Physical Therapy Reviews 2004; **9**: 51–59

PHYSICAL THERAPISTS SHOULD CONSIDER INCLUDING STRENGTH TRAINING AS PART OF FRACTURE REHABILITATION

ALISON MURDOCH, NICHOLAS TAYLOR AND KAREN DODD

Musculoskeletal Research Centre, School of Physiotherapy, La Trobe University, Victoria, Australia

ABSTRACT

Because muscle weakness is a common and persistent complication after bony fracture, we reviewed the literature systematically to find out if strength-training can reduce disability after adult fracture. Searching of electronic databases with inclusion criteria resulted in a final yield of three papers. These three studies were conducted after lower limb fractures and the calculated effect sizes collectively demonstrated that strength training led to increased muscle strength and activity levels. However, subsequent losses of strength and activity were found in the two studies that included a follow-up period. Despite a clear rationale for including strength-training programs as part of fracture rehabilitation to improve muscle weakness, very little research has been carried out. This systematic review provides preliminary evidence that strength-training may be beneficial after fracture and should be considered as a rehabilitation option by physical therapists. Further high quality studies are required to find out if the results can be replicated and generalised.

Keywords: Strength training; fracture; rehabilitation

INTRODUCTION

Muscle weakness is common in adults after upper limb[1,2] and lower limb fractures.[3,4] Furthermore, weakness can persist for months and even years after a bone has fully healed.[1,5–7] This loss of strength can be due to pain,[8] associated soft tissue injury and limb immobilisation as part of fracture management.[9]

Weakness can be a major factor contributing to disability after fracture. Studies have shown that weakness can impact upon the ability to perform everyday functional activities, such as grasping and lifting objects,[10] maintaining balance in standing[11,12] and walking.[3,13] Weakness has also been associated with an increased risk of further fracture.[14] The combination of weakness, increased incidence of falls and reduced bone strength (*i.e.* osteoporosis) is thought to contribute to this increased risk of a subsequent fracture, especially in older people.[15,16]

Progressive resistance strength training could be a suitable method to increase strength after fracture. Progressive resistance strength training is an intervention where sufficient resistance is applied to a muscle so that only a relatively small number of repetitions can be completed before fatigue. Resistance is progressed as muscle strength increases. Recent guidelines suggest that optimal strengthening can be obtained from completing 1–3 sets of 6–12 repetitions of an exercise, working at an intensity of 80% of the amount of weight that can be lifted once (1-RM), with exercises completed 3 times per week.[17]

Whether progressive resistance strength training after fracture improves strength and the performance of functional activities or the ability to participate

DOI 10.1179/108331904225003982

fully in societal roles remains open to question. Despite the rationale for its use, some clinicians have suggested that progressive resistance exercises should be avoided in the early rehabilitation period after fracture because the intensity of the exercise may put excessive stress through the healing bone.[18]

The aim of this study was to review systematically the available scientific literature to determine: (i) the extent to which progressive resistance strength training has been applied to fracture rehabilitation; and (ii) if progressive resistance strength training can be effective in reducing impairment, activity limitation and participation restriction in adults after fracture.

METHODS

Study identification and selection

Electronic databases (AMI, CINAHL, DARE, Cochrane, EMBASE, MEDLINE, PEDro, PubMed and Sport Discus) were searched back to 1966 using the following keywords: 'fracture' combined with each of 'exercise', 'strength', 'resistance' and 'physical training'. This search was supplemented by reviewing the reference lists of relevant articles to identify any further papers. The search was limited to full articles written in English. Two reviewers (AM and NT) independently assessed the titles and abstracts of articles identified by the initial search strategy for the following inclusion criteria: (i) population – adults aged 19 years or more recovering from a fracture; (ii) intervention – progressive resistance strength training program; and (iii) outcome – measurement of a change in strength or other body function, activity limitation or societal participation. When the title or abstract did not clearly indicate if an article should be included, the full article was read and evaluated for the inclusion criteria. Articles needed to fulfil all three criteria to be included in the review.

Quality assessment

Two reviewers (AM and NT) independently rated the quality of all of the trials that met the inclusion criteria with the PEDro scale.[19] The PEDro scale is used to rate the following aspects of methodological quality: (i) detailed criteria for participant eligibility; (ii) random allocation; (iii) concealed allocation; (iv) baseline prognostic similarity between groups; (v) blinding of the participant; (vi) blinding of the therapist; (vii) blinding of the outcome assessor; (viii) more than 85% follow-up for at least one primary outcome; (ix) intention-to-treat analysis; (x) between or within group statistical analysis for at least one primary outcome; and (xi) point estimates of variability for at least one primary outcome. Criteria (ii)–(xi) are used for scoring, so that a score out of 10 is obtained.[19] The PEDro scale has demonstrated high content validity[20] and high inter-observer reliability (kappa = 0.88).[21] To improve reliability further, disagreements between the reviewers were discussed until consensus was reached.

Description of outcome measures

The outcomes of progressive resistance strength training after fracture were classified according to the domains of the International Classification of Functioning, Disability and Health (ICF).[22] For the body structure and function domain, outcomes were quantified for muscle strength. For the activity domain, changes in performance were measured for walking, standing balance, stair climbing, moving from sit to stand, as well as general activity as measured with scales such as the Barthel Index, the Elderly Mobility Scale (this scale measures the performance of locomotion, balance and transfers) and Tinetti's Performance Oriented Mobility Assessment (this scale measures changes in the performance of balance in sitting and standing and walking). For the participation domain, changes in the ability to participate in leisure, family and community roles were considered. Following the ICF guidelines, we also considered the impact that personal and environmental contextual factors might have on the outcomes of strength training after fracture.

Data analysis

To compare the outcomes reported in the clinical trials that included a control group, effect sizes with 95% confidence intervals (CI) were obtained by subtracting the post-intervention mean of the control group from that of the experimental group, and dividing this by the combined SD of both groups.[23] Accordingly, to determine effect sizes, the studies needed to report post-intervention mean and SD, or the absolute change and SD for both groups.

An effect size was calculated for studies without a control group by subtracting the post-treatment mean from the pre-treatment mean and dividing by the SD of the difference scores. Because the SD cannot be calculated without access to the raw data, an approximation was arrived at by relating the SD of the difference scores to the correlation between the two sets of data.[21] A meta-analysis (*i.e.* a statistically combined estimate of effect size and associated 95% CI across

Table 1. Summary of sample and intervention details of the empirical studies

Study	PEDro score	Design	Sample size	Gender	Average age (years ± SD)	Fracture type	Muscle group targeted	Timing of intervention	Program details	Intensity
Hauer (2002)[33]	6	RCT	28	Female	81.3 ± 3.9	Neck of femur fractures	Hip and knee extensors, plantar flexors	6–8 weeks post-fracture	Weight machines and body weight; 2 sets, 3 per week for 12 weeks; and 45 min balance training	70–90% of individuals maximal work load
Mitchell (2001)[35]	5	RCT	80	Male & female	81.0 ± 1.2*; 79.1 ± 1.3**	Neck of femur fractures	Leg extensors	15 days* or 16 days** post-fracture	Weighted sandbags; 3 sets, 12 reps, 2 per week for 6 weeks	50–80% of individuals 1-RM
Shaffer (2000)[36]	4	Pre-post clinical trial	10	Male & female	35 ± 4	Fracture of ankle malleolus	Plantar flexors	10 weeks post-fracture	Customised hydraulic apparatus; 3 sets, 8 reps, 3 per week for 10 weeks	50–80% of individuals 1-RM

*Intervention group; **control group; RCT, randomised controlled trial; RM, repetition maximum.

Table 2. Summary of outcome measures

Study	Impairment outcome	Activity outcome	Participation outcome	Environmental factors			Personal factors
				Group or individual training	Site	Supervision	Cognitive status
Hauer (2002)[33]	Maximum dynamic and isometric muscle strength, FHI (including fear of falling)	Tinetti's POMA; Balance score; Functional Reach; Walking Velocity, TUAG; Timed Chair rise; Timed Stair rise; Barthel ADL Index	Total physical activity (concerning household and sports activities)	Group training	Public health club	Yes (did not specify who)	Excluded if had major depression or severe cognitive impairment as measured by MMSE
Mitchell (2001)[35]	Leg extensor power	EMS, including functional reach, TUAG; Barthel ADL Index	NHP (problems about social and family life, housework, hobbies, *etc.*)	Did not specify	Orthogeriatric unit	Did not specify	Excluded if had an abbreviated mental test score <6
Shaffer (2000)[36]	Plantarflexion: isometric and isokinetic peak torque; endurance (fatigue resistance)	Timed walks: 9.1 m 15.2 m and 30.5 m; stairs up and down		Did not specify	Did not specify	Yes (did not specify who)	Did not specify

RM, repetition maximum; POMA, performance oriented mobility assessment; TUAG, timed up and go; ADL, activity of daily living; EMS, elderly mobility score; FHI, falls handicap inventory; NHP, Nottingham health profile; MMSE, mini-mental-state examination.

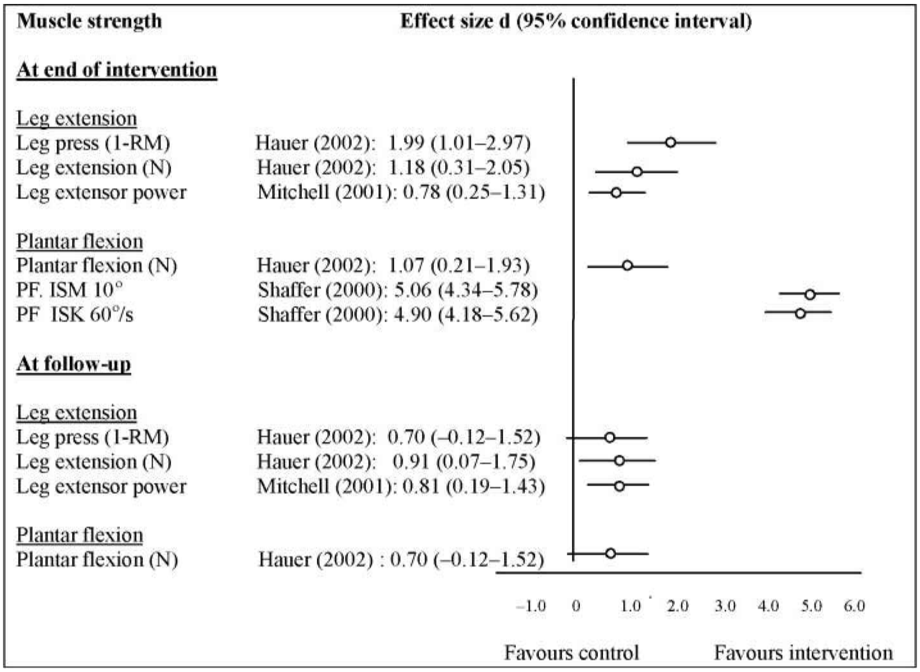

Fig. 1. Effect sizes with 95% CI for muscle strength (RM, repetition maximum; PF, plantarflexion; ISM, isometric peak torque; ISK, isokinetic peak torque).

the different trials) was not performed because of the heterogeneity of fracture location, training program details and outcome measures.

RESULTS

The initial search strategy yielded 160 articles. After the initial screening, 13 potentially relevant papers remained. Complete copies of each of these articles were obtained and a further 10 papers were excluded because they did not meet the inclusion criteria. A systematic review[24] was excluded as its focus was not on strength training after fracture. Six papers were excluded because although the intervention included strengthening, the programs did not include progression of resistance at sufficient intensity.[25–30] One article was excluded because the participants did not have a fracture.[31] Information from one article[32] was contained in a later report[33] which was included in the review. A further article did not adequately describe the strength-training program.[34]

Tables 1 and 2 summarise the main findings of the three included articles.[33,35,36] As shown in Table 1, the highest quality article scored 6/10 on the PEDro scale.[33] For this review, it was not expected that participants or therapists administering the program would be blind to the intervention; therefore, a maximum score of 8 was predicted. Consequently, a score of 6 indicates a moderately high quality study. The only article that was not a randomised control trial[36] obtained the lowest score on the scale (4/10).

As Table 1 shows, there was variation in the personal and environmental contextual factors. Regarding personal factors, Hauer *et al.*[33] and Mitchell *et al.*[35] both investigated older people. Shaffer *et al.*[36] did not specify a minimum age with the consequence that subjects in this study were younger. In all studies, the participants had sustained a lower limb fracture. Regarding environmental factors, two studies started strength training at bony union 6–10 weeks after fracture,[33,36] while the third study began strength-training just over 2 weeks after surgical fixation of the fracture.[35] The length of the strengthening programs ranged from 6–12 weeks, two or three sessions a week, working at an intensity of between 50–90% of the participants' one-repetition maximum. Exercise sessions were closely supervised by a physical therapist[35,36] or a fitness instructor[33] and were conducted at a rehabilitation unit[35] or community gymnasium.[33] The setting for one program was not specified.[36] To find out if the effects were maintained after training stopped, Hauer *et al.*[33] and Mitchell *et al.*[35] included a follow-up period 10–12 weeks after the end of the intervention. Shaffer *et al.*[36] did not include a follow-up period.

Hauer *et al.*[33] reported that no training-related medical problems or adverse events occurred in the intervention group. The other studies did not report that any injuries had occurred. However, all three studies noted that any minor problems (*e.g.* aching muscles and cramps) that arose were managed with appropriate adjustment of training

Variation was noted in the adherence and the drop-out rates of participants among the different studies. Hauer *et al.*[33] stated that 86% of their patients completed all measurements, and adherence was 93% and 96% for the intervention and control groups, respectively. Mitchell *et al.*[35] reported that 50% of the intervention and 60% of the control groups completed the follow-up. Shaffer *et al.*[36] did not state the adherence rates in their study.

Body structure and function

Figure 1 shows the individual effect sizes with 95% CI for strength changes. All studies reported large and positive strength-training effects, ranging from d =

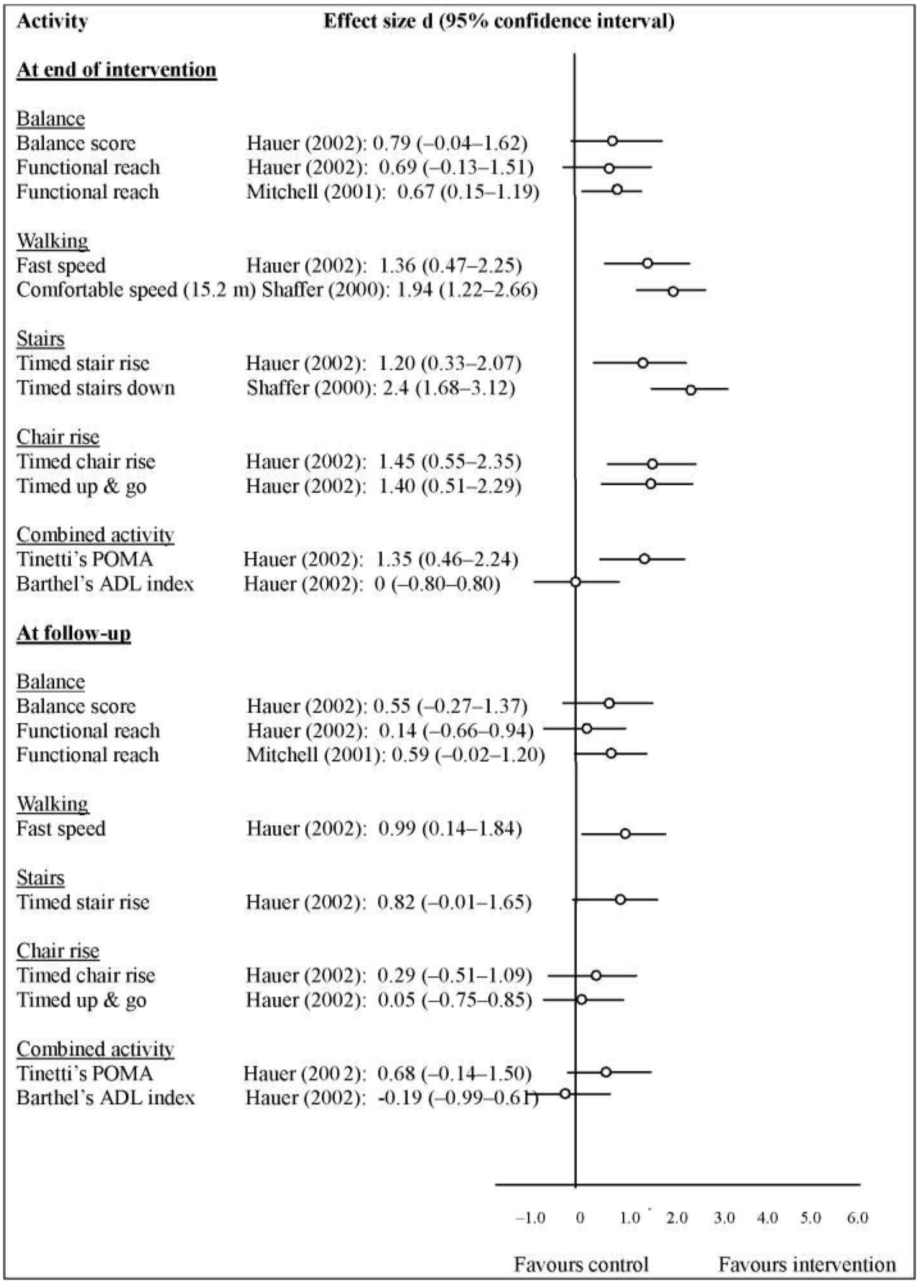

Fig. 2. Effect sizes with 95% CI for activity (POMA, performance oriented mobility assessment; ADL, activities of daily living).

0.78 to d = 5.06. Improvements in strength were partially lost in the follow-up period; however, leg extension strength remained significantly stronger than at baseline.[33,35]

Activity

Figure 2 shows the individual effect sizes with 95% CI for activity. At the end of intervention, most of the effect sizes for activity were positive in favour of strength training. Activities such as fast and self-selected walking speed, going up and down stairs, and rising from a chair all demonstrated large and significant effect sizes (range d = 1.36 to d = 2.4). Measures of standing balance appeared to be smaller than the effects of other activity measures.

Combined measures of activity also demonstrated positive effects for Tinetti's performance orientated mobility assessment[33] and the Elderly Mobility Scale.[35] There was no effect in favour of strength training for the Barthel activities of daily living index in one study.[33] However, Mitchell *et al.*[35] reported significant improvements in the Barthel Index at the end of their intervention. Some measures such as the Elderly Mobility Scale and Barthel Index were reported in non-parametric form by Mitchell *et al.*[35] so that effect sizes could not be calculated.

At follow-up, the positive effects of strength training on measures of activity appeared to have been reduced. As can be seen in Figure 2, confidence intervals for most measures at follow-up crossed zero indicating that in most cases the effect did not remain significant at 10–12 weeks after the strength-training program finished. The only activities that showed a significant benefit in favour of strength training at follow-up were fast walking speed,[33] and the Elderly Mobility Scale.[35]

Participation

The physical activity questionnaire used in Hauer *et al.*[33] contains questions concerning housework, sport and leisure activities, which conforms to the ICF definition of participation.[22] Hauer *et al.* reported a significant difference between the strength training and control groups with an effect size of d = 3.39 (95% CI, 2.14–4.64). However, the effect was reduced after the training had ceased (d = 0.85; 95% CI, 0.01–1.69). Mitchell *et al.*[35] reported that there was a tendency for all the different components, such as social interaction and hobbies, of the Nottingham Health Profile to show improvements, but they were not statistically significant. Shaffer *et al.*[36] did not measure the effect of the strength-training program on participation restriction.

DISCUSSION

The results of this review suggest that adults recovering from fracture benefit from participating in a progressive resistance strength-training program by increasing their muscle strength and improving their speed of walking and stair climbing, as well as their ability to move from sit to stand. Trends show that although the effect was smaller than for the other activities, standing balance might also be enhanced. These findings were consistent across all of the studies reviewed despite differences in the age of the participants, the intensity and duration of the different training programs, the equipment and exercise details and the outcomes used to evaluate change in muscle strength. Although differences existed, generally exercise sessions were conducted 2–3 times each week for between 6–12 weeks at a resistance level of between 50–90% of each person's 1-RM and resistance was regularly increased as strength increased in order to ensure that exercises were of sufficient intensity. These parameters are consistent with the American College of Sports Medicine guidelines[17] for strength-training in adults. The benefits of strength training found from this review are consistent with that of a recent systematic review of progressive resistance strength training for healthy older adults which also concluded that participation in a strength-training program can lead to strength gains and improvements in the performance of physical activities such as walking speed and endurance, stair climbing and standing balance.[37]

Progressive resistive strength training appears to be safe for people recovering from a fracture. This is true even for older people. In two of the studies, training began at the union stage of bony healing, 6–8 weeks[33] and 10 weeks[36] after the fracture had occurred. In the other study, training was started just over 2 weeks after surgical fixation of the fracture, although the intensity of the program was kept low (50% of the participants' 1-RM) for the first two weeks.[35] No serious training related injuries were reported in any of the studies reviewed. The only negative outcomes reported were minor discomforts such as muscle soreness (common in anyone commencing a strengthening program). It was reported that these problems were resolved by simply adjusting the training regimen. Therefore, the concern that applying high repetitive forces through a well-fixated or united fracture might cause serious problems such as re-fracture is not supported by this review.

Despite the rationale for its use, progressive resistance strength training appears to have been used little in fracture rehabilitation. For in-patients, the focus of physical therapy after fracture often appears to be on facilitating discharge from hospital.[38,39] For example, therapists teach patients appropriate use of gait aids including steps and safe, independent transfers. For outpatients, the focus often appears to be on restoring joint range of movement.[40,41] A number of studies have shown that weakness can persist long after full bony healing has occurred and this weakness can be a major factor contributing to disability. It cannot be assumed, and indeed would not be expected, that teaching gait and transfer skills and increasing joint range of movement would address the problem of muscle weakness after fracture. A more intensive and focused exercise program with progression of resistance would be required to increase muscle strength.[17] This review suggests physical therapists should consider including progressive resistance strength training as part of fracture rehabilitation, in addition to the important goals of facilitating discharge planning and restoring joint range.

The increases in strength and physical activity of the participants in both Hauer *et al.*[33] and Mitchell *et al.*[35] studies have important clinical implications for the functioning of older people. Falls are common in older people and these can be associated with an increased incidence of fractures.[16] The older populations of both studies showed improvements in the majority of activity outcomes measured, with trends toward improved standing balance as well. Improvements in standing balance are likely to be associated with a decreased risk of falls, and a consequent decreased risk of subsequent fractures.

An on-going training regimen might be needed to maintain the benefits of strength training for people recovering from fractures. The studies that included a follow-up period[33,35] indicated that the increased strength and improved activity levels found immediately after completing the progressive resistance training were reduced after 10 week[35] and 12 week[33] rest periods. These losses were more pronounced in activity levels than in muscle strength. These findings contrast with those of McCartney *et al.*[42] and Sforzo *et al.*[43] who investigated the effects of a progressive resistance strength-training program for healthy older people. McCartney *et al.*[42] in a randomised controlled trial of 119 people found that a rest period of 3 weeks after 1 year of training led to little strength loss when training resumed. In a trial that involved 35 people with a mean age of 69 years, Sforzo *et al.*[43] also found that a rest of up to 5 weeks after a training period of 8 months did not produce significant loss of strength. The reason for these differences remains unknown. However, it is possible that rest periods of longer than 5 weeks lead to accelerated losses of muscle strength or that longer initial training periods are required before strength gains are maintained during periods of rest from training.

Although there is evidence that strength training can improve muscle strength and many everyday physical activities, the effect of strengthening on participation restriction remains uncertain. Limited information is currently available about the effects of strength training on the participation aspects of the lifestyle of older people, as this issue is infrequently addressed in the literature. The effectiveness of all health-related programs should be considered in relation to a client's increased ability to participate in normal life situations.

Also the impact that environmental factors such as where the program is held, group or individual training and amount of supervision might have on the outcomes of strength training after fracture have not been fully evaluated. Strength-training programs conducted at hospitals or community gymnasiums under the close supervision of a physical therapist or trained fitness instructor appear to be successful. However, further investigation is needed to establish whether similar improvements would result from a less closely supervised home-based exercise program. This information would be especially valuable to clinicians when considering the benefits and feasibility of prescribing strengthening programs for people who have returned home after a fracture.[44]

The only research found has investigated progressive resistance training in conjunction with lower limb fractures. Other fractures that frequently occur in adults, particularly older people, include fractures of the proximal humerus, wrist and vertebrae.[45] For example, one in seven women over the age of 50 years sustain fractures of the distal radius, commonly known as a Colles' fracture.[46] Furthermore, clinical research has indicated that after a Colles' fracture older people are twice as likely to sustain a fracture of the neck of femur and 5 times as likely to sustain a compression fracture of a vertebra.[46] Accordingly, further studies are required to evaluate the impact of a progressive resistance strength-training program on recovery after fractures of other bones in the body.

CONCLUSIONS

This review has examined the effects of progressive resistance strength-training program on people recovering from a fracture. Only three studies were located and all of these were conducted as supervised programs following lower limb fractures. These studies collectively demonstrated increased muscle strength and activity levels after a strength-training program. However, subsequent losses in strength, and notably activity, were reported in the studies that included a follow-up period. Further research is required to replicate the findings of these three studies. Also research needs to be conducted to evaluate the effects of strengthening on recovery after fractures in bones other than those in the lower limbs, and to determine whether progressive resistance strength training is feasible and beneficial if conducted in the home environment, with lower supervision from a physical therapist.

REFERENCES

The most important references are denoted with an asterisk.

1 Bond CD, Shin AY, McBride MT, Dao KD. Percutaneous screw fixation or cast immobilization for non-displaced scaphoid fractures. *J Bone Joint Surg Am* 2001:**83**:483–8

2 Lagerstrom CB, Nordgren B, Rahme H. Recovery of isometric grip strength after Colles' fracture: a prospective two-year study. *Scan J Rehabil Med* 1999;**31**:55–62

3 Bain GI, Zacest AC, Paterson DC, Middleton J, Pohl AP. Abduction strength following intramedullary nailing of the femur. *J Orthop Trauma* 1997;**11**:93–7

4 Tropp H, Norlin R. Ankle performance after ankle fracture: a randomized study of early mobilization. *Foot Ankle Int* 1995;**16**:79–83

5 Besli K, Sener E, Meray J, Ozturk AM, Kazimoglu C. Evaluation of functional results following surgical treatment of supracondylar femoral fractures. *Acta Orthop Traumatol Turc* 2002;**36**:310–5

6 Danckwardt-Lilliestrom G, Sjogren S. Postoperative restoration of muscle strength after intramedullary nailing of fractures of the femoral shaft. *Acta Orthop Scand* 1976;**47**:101–7

7 Faergemann C, Frandsen PA, Rock ND. Residual impairment after lower extremity fracture. *J Trauma* 1998;**45**:123–6

8 Feldt KS, Finch M. Older adults with hip fractures: Treatment of pain following hospitalization. *J Gerontol Nurs* 2002;**28**:27–35

9 Herbert R, Human strength adaptations –- implications for therapy. In: Crosbie J, McConnell J. (eds) *Key Issues in Musculoskeletal Physiotherapy*. Oxford: Butterworth-Heinemann, 1993:142–71

10 Tremayne A, Taylor NF, McBurney H, Baskus K. Correlation of impairment and activity limitation after wrist fracture. *Physiother Res Int* 2002;**7**:90–9

11 Campbell AJ, Borrie MJ, Spears GF. Risk factors for falls in a community based prospective study of people 70 years and older. *J Gerontol A Biol Sci Med Sci* 1989;**44**:112–7

12 Nevitt MC, Cummings SR, Hudes ES. Risk factors for injurious falls: a prospective study. *J Gerontol A Biol Sci Med Sci* 1991;**46**:154–70

13 Lamb SE, Morse RE, Evans JG. Mobility after proximal femoral fracture: the relevance of leg extensor power, postural sway and other factors. *Age Ageing* 1995;**24**:308–14

14 Marks R, Allegrante JP, MacKenzie R, Lane JM. Hip fractures among the elderly: Causes, consequences and control. *Ageing Res Rev* 2003;**2**:57–93

15 Cuddihy MT, Gabriel SE, Crowson CS, O'Fallon WM, Melton LJ. Forearm fractures as predictors of subsequent osteoporotic fractures. *Osteoporos Int* 1999;**9**:469–75

16 Sambrook PN, Seeman E, Phillips SR, Ebeling PR. Preventing osteoporosis: Outcome of the Australian Fracture Prevention Summit. *Med J Aust* 2002;**176**(Suppl):S1–16

17 American College of Sports Medicine. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 2002;**34**:364–80

18 Taylor NF, Pizzari T. Therapeutic guidelines for the rehabilitation of older people following fracture. In: Morris M, Schoo A. (eds) *Optimizing evercise and Physical Activity in Older People*. Oxford: Butterworth-Heinemann, 2004; Ch. 9

19 PEDro. The physiotherapy evidence database (PEDro) frequently asked questions: how are trials rated? Available at: <http://www.cchs.usyd.edu.au/pedro> accessed on June 2003

20 Verhagen A, de Vet H, de Bie R *et al.* The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *J Clin Epidemiol* 1998;**51**:1235–41

21 Dodd KJ, Taylor NF, Damiano DL. A systematic review of the effectiveness of strength-training programs for people with cerebral palsy. *Arch Phys Med Rehabil* 2002;**83**:1157–62

22 World Health Organization. *ICF: International Classification of Functioning, Disability and Health (short version)*. Geneva: WHO, 2001

23 Hedges LV, Olkin I. *Statistical Methods for Meta-analysis*. Orlando: Academic Press, 1985

24 Handoll HH. Mobilisation strategies after hip surgery in adults (Cochrane Review). In: *The Cochrane Library*. Oxford: Update Software, 2003

25 Finsen V, Saetermo R, Kibsgaard L *et al.* Early postoperative weight-bearing and muscle activity in patients who have a fracture of the ankle [comment]. *J Bone Joint Surg Am* 1989;**1**:23–7

26 Karumo I. Intensive physical therapy after fractures of the femoral shaft. *Ann Chir Gynaecol* 1977;**66**:278–83

27 Karumo I. Recovery and rehabilitation of elderly subjects with femoral neck fractures. *Ann Chir Gynaecol* 1977;**66**:170–6

28 Krolner B, Toft B, Pors Nielsen S, Tondevold E. Physical exercise as prophylaxis against involutional vertebral bone loss: a controlled trial. *Clin Sci* 1983;**64**:541–6

29 Malmros B, Mortensen L, Jensen MB, Charles P. Positive effects of physiotherapy on chronic pain and performance in osteoporosis. *Osteoporos Int* 1998;**8**:215–21

30 Sherrington C, Lord SR. Home exercise to improve strength and walking velocity after hip fracture: a randomized controlled trial. *Arch Phys Med Rehabil* 1997;**78**:208–12

31 Latham NK, Stretton C, Ronald M. Progressive resistance strength-training in hospitalised older people: a preliminary investigation. *NZ J Physiother* 2001;**29**:41–8

32 Hauer K, Rost B, Rutschle K *et al.* Exercise training for rehabilitation and secondary prevention of falls in geriatric patients with a history of injurious falls. *J Am Geriatr Soc* 2001;**49**:10–20

33* Hauer K, Specht N, Schuler M, Bartsch P, Oster P. Intensive physical training in geriatric patients after severe falls and hip surgery. *Age Ageing* 2002;**31**:49–57

34. Ruchlin HS, Elkin EB, Allegrante JP. The economic impact of a multifactorial intervention to improve postoperative rehabilitation of hip fracture patients. *Arthritis Rheum* 2001;**45**:446–52

35* Mitchell SL, Stott DJ, Martin BJ, Grant SJ. Randomized controlled trial of quadriceps training after proximal femoral fracture. *Clin Rehabil* 2001;**15**:282–90

36* Shaffer MA, Okereke E, Esterhai JL *et al.* Effects of immobilization on plantar-flexion torque, fatigue resistance, and functional ability following an ankle fracture. *Phys Ther* 2000;**80**:769–80

37 Dodd KJ, Taylor NF, Bradley S. Strength-training for older people. In: Morris M, Schoo A. (eds) *Optimizing evercise and Physical Activity in Older People*. Oxford: Butterworth-Heinemann, 2004;Ch. 7

38 Duke RG, Keating JL. An investigation of factors predictive of independence in transfers and ambulation after hip fracture. *Arch Phys Med Rehabil* 2002;**83**:158–64
39 Jette DU, Grover L, Keck CP. A qualitative study of clinical decision making in recommending discharge placement from the acute care setting. *Phys Ther* 2003;**83**:224–36
40 Hertling D, Kessler RM. The wrist and hand complex. In: Hertling D, Kessler RM. (eds) *Management of Common Musculoskeletal Disorders: Physical Therapy Principles and Methods.* Philadelphia: Lippincott, 1996;270–1
41 Weinstock TB. Management of fractures of the distal radius: therapist's commentary. *J Hand Ther* 1999;**64**:99–102
42 McCartney N, Hicks A, Martin J, Webber CE. A longitudinal trial of weight training in the elderly: continued improvements in year 2. *J Gerontol: Biol Sci* 1996;**51**:425–33
43 Sforzo GA, McManis BG, Black DM, Luniewski D, Scriber KC. Resilience to exercise detraining in healthy older adults. *J Am Geriatr Soc* 1995;**43**:209–15
44 Jette AM, Harris BA, Sleeper L *et al*. A home-based exercise program for nondisabled older adults. *J Am Geriatr Soc* 1996;**44**:644–9
45 Nguyen TV, Center JR, Sambrook PN, Eisman JA. Risk factors for proximal humerus, forearm and wrist fractures in elderly men and women: the Dubbo Osteoporosis Epidemiology Study. *Am J Epidemiol* 2001;**153**:587–95
46 Masud T, Jordan D, Hosking DJ. Distal forearm fracture history in an older community-dwelling population: the Nottingham Community Osteoporosis (NOCOS) study. *Age Ageing* 2001;**30**:255–8

ALISON MURDOCH, NICHOLAS TAYLOR (for correspondence:
Tel: +61 3 9479 5766; Fax: +61 3 9479 5768; E-mail: n.taylor@latrobe.edu.au) and
KAREN DODD, Musculoskeletal Research Centre, School of Physiotherapy, La Trobe University, Victoria 3086, Australia