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Resistance training in musculoskeletal rehabilitation: a systematic review

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ABSTRACT

Objective To review the efficacy of resistance training (RT) as a therapeutic modality in various musculoskeletal conditions.

Design Systematic review.

Subjects Data from 1545 rehabilitation patients who had participated in structured RT programmes were included into the review. The total number of patients was composed of separate musculoskeletal conditions—chronic low back pain (CLBP) (549), tendinopathy (299), knee osteoarthritis (433), anterior cruciate ligament reconstruction (189) and hip replacement surgery (75).

Results Evidence suggests that RT can increase muscle strength, reduce pain and improve functional ability in patients suffering from CLBP, knee osteoarthritis, and chronic tendinopathy and those under recovery after hip replacement surgery.

Conclusion RT can be used successfully as a therapeutic modality in several musculoskeletal conditions, especially those of a chronic variety. Although the exact application of training intensity and volume for maximal therapeutic effects is still unclear, it appears that RT guidelines, which have proven effective in a healthy population, can also be successfully applied in a rehabilitation context.

INTRODUCTION

The effects of musculoskeletal resistance training (RT) on the development of strength and power in a healthy population have been well covered in the literature.[1–4] Specifically, RT can result in increased muscle size, maximal strength and muscle power through several mechanisms. These range from skeletal muscle hypertrophy and changes in muscle architecture to neural adaptations such as increased motor unit activation and supraspinal adaptations.[2 5–8] However, relatively little is known about the effects of RT in an injured population and, moreover, even less is known about what constitutes the optimal guidelines for its use. In recent years, the increased prevalence of RT in various rehabilitation programmes lends some empirical evidence to its beneficial effects in a rehabilitation context; however, the scientific evidence for the use of RT in rehabilitation is not as extensive as the evidence presented in a healthy population. The objective of this review was to summarise the effects of RT in a rehabilitation context with regards to its effects on maximal strength, functional ability, alleviation of pain and quality of life (QoL) parameters in the musculoskeletal conditions, where RT is most commonly prescribed throughout the literature. Furthermore, this review will also seek to critically evaluate the validity of the RT methods most commonly used in musculoskeletal rehabilitation programmes.

METHODS

A comprehensive search of the PUBMED/MEDLINE, CINAHL and SportDiscus databases was conducted by the authors. All publications in the English language listed up until April 2010 (including online format only) were considered for inclusion. Abstracts were initially screened and then full-text versions accessed when included.

The following inclusion criteria were adhered to: (1) studies with an intervention period lasting minimum 4 weeks, (2) studies with more than one clinically relevant outcome measure, (3) studies using patients suffering from a clinically diagnosed musculoskeletal condition and (4) studies using external resistance in addition to bodyweight as part of the RT intervention. Both randomised controlled trials and observational studies were included into the review.

The comprehensive database search based on relevant MeSH terms (RT, chronic low back pain (CLBP), knee osteoarthritis, achilles/patellar tendinopathy, anterior cruciate ligament (ACL) reconstruction, hip replacement surgery) identified a number of studies (figure 1).

A summary of the changes in outcome measures in the papers included into this review can be found in table 1.

RESULTS

Chronic low back pain

Chronic low back pain (CLBP) is the most common musculoskeletal condition affecting a wide array of people from both athletic and non-athletic backgrounds. In most cases, the aetiology of the condition appears to be multifactorial but, nevertheless, is associated with a deconditioning of the extensor muscles of the back and resultant loss of muscle strength,[9–12] thus creating a potential target for RT in CLBP rehabilitation.

RT has been shown to improve strength[13–17] and reduce self-reported pain in patients with CLBP,[14 17] thereby serving as an effective therapeutic modality in this common condition.[18 19] Long-term benefits after RT intervention can be observed in patients with CLBP[20] but also appear to be further influenced by extrinsic factors such as physical activity, smoking and treatment outcome expectations.[21] Isolated data have suggested that RT offers no benefits over normal physical therapy in the treatment of CLBP;[22] however,

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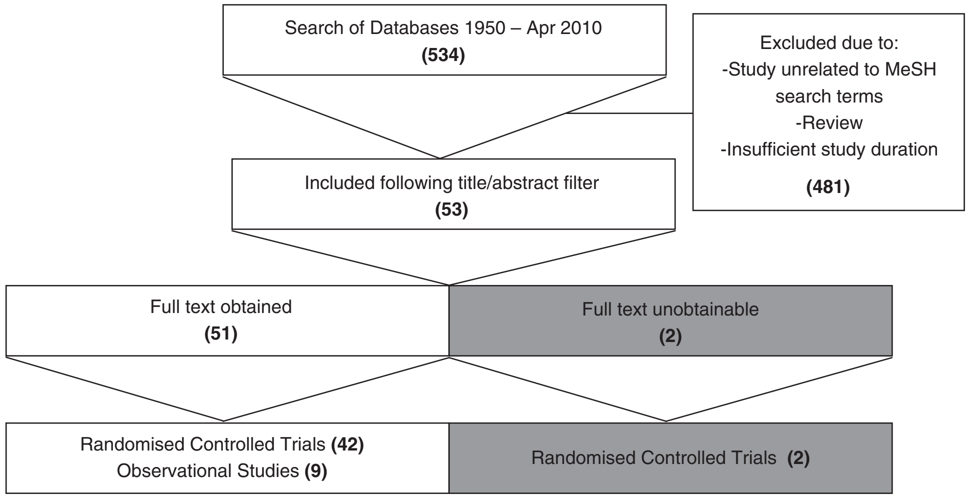

Figure 1 Search strategy. Numbers of studies either used or rejected are indicated in brackets.

such conclusions are not supported by the majority of the current literature.

The details of what constitutes an optimal RT programme in CLBP such as training intensity, volume and contraction type are largely unknown at present, as evidenced by the widely differing RT methodology employed by different studies.[13 15–18] Sertpoyraz *et al*[23] saw increased lumbar extension strength and reduced self-reported pain in patients after participation in an isokinetic RT programme; however, the results were not significantly different when compared with a standard therapeutic exercise programme. Unfortunately, the authors failed to provide a description of the standard exercise programme, thus making a direct comparison of the two training programmes difficult.

With regards to RT volume in the treatment of CLBP, Limke *et al*[24] reported that completing two sets rather than one set of a RT exercise did not lead to increased benefits either on measures of strength or self-reported pain. This is directly contradictory to evidence from a healthy population where meta-analysis has confirmed the superiority of a multiple-set approach for eliciting maximal strength gains.[25–28] However, the study by Limke *et al*[24] was strictly speaking not a single-set study design as the authors did make use of five to six different strengthening exercises in their training protocol leading to a higher accumulated training volume.

With regards to RT intensity, Helmhout *et al*[20] compared high- and low-intensity lumbar strengthening programmes showing greater strength gains with a high-intensity approach but less reduction in kinesiophobia, prompting the authors to conclude that high-intensity RT offered no added benefits over low-intensity RT in restoring back function in CLBP. Similarly, Harts *et al*[17] found that participation in a high-intensity RT programme did not lead to greater strength gains when compared with a low-intensity programme; however, it did seem to improve patient-reported QoL more. However, in both these above studies, the definition of high-intensity RT was different to the conventional definition of high-intensity RT in a healthy population. It is widely accepted that an exercise intensity >70% of 1RM is the threshold above which neuromuscular adaptations occur in response to RT and where the training can be classified as high-intensity.[29–32] The methodology of Harts *et al*[17] consisted of a 'high-intensity' group exercising at 50% of 1RM, an exercise intensity which is insufficient for eliciting strength gains in a healthy population. Unsurprisingly, the authors failed to see significant strength gains even in the 'high-intensity' group, indicating that sufficient exercise intensity is needed to elicit neuromuscular adaptations even in an injured population. Incidentally, the study by Helmhout *et al*,[22] which concluded that RT offered no benefits over normal physical therapy in the treatment of CLBP, used the same insufficient exercise intensity in the RT protocol.

Recently, periodised RT, which is the most effective form of RT in a healthy population,[32] has also been shown to be effective at increasing muscular strength, reducing pain and improving QoL in patients with CLBP.[33 34] In a study by Kell *et al*,[33] CLBP patients engaged in either a 16-week whole-body periodised RT programme using an exercise intensity range of 53–72% of 1RM or a periodised aerobic training programme. Interestingly, only the RT programme resulted in a reduction of pain scores and improvements in QoL parameters. In a follow-up study by Jackson *et al*,[34] CLBP patients used an exercise intensity ranging from 55% to 79% of 1RM. Again, increased muscle strength, reduced pain and increased functional ability were evident after participation in the RT programme, which was well-tolerated by all patients.[34] These results indicate that improving maximal muscle strength through an effective RT programme can reduce symptoms in CLBP patients and that such an approach may be considered a valid therapeutic modality.

Chronic tendinopathy

Chronic tendinopathy is prevalent in both recreational and elite athletes, especially in those who engage in sporting activities with a heavy emphasis on running and jumping. In recent years, the potential use of RT as a therapeutic modality in the treatment of chronic tendinopathy has received increased interest. The majority of this interest has focused on the use of eccentric-only exercise to reduce pain and improve QoL of those affected by the condition. This type of RT uses only the eccentric or 'muscle-lengthening' component of muscle contractions to load the muscles being exercised.

Particularly in chronic Achilles tendinopathy, the results seem promising. In this condition, eccentric-only RT has been associated with decreased pain and improved function immediately after exercise intervention.[35–39] In one study, these improvements were still observed at long-term follow-up at

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Table 1 Papers included into the systematic review

Study	Number of participants (n)	Mean age (years)	Change in outcome measures
Chronic low back pain			
Manniche, 1991	35	45	↓PS
Risch *et al*, 1993	31	45	↑MS, ↓PS, ↑FA
Rissanen *et al*, 1995	30	40	↑MS, ↑CSA
Danneels *et al*, 2001	40	44	↑MS, ↑CSA
Harts *et al*, 2008	20	44	→MS, ↑QoL
Helmhout *et al*, 2004	40	41	↑FA, ↑MS, ↑QoL
Petersen *et al*, 2007	130	35	↑FA, ↓PS
Helmhout *et al*, 2008	64	37	↑FA, ↓PS
Limke *et al*, 2008	100	47	↑MS, ↓PS, ↑FA
Sertpoyraz *et al*, 2009	20	39	↓PS, ↑MS, ↑FA
Kell *et al*, 2009	9	40	↑MS, ↓PS, ↑QoL, ↑BC
Jackson *et al*, 2010	30	52^1, 63^2	↑MS, ↓PS, ↑FA, ↑QoL
Tendinopathy			
Alfredson *et al*, 1998	15	44	↑MS, ↓PS
Mafi *et al*, 2001	44	48	↓PS
Roos *et al*, 2004	15	45	↑FA, ↓PS
Langberg *et al*, 2007	12	26	↓PS
Mafulli *et al*, 2008	45	26^1, 28^2	↓PS, ↑FA
Gardin *et al*, 2010	20	49	↑FA, ↓PS
Silbernagel *et al*, 2001	22	45	↓PS, ↑FA
Purdam *et al*, 2004	9	28	↓PS
Young *et al*, 2005	17	27	↑FA, ↓PS
Frohm *et al*, 2007	20	26^1, 28^2	↓PS, ↑FA, ↑MS
Visnes *et al*, 2005	13	27	FA
Jonsson and Alfredson, 2005	15	25	↓PS, ↑FA
Bahr *et al*, 2006	10	31	↑MS, ↑FA
Kongsgaard *et al*, 2009	26	31^1, 32^2	↑MS, ↓PS, ↑FA
Kongsgaard *et al*, 2010	8	33	↓PS, ↑FA
Knee osteoarthritis			
Ettinger *et al*, 1997	147	68	↑FA, ↓PS, ↑MS
Gur *et al*, 2002	17	55^1, 56^2	↑MS, ↑FA, ↓PS, ↑CSA
Topp *et al*, 2002	67	66^1, 64^2	↑FA, ↓PS
Schilke *et al*, 1996	10	65	↑MS, ↑FA, ↓PS
Mikesky *et al*, 2006	113	69	(↓)MS
King *et al*, 2008	14	48	↑MS, ↑FA
Jan *et al*, 2008	68	63^1, 62^2	↑FA, ↓PS, ↑MS
Anterior cruciate ligament reconstruction			
Mikkelsen *et al*, 2000	44	26^1, 19^2, 25^3, 19^4	↑MS
Morissey *et al*, 2002	43	29^1, 28^2	↓PS, ↑MS
Holm *et al*, 2006	26	26	↑MS, ↑CSA
Liu-Ambrose *et al*, 2003	5	25	↑MS, ↑FA
Risberg *et al*, 2007	35	27^1, 31^2	↓PS, (↓)MS
Gerber *et al*, 2007[83]	16	29^1, 31^2	↑MS, ↑FA
Gerber *et al*, 2007[84]	20	29	↑CSA
Hip replacement			
Hauer *et al*, 2002	15	82	↑MS, ↑FA
Suetta *et al*, 2004[90]	13	69	↑MS, ↑FA, ↑CSA
Suetta *et al*, 2004[91]	12	71	↑MS, ↑CSA
Suetta *et al*, 2008	12	71	↑MS, ↑CSA, ↑FA
Husby *et al*, 2009	12	58	↑MS, ↑FA, ↑QoL
Husby *et al*, 2010	11	58	↑MS, ↑FA

Arrows indicate changes in outcome measures. Numbers in superscript indicate separate intervention groups.
BC, body composition; CSA, cross-sectional area; FA, functional ability; MS, muscle strength; PS, pain score; QoL, quality-of-life parameters.

1-year postintervention,[37] and in another study continued improvements were seen more than 4-year postintervention.[40] Some evidence suggest that eccentric-only training may offer additional pain-relieving benefits over concentric-only training,[36] and eccentric-concentric training.[41] However, the methodology of several of these eccentric-only studies has been criticised, leading some authors to conclude that the possible beneficial effects of eccentric loading as a

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therapeutic modality in Achilles tendinopathy are still not fully documented.[42 43]

Currently, it is unclear what constitutes an effective eccentric training volume for eliciting optimal effects,[44] and doubt has also been cast on whether these eccentric-only training protocols can be classified as RT per se. Although the majority of studies have used external resistance in addition to bodyweight as part of the training progression, the exercise intensity used in these studies is generally below the level considered necessary for eliciting strength gains through neural and morphological adaptations, at least in a healthy population.[1 29–31] In fact, it has recently been proposed that the beneficial effects of eccentric-only exercise in Achilles tendinopathy are the result of stretching of passive structures rather than actual muscle strengthening through eccentric loading.[45] Currently, no research has investigated if high-intensity RT, utilising eccentric/concentric muscle actions has therapeutic benefits in the treatment of chronic Achilles tendinopathy.

RT has also been investigated as a potential therapeutic modality in patients suffering from patellar tendinopathy. However, here the literature is less extensive and more inconsistent. Some studies have reported improved function and pain reduction after eccentric-only exercise.[46–48] On the contrary, Visnes *et al*[49] reported no pain-reducing effects of eccentric-only exercise in competitive athletes suffering from patellar tendinopathy, at least when performed in the competitive season. As in Achilles tendinopathy, only very limited evidence exists to suggest that eccentric-only quadriceps training is more effective than other types of RT at alleviating pain in patients suffering from patellar tendinopathy.[50] However, when compared with more aggressive treatments such as surgery, eccentric-only exercise appeared no better at reducing patient-reported pain and only ~35% of patients were symptom-free 1 year after the exercise intervention.[51] Taken together, these results indicate that the use of eccentric-only training in the management of patellar tendinopathy is associated with a degree of uncertainty with regards to treatment outcome.

Very little data exist on the effects of conventional eccentric-concentric RT in the treatment of patellar tendinopathy. A recent study by Kongsgaard *et al*[52] reported superior effects after 12 weeks of heavy slow RT when compared with eccentric-only training in patients suffering from patellar tendinopathy. Both groups saw improvements in patient-reported pain; however, only heavy slow RT led to improvements in tendon pathology. These positive effects included reductions in tendon swelling and vascularisation along with increased collagen turnover. These findings are interesting because this is the only study in patellar tendinopathy which has used an exercise intensity of sufficient magnitude to elicit neural and morphological adaptations.[29–31] The above-mentioned study used a variety of RT exercises to specifically target and strengthen the muscles around the knee and hip joint, and, interestingly, this general strengthening approach did appear to effectively alleviate the symptoms of patellar tendinopathy. Furthermore, at the 6-month follow-up, the patients who had completed the heavy RT programme were more satisfied with their treatment outcome than those who had undergone an eccentric-only training programme. In a recent follow-up study, Kongsgaard *et al*[53] reported that heavy slow RT improved abnormal tendon morphology in patellar tendinopathy, leading the authors to hypothesise that this is the potential mechanism of action by which heavy RT improves the clinical outcome of this chronic condition. Thus, these two recent studies indicate that participation in a heavy RT programme may offer additional benefits over both eccentric-only and low-intensity RT in patients suffering from patellar tendinopathy by improving a wider range of outcome measures. Also, based on the current literature in chronic lower limb tendinopathy, it appears that RT is effective at reducing symptoms in both young and old patients alike and that this effectiveness persists regardless of gender.

Knee osteoarthritis

Knee osteoarthritis is a degenerative condition which predominantly affects the middle-aged and older population. However, other key risk factors include obesity and prior sports-related knee injury. Weakness of the quadriceps muscle has been shown to correlate significantly with both functional ability and pain in knee osteoarthritis.[54 55] Thus, strengthening of the quadriceps muscle with RT potentially offers benefits in the treatment of knee osteoarthritis.

It has been reported that patients who participate in RT show improvements in pain and functional ability.[56–60] Participation in a RT programme can attenuate the progressive loss of muscle strength commonly seen in older knee osteoarthritis patients and may retard disease progression.[61] Some evidence suggests that the positive therapeutic effects of RT are evident even in patients with advanced knee osteoarthritis.[62] However, these studies have used a variety of different RT methods, and it appears unclear what constitutes the optimal training methods to employ in the treatment of knee osteoarthritis.[59]

Gur *et al*[57] used isokinetic RT, which due to the fixed angular velocities does not mimic the contraction pattern of real-life movements, and is generally viewed as less functional than dynamic isotonic RT.[29–31] Despite this notion, the authors still saw significant improvements in muscular strength and functional ability with isokinetic RT. However, the authors[57] did observe better results from combined eccentric-concentric training than from concentric-only RT, indicating that methods which use the conventional contraction coupling, that is, the stretch-shortening cycle, may be more effective in the treatment of knee osteoarthritis. Interestingly, the latter seems to be challenged by Topp *et al*,[58] who saw no increased therapeutic benefit of dynamic over isometric resistance exercise. In this particular study, both types of RT resulted in similar improvements in patient-reported pain and functional ability. The improvements in muscular strength from isometric training are generally thought to be angle specific;[29–31] however, Topp *et al*[58] used isometric training at a variety of joint angles, thereby strengthening the musculature in a method akin to a full range of motion. This potentially explains the beneficial effects of isometric RT in the study.

Furthermore, it appears unclear what exercise intensity is needed to observe optimal results from RT when used as a therapeutic modality in knee osteoarthritis. Although not significant, Jan *et al*[63] observed a trend towards better results with high-intensity RT with regards to improving strength, reducing pain and improving functional ability. In this particular study, the high-intensity group exercised at an intensity of 60% of 1RM, which although lower than what is recommended for optimal results in a healthy population,[32] is potentially still sufficient to elicit some neuromuscular adaptations.[29–31] The authors suggested that resistance exercise of >80% of 1RM is not feasible in knee osteoarthritis patients due to pain and possible detrimental effects associated with repetitive heavy loading, a view that is supported by others in theory.[64] However,

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other evidence suggests that heavy RT does not exacerbate joint problems in middle-aged and older individuals,[5] and Andersen *et al*[65] even speculated that the inclusion of heavy RT exercises in a knee rehabilitation programme would lead to superior results owing to the increased neuromuscular activation observed when compared with conventional therapeutic rehabilitation exercises. Lange *et al*[66] reported that participation in a progressive high-intensity RT programme, using an exercise intensity of ~ 80% of 1RM retarded disease progression in knee osteoarthritis patients by favourably impacting cartilage morphology, thereby disproving the notion that high-intensity RT is not feasible in knee osteoarthritis rehabilitation.

Although some evidence suggests that RT above 60% of 1RM may offer beneficial therapeutic effects in the treatment of knee osteoarthritis, additional research is needed to conclusively establish if this method offers additional benefits over lighter, less-intense RT in the treatment of knee osteoarthritis.

Rehabilitation after ACL reconstruction

RT has been studied comprehensively as a potential adjunct therapy after knee surgery. Following ACL reconstruction surgery, RT is routinely prescribed as part of the rehabilitation process.[67–69] Loss of quadriceps muscle strength and joint range of motion are two well-established complications of ACL reconstruction surgery,[70–73] and this weakness can persist for years after surgery if not adequately addressed by an effective rehabilitation programme.[70 71 74] Consequently, some authors emphasise that restoring quadriceps strength is vital to a successful therapeutic outcome,[68 75 76] and some evidence suggests that RT is effective at improving strength, functional ability and reducing pain in patients postsurgery,[77–79] however, not more so than a proprioception training programme[80] or neuromuscular training programme.[81] Interestingly, other types of exercise such as stair climbing and cycle ergometry also appear to lead to significant gains in quadriceps muscle strength when used in postoperative rehabilitation following ACL reconstructive surgery.[82] This indicates that postsurgery, RT offers no additional benefits over other conventional types of exercise in promoting a return of muscle strength and functional ability, at least in the short term.

The use of eccentric-only resistance exercise has also been investigated as potential treatment modality after ACL reconstruction. Gerber *et al*[83 84] reported that eccentric-only RT resulted in greater strength gains, daily activity level and quadriceps muscle hypertrophy when compared with a standard rehabilitation protocol, with the beneficial effects persisting 1 year postsurgery.[85] However, in the above studies, the eccentric RT consisted of eccentric cycle ergometry with no definitive description of the intensity level used, making it difficult to actually classify this intervention as an actual RT programme. Thus, based on the above studies, it is not possible to conclude whether eccentric-only RT offers additional benefits over traditional RT methods in the rehabilitation period following ACL reconstruction surgery.

As even low-to moderate-intensity exercise results in significant strength gains after ACL reconstruction surgery, there is little to be gained from the use of high-intensity RT in the immediate period following ACL reconstruction surgery. However, it is not clear whether this type of RT could potentially benefit patients in the long-term, especially considering that persistent muscle weakness is evident in many patients, sometimes even years after participation in traditional rehabilitation programmes.[69 70 73] Therefore, additional research is needed to investigate if high-intensity RT can be introduced successfully into a rehabilitation protocol at a later stage and potentially improve the long-term prognosis for patients who have undergone ACL reconstruction surgery.

Rehabilitation after hip replacement surgery

Hip osteoarthritis is a degenerative condition, which particularly affects the older population and often leads to the need for hip replacement surgery. Recent data suggest that this procedure is being carried out with increasing frequency in the UK,[86] thus creating a need for increasingly efficient rehabilitation strategies. Evidence suggests that hip replacement patients often fail to fully regain the muscle strength and functional ability lost due to the hospitalisation/immobilisation process.[87 88] Consequently, it has been speculated that RT, due to its ability to increase maximal muscle strength, may ameliorate this postsurgery strength loss and thus serve as a distinct therapeutic modality.

Participation in an RT programme increases maximal muscle strength in patients having undergone hip replacement surgery.[89–94] This increase in maximal strength has been observed as early as 4–5 weeks after the start of an RT programme,[90 91 93] with some of the strength gains and neuromuscular adaptations still evident 11 months after cessation of the RT programme.[93] Similarly, a range of functional performance parameters such as walking speed, stair climbing and seated-to-standing time also appear to be significantly improved by RT after hip replacement surgery.[89 90] Suetta *et al*[90] compared the effects of RT, percutaneous neuromuscular electrical stimulation (NMES) and conventional rehabilitation in patients having undergone hip replacement surgery. When all three training methods were commenced while patients were still in hospital recovering after surgery, only RT resulted in a significantly reduced length of stay in hospital. Similarly, only RT prevented postsurgery muscle atrophy and was the only intervention resulting in increased muscle cross-sectional area and maximal muscle strength 12 weeks postsurgery. However, it is worth noting that both the RT and NMES groups showed significant improvements in functional performance tests such as walking speed and stair-climbing 12 weeks postsurgery, indicating some merit to the use of NMES in the postsurgery recovery period. In the study by Suetta *et al*,[90] the RT protocol consisted of a progressive increase in training intensity from 65% of 1RM immediately after hospital discharge up to 80% of 1RM for the last 6 weeks. Thus, the training intensity eventually surpassed the theoretical minimum for neuromuscular adaptations to take place, and, not surprisingly, the last 6 weeks of the study also saw the greatest increases in peak force.

Another study by Suetta *et al*[91] found that RT was the only training method which resulted in significant increases in muscle rate of force development (RFD). This RT-induced increase in RFD has been corroborated by recent studies[93 94] and is potentially linked to evidence suggesting that older hip replacement patients experience proportionately greater increases in fast-twitch type IIx muscle fibre area in response to RT.[92] The increase in RFD seems particularly relevant from a functional performance point of view and has lead some to conclude that RT would make older patients more able to prevent falls due to their increased ability to rapidly generate muscle force in situations where balance is lost.

When used as a therapeutic modality after hip replacement surgery, it is evident that high-intensity RT (>70% of 1RM) can be used successfully to elicit improvements in

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maximal strength, RFD, muscle morphology and functional performance.[89–94] It appears that these beneficial results can be achieved even in older patients (+60 years) who take longer to regain strength after a period of disuse/immobilisation than younger individuals.[95] Nevertheless, the positive effects of RT are still evident despite an advanced age.

The results are evident either by utilising a progressive increase in training intensity before attempting heavier loads,[90–92] or by using high-intensity RT immediately postdischarge without a progressive build-up.[89 93 94] Both approaches appear to be equally well tolerated by hip replacement patients, although there is some evidence to suggest that the sooner the patients start to train using a high intensity, the quicker the increase in maximal strength is manifested.[89 93] Taken together, these results indicate that the use of RT immediately postoperatively in hip replacement patients shortens the time before hospital discharge and that continuing RT postdischarge can increase maximal strength, RFD and functional performance even in an advanced age group.

DISCUSSION

Based on existing literature, RT is a useful tool in the rehabilitation of a variety of musculoskeletal conditions, especially those where loss of muscular strength and functional ability is evident (see table 1). As such, the beneficial effects of RT are apparent in chronic conditions such a recurrent low back pain, knee osteoarthritis and patellar tendinopathy, whereas the effectiveness of RT in a postsurgical setting seems to vary. High-intensity RT does not appear feasible post ACL reconstruction surgery to avoid stressing the knee joint and consequently jeopardising the integrity of the new graft. However, high-intensity RT shows clear beneficial effects when commenced very shortly after hip replacement surgery. Part of the explanation for this is potentially that after hip replacement surgery, the high-intensity RT protocols found in the existing literature predominantly stress the muscles of the knee joint (quadriceps) and exercises are performed in a supine position to avoid hip luxation. Thus, the success of RT in increasing muscle strength and functional ability after hip replacement surgery is potentially attributable to the fact that physical stress on the new hip joint is kept to a minimum, while the surrounding muscles are strengthened through contractile activity. Future work need to determine whether such a paradigm could make RT equally effective after ACL reconstruction, that is, by performing exercises which predominantly stress the hip rather than the knee joint.

Reduced capacity to adapt to a given exercise stimulus is a complication of advanced age; however, the positive effects of RT in a rehabilitation context are evident even in patients of advanced age. Although it is likely that younger patients still respond more favourably to RT than their older counterparts, RT can still be used across all ages as an effective therapeutic tool.

The current notion that RT in a rehabilitation context should be less intense than what is successfully used in a healthy population is based on the concern that high-intensity RT is potentially injurious and detrimental in an already injured population. Given the therapeutic context this is a legitimate concern, however, the recent studies which have used high-intensity RT protocols (~70% of 1RM) in the rehabilitation of musculoskeletal injuries have shown that this approach is well tolerated by patients and clearly ameliorates rather than exacerbates symptoms.[33 34 66 89–94] However, a key point in the safe application of high-intensity RT in the rehabilitation of musculoskeletal injuries may be the use of periodised RT. Incidentally, this approach to RT is also the most effective form of resistance exercise in a healthy population.[30 32 96 97] Periodised RT in rehabilitation will allow patients to gradually improve their maximal strength and become accustomed to handling heavier loads. As previously discussed, this approach has been shown to be effective at improving muscular strength and functional ability and reducing patient symptoms.[33 34 90–93] Although more research is needed to further elucidate what constitutes optimal RT protocols in musculoskeletal rehabilitation, new findings indicate that the principles of effective RT programme design, which have originated in a healthy population, can also be applied successfully in an injured population, despite the inherent concerns by the majority of authors.

What is already known on this topic

It is already known that resistance training (RT) is a useful tool in the rehabilitation of musculoskeletal injuries and that its use may lead to a more successful treatment outcome.

What this study adds

This study reviews the current literature regarding the effectiveness of RT in the treatment of some of the most common musculoskeletal conditions. In addition it compares which RT variables (intensity, volume etc.) are important for a successful training outcome in rehabilitation.

MAJOR FINDINGS

- RT is a valid therapeutic tool in the treatment of the most common musculoskeletal injuries, especially those of a chronic variety.
- RT is effective across age and gender.
- A high-intensity approach (>70% of 1RM) appears to be more effective than a low-intensity approach.
- High-intensity RT training does not increase the likelihood of injury, provided that patients are gradually introduced to heavier loads through periodised RT.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

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