (10)	20 (10)	10 (9)	12 (9)	−14 (12)	−10 (10)	−17 (9)	−18 (11)	−7 (−13 to −2)	−2 (−7 to 3)
PRWE function *(0 to 50)*, mean (SD)	28 (12)	32 (13)	9 (10)	16 (10)	6 (11)	10 (11)	−19 (11)	−16 (11)	−22 (13)	−21 (14)	−7 (−12 to −2)	−4 (−9 to 2)
PRWE total *(0 to 100)*, mean (SD)	53 (22)	61 (33)	22 (19)	36 (19)	16 (20)	21 (20)	−33 (21)	−25 (19)	−39 (20)	−39 (22)	−13 (−23 to −4)	−5 (−15 to 5)
QuickDASH *(0 to 100)*, mean (SD)	50 (19)	58 (21)	22 (15)	32 (15)	14 (16)	23 (16)	31 (17)	−23 (14)	−38 (16)	−33 (18)	−11 (−18 to −3)	−8 (−17 to 0)
SF-8 PCS *(0 to 100)*, mean (SD)	41 (7)	37 (10)	49 (8)	46 (8)	52 (7)	51 (8)	8 (9)	9 (10)	11 (8)	12 (20)	3 (−1 to 8)	1 (−3 to 5)
SF-8 MCS (*0 to 100)*, mean (SD)	50 (9)	47 (12)	53 (7)	52 (7)	53 (9)	50 (9)	4 (9)	5 (11)	4 (10)	3 (14)	2 (−2 to 5)	2 (−2 to 7)

Means adjusted for baseline value of the outcome measure.
Con = control group, Exp = experimental group, PRWE = Patient-Related Wrist Evaluation, QuickDASH = Quick Disabilities of the Arm, Shoulder and Hand questionnaire, SF-8 PCS = Short-Form 8-item Quality of Life questionnaire physical component summary, SF-8 MCS = Short-Form 8-item Quality of Life questionnaire mental component summary, shaded cell = primary outcome.

Adherence

The 52-week follow-up was completed by 65 (97%) of the 67 participants. All four physiotherapy sessions were attended by 91% of participants in both groups. Exercise diaries were completed and returned by 79% (26/33) participants in the experimental group and 71% (24/34) of participants in the control group. In both groups, 92% of participants performed $\geq$ 70% of prescribed home exercises, which is a threshold for exercise adherence used in previous research.[26]

Adverse effects

Nine participants (27%) in the experimental group and five (15%) in the control group reported some mild pain ($<$ 3/10) or discomfort lasting $<$ 30 minutes after the exercises.

Discussion

In the management of distal radius fractures, MWM appears to be an effective adjunct to range of motion exercises and advice, leading to better outcomes within 4 weeks of cast removal. On average, the addition of MWM produced a moderate effect on the primary outcome of supination at 4 weeks; there was a 12-deg difference between groups in favour of MWM. This estimated effect exceeds the MCID of 8 deg, but the confidence interval around this estimate spans the MCID, indicating that there is some uncertainty about whether the true average effect of MWM on this outcome is large enough to be clinically worthwhile. There was still a moderate effect at 12 weeks, with the 8-deg difference between groups equalling the MCID and with the confidence interval not excluding the possibility of a trivial effect (ie, a benefit of only 1 deg).

Similarly, other outcomes mirror this improvement. Adding MWM caused moderate to large improvements in wrist extension and flexion range at both 4 and 12 weeks. The mean between-group difference exceeded the MCID of 7 deg for extension and 6 deg for flexion at both 4 and 12 weeks. The associated confidence intervals mostly (although not completely) exceeded the MCID, suggesting that the average effects are likely to be worthwhile.

Table 3
Number (%) of participants in each group and risk difference (95% CI) between groups at 4 and 12 weeks, for dichotomous outcomes.

Outcome	Week 4		Week 12		Week 4	Week 12
	Exp (n = 32)	Con (n = 32)	Exp (n = 32)	Con (n = 31)	Risk difference between groups *(%)* Exp relative to Con	
No difficulty pouring into supination, n (%)	29 (90)	25 (78)	32 (100)	25 (81)	12 (6 to 30)	19 (5 to 36)
No difficulty pouring into pronation, n (%)	30 (94)	25 (78)	32 (100)	25 (81)	16 (2 to 33)	19 (5 to 36)
GROC 'improved', n (%)	31 (97)	24 (75)	30 (94)	30 (97)	22 (5 to 39)	−3 (−17 to 10)

Con = control group, Exp = experimental group, GROC = Global Rating of Change (improved = +3 or higher on a scale from −5 'very much worse' to 5 'complete recovery').

Pain and function with upper limb tasks were improved on the total PRWE in the experimental group at 4 weeks, with the between-group difference of 13 approximately equal to the MCID of 14. However, by 12 weeks it was no longer clear whether the effect on total PRWE was beneficial. The function sub-scale of the PRWE showed similar effects. The QuickDASH showed benefits for the experimental group; there was less disability than the control group at 4 and 12 weeks. The improvement in function was also evident in the tests of difficulty pouring. MWM increased the likelihood that participants could pour into supination or into pronation without difficulty at both time points by between 12% and 19%. The confidence intervals around these estimates spanned from very strong to very mild effects, so it remains uncertain whether the effects would be clinically worthwhile.

There was no difference in quality of life, which was measured with a global measure of overall health between the two groups. However, participants were more likely to report that they were 'improved' on a global rating of change scale at 4 weeks if in the experimental group.

The estimated effect of adding MWM on grip strength was small to none, with fairly narrow confidence intervals. Although no MCID was prospectively nominated, it seems reasonable to conclude that any effect on grip strength was negligible. This could be because strengthening exercises were not prescribed.

At the time of the fracture, 48% of participants were still employed and 40% fractured their dominant hand. This injury could have major implications on ability to work and participate in sport and usual physical activity, so a quicker return of movement and function and less pain would be beneficial.

Many of the individual estimates discussed above have favourable and worthwhile mean estimates, but confidence intervals that span from trivial to worthwhile effects. A larger sample size would have helped to narrow these confidence intervals to give more precise estimates of the treatment effects. In assisting patients to interpret these results and decide on whether they would like to incorporate MWM in their rehabilitation, it is important to consider the pool of anticipated benefits. That is: the effect on one outcome may or may not be clinically worthwhile in isolation, but the study identified multiple benefits, the best estimates for which are clinically worthwhile — so it is likely that the overall benefit would be worthwhile.

Another important interpretation to highlight to patients relates to the difference between the short-term and long-term outcomes. Because benefits from MWM were observed at 4 and 12 weeks and not 26 and 52 weeks, people with distal radius fractures managed with range exercises and advice can anticipate that they will eventually reach a similar degree of improvement, regardless of whether MWM is used, but that MWM will induce faster improvement in pain and disability.

This study's estimates of several benefits from adding MWM to advice and exercise is in contrast to the previous limited and 'ambiguous evidence' reported in a systematic review of this modality in hand therapy.[10] That review included three studies,[5,8,9] two of which showed mixed results on joint movement and the other one no effects on joint movement. Two previous clinical trials that were not included in that systematic review studied unspecified joint mobilisations in combination with physiotherapy and compared this program with exercise and advice. They reported more consistent improvements in wrist joint movements.[27,28] The lack of clear descriptions of all the joint mobilisation procedures applied in those studies makes it hard to replicate their findings. In contrast, the current study clearly described the type and amount of joint mobilisation that was studied, to enable replication and translation into clinical practice.

The present study did not find a between-group difference for grip strength, although both groups improved at 12 weeks. This probably reflects natural recovery because neither intervention included any strengthening exercise. Future studies could examine whether incorporating strengthening improves strength and influences other outcomes. A study by Watt et al reported a significantly greater increase in grip strength for the physiotherapy intervention group than the non-physiotherapy group (given a home exercise sheet) between the initial measurement and the 6-week follow-up, but did not report what the actual active exercises were or whether they included strengthening exercises.[28]

It is important to consider why the addition of MWM to exercise and advice resulted in greater improvements in range of wrist motion, pain and disability over at least the first 12 weeks after cast removal. The experimental group underwent more movement in their rehabilitation: 24 additional self-administered supination and extension movements per day and between 32 and 72 repetitions applied by the clinician over the 4 weeks. Thus, the benefits seen in the MWM groups might have been due to performing more movement. It is currently unknown what amount of movement is optimal in rehabilitation for non-surgically managed distal radius fracture. An inherent part of applying MWMs is that they are performed pain free, which likely encourages adherence to rehabilitation. The immediacy of this pain-free movement with MWM might be associated with both physiological and psychological effects. It has been proposed that MWM may generate a mechanical hypoalgesia by stimulating endogenous pain modulation,[12] which conceivably would enable a patient to move better and more often, contributing to the better outcomes seen in this study. Either through this mechanism of pain modulation or through other means, being able to move better with less pain is likely to reduce any negative psychological manifestations of the fracture injury and ensuing immobilisation, thereby empowering the patient to engage in rehabilitation exercises. There is evidence to support the use of self-management in many conditions, which encourages patient independence, self-efficacy and empowerment.[29,30] The intervention is easy to perform as a self-mobilisation. Participants in the study were up to 79 years old in the experimental group. They were able to successfully apply the self-MWM after being instructed by the physiotherapist, who also gave them printed instructions on how to perform the MWM and a video of the participant performing the self-MWM was offered on their phone as well.

Despite random allocation there were some between-group differences at baseline. Those in the experimental group had twice the grip strength (12 kg) of the control group (6 kg) at baseline. Even though the difference was less than the MCID of 6.5 kg,[31] it may indicate that the experimental group had a less severe injury or was less affected by the injury and casting. Fifty-eight per cent of participants in the experimental group were employed before the accident compared with 38% of the control group. So perhaps the experimental group were better in some ways, more motivated to do the exercises, had better self-efficacy or psychological factors making them more responsive to a self-treatment.

Supination was chosen as the primary outcome after consultation with specialist hand therapists who manage the rehabilitation of patients with distal radius fractures after cast removal. In retrospect, extension and flexion movements might have been more relevant primary outcomes because those movements were 53% of normal range at baseline, whereas supination was 83% of normal range. Other authors used wrist extension as the primary outcome because they believed it is an important indicator of hand function and is often the most restricted movement following cast removal after a distal radius fracture due to the casting position.[28] The decision between supination and flexion/extension as the primary outcome in the present study is inconsequential because substantial benefits were observed on them all (Table 2).

Another potential source of bias that might have contributed to the better outcomes in the experimental group was that both interventions were delivered by the same clinicians. To counter this, clinicians were instructed to provide similar encouragement to mobilise/exercise in both groups and the research assistant taking any physical measures (ie, primary outcome of supination) was kept blind to allocated intervention.

The current study did not include an economic evaluation. Given that there was a benefit gained with greater wrist function with the addition of self-applied MWM to exercise and advice, there might be a potential economic benefit. With estimated costs for distal radius fractures of AUD 47 million in NSW and ACT alone in 2012 (AUD 10 million on rehabilitation and medical management),[2] the addition of MWM might convey an economic benefit as well. This remains to be evaluated.

A strength of this study was the small number of dropouts, as 65 of the 67 participants (97%) completed the 12-month follow-up. There was excellent adherence by participants to physiotherapist intervention sessions, completing the diaries and performing self-treatment and home exercises. This supports previous research that programs with individual sessions with a therapist or in a clinical setting have been shown to have better adherence than solely self-managed rehabilitation.[30] Exercise diaries have been used in other studies and have been noted as a strategy that may increase adherence.[26,32] We propose that the results of this study can be generalised to a broader clinical context because participants were seen by seven different clinicians for their rehabilitation. Although there was a mean age of 60 years, the range was 23 to 92 years, which supports the implementation of the findings across a broad age range. The MWM intervention is easy to perform as a self-mobilisation, as the forces applied are very low. Participants in the study were aged up to 79 years in the MWM group; they were able to successfully apply the self-MWM after being instructed by the physiotherapist who also gave them printed instructions on how to perform the MWM and a video of the participant performing the self-MWM was also offered on their phone.

Another strength of this study is that it was designed to overcome some previously identified sources of bias.[6] For example, the physical outcome measures of range of motion were taken by people who did not know the group to which the patient was assigned, and the participant-rated outcomes were completed by participants who were unaware that a specific MWM rehabilitation approach was being tested. Participants were followed up for $>$ 12 months, which has not been done in previous studies of wrist mobilisation and exercise.

Based on this study, it is recommended that patients would benefit from MWM interventions in addition to range of motion exercises and advice on distal radius fracture management. The findings of this study may lead to a change in clinical practice, which has the potential to improve the quality of outcomes for a large proportion of the community.

What was already known on this topic: Distal radius fracture is the most common fracture in the elderly, with a predicted increase in incidence and costs. Systematic reviews conclude that there is insufficient evidence to determine the best rehabilitation following a distal radius fracture. There is some evidence that exercise or joint mobilisations might improve outcomes after cast removal for a distal radius fracture

What this study adds: Range of motion exercises and advice provide better outcomes if given with mobilisation with movements. Typical impairments of motion of the forearm, wrist and hand are restored more quickly with the combined mobilisation, exercise and advice than without the mobilisation. Patient-rated disability and perception of global recovery improve more quickly after 4 weeks of the combined rehabilitation, even though at 52 weeks the outcomes are much the same.

Footnotes: [a] Qualtrics XM, Dallas, USA.[b] IBM Statistical Package for Social Sciences, version 25, SPSS Inc. Chicago, USA.

eAddenda: Tables 4, 5 and 6, and Appendices 1, 2 and 3 can be found online at https://doi.org/10.1016/j.jphys.2020.03.010.

Ethics approval: The Australian Catholic University Human Ethics Committee approved this study. All participants gave written informed consent before data collection began.

Competing interests: The Mulligan Concept Teachers Association partially funded this study. One author of the study (JA) is a member of this association, while the other two authors SR and BV are honorary members of this association. Contributions: SR, BV and JA conceived the study and were involved in securing funding for the study. BV, SR and JA designed the study. SR supervised participant recruitment, the interventions and data collection. SR and BV did the study analyses and wrote the article with assistance from JA. All authors approved the final version of the manuscript.

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