ORIGINAL CLINICAL REPORT

OPEN

Passive Movements Do not Appear to Prevent or Reduce Joint Stiffness in Medium to Long-Stay ICU Patients: A Randomized, Controlled, Within-Participant Trial

Kathy R. Stiller, BASc, PhD[1]

Simone Dafoe, BASc[2]

Christabel S. Jesudason, BASc, MHSc[3]

Tony M. McDonald, BASc[4]

Rocky J. Callisto, BASc[2]

OBJECTIVES: ICU patients have an increased risk of joint stiffness because of their critical illness and reduced mobility. There is a paucity of evidence evaluating the efficacy of passive movements (PMs). We investigated whether PMs prevent or reduce joint stiffness in ICU patients.

DESIGN: A randomized, controlled, within-participant, assessor-blinded study.

SETTING: A 48-bed tertiary care adult ICU.

PATIENTS: Intubated patients who were expected to be invasively mechanically ventilated for greater than 48 hours with an ICU length of stay greater than or equal to 5 days, and unable to voluntarily move their limbs through full range of motion (ROM).

INTERVENTIONS: The ankle and elbow on one side of each participant's body received PMs (10 min each joint, morning and afternoon, 5 d/wk). The other side acted as the control. The PMs intervention continued for as long as clinically indicated to a maximum of 4 weeks.

MEASUREMENTS: The primary outcome was ankle dorsiflexion ROM at cessation of PMs. Plantarflexion, elbow flexion and extension ROM, and participant-reported joint pain and stiffness (verbal analog scale [VAS]) were also measured. Outcomes were recorded at baseline and cessation of PMs. For participants whose PMs intervention ceased early due to recovery, additional post-early-cessation of PMs review measurements were undertaken as near as possible to 4 weeks.

MAIN RESULTS: We analyzed data from 25 participants with a median (interquartile range) ICU stay of 15.6 days (11.3–25.4). The mean (95% CI) between-side difference for dorsiflexion ROM (with knee extension) at cessation of PMs was 0.4 degrees (−4.4 to 5.2; $p = 0.882$), favoring the intervention side, indicating there was not a clinically meaningful effect of 5 degrees. No statistically significant differences were found between the intervention and control sides for any ROM or VAS data.

CONCLUSIONS: PMs, as provided to this sample of medium to long-stay ICU patients, did not prevent or reduce joint stiffness.

KEY WORDS: contracture; critical care; exercise therapy; physical therapy modalities; range of motion, articular

From 2019 to 2020 190,094 adults were admitted to Australian and New Zealand ICUs with a median length of stay (LOS) of 1.7 days and, from 2017 to 2018, only 2.4% had an ICU LOS greater than 14 days (1, 2). ICU survival has increased but has been accompanied by an increase in adverse long-term sequelae including physical, psychologic, and cognitive impairments

DOI: 10.1097/CCE.0000000000001006

KEY POINTS

Question: Do passive movements prevent or reduce joint stiffness in ICU patients?

Findings: In this randomized, controlled, within-participant study, we did not find a clinically meaningful effect of passive movements on range of motion.

Meaning: Passive movements, as provided to this sample of medium to long-stay ICU patients, did not prevent or reduce joint stiffness.

(3). These are believed to result from the underlying critical illness and medical/pharmacologic interventions used. The physical sequelae include weakness, reduced mobility, soft-tissue contracture, and reduced joint range of motion (ROM), and evidence of critical illness neuromuscular abnormalities is found in nearly 50% of ICU patients with sepsis, multiple organ failure, or protracted mechanical ventilation (4). These can cause pain, sleep disturbances, limit mobility, complicate delivery of hospital care, delay hospital discharge, and adversely affect function and quality of life (5).

The term "joint contracture" describes a limitation in the passive ROM of a mobile joint and results from limited extensibility of intra-articular (bone, cartilage, capsule) or extra-articular (muscles, tendons, skin) structures (6–9). Neurally mediated factors, such as spasticity which limits extensibility of the muscle-tendon unit, can also increase risk of contracture (10). A contracture is the final common result of numerous conditions preventing the movement of a joint through its full ROM (7). ICU patients have an increased risk of joint stiffness/contracture because of their critical illness and reduced mobility (5, 6, 9, 11). Contracture has been found in up to 39% of ICU patients in ICU greater than or equal to 14 days, with time in ICU a risk factor, resulting in greater long-term mortality and mobility limitations (3, 12).

The interventions commonly used to prevent/treat joint stiffness and contracture are passive movements (PMs) and stretch. These interventions are used for various conditions including spinal cord injury, brain injury, and ICU patients. PMs can be described as the repeated movement of a joint within the available ROM without volitional control, usually undertaken by another person (13–15). One of the main aims of PMs is to maintain/increase joint mobility (8, 13, 14). The rationale is that if lack of movement causes contracture, then imposed movement will prevent contracture (8). Theoretically, PMs might do this by preventing formation of cross-bridges within collagen, improving extensibility of soft tissues overlying joints, and influencing the excitability of lower motor neurons. Stretch involves the mechanical elongation of soft tissues for varying periods of time and can be applied manually (self-administered or by another person), using splints/casts or positioning (16). The mechanisms by which PMs and stretch may work were summarized by Harvey et al (16). They noted that animal and human studies have shown immediate increases in the extensibility of soft tissue with stretch, with immediate increases in joint ROM and decreases in resistance to passive joint movement. This phenomenon is termed viscous deformation but only lasts briefly once the stretch is removed. The lasting effects of PMs and stretch are more important for the treatment/prevention of joint stiffness and contracture, but the mechanisms underlying possible lasting effects are less well understood.

Three Cochrane reviews have addressed the effectiveness of PMs and stretch (8, 16–18). Prabhu et al (8) concluded from two studies that it is unclear whether PMs are effective for the prevention/treatment of contractures. Harvey et al (17) found moderate level evidence that continuous passive motion after total knee arthroplasty does not have clinically important short-term effects on active knee flexion, with similar findings for medium- and long-term effects albeit with a lower level of evidence. Harvey et al (16, 18) reported high-level evidence to indicate that stretch administered regularly does not have clinically important short- or long-term effects on joint mobility in people with or without neurologic conditions when performed for less than 7 months. Harvey et al (16, 18) noted it is not clear whether PMs have a different effect from stretch, hypothesizing that perhaps the cyclic movement associated with PMs provides a different mechanical stimulus than stretch.

Although infrequently reported, there seems to be marked regional variability in the routine delivery of PMs in ICUs, with Australian data reporting a prevalence of 14% (15), whereas U.K. data report a prevalence

as high as 99% (13). There is a paucity of RCTs assessing the efficacy of this intervention in critically ill populations. In the only study identified, a randomized, comparative trial by Shamsi et al (19) compared the effect of manual stretch to manual stretch plus transcutaneous electrical nerve stimulation (TENS) to the ankles of 36 ICU patients unable to move their legs actively (treatments given three times per week for 2 wk). ROM (dorsiflexion, plantarflexion) improved over time in both groups but was better for the group receiving TENS, although the between-group differences were of questionable clinical importance (< 5 degrees). This paucity of research is an important oversight given the potentially time-consuming nature of performing PMs routinely for all ICU patients. Therefore, the aim of this study was to investigate whether PMs prevent or reduce joint stiffness in ICU patients, with our hypothesis being that PMs will reduce joint stiffness.

MATERIALS AND METHODS

Design

A randomized, controlled, within-participant, assessor-blinded study with concealed allocation was undertaken and conducted in accordance with the Helsinki Declaration of 1975. The study was approved by the Central Adelaide Local Health Network Human Research Ethics Committee (number 13731, October 7, 2020), registered with the Australian New Zealand Clinical Trials Registry (ACTRN12620001202954) and supported by an Alison Kinsman AM Physiotherapy Research Grant.

Setting and Participants

The study was conducted at the Royal Adelaide Hospital, an 800-bed, tertiary, public hospital in Australia, from February 2021 to January 2023. The ICU has 48 beds and approximately 3,500 admissions per year. All patients admitted to the ICU were screened for eligibility by an ICU research nurse. Potential participants were adults (≥ 18 yr) who were intubated and expected to be invasively mechanically ventilated for greater than 48 hours with an ICU LOS greater than or equal to 5 days, and unable to voluntarily move their limbs through full ROM. The latter was clinically assessed (observation and, if possible, response to verbal command) by the ICU research nurse and, if unclear, an investigator. These criteria were likely to include longer-stay patients with neurologic conditions, spinal cord or traumatic brain injury, and/or medical illnesses (e.g., severe respiratory failure, sepsis). No limits were placed on when recruitment occurred within the hospital or ICU admission. Exclusion criteria were: refused consent, burn injury, COVID-19 diagnosis, preexisting condition/injury adversely affecting joint ROM (e.g., rheumatoid arthritis, neurologic condition with spasticity/contracture), unable to understand written/spoken English, medical/surgical condition where management included no PMs to a limb (e.g., limb fracture), death deemed inevitable from the current illness, non-index ICU admissions.

Study Protocol

Informed written consent was sought for potentially eligible patients from the person legally responsible. Once recruited, participants had one side of their body randomly allocated to receive the intervention (PMs) and the other side to act as a control. A computer-generated randomization table was kept by an independent person remote from the ICU and side-of-body allocation was revealed by phone.

Intervention

PMs interventions were provided to the ankle and elbow joints on the allocated side, with these joints selected based on previous research (5, 11, 20). The intensity, frequency, and duration of the PMs intervention were based on the protocol used by Harvey et al (21) and survey responses reported by Wiles and Stiller (15). An intensive PMs regimen was delivered to maximize the likelihood of finding a treatment effect. PMs were given to the ankle and elbow on the allocated side for 10 minutes each, morning and afternoon, 5 d/wk, for up to 4 weeks by a treating physiotherapist. Ankle PMs involved dorsiflexion (knee in extension and flexion), plantarflexion, inversion, and eversion. Elbow PMs comprised flexion, extension, pronation, and supination. No force was used at end of ROM. No specific advice was given regarding cadence of PMs. If the participant transferred out of the ICU before study completion, the PMs intervention continued in the ward setting. Compliance with the PMs intervention was recorded on a daily log completed by the treating physiotherapist. In keeping

with our usual clinical practice, the treating physiotherapist assessed, daily, each participant's ability to actively move their limbs, and the PMs intervention was ceased early if the participant recovered such that they could actively move their ankles and elbows (bilaterally) through full antigravity ROM. The decision for early cessation of PMs was initiated by the treating physiotherapist and confirmed by a blinded physiotherapist, using a standardized assessment, and the time point recorded.

The side of the body allocated as the control side did not receive any PMs. Apart from the study PMs intervention, all other healthcare continued as per usual. Any intervention that may have affected ankle/elbow ROM was recorded daily by the treating physiotherapist. Adverse events resulting from the treatment/control interventions were documented. This included a safety fall-back position whereby the treating physiotherapist flagged any participant they believed was developing marked joint stiffness and reported it to an investigator. In this scenario, ROM was subsequently measured by the blinded assessors and if loss of ROM had occurred the study interventions ceased. The number of participants requiring this was recorded and ongoing outcome measurements were recorded as per the study protocol.

Outcome Measures

The primary outcome was passive ankle dorsiflexion ROM (with knee extension). Ankle dorsiflexion with knee flexion, plantarflexion, elbow flexion, and extension were also measured. These outcomes were recorded at baseline and cessation of PMs which was as near as possible to 4 weeks. For participants whose PMs intervention was ceased early due to recovery, additional post-early-cessation of PMs review measurements were undertaken as near as possible to 4 weeks.

ROM was measured by two physiotherapists, blinded to the side-of-body allocation, with one moving the joint passively and the other measuring ROM. Both assessors were experienced in measuring joint ROM, familiar with the ICU environment, and undertook a period of training prerecruitment to ensure a consistent procedure. ROM was measured noninvasively using a goniometer, with the participant supine and standardized positioning of the goniometer's arms and fulcrum (22). Before measurement, each joint was moved through a full passive ROM 3–5 times. The assessors determined the degree of "push" required to reach end of passive ROM on an individual basis for each joint ROM.

Other outcomes included participant-reported joint pain and stiffness (measured separately on a verbal analog scale [VAS] where 0 = no pain/stiffness and 10 = worst pain/stiffness imaginable), with measures taken for the intervention and control sides at baseline and cessation of PMs.

If a participant was transferred from the ICU, follow-up measurements were undertaken in the ward. If a participant was transferred to another healthcare facility or discharged home, these data were recorded just before transfer/discharge. If a participant's medical condition became critical and their overall outcome uncertain, cessation of PMs data were recorded before 4 weeks.

Sample Size and Analyses

A sample size calculation was undertaken based on ankle dorsiflexion ROM reported by Harvey et al ([21], page 64) using a paired Student *t* test for the mean difference. Using 80% power to detect a treatment effect of 5 degrees, assuming a SD of 9.5 degrees, correlation of 0.6, alpha of 0.05, and a two-sided test, a sample size of 25 participants was required.

Descriptive statistics were used to describe participants' characteristics. Linear mixed methods analyses (with participant identification as a random intercept) were used to compare differences between intervention and control sides for change in ROM outcomes from baseline to cessation of PMs, and VAS outcomes at cessation of PMs. As a post hoc analysis, we tested the interaction between number of interventions (≤ 10 [n = 13]), 11+ [n = 12]) and the between-condition effects of the intervention on change in ROM outcomes. SPSS, v28 (IBM Corp, Armonk, NY) was used for all analyses. A p value of less than 0.05 was considered statistically significant, and a mean difference in ROM of greater than or equal to 5 degrees between the intervention and control sides was considered clinically significant for the primary outcome (dorsiflexion) (21, 23–25).

RESULTS

Study Participants

Two hundred sixty-eight patients were screened (**Fig. 1**). Twenty-nine patients were recruited, four of whom died with only baseline measures recorded, resulting in a sample size of 25 being analyzed. Two hundred thirty-nine patients were excluded, most often due to a medical/surgical condition where management included no PMs in at least one limb (*n* = 49 [e.g., limb fracture]) and death deemed inevitable (*n* = 45). Of the 25 participants, 18 (72%) were male and a median (IQR) age of 55 years (40–70) was recorded (**Table 1**). Mean values for participants' highest level of mobility improved over the study duration (26).

Compliance With Trial

All 25 participants had baseline and cessation-of-PMs ROM assessments performed, the latter occurring at a median (IQR) of 8.0 days (6.0–23.0) (Table 1). Fifteen participants (60%) had their PMs intervention ceased early due to recovery, at a median (IQR) of 6.0 days (5.0–8.0). Thirteen of these had additional ROM outcomes measured at the post-early-cessation of PMs review at a median (IQR) of 23.0 days (14.0–28.0) (one self-discharged from hospital unexpectedly, and one died). The independent assessors reported no instances of unblinding.

Participant-reported joint pain and stiffness VAS data were provided by 0 participants at baseline and 13 of 25 participants at cessation of PMs. Missing data resulted from participants' inability to communicate (neurologic status).

Mean (SD) days and number of PMs interventions are shown in Table 1. For all participants across the study, 411 of a potential 451 (91%) PMs interventions were provided as per the study protocol. Reasons for the 40 missed PMs interventions were: medical procedure (*n* = 14 [35%]), medically unstable (*n* = 9 [22%]), declined (*n* = 8 [23%]), noncompliant (*n* = 4 [10%]), staffing issues (*n* = 4 [10%]), and family wishes (*n* = 1 [3%]). No adverse effects resulting from the PMs or control interventions were reported. No participants had cessation of the study interventions because of

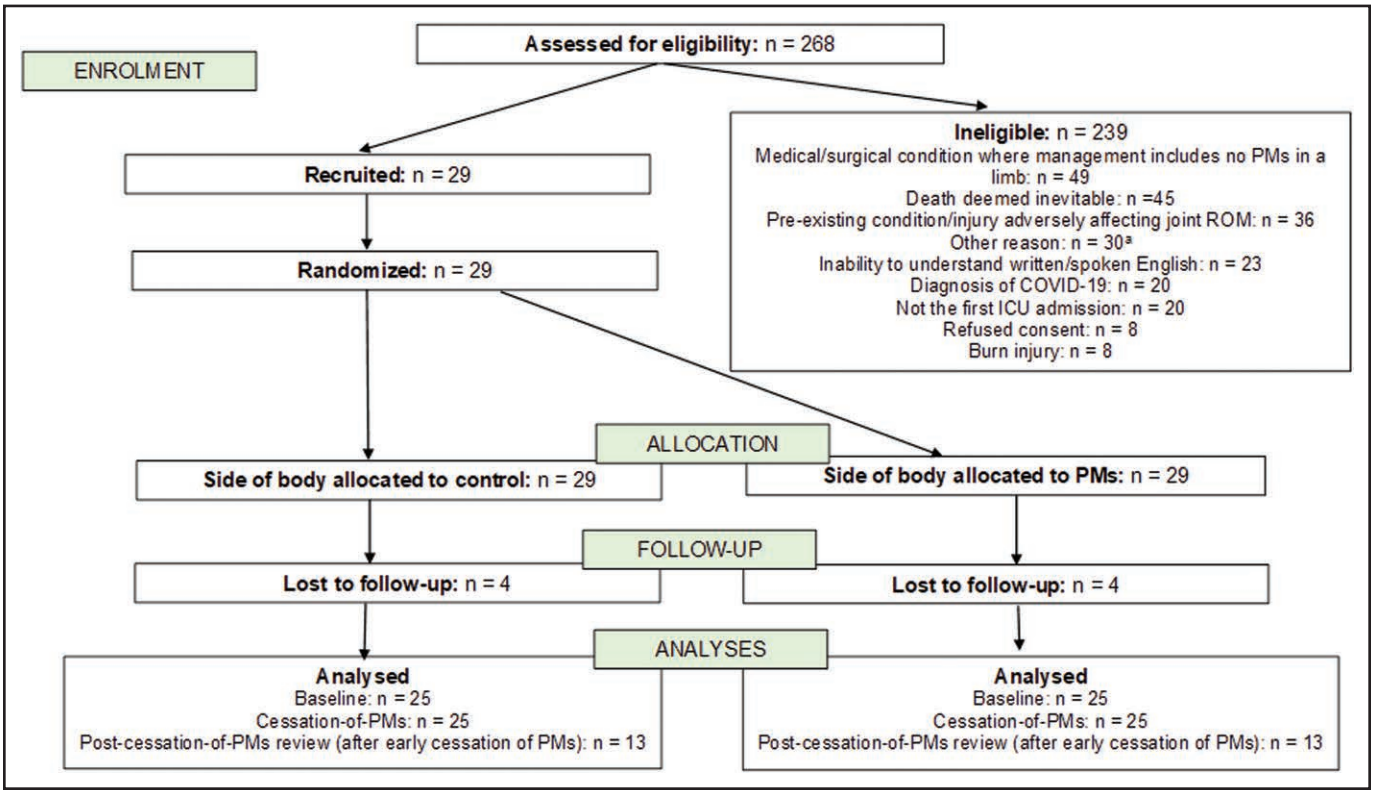

Figure 1. Design and flow of participants through the study. [a]Other reasons: enrolled in another study, *n* = 8; refused enrollment in another study so not approached, *n* = 5; not documented, *n* = 5; awaiting COVID-19 clearance, *n* = 3; medical decision, *n* = 3; no next of kin, *n* = 2; prisoner, *n* = 1; late transfer to ICU from interstate, *n* = 1; uncooperative, *n* = 1; family too distressed to approach, *n* = 1. PMs = passive movements, ROM = range of motion.

TABLE 1.
Demographic and Descriptive Data for the 25 Participants

Characteristics of Participants	
Sex, *n* (%)	
Male	18 (72)
Female	7 (28)
Age, yr, median (IQR)	55.0 (40.0–70.0)
Body mass index, kg/m^2, mean (SD)	31.3 (5.2)
Primary diagnosis, *n* (%)	
Neurologic condition	10 (40)
Postoperative	6 (24)
Respiratory failure	3 (12)
Trauma with head injury	2 (8)
Trauma without head injury	2 (8)
Sepsis	2 (8)
Intervention side, *n* (%)	
Dominant	13 (52)
Right	13 (52)
Left	0 (0)
Nondominant	12 (48)
Right	2 (8)
Left	10 (40)
Day of recruitment, median (IQR)	
After ICU admission	4.0 (2.5–6.0)
After commencement of mechanical ventilation	3.0 (2.0–5.0)
Total number of interventions, mean (SD)	16.4 (13.5)
Days of intervention, mean (SD)	9.0 (7.2)
Timing of follow-up outcome measurements, days postrecruitment, median (IQR)	
Cessation of PMs ($n = 25$)	8.0 (6.0–23.0)
Post-early-cessation of PMs review ($n = 13$)	23.0 (14.0–28.0)
Duration of mechanical ventilation, d, median (IQR)	10.3 (6.7–16.9)
ICU mobility scale, median (IQR)[a]	
Baseline ($n = 25$)	0.0 (0.0–0.0)
Cessation of PMs ($n = 25$)	3.0 (0.0–3.0)
Post-early-cessation of PMs review ($n = 13$)	8.0 (7.5–8.0)
ICU LOS, d, median (IQR)	15.6 (11.3–25.4)
Hospital LOS, d, median (IRQ)	31.0 (20.5–50.5)

IQR = interquartile range, LOS = length of stay, PM = passive movement.
[a]ICU mobility scale (26).

concerns regarding loss of ROM. Three participants were fitted bilaterally with ankle-foot orthoses because their feet were resting in plantarflexion (days 1, 2, and 9 postrecruitment).

Main Results

There was little change in mean ROM from baseline to cessation of PMs for either the intervention or control

sides, with all changes less than 5 degrees (**Table 2**, **Fig. 2**; and **Supplemental Appendix 1** [figures], http://links.lww.com/CCX/B273). For the primary outcome, ankle dorsiflexion (with knee extension), ROM reduced from baseline to cessation of PMs, with the mean (95% CI) difference in the change in ROM between intervention and control sides 0.4 degrees (–4.4 to 5.2; $p = 0.882$), favoring the intervention side. No statistically significant differences were found for any ROM data.

To investigate if early cessation of PMs influenced the results, the ROM data for the 15 participants who

TABLE 2.
Range of Motion Data for the Control and Intervention Sides for the 25 Participants

Range of Motion Outcomes	Baseline ($n = 25$)		Cessation of Passive Movements ($n = 25$)	
	Control	Intervention	Control	Intervention
Ankle dorsiflexion with knee extension				
Mean (SD)	10.4 (7.0)	11.0 (7.9)	8.5 (6.1)	9.5 (7.3)
Change since baseline (within condition), mean (95% CI)	–	–	−1.8 (−5.2 to 1.6)	−1.5 (−4.9 to 1.9)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	0.4 (−4.4 to 5.2) $p = 0.882$
Ankle dorsiflexion with knee flexion				
Mean (SD)	10.6 (7.8)	12.0 (7.9)	11.0 (7.4)	13.0 (9.1)
Change since baseline (within condition), mean (95% CI)	–	–	0.4 (−3.1 to 3.9)	1.0 (−2.5 to 4.4)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	0.6 (−4.4 to 5.5) $p = 0.821$
Ankle plantarflexion				
Mean (SD)	41.4 (8.7)	43.3 (8.8)	45.5 (10.5)	44.8 (9.4)
Change since baseline (within condition), mean (95% CI)	–	–	4.2 (0.9 to 7.4)	1.5 (−1.8 to 4.8)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	−2.6 (−7.3 to 2.0) $p = 0.260$
Elbow flexion				
Mean (SD)	140.7 (8.8)	139.7 (9.1)	139.3 (9.6)	138.1 (9.5)
Change since baseline (within condition), mean (95% CI)	–	–	−1.4 (−5.8 to 3.0)	−1.6 (−6.0 to 2.8)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	−0.2 (−6.4 to 6.0) $p = 0.949$
Elbow extension				
Mean (SD)	1.2 (3.9)	2.4 (4.6)	0.6 (6.4)	−1.4 (8.5)
Change since baseline (within condition), mean (95% CI)	–	–	−0.6 (−3.3 to 2.1)	−3.8 (−6.5 to −1.1)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	−3.2 (−7.1 to 0.6) $p = 0.101$

Dashes indicate not appropriate.

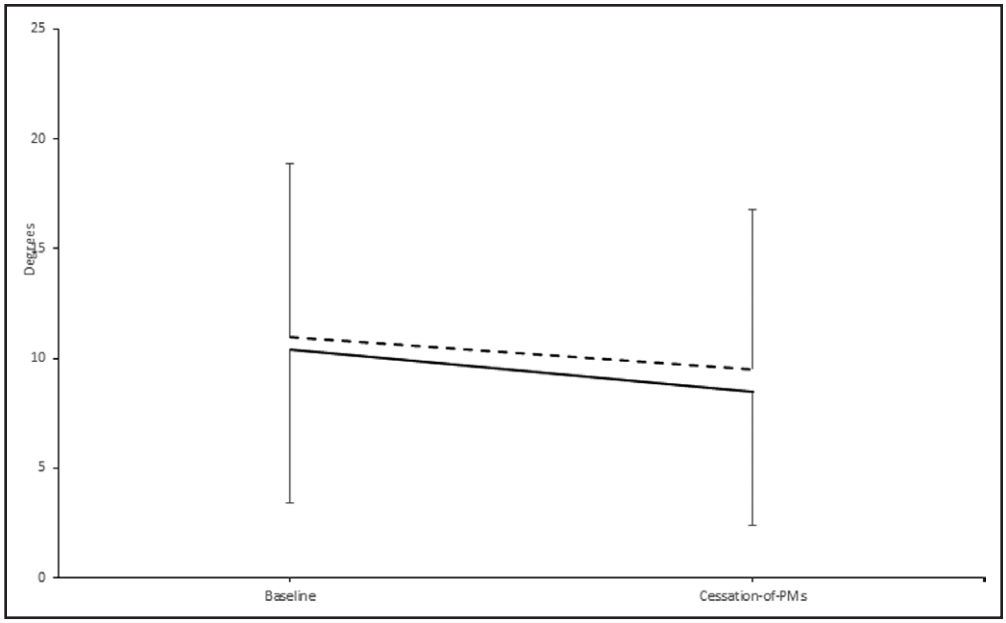

Figure 2. Dorsiflexion (with knee extension) range of motion for the 25 participants. *Solid line* represents control side, *dashed line* represents intervention side. *Bars* indicate SD. PMs = passive movements.

had early cessation of PMs due to recovery were separately analyzed (**Table 3**). Little change was seen in ROM for the intervention or control sides from baseline to cessation of PMs or the post-early-cessation of PMs review.

No statistically significant interactions were found when we investigated whether the number of interventions participants received affected ROM; however, we cannot rule out the possibility of intervention length influencing the between-condition effects of the intervention on change in ROM outcomes (**Supplemental Table 1**, http://links.lww.com/CCX/B273). Additionally, ROM data for the six participants who received the study interventions for the entire 4 weeks were reviewed individually (**Supplemental Appendix 2** [figures], http://links.lww.com/CCX/B273). There was no indication that the change in ROM over time differed consistently between intervention and control sides.

Secondary Outcomes

Mean VAS scores for participant-reported ankle and elbow joint pain and stiffness at cessation of PMs were less than 2 and no significant differences were found between intervention and control sides (**Table 4**).

DISCUSSION

This study is the first RCT investigating whether PMs prevent or reduce joint stiffness in ICU patients. The mean (95% CI) between-side difference for the primary outcome of dorsiflexion (0.4 degrees [–4.4 to 5.2] at cessation of PMs) indicated there was not a clinically meaningful effect of 5 degrees. No statistically significant differences were found between intervention and control sides for ROM or participant-rated pain and stiffness. Therefore, we were unable to provide any evidence that PMs are effective at preventing or reducing joint stiffness in this sample of ICU patients.

Comparing our results to previous research, our frequency of contractures was lower than the 39% reported by Clavet et al (11), with five (20%) participants in our study developing an ankle contracture (using a decrease ≥ 10 degrees in ankle dorsiflexion [knee extension] to define contracture; three on both intervention and control sides, two on intervention side), and one (4%) participant an elbow contracture (using a decrease ≥ 30 degrees in elbow ROM to define contracture; one on control side). This may reflect that their sample only included patients in ICU greater than or equal to 14 days, whereas our sample had a more variable length of ICU stay, and their contracture data were based on ROM data retrospectively retrieved from medical records. The changes in ROM that we recorded over time for dorsiflexion and plantarflexion were similar in magnitude (i.e., < 5 degrees) to those reported by Shamsi et al (19) for 36 patients in ICU greater than 1 week and Harvey et al (21) for 20 community-dwelling tetraplegics, whereas Nepomuceno et al (27) found greater reductions in ankle and elbow ROM (approximately 5 and 11 degrees, respectively) in their sample of 22 ICU patients with an ICU stay of greater than 72 hours. The reason for the greater ROM reductions reported by Nepomuceno (27) is not clear:

TABLE 3.

Range of Motion Data for the Control and Intervention Sides for the 15 Participants Who had Early Cessation of Passive Movements

	Baseline ($n = 15$)		Cessation of Passive Movements ($n = 15$)		Post-Early-Cessation of Passive Movements Review ($n = 13$)	
Range of Motion Outcomes	**Control**	**Intervention**	**Control**	**Intervention**	**Control**	**Intervention**
Ankle dorsiflexion with knee extension						
Mean (SD)	9.1 (5.9)	11.3 (6.5)	8.2 (5.1)	7.6 (5.6)	7.2 (4.5)	7.3 (4.6)
Change since baseline (within condition), mean (95% CI)	–	–	−0.9 (−4.9 to 3.0)	−3.7 (−7.7 to 0.2)	−1.9 (−6.0 to 2.2)	−4.0 (−8.2 to 0.1)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	−2.8 (−8.4 to 2.8) $p = 0.325$	–	−2.1 (−8.0 to 3.7) $p = 0.471$
Ankle dorsiflexion with knee flexion						
Mean (SD)	9.3 (5.6)	12.4 (8.8)	8.7 (6.6)	11.2 (7.4)	7.9 (7.3)	10.5 (6.8)
Change since baseline (within condition), mean (95% CI)	–	–	−0.6 (−5.8 to 4.6)	−1.2 (−6.4 to 4.0)	−1.3 (−6.7 to 4.1)	−1.9 (−7.3 to 3.5)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	−0.6 (−8.0 to 6.8) $p = 0.871$	–	−0.6 (−8.2 to 7.0) $p = 0.877$
Ankle plantarflexion						
Mean (SD)	39.9 (8.2)	41.8 (8.2)	42.7 (9.1)	44.1 (9.6)	46.2 (9.0)	42.5 (7.4)
Change since baseline (within condition), mean (95% CI)	–	–	2.8 (−3.5 to 9.1)	2.3 (−3.9 to 8.6)	6.3 (−0.2 to 12.8)	0.7 (−5.8 to 7.2)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	−0.5 (−9.3 to 8.4) $p = 0.917$	–	−5.5 (−14.7 to 3.6) $p = 0.233$
Elbow flexion						
Mean (SD)	140.9 (9.1)	138.7 (9.1)	139.7 (10.4)	136.7 (10.4)	140.2 (7.3)	142.1 (8.2)
Change since baseline (within condition), mean (95% CI)	–	–	−1.3 (−8.0 to 5.4)	−2.0 (−8.7 to 4.7)	−0.8 (−7.7 to 6.2)	3.3 (−3.6 to 10.3)

(*Continued*)

TABLE 3. (*Continued*)

Range of Motion Data for the Control and Intervention Sides for the 15 Participants Who had Early Cessation of Passive Movements

	Baseline ($n = 15$)		Cessation of Passive Movements ($n = 15$)		Post-Early-Cessation of Passive Movements Review ($n = 13$)	
Range of Motion Outcomes	**Control**	**Intervention**	**Control**	**Intervention**	**Control**	**Intervention**
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	−0.7 (−10.2 to 8.7) $p = 0.878$	–	4.1 (−5.7 to 13.9) $p = 0.406$
Elbow extension						
Mean (SD)	0.2 (4.3)	1.3 (5.1)	0.6 (7.7)	−3.3 (9.3)	1.8 (3.3)	1.2 (3.1)
Change since baseline (within condition), mean (95% CI)	–	–	0.4 (−4.0 to 4.8)	−4.6 (−9.0 to −0.2)	1.6 (−3.0 to 6.1)	−0.1 (−4.6 to 4.4)
Difference in change since baseline between intervention and control (between conditions), mean (95% CI), *p* values	–	–	–	−5.0 (−11.2 to 1.2) $p = 0.112$	–	−1.7 (−8.1 to 4.8) $p = 0.606$

Dashes indicate not appropriate.

TABLE 4.
Participant-Reported Verbal Analog Scale Scores for Joint Pain and Stiffness

Verbal Analog Scale Scores	Cessation of Passive Movements	
	Control ($n = 12$)	Intervention ($n = 13$)
Ankle pain		
Mean (SD)	1.3 (2.6)	0.4 (0.8)
Difference between intervention and control (between conditions), mean (95% CI), p values	–	−1.0 (−2.4 to 0.4) $p = 0.146$
Elbow pain		
Mean (SD)	0.4 (1.0)	0.9 (1.8)
Difference between intervention and control (between conditions), mean (95% CI), p values	–	0.5 (−0.8 to 1.8) $p = 0.395$
Ankle stiffness		
Mean (SD)	0.9 (2.2)	1.0 (1.8)
Difference between intervention and control (between conditions), mean (95% CI), p values	–	0.0 (−1.4 to 1.5) $p = 0.964$
Elbow stiffness		
Mean (SD)	1.1 (2.5)	0.8 (1.7)
Difference between intervention and control (between conditions), mean (95% CI), p values	–	−0.3 (−1.1 to 1.6) $p = 0.689$

Dashes indicate not appropriate.

their sample was similar to ours with a neurologic diagnosis most common (41% vs 48%) and comparable ICU LOS (13.0 vs. 15.6 d).

Limitations

We chose to use a randomized, controlled, within-subject design as we believed ROM was likely to be affected by factors unique to each individual (e.g., preexisting condition, current illness). It would have been preferable if all participants received the PMs intervention for the entire 4-week period. Although we tailored our eligibility criteria with the aim of recruiting long-term ICU patients, it proved very difficult, even for experienced ICU staff, to identify which patients would become long-term early in their admission. Nevertheless, the ICU LOSs for participants in our study (range, 4.5–80.9 d) exceed the median ICU LOS of 1.7 days in Australia and New Zealand (1) and are classified as medium to long LOSs (28–30). A limitation of our study was the variable time at which the cessation of PMs outcome was measured. However, this reflects the changeable nature of the ICU population, with some recovering to a point where PMs were no longer required and others receiving the PMs intervention for the full 4 weeks. We acknowledge that other interventions/therapy (e.g., standing, walking) commenced after early cessation of PMs would have influenced the post-early-cessation of PMs ROM data (13 participants). In contrast, we believe the cessation of PMs ROM data data are unlikely to have been contaminated by other interventions/therapy as patients in our ICU only receive PMs intervention from physiotherapists and the ankle-foot orthoses worn by three participants should have affected ankle ROM bilaterally if at all. Although we achieved the sample size calculated a priori, we acknowledge that a larger sample size would have strengthened the generalizability of our results. The large number of patients excluded from participation also limits generalizability. However, with the exception of those excluded due to a preexisting condition/injury adversely affecting joint ROM or burn injury, there is no reason to believe these excluded patients would have responded differently. Consideration was given to the study protocol including a requirement that participants receive a minimum number of PMs interventions. However, there are no data to guide

a minimum threshold of efficacy for PMs interventions. Furthermore, inclusion of a mandatory minimum number of PMs interventions would have extended the recruitment period beyond the 2-year period which would have been impractical. Given that few participants developed joint contracture it is unlikely that a more intensive PMs intervention would have been any more effective. Although consideration was given to measuring ROM with a device that ensured that a standard torque was applied, we decided this was unnecessary as the assessors were blinded, the "push" was determined by the assessors (and not participants who could have become more tolerant of any discomfort) and for the practical reason of simplicity. The missing data for participant-reported outcomes (VAS), arising from participants' inability to communicate, reduces our confidence in these results. Although it would have been preferable to have included outcomes (apart from the ICU mobility scale) that measured function, participation in activities of daily living, and/or health-related quality of life, currently available outcome measures would not have been able to differentiate between the intervention and control sides of the body. Awareness of these limitations, particularly regarding the feasibility of conducting a clinical trial on this topic, will be useful for future studies investigating the effectiveness of PMs for ICU patients.

Clinical Implications

Our results concur with evidence summarized in Cochrane reviews regarding the ineffectiveness of PMs and stretches to prevent/reduce loss of joint mobility (8, 16–18). These findings of no therapeutic benefit might suggest de-investing in undertaking PMs, particularly routinely, in the ICU setting. The overuse of unnecessary care is widespread and, as well as providing no benefit for the patient, can waste limited resources and, in some instances, cause harm (31). However, although our results suggest PMs are not effective at preventing or reducing joint stiffness, until further studies confirm or refute these findings, we believe it is too early to suggest de-investing in routine PMs, especially for ICU patients with a protracted stay. Based on our findings, our clinical practice will be to assess joint ROM of longer-term ICU patients and only provide PMs if loss of joint ROM occurs.

CONCLUSIONS

PMs, as provided in this study, did not appear to prevent or reduce loss of joint ROM in medium to long-stay ICU patients nor affect participant-reported joint stiffness or pain.

ACKNOWLEDGMENTS

The authors thank the patients and their next of kin who agreed to their participation in this study, Professor Lisa Harvey (Senior Researcher, Kolling Institute, Faculty of Medicine and Health, The University of Sydney, Sydney, Australia) for her assistance with the study design and troubleshooting, ICU Research Nurses (Nerissa Brown, Kathleen Glasby, Stephanie O'Connor, Justine Rivett) for screening and recruitment, treating physiotherapists (Jordan Afford, Bree Bishop, Steven Buda, Lauren Burge, Tobi Connor-Trabilsie, Kerryn Dignam, Claudia Farese, Sophie Gill, Emily Harries, Molly Haylock, Vivek Kadam, Ellen Messenger, Jayme Miller, Emma Orgar, Eloise Patel, Madeline Simpson, Anna Threadgold, Sara Turnbull), Brad Schmitt and Scott Morrow (assistance with range of motion assessments) and Terry Boyle (University of South Australia) for his assistance with statistical analyses.

1 *Central Adelaide Local Health Network, Adelaide, South Australia, Australia.*

2 *Physiotherapy, Acute Care and Surgery, Royal Adelaide Hospital, Adelaide, South Australia, Australia.*

3 *Physiotherapy, Orthopaedics, Royal Adelaide Hospital, Adelaide, South Australia, Australia.*

4 *Physiotherapy, Spinal Injuries Unit, Royal Adelaide Hospital, Adelaide, South Australia, Australia.*

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (http://journals.lww.com/ccejournal).

Dr. Stiller conceived and designed this study, contributed to data entry, analyses, interpretation of the results, and was responsible for drafting, editing, and submission of the article. Ms. Dafoe contributed to the study design, day-to-day oversight of the study, data acquisition and interpretation, and drafting of the article. Ms. Jesudason and Mr. McDonald contributed to the study design and outcome measurements. Mr. Callisto contributed to the day-to-day oversight of the study. All authors reviewed, discussed, and approved the final article.

The study was conducted with funding from an Alison Kinsman AM Physiotherapy Research Grant. The article publication charge was funded by the Health Services Charitable Gifts Board. The authors have disclosed that they do not have any potential conflicts of interest.

For information regarding this article, E-mail: Kathy.Stiller@sa.gov.au

REFERENCES

1. Australian and New Zealand Intensive Care Society: ANZICS Centre for Outcome and Resource Evaluation 2020 Report Melbourne, Australia. Available at: https://www.anzics.com.au/wp-content/uploads/2021/09/2020-ANZICS-CORE-Report.pdf. Accessed August 17, 2023
2. Australian and New Zealand Intensive Care Society: ANZICS Centre for Outcome and Resource Evaluation 2018 Report. Available at: https://www.anzics.com.au/wp-content/uploads/2019/10/2018-ANZICS-CORE-Report.pdf. Accessed September 13, 2023
3. Elliott D: Surviving critical illness. *Aust Crit Care* 2011; 24:152–154
4. Stevens RD, Dowdy DW, Michaels RK, et al: Neuromuscular dysfunction acquired in critical illness: A systematic review. *Intensive Care Med* 2007; 33:1876–1891
5. Clavet H, Hébert PC, Fergusson DA, et al: Joint contractures in the intensive care unit: Association with resource utilization and ambulatory status at discharge. *Disabil Rehabil* 2011; 33:105–112
6. Born CT, Gil JA, Goodman AD: Joint contractures resulting from prolonged immobilization: Etiology, prevention, and management. *J Am Acad Orthop Surg* 2017; 25:110–116
7. Campbell TM, Dudek N, Trudel G: Joint contractures. In: *Essentials of Physical Medicine and Rehabilitation*. Fourth Edition. Frontera WR, Silver J, Rizzo TD (Eds). Philadelphia, PA, Elsevier, 2019, Chapter 127, pp 704–709
8. Prabhu RK, Swaminathan N, Harvey LA: Passive movements for the treatment and prevention of contractures. *Cochrane Database Syst Rev* 2013: (12):CD009331
9. Wong K, Trudel G, Laneuville O: Noninflammatory joint contractures arising from immobility: Animal models to future treatments. *Biomed Res Int* 2015; 2015:848290
10. Lieber RL, Steinman S, Barash IA, et al: Structural and functional changes in spastic skeletal muscle. *Muscle Nerve* 2004; 29:615–627
11. Clavet H, Hébert PC, Fergusson D, et al: Joint contracture following prolonged stay in the intensive care unit. *CMAJ* 2008; 178:691–697
12. Clavet H, Doucette S, Trudel G: Joint contractures in the intensive care unit: Quality of life and function 33 years after hospital discharge. *Disabil Rehabil* 2015; 37:207–213
13. Stockley RC, Hughes J, Morrison J, et al: An investigation of the use of passive movements in intensive care by UK physiotherapists. *Physiother* 2010; 96:228–233
14. Stockley RC, Morrison J, Rooney J, et al: Move it or lose it?: A survey of the aims of treatment when using passive movements in intensive care. *Intensive Crit Care Nurs* 2012; 28:82–87
15. Wiles L, Stiller K: Passive limb movements for patients in an intensive care unit: A survey of physiotherapy practice in Australia. *J Crit Care* 2010; 25:501–508
16. Harvey LA, Katalinic OM, Herbert RD, et al: Stretch for the treatment and prevention of contractures. *Cochrane Database Syst Rev* 2017; 1:CD007455
17. Harvey LA, Brosseau L, Herbert RD: Continuous passive motion following total knee arthroplasty in people with arthritis. *Cochrane Database Syst Rev* 2014:CD004260
18. Harvey LA, Katalinic OM, Herbert RD, et al: Stretch for the treatment and prevention of contracture: An abridged republication of a Cochrane Systematic Review. *J Physiother* 2017; 63:67–75
19. Shamsi MB, Vaisi-Raygani A, Rostami A, et al: The effect of adding TENS to stretch on improvement of ankle range of motion in inactive patients in intensive care units: A pilot trial. *BMC Sports Sci Med Rehabil* 2019; 11:15
20. Zanni JM, Korupolu R, Fan E, et al: Rehabilitation therapy and outcomes in acute respiratory failure: an observational pilot project. *J Crit Care* 2010; 25:254–262
21. Harvey LA, Herbert RD, Glinsky J, et al: Effects of 6 months of regular passive movements on ankle joint mobility in people with spinal cord injury: A randomized controlled trial. *Spinal Cord* 2009; 47:62–66
22. Reese NB, Bandy WB: *Joint Range of Motion and Muscle Length Testing*. Third edition. St Louis, MO, Elsevier, 2017
23. Harvey LA, Batty J, Crosbie J, et al: A randomized trial assessing the effects of 4 weeks of daily stretching on ankle mobility in patients with spinal cord injuries. *Arch Phys Med Rehabil* 2000; 81:1340–1347
24. Young R, Nix S, Wholohan A, et al: Interventions for increasing ankle joint dorsiflexion: A systematic review and meta-analysis. *J Foot Ankle Res* 2013; 6:46
25. Hastings-Ison T, Blackburn C, Opie NL, et al: Reproducibility of an instrumented measure for passive ankle dorsiflexion in conscious and anaesthetized children with cerebral palsy. *Dev Med Child Neurol* 2014; 56:378–385
26. Hodgson C, Needham D, Haines K, et al: Feasibility and inter-rater reliability of the ICU mobility scale. *Heart Lung* 2014; 43:19–24
27. Nepomuceno BR Jr, Martinez BP, Gomes Neto M: Impact of hospitalization in an intensive care unit on range of motion of critically ill patients: A pilot study. *Rev Bras Ter Intensiva* 2014; 26:65–70
28. Crozier TM, Pilcher DV, Bailey MJ, et al: Long-stay patients in Australian and New Zealand intensive care units: Demographics and outcomes. *Crit Care Resusc* 2007; 9:327–333
29. Laupland KB, Ramanan M, Shekar K, et al: Long-term outcome of prolonged critical illness: A multicentered study in North Brisbane, Australia. *PLoS One* 2021; 16: e0249840
30. Osuagwu UL, Xu M, Piya MK, et al: Factors associated with long intensive care unit (ICU) admission among inpatients with and without diabetes in South Western Sydney public hospitals using the New South Wales admission patient data collection (2014-2017). *BMC Endocr Disord* 2022; 22:27
31. Verkerk EW, Tanke MAC, Kool RB, et al: Limit, lean or listen? A typology of low-value care that gives direction in de-implementation. *Int J Qual Health Care* 2018; 30:736–739