Journal of Physiotherapy 62 (2016) 182–187

ELSEVIER

Journal of PHYSIOTHERAPY

journal homepage: www.elsevier.com/locate/jphys

Research

Increasing the amount of usual rehabilitation improves activity after stroke: a systematic review

Emma J Schneider [a,b], Natasha A Lannin [a,b,c], Louise Ada [d], Julia Schmidt [a,e]

[a] Discipline of Occupational Therapy, School of Allied Health, College of Science, Health and Engineering, La Trobe University; [b] Occupational Therapy Department, Alfred Health, Melbourne; [c] John Walsh Centre for Rehabilitation Research, Sydney Medical School (Northern), The University of Sydney; [d] Discipline of Physiotherapy, Faculty of Health Sciences, The University of Sydney, Sydney, Australia; [e] Department of Physical Therapy, Faculty of Medicine, University of British Columbia, Vancouver BC, Canada

KEY WORDS

Stroke
Rehabilitation
Occupational therapy
Physical therapy modalities
Review

CrossMark

ABSTRACT

Questions: In people receiving rehabilitation aimed at reducing activity limitations of the lower and/or upper limb after stroke, does adding extra rehabilitation (of the same content as the usual rehabilitation) improve activity? What is the amount of extra rehabilitation that needs to be provided to achieve a beneficial effect? **Design:** Systematic review with meta-analysis of randomised trials. **Participants:** Adults aged 18 years or older that had a diagnosis of stroke. **Intervention:** Extra rehabilitation with the same content as usual rehabilitation aimed at reducing activity limitations of the lower and/or upper limb. **Outcome measures:** Activity measured as lower or upper limb ability. **Results:** A total of 14 studies, comprising 15 comparisons, met the inclusion criteria. Pooling data from all the included studies showed that extra rehabilitation improved activity immediately after the intervention period (SMD = 0.39, 95% CI 0.07 to 0.71, I^2 = 66%). When only studies with a large increase in rehabilitation (> 100%) were included, the effect was greater (SMD 0.59, 95% CI 0.23 to 0.94, I^2 = 44%). There was a trend towards a positive relationship (r = 0.53, p = 0.09) between extra rehabilitation and improved activity. The turning point on the ROC curve of false versus true benefit (AUC = 0.88, p = 0.04) indicated that at least an extra 240% of rehabilitation was needed for significant likelihood that extra rehabilitation would improve activity. **Conclusion:** Increasing the amount of usual rehabilitation aimed at reducing activity limitations improves activity in people after stroke. The amount of extra rehabilitation that needs to be provided to achieve a beneficial effect is large. **Trial registration:** PROSPERO CRD42012003221. **[Schneider EJ, Lannin NA, Ada L, Schmidt J (2016) Increasing the amount of usual rehabilitation improves activity after stroke: a systematic review. *Journal of Physiotherapy* 62: 182–187]**

Introduction

Stroke is the leading cause of disability worldwide.[1] Difficulty walking and using the arm to complete self-care tasks are the most common activity limitations reported by stroke survivors.[2,3] Practice is essential for motor learning and needs to be structured to offer a progressive challenge to reduce activity limitations.[4–7] Consequently, clinical practice guidelines for stroke rehabilitation worldwide recommend that programs deliver a large amount of practice in order to maximise outcome after stroke.[8–10]

Several systematic reviews have explored the effect of the amount of practice on outcome after stroke.[5–7,11–14] Three systematic reviews with meta-analyses have specifically investigated the effect of extra practice on motor outcomes after stroke. Kwakkel et al[11] found that extra rehabilitation improved activities of daily living (SMD 0.13, 95% CI 0.03 to 0.23, 24 randomised trials). Verbeek et al[6] found that extra lower limb rehabilitation within 6 months of stroke improved walking ability (SMD 0.32, 95% CI 0.11 to 0.52, 11 randomised trials) and walking speed (SMD 0.22, 95% CI 0.01 to 0.43, eight randomised trials). Most recently, Lohse et al[5] found that extra rehabilitation improved outcome (SMD 0.35, 95% CI 0.26 to 0.45, 34 randomised trials). Furthermore, previous reviews have suggested that there is a dose-response relationship, where the greater the extra rehabilitation, the greater the benefit,[5–7,11,12,14] regardless of time after stroke.[5]

Importantly, however, these previous systematic reviews included trials that did not investigate different doses of the same content of rehabilitation. For example, some of the included trials compared the effect of rehabilitation with no rehabilitation. Other included trials provided extra rehabilitation that was of different content to the usual rehabilitation, thereby confounding the analysis of amount of rehabilitation with type of rehabilitation. Cooke et al[12] recognised these limitations and examined seven trials where the extra rehabilitation was delivered on top of usual rehabilitation and was of the same content. A meta-analysis of the seven studies was not performed, but the effect sizes of several trials with the same outcomes suggested that there was some evidence supporting the hypothesis that extra rehabilitation on top of usual rehabilitation improves outcomes after stroke.[12]

Rehabilitation is resource intensive, both on the part of the patient and the healthcare system. It is therefore important to

http://dx.doi.org/10.1016/j.jphys.2016.08.006
1836-9553/

determine the effect of increasing the amount of usual rehabilitation after stroke, and to ensure that this estimate is not confounded by the effect of extra rehabilitation of different content. Therefore, the aim of this review was to examine the effect of extra rehabilitation of the same content on top of usual rehabilitation.

Therefore, the research questions for this systematic review were:

1. In people receiving rehabilitation aimed at reducing activity limitations of the lower and/or upper limb after stroke, does adding extra rehabilitation (of the same content as the usual rehabilitation) improve activity?
2. What is the amount of extra rehabilitation that needs to be provided to achieve a beneficial effect?

Box 1. Inclusion criteria.

Design
- Randomised or quasi-randomised trial

Participants
- Adults (≥ 18 years old)
- Diagnosis of stroke (≥ 80% participants with stroke, others being stroke-like)

Intervention
- Extra rehabilitation (of the same content as usual rehabilitation) aimed at reducing activity limitations (of lower and/or upper limb)

Outcome measures
- Measures of activity

Comparisons
- Extra rehabilitation on top of usual rehabilitation versus usual rehabilitation

Method

Identification and selection of studies

A systematic review of randomised or quasi-randomised trials was undertaken so that guidelines could be based on the highest level of evidence. Searches were conducted of Medline, EMBASE, CINAHL, and the Cochrane Register of Controlled Trials (CENTRAL) databases, from the earliest date available until October 2015, for relevant articles available in English. Search terms included words related to *stroke*, *physical therapy*, *occupational therapy*, *rehabilitation* and *intensity* (such as dose, frequency, quantity, duration and amount) (see Appendix 1 on the eAddenda for full search strategy). Titles and abstracts were displayed and screened by one reviewer to identify potentially relevant studies. Full paper copies of potentially relevant papers were retrieved. Reference lists of articles included in this review and of similar systematic reviews were screened to determine any additional studies meeting the inclusion criteria. The methods of retrieved papers were reviewed independently by two reviewers (ES and JS) using predetermined criteria (Box 1). An independent reviewer (NL or LA) adjudicated any disagreements.

Assessment of characteristics of studies

Quality

The quality of the included studies was assessed by extracting PEDro scores from the Physiotherapy Evidence Database (www.pedro.org.au). The PEDro scale generates a score out of 10 depending on whether the quality of each study meets each item of the tool.[15] Where a study was not included on the database, two review authors independently scored the study (ES and JS), and a third review author resolved any disagreements (NL).

Participants

Studies were included if ≥ 80% participants were adults with stroke (with the remainder being stroke-like conditions such as cerebral aneurysm). Characteristics of participants, such as age, gender, time since stroke and type of rehabilitation service, were examined to assess the similarity of the studies.

Intervention

Studies were included if they examined the effect of an increased dose of rehabilitation. That is, the experimental group received extra rehabilitation (of the same content as usual rehabilitation) on top of usual rehabilitation aimed at improving lower limb activity or upper limb activity or both. The control group received usual rehabilitation alone. The dose of usual rehabilitation was calculated as the amount of time dedicated to rehabilitation of the activity included in the extra rehabilitation. For example, if the experimental group received 30 minutes of extra upper limb rehabilitation, and the control group received 60 minutes of rehabilitation consisting of 30 minutes upper limb and 30 minutes lower limb, the comparison of the same content would be 30 minutes extra upper limb rehabilitation plus 30 minutes usual upper limb rehabilitation (60 minutes) versus 30 minutes usual upper limb rehabilitation.

Outcome measures

Measures involving direct observation of upper or lower limb activity were used, regardless of whether they produced continuous data (eg, Box and Block Test, 10-m Walk Test) or ordinal data (eg, Action Research Arm Test, Functional Ambulation Category).

Data analysis

Information about the method (ie, design, participants, intervention, measures) and results (ie, number of participants and mean (SD) of outcomes) were extracted by one reviewer and crosschecked by another reviewer. Data were converted, where necessary, using methods recommended by the *Cochrane Handbook of Systematic Reviews*.[16] Authors were contacted where information was unavailable.

Post-intervention scores were used to obtain the pooled estimate of the effect of extra rehabilitation using RevMan 5.1 software.[17] Since different outcome measures were used, the effect size was reported as Cohen's standardised mean difference (SMD) with a 95% CI. A random-effects model was used and in the case of significant heterogeneity ($I^2 > 50\%$), a sensitivity analysis was carried out to confirm the source of heterogeneity. Sub-group analyses according to the time after stroke (acute versus chronic) and body part (upper versus lower limb) were planned *a priori* where there were a sufficient number of comparable studies. The relationship between percentage of extra rehabilitation provided and the effect size was calculated using Pearson correlation coefficient. The amount of extra rehabilitation needed to provide a beneficial effect was determined from a receiver-operator characteristic (ROC) curve.

Results

Flow of studies through the review

The electronic search strategy identified 5141 studies, of which 284 were duplicates. After screening titles, abstracts and reference lists, 89 potentially relevant papers were retrieved. Among these, 74 papers failed to meet the inclusion criteria (see Appendix 2 on the eAddenda for a summary of excluded papers), and therefore 15 papers reporting 14 studies were included in the review (Figure 1).

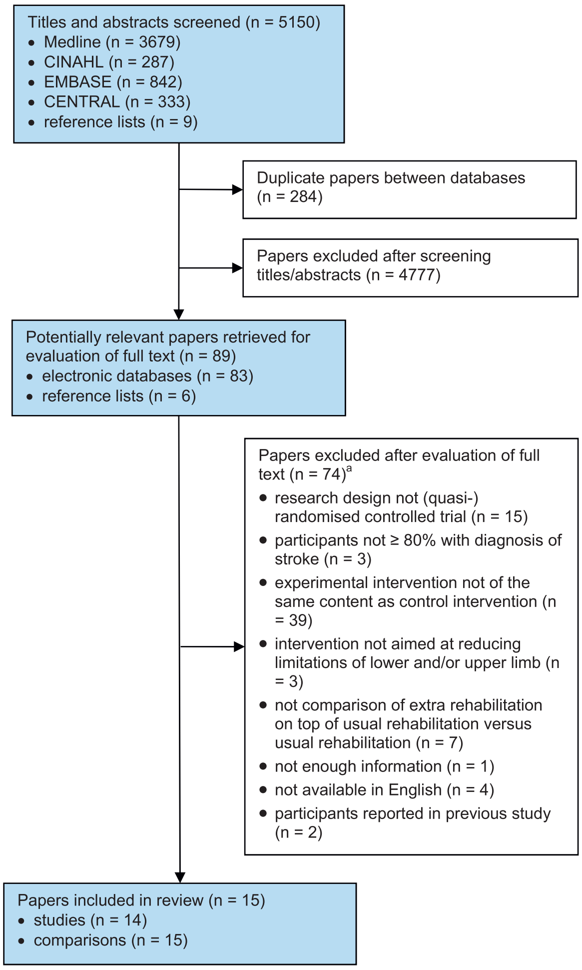

Figure 1. Flow of studies through the review.
[a] Papers may have been excluded for failing to meet more than one inclusion criterion.

Characteristics of included studies

The 14 studies included in this review involved 954 participants in 15 comparisons investigating the effect of extra rehabilitation on top of usual rehabilitation for improving activity (Table 1).[18–32] Additional information was requested from the authors of four studies.[21,28,29,31]

Quality

The mean PEDro score of included papers was 6.9 out of 10, with individual study scores ranging from 5 to 8 (Table 2). All of the papers reported random allocation, baseline similarity, between-group difference, and point estimate variability. The majority of papers reported concealed allocation (80%), assessor blinding (87%), and < 15% loss to follow-up (87%). No papers reported participants or therapist blinding and 40% reported performing an intention-to-treat analysis.

Participants

Across the studies, the mean age ranged from 49 to 75 years. Time after stroke ranged from a few weeks to > 6 months, with 86% of the studies carried out within 6 months after stroke.

Intervention

All the studies involved the experimental group receiving extra rehabilitation on top of usual rehabilitation, and the control group receiving usual rehabilitation. Furthermore, the extra rehabilitation was the same content as usual (or a component of usual) rehabilitation. Extra rehabilitation included upper limb activity (nine comparisons), lower limb activity (four comparisons), or both upper and lower limb activity (two comparisons). One included study involved three trial arms; only the experimental group receiving therapy 7 days per week and the control group receiving usual care were included.[19]

Outcome measures

Upper limb activity was measured using the Wolf Motor Function Test (two comparisons) or the Action Research Arm Test (seven comparisons). Lower limb activity was measured using timed tests of walking speed (five comparisons) and the Rivermead Mobility Index (one comparison).

Effect of extra rehabilitation on top of usual rehabilitation

The immediate effect of extra rehabilitation on top of usual rehabilitation was examined by pooling post-intervention data using a random effects model from 11 comparisons that measured activity immediately after the intervention period. These comparisons were from studies of good quality (PEDro score 7.2 out of 10) and comprised 577 participants. Extra rehabilitation improved activity immediately after the intervention period (SMD = 0.39, 95% CI 0.07 to 0.71) (Figure 2); see Figure 3 on the eAddenda for a detailed forest plot. Four comparisons could not be included in the analysis: one because there was no immediate data,[31] one because there was no post-intervention data,[18] and two because the data were too skewed to enable conversion from non-parametric data to parametric data.[26,28(upper limb)] There was substantial statistical heterogeneity (I^2 = 66%), indicating that the variation between the results of the trials was above the variation expected by chance. A sensitivity analysis revealed that the heterogeneity was not explained by the quality of the trials (PEDro score > 6/10), assessor blinding (yes or no), sample size (> 20 participants per trial), severity of participants (> 20% normal activity), chronicity of participants (> 6 months post stroke) or limb rehabilitated (upper versus lower). However, heterogeneity was partially explained by the amount of extra practice. In order to standardise extra rehabilitation across the comparisons, it was expressed as percentage increase per week. When re-analysed, separating trials into small (≤ 100%) or large (> 100%) increases in amount of

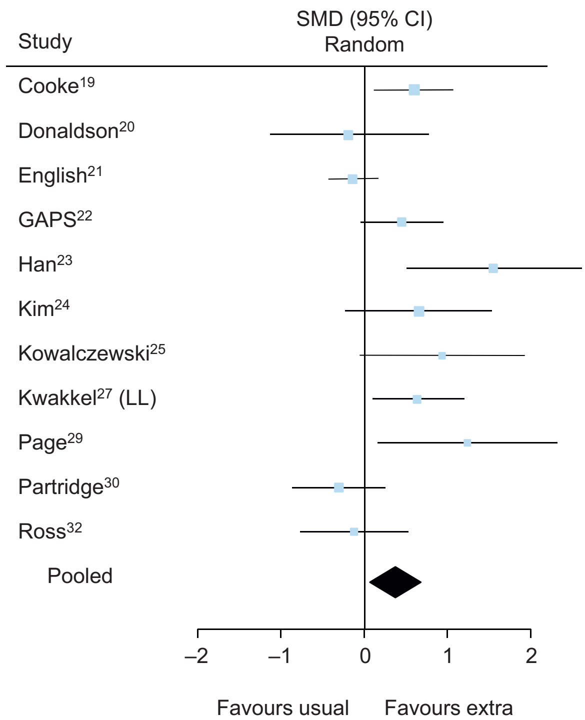

Figure 2. Standardised mean difference (95% CI) of the effect of extra rehabilitation on top of usual rehabilitation compared with usual rehabilitation for activity immediately after the period of intervention (n = 577 participants). LL = lower limb.

Table 1
Summary of included studies (n = 14).

Study	Design	Participants	Intervention	Outcome measures [a]
Burgar[18]	QRCT	n = 36 Age (*yr*) = 61 (SD n/s) Gender = n/s Time since stroke < 6 mth	Extra = UL rehabilitation 60 min x 5/wk x 3 wk (↑ 100%) Usual = UL rehabilitation 60 min x 5/wk x 3 wk	• UL activity = Wolf Motor Function Test (ability, 0 to 5) • Timing = 0, 3, 26 wk
Cooke[19]	RCT	n = 73 Age (*yr*) = 67 (SD 13) Gender = 59% male Time since stroke < 6 mth	Extra = LL rehabilitation 60 min x 4/wk x 6 wk (↑ 240%) Usual = LL rehabilitation 20 min x 5/wk x 6 wk	• LL activity = 10-m Walking Test (comfortable speed, m/s) • Timing = 0, 6, 12 wk
Donaldson[20]	RCT	n = 20 Age (*yr*) = range 44 to 90 Gender = 50% male Time since stroke < 6 mth	Extra = UL rehabilitation 60 min x 4/wk x 6 wk (↑ 240%) Usual = UL rehabilitation 20 min x 5/wk x 6 wk	• UL activity = Action Research Arm Test (0 to 57) • Timing = 0, 6, 12 wk
English[21]	RCT	n = 190 Age (yr) = 69 (SD 13) Gender = 58% male Time since stroke < 6 mth	Extra = LL rehabilitation 12 min x 2/wk x 4 wk (↑ 40%) Usual = LL rehabilitation 12 min x 5/wk x 4 wk	• LL activity = 6-min Walking Test (m/s) • Timing = 0, 4, 26 wk
GAPS[22]	RCT	n = 70 Age (*yr*) = 68 (SD 11) Gender = 59% male Time since stroke < 6 mth	Extra = UL + LL rehabilitation 30 to 40 min x 5/wk x 10 wk (↑ 100%) Usual = UL + LL rehabilitation 30 to 40 min x 5/wk x 10 wk	• LL activity = Rivermead Mobility Index (0 to 15) • Timing = 0, 12, 26 wk
Han[23]	RCT	n = 20 Age (*yr*) = 49 (SD 6) Gender = 75% male Time since stroke < 6 mth	Extra = UL rehabilitation 120 min x 5/wk x 6 wk (↑ 200%) Usual = UL rehabilitation 60 min x 5/wk x 6 wk	• UL activity = Action Research Arm Test (0 to 57) • Timing = 0, 6 wk
Kim[24]	RCT	n = 22 Age (*yr*) = 51 (SD 9) Gender = 59% male Time since stroke > 6 mth	Extra = LL rehabilitation 30 min x 5/wk x 4 wk (↑ 300%) Usual = LL rehabilitation 10 min x 5/wk x 4 wk	• LL activity = 10-m Walking Test (comfortable speed, m/s) • Timing = 0, 4 wk
Kowalczewski[25]	RCT	n = 19 Age (*yr*) = 61 (SD 16) Gender = 53% male Time since stroke < 6 mth	Extra = UL rehabilitation 60 min x 4/wk x 3 to 4 wk (↑ 400%) Usual = UL rehabilitation 60 min x 1/wk x 3 to 4 wk	• UL activity = Wolf Motor Function Test (ability, 0 to 5) • Timing = 0, 4, 26 wk
Kwakkel[26,27]	RCT	n = 101 Age (*yr*) = 66 (SD 12) Gender = 43% male Time since stroke < 6 mth	Extra 1 = UL rehabilitation 30 min x 5/wk x 20 wk (↑ 200%) Extra 2 = LL rehabilitation 30 min x 5/wk x 20 wk (↑ 200%) Usual = LL rehabilitation 15 min x 5/wk x 20 wk UL rehabilitation 15 min x 5/wk x 20 wk	• UL activity = Action Research Arm Test (0 to 57) • LL activity = 10-m Walking Test (comfortable speed, m/s) • Timing = 0, 20, 26 wk
Lincoln[28]	RCT	n = 189 Age (*yr*) = 73 (SD n/s) Gender = 51% male Time since stroke < 6 mth	Extra = UL rehabilitation 24 min x 5/wk x 5 wk (↑ ?%) Usual = UL + LL rehabilitation 30 to 45 min x 5/wk x 5 wk	• UL activity = Action Research Arm Test (0 to 57) • Timing = 0, 6, 26 wk
Page[29]	RCT	n = 17 Age (*yr*) = range 38 to 75 Gender = 59% male Time since stroke > 6 mth	Extra = UL rehabilitation 90 min x 5/wk x 8 wk (↑ 300%) Usual = UL rehabilitation 30 min x 5/wk x 8 wk	• UL activity = Action Research Arm Test (0 to 57) • Timing = –1, 9 wk
Partridge[30]	RCT	n = 55 Age (*yr*) = range 60 to 94 Gender = n/s Time since stroke = n/s	Extra = UL + LL rehabilitation 30 min x 5/wk x 6 wk (↑ 100%) Usual = UL + LL rehabilitation 30 min x 5/wk x 6 wk	• LL activity = 5-m Walking Test (comfortable speed, m/s) • Timing = 0, 6, 26 wk
Rodgers[31]	RCT	n = 105 Age (*yr*) = 75 (SD n/s) Gender = 55% male Time since stroke < 6 mth	Extra = UL rehabilitation 30 min x 5/wk x 6 wk (↑ ?%) Usual = UL + LL rehabilitation 45 min x 5/wk x 6 wk	• UL activity = Action Research Arm Test (0 to 57) • Follow up = 0, 26 wk
Ross[32]	RCT	n = 37 Age (*yr*) = 59 (SD 19) Gender = 57% male Time since stroke < 6 mth	Extra = UL rehabilitation 60 min x 5/wk x 6 wk (↑ 200%) Usual [b] = UL rehabilitation 30 min x 5/wk x 6 wk	• UL activity = Action Research Arm Test (0 to 57) • Timing = 0, 6 wk

LL = lower limb, n/s = not stated, QRCT = quasi-randomised controlled trial, RCT = randomised controlled trial, UL = upper limb, ? = unknown.
[a] Outcome measures and their timing listed are those analysed in the review. There may have been other measures reported in the paper.
[b] Information was provided by authors.

practice, the large increase in rehabilitation improved activity (SMD 0.59, 95% CI 0.23 to 0.94, I^2 = 44%) (Figure 4); see Figure 5 on the eAddenda for a detailed forest plot.

Amount of extra rehabilitation needed to achieve a beneficial effect

There was a trend towards a positive relationship (r = 0.53, p = 0.09) between the amount of extra rehabilitation and improved activity when examining the 11 comparisons with data available immediately after the intervention period. Extra rehabilitation was expressed as percentage increase per week and deemed beneficial when the SMD was 0.5 in favour of the experimental group. The turning point on the ROC curve of false versus true benefit (AUC = 0.88, p = 0.04) indicated that at least an extra 240% rehabilitation is needed for significant likelihood that the amount of rehabilitation will improve activity in stroke survivors (Figure 6). That is, the amount of practice required would need to be more than tripled from what is usually provided.

Discussion

This review provides evidence that extra rehabilitation aimed at reducing activity limitations in either the upper or lower limb, added to usual rehabilitation, improves activity in people after stroke. Furthermore, given that the extra practice was of the same

Table 2
PEDro criteria and scores for included papers (n = 15).

Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0 to 10)
Burgar[18]	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Cooke[19]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Donaldson[20]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
English[21]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
GAPS[22]	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Han[23]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Kim[24]	Y	Y	Y	N	N	Y	N	N	Y	Y	6
Kowalczewski[25]	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Kwakkel[27]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Kwakkel[26]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Lincoln[28]	Y	Y	Y	N	N	Y	N	N	Y	Y	6
Page[29]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Partridge[30]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Rodgers[31]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Ross[32]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8

N = no, Y = yes.

content as usual rehabilitation, the effect was purely a result of an increase in the amount of rehabilitation. The amount of extra rehabilitation that needs to be provided to achieve a beneficial effect is large – in the order of 240%.

The effect size of 0.59 for a large (> 100%) increase in extra rehabilitation is encouraging. In order to compare the amount of extra rehabilitation across studies, the extra was presented as a percentage increase. This method, while accurate, produces high numbers. For example, if usual rehabilitation involved 15 minutes of walking practice, and the extra amount of walking delivered was 30 minutes, then the increase was 200%. Also, these calculations used 'intended' increase in rehabilitation, because this was consistently reported across the studies. It is possible that the 'intended' increase in rehabilitation did not match the 'actual' amount delivered. However, in those studies that reported both (intended and actual), 93% of the intended amount was actually delivered. Of the studies that delivered a large increase in rehabilitation amount, the average dose of usual rehabilitation was approximately 25 minutes per day in the control group and the average dose of extra rehabilitation provided was 260% (ie, 90 minutes per day) in the experimental group. These numbers align well with the findings from the ROC curve analysis, suggesting that at least a 240% increase in rehabilitation is necessary to result in an improvement in activity. Clinically, for example, if a therapy service usually provides 30 minutes of reach and grasp rehabilitation per day, in order to ensure a better outcome, approximately 100 minutes of reach and grasp rehabilitation per day would be required.

Overall, the results of this review are in line with previous meta-analyses that investigated 'dose', which suggest a beneficial effect of extra rehabilitation after stroke.[5,6,11] The finding from our meta-analysis, with all studies included, produced an effect size of 0.39, which is similar to the small effect sizes ranging from 0.13 to 0.35 found previously. However, when

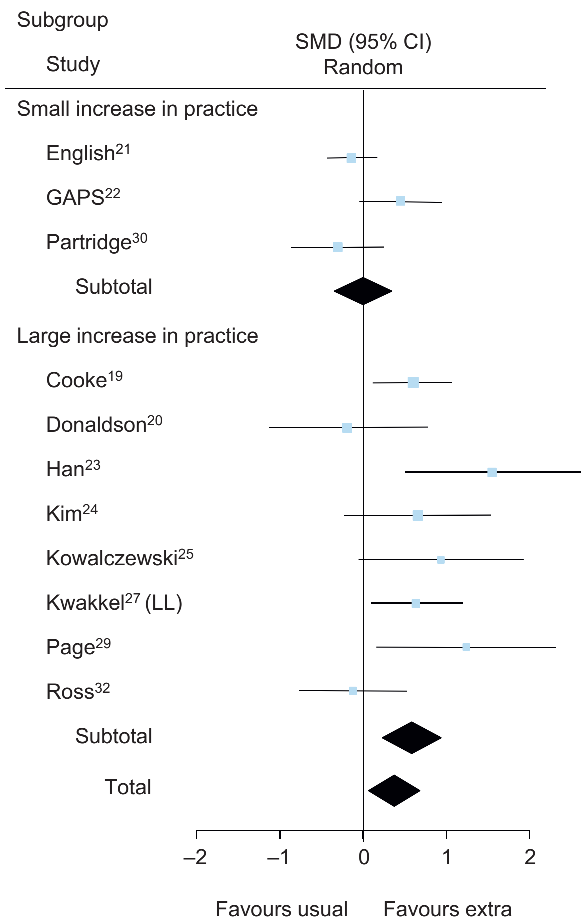

Figure 4. Standardised mean difference (95% CI) of the effect of the extra rehabilitation on top of usual rehabilitation compared with usual rehabilitation for activity, subgrouped by the relative amount of extra practice into small (≤100%) or large (>100%) increase.
LL = lower limb.

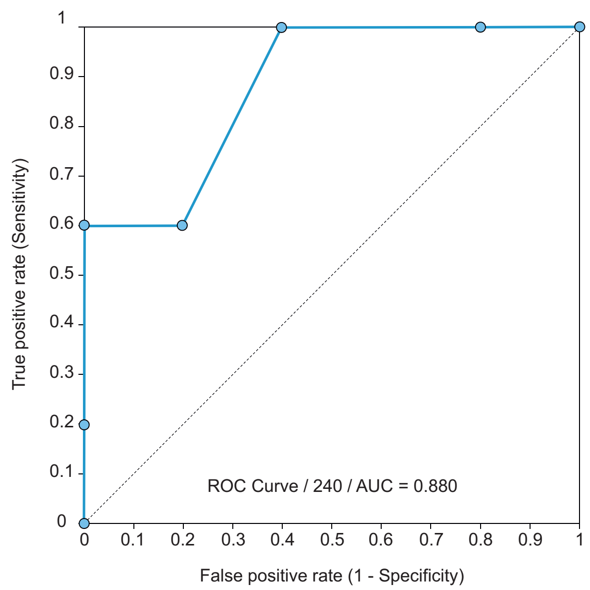

Figure 6. ROC curve of the true versus false benefit for amount of extra rehabilitation per week immediately after the period of intervention (n = 11 comparisons).

excluding studies that delivered only a small increase in rehabilitation, we found a larger effect size of 0.59. We used specific criteria to define 'extra rehabilitation' to mean additional practice of exactly the same activity provided in usual practice. Because of this tight definition of 'extra' rehabilitation, we excluded some studies that had been included in previous reviews;[5,6,11] this may account for our finding of a larger effect size than the previous reviews.

Our meta-analyses may have been affected by small study bias, with an average number of 35 participants per study. Also, the number of comparisons included in the meta-analysis was reduced by the reporting of medians in clinical trials where there were highly skewed data that could not be converted to means (SD). However, the mean PEDro score (> 7/10) showed that the included studies were of high quality and the findings therefore were robust. The strengths of this review were that by using these high-quality studies, we have estimated the effect of extra rehabilitation after stroke unconfounded by type of practice, and used this to estimate a threshold amount of extra practice needed to improve activity after stroke.

This review suggests that the provision of extra rehabilitation is feasible, and that programs need to provide a substantial amount of rehabilitation to guarantee an improvement in activity. Future randomised trials investigating substantial increases in practice (ie, more than 240% extra rehabilitation) would further clarify the relationship between increasing the amount of rehabilitation and activity after stroke. The challenge now is to determine how to increase the amount of rehabilitation. Implementation will demand a change in clinical practice that is far-reaching; models of delivery, patient expectations, and therapist beliefs should be guided by our findings.

What is already known on this topic: After stroke, difficulties with walking and using the arm for self-care are common, but rehabilitation can reduce these activity limitations. Previous systematic reviews have not distinguished the effect of increasing the amount of the same type of rehabilitation from the effect of adding extra rehabilitation of a different type.
What this study adds: Increasing the amount of rehabilitation after stroke improves activity, but a large amount of extra rehabilitation needs to be provided to achieve a beneficial effect.

eAddenda: Figures 3 and 5, and Appendices 1 and 2 can be found online at doi:10.1016/j.jphys.2016.08.006

Ethics approval: Not required.
Competing interests: Nil.
Source of support: Nil.
Acknowledgements: NAL was supported by a fellowship from the National Health and Medical Research Council (NHMRC; 1112158). No funding for this research was provided.
Provenance: Not invited. Peer reviewed.
Correspondence: Emma Schneider, Department of Occupational Therapy, Caulfield Hospital, Alfred Health, Australia. Email: e.schneider@alfred.org.au

References

1. Langhammer B, Becker F, Sunnerhagen KS, Zhang T, Du X, Bushnik T, et al. Specialized stroke rehabilitation services in seven countries: Preliminary results from nine rehabilitation centers. *Int J Stroke.* 2015;10:1236–1246.
2. Andrenelli E, Ippoliti E, Coccia M, Millevolte M, Cicconi B, Latini L, et al. Features and predictors of activity limitations and participation restriction 2 years after intensive rehabilitation following first-ever stroke. *Eur J Phys Rehabil Med.* 2015;51:575–585.
3. Medis S. Stroke disability and recovery of stroke: World Health Organization perspective. *Int J Stroke.* 2013;8:3–4.
4. Carr JH, Shepherd RB. A motor learning model for stroke rehabilitation. *Physiotherapy.* 1989;75:372–380.
5. Lohse KR, Lang CE, Boyd LA. Is more better? Using metadata to explore dose-response relationships in stroke rehabilitation. *Stroke.* 2014;45:2053–2058.
6. Veerbeek JM, Koolstra M, Ket JC, van Wegen EE, Kwakkel G. Effects of augmented exercise therapy on outcome of gait and gait-related activities in the first 6 months after stroke: a meta-analysis. *Stroke.* 2011;42:3311–3315.
7. Veerbeek JM, van Wegen E, van Peppen R, van der Wees PJ, Hendriks E, Rietberg M, et al. What is the evidence for physical therapy poststroke? A systematic review and meta-analysis. *PloS one.* 2014;9:e87987.
8. Clinical Guidelines for Stroke Management Australia. Melboure: National Stroke Foundation; 2010.
9. Management of patients with stroke: Rehabilitation, prevention and management of complications, and discharge planning. *A national clinical guideline*. The United Kingdom: Scottish Intercollegiate Guidelines Network; 2010.
10. Canadian best practice recommendations for stroke care. Section 5.3: Delivery of inpatient stroke rehabilitation. 4th edition ed. Ottawa: Canadian Stroke Network; 2013.
11. Kwakkel G, van Peppen R, Wagenaar RC, Wood Dauphinee S, Richards C, Ashburn A, et al. Effects of augmented exercise therapy time after stroke: a meta-analysis. *Stroke.* 2004;35:2529–2539.
12. Cooke EV, Mares K, Clark A, Tallis RC, Pomeroy VM. The effects of increased dose of exercise-based therapies to enhance motor recovery after stroke: a systematic review and meta-analysis. *BMC Med.* 2010;8:60.
13. Hayward KS, Barker RN, Carson RG, Brauer SG. The effect of altering a single component of a rehabilitation programme on the functional recovery of stroke patients: a systematic review and meta-analysis. *Clin Rehabil.* 2014;28:107–117.
14. Langhorne P, Wagenaar R, Partridge C. Physiotherapy after stroke: more is better? *Physiother Res Int.* 1996;1:75–88.
15. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys Ther.* 2003;83:713–721.
16. Higgins JPT, Green S, eds. In: *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0.*. The Cochrane Collaboration; 2011.
17. *Review Manager (RevMan)* [computer program]. The Nordic Cochrane Centre: The Cochrane Collaboration; 2011.
18. Burgar CG, Lum PS, Scremin AM, Garber SL, Van der Loos HF, Kenney D, et al. Robot-assisted upper-limb therapy in acute rehabilitation setting following stroke: Department of Veterans Affairs multisite clinical trial. *J Rehabil Res Dev.* 2011;48:445–458.
19. Cooke EV, Tallis RC, Clark A, Pomeroy VM. Efficacy of functional strength training on restoration of lower-limb motor function early after stroke: phase I randomized controlled trial. *Neurorehabil Neural Repair.* 2010;24:88–96.
20. Donaldson C, Tallis R, Miller S, Sunderland A, Lemon R, Pomeroy V. Effects of conventional physical therapy and functional strength training on upper limb motor recovery after stroke: a randomized phase II study. *Neurorehabil Neural Repair.* 2009;23:389–397.
21. English C, Bernhardt J, Crotty M, Esterman A, Segal L, Hillier S. Circuit class therapy or seven-day week therapy for increasing rehabilitation intensity of therapy after stroke (CIRCIT): a randomized controlled trial. *Int J Stroke.* 2015;10:594–602.
22. Group GAPS. Can augmented physiotherapy input enhance recovery of mobility after stroke? A randomized controlled trial. *Clin Rehabil.* 2004;18:529–537.
23. Han C, Wang Q, Meng PP, Qi MZ. Effects of intensity of arm training on hemiplegic upper extremity motor recovery in stroke patients: a randomized controlled trial. *Clin Rehabil.* 2013;27:75–81.
24. Kim M, Cho K, Lee W. Community walking training program improves walking function and social participation in chronic stroke patients. *Tohoku J Exp Med.* 2014;234:281–286.
25. Kowalczewski J, Gritsenko V, Ashworth N, Ellaway P, Prochazka A. Upper-extremity functional electric stimulation-assisted exercises on a workstation in the subacute phase of stroke recovery. *Arch Phys Med Rehabil.* 2007;88:833–839.
26. Kwakkel G, Wagenaar RC, Twisk JW, Lankhorst GJ, Koetsier JC. Intensity of leg and arm training after primary middle-cerebral-artery stroke: a randomised trial. *Lancet.* 1999;354(9174):191–196.
27. Kwakkel G, Kollen BJ, Wagenaar RC. Long term effects of intensity of upper and lower limb training after stroke: a randomised trial. *J Neurol Neurosurg Psychiatry.* 2002;72:473–479.
28. Lincoln NB, Parry RH, Vass CD. Randomized, controlled trial to evaluate increased intensity of physiotherapy treatment of arm function after stroke. *Stroke.* 1999;30:573–579.
29. Page SJ, Levin L, Hermann V, Dunning K, Levine P. Longer versus shorter daily durations of electrical stimulation during task-specific practice in moderately impaired stroke. *Arch Phys Med Rehabil.* 2012;93:200–206.
30. Partridge C, Mackenzie M, Edwards S, Reid A, Jayawardena S, Guck N, et al. Is dosage of physiotherapy a critical factor in deciding patterns of recovery from stroke: a pragmatic randomized controlled trial. *Physiother Res Int.* 2000;5:230–240.
31. Rodgers H, Mackintosh J, Price C, Wood R, McNamee P, Fearon T, et al. Does an early increased-intensity interdisciplinary upper limb therapy programme following acute stroke improve outcome? *Clin Rehabil.* 2003;17:579–589.
32. Ross LF, Harvey LA, Lannin NA. Do people with acquired brain impairment benefit from additional therapy specifically directed at the hand? A randomized controlled trial. *Clin Rehabil.* 2009;23:492–503.