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- Changes in walking levels of people with stroke following discharge
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PHYSIOTHERAPY NEW ZEALAND
Kōmiri Aotearoa

MOVEMENT FOR LIFE

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Non-medical prescribing - implications for physiotherapy education in Australia and New Zealand

As the profession in Australia moves iteratively and carefully towards physiotherapist prescribing of medicines, it is timely to consider the implications of this development on entry-level and postgraduate physiotherapy education in Australia and New Zealand. Although the likely model for Australian physiotherapy prescribing has not yet been decided, a number of educational factors are clear regardless of the model. These are outlined herein.

The Australian Health Professionals Prescribing Pathway (HPPP) (Health Workforce Australia, 2013) project report "sets out five important steps to safe and competent prescribing by health professionals". The first step is the completion by the health professional of education and training that is congruent with the profession's scope of practice and with the individual practitioner's level of competency. A number of facts are known and are based on the safety and quality requirements of the HPPP, the education precedents in other professions where non-medical prescribing has been included (e.g., nurse practitioners and optometrists), and existing curriculum content for preparation of health professional prescribers. Prescribing courses are required to adhere to the national prescribing competency framework, to be accessible, flexible and assessable, and include clinically supervised practice.[2] Moreover, prescribing competencies once developed need to be maintained and enhanced. As noted in the HPPP, it is imperative that education providers are included in the development of physiotherapists' quality use of medicines as part of the profession's scope of practice.

Regardless of the physiotherapy prescribing model that may be enacted in the future, content of non-medical prescribing papers will require the theoretical knowledge and practice components that align with the seven competency domains detailed in the National Prescribing Service (NPS) Better Choices Better Health document (National Prescribing Service Limited, 2012). The NPS knowledge, skills and behaviours competencies are specifically designed to ensure the quality use of medicines by all prescribers. Whilst mapping of Australian physiotherapy curricula (Cardiff, 2016, personal communication) has found that a number of these competencies are already addressed in Australian physiotherapy programmes (thus by equivalence, in New Zealand programmes) three components specific to prescribing are deficient, that is, pharmacology (pharmacokinetics, pharmacodynamics and pharmacogenomics), evidence and quality use of medicines, and specific medicines and prescribing content. That is, the theoretical content and the practice-based content.

For physiotherapy programmes to satisfactorily accommodate content that aligns with the NPS framework, at least two university-level papers (each of the equivalent of 10 hours per week of content, study and assessment) would need to be undertaken by physiotherapists who will prescribe. That is, the equivalent of 50% of a full-time study load for one semester at an accredited higher education institution. Up to 150 hours of embedded supervised practice is likely to be required during clinical placements.

Clinically supervised practice will likely be one of the greatest hurdles for implementing the HPPP in physiotherapy. Lum, Mitchell and Coombes (2013) describe the twelve core competencies for safe prescribing as part of the four stages of prescribing (information gathering, clinical decision making, communication, and monitoring and review), and enunciate the underpinning elements. Presently, it is understood that development of many if not all of the competencies described by Lum and colleagues can be achieved effectively using simulations, and then observed and assessed in clinical placements. The supervisory burden will be undertaken in existing clinical placement settings. For example, clinical educators could be tasked with asking for, and assessing the responses of students to foundational questions integrated into the existing physiotherapy assessment and treatment scenario, including:

- What medicines is the patient on? (as is already done)
- What kind of potential interactions would such medications have?
- How would you (the student) integrate your knowledge of the patient's medications into your physiotherapy plans?
- What would be your (the student's) possible plans for medicines?

The physical act of writing a prescription could be practised and assessed as a technical process pre-clinically, and subsequently audited in the clinical placement setting in the same way that patient records and referral letters are currently reviewed. The higher level supervision of decision-making regarding possible medicines for prescription could be discussed with and notionally approved in a clinical setting where medical staff are available, or where there is a suitably endorsed physiotherapist.

The communication competency already considered a part of physiotherapy could be expanded to include communication with colleagues about de-/prescribing in the context of the prescribing competencies, requiring the integration of prescribing competencies into usual physiotherapy practice. It is expected that the identification of such competencies in university curricula will be a part of a toolkit being developed in Australia.

In addition to the matters outlined above, is the critical requirement by Australian government health departments for non-medical prescribing to be cost-effective and of benefit to the whole community. This aspect is likely also to be of particular interest to the Physiotherapy Board of New Zealand. Although the ultimate delivery model has not yet been finalised, physiotherapist prescribing is unlikely to become a reality if a number of matters such as safety, regulation and the value to the community cannot be established and subsequently enacted. Without diminishing the importance of safety and regulation, value to the community is just as important because the costs involved in establishing physiotherapist prescribing would not be efficient or effective if the uptake of prescribing were to be restricted only to a small percentage of physiotherapists as has occurred thus far in the United Kingdom. If Australia were to follow the prescribing model adopted in the UK the most likely model of education would be at the postgraduate level. Given that postgraduate education currently languishes in Australia due to factors such as cost and accessibility, uptake of postgraduate prescribing studies is projected to be relatively low as has been witnessed where trials of physiotherapist prescribing are occurring (e.g., in Queensland's Department of Health). Access, flexibility and supervised practice elements of prescribing courses are likely to be constrained as universities would not see the financial benefits of offering such courses to low numbers of potential students. The result would be mutually conflicting and dependent conditions wherein the number of prescribers could not increase if access to courses were limited, and courses would not be offered if there was not sufficient demand. The final outcome would not satisfy the value-based care test.

The most likely scenario that would fit a value-based imperative scaffolded by safety, quality and regulatory requirements, is that of graduate physiotherapists being prepared for prescribing within scope at entry to practice (summarised in Figure 1). Such a scenario would incorporate (1) theoretical content regarding pharmacology early in an entry-level programme after the study of the basic and enabling sciences for physiotherapy and prescribing; (2) theoretical medicines and prescribing content would follow pharmacology content and precede clinical placements; and, (3) supervised prescribing practice would be integrated as part of physiotherapy clinical placements.

Medicines likely to be the focus of learning at entry-level would be those most likely to be used by the new graduate or early career physiotherapist such as simple analgesics, NSAIDs and bronchodilators. In Australia, different states have different legislative prescribing requirements of registered health practitioners which at the very least will require familiarisation by the physiotherapy learner, and at best may be a driver for harmonisation of such legislation. Finally, inclusion of additional content in entry-level programmes should not occur at the expense of existing physiotherapy content, and would likely require extension in the length of programmes (as has occurred in other professions in Australia such as optometry) thus creating its own obstacles to implementation.

Postgraduate education would be required and would emphasise the fifth step of the HPPP, the maintenance and enhancement of competence to prescribe. Postgraduate education would focus on medicines required for advanced and extended level physiotherapy practice (such as muscle relaxants and opioids) where required for the individual's scope of practice and for the care of more complex clients/patients. Furthermore, the education and upskilling of already registered physiotherapists who have not undertaken the entry-level education pathway and who wish to prescribe medicines would occur by offering access to existing entry-level courses preferably designed to allow access to some degree of on-line learning, and subsequently to the postgraduate education for those working at a more advanced level (Figure 1).

Additional work remains in order to establish the value-based case for physiotherapist prescribing as well as ensuring that all of the steps of the HPPP are in place in preparation for enacting physiotherapist prescribing. Some would argue that the most significant potential role for physiotherapist prescribers would

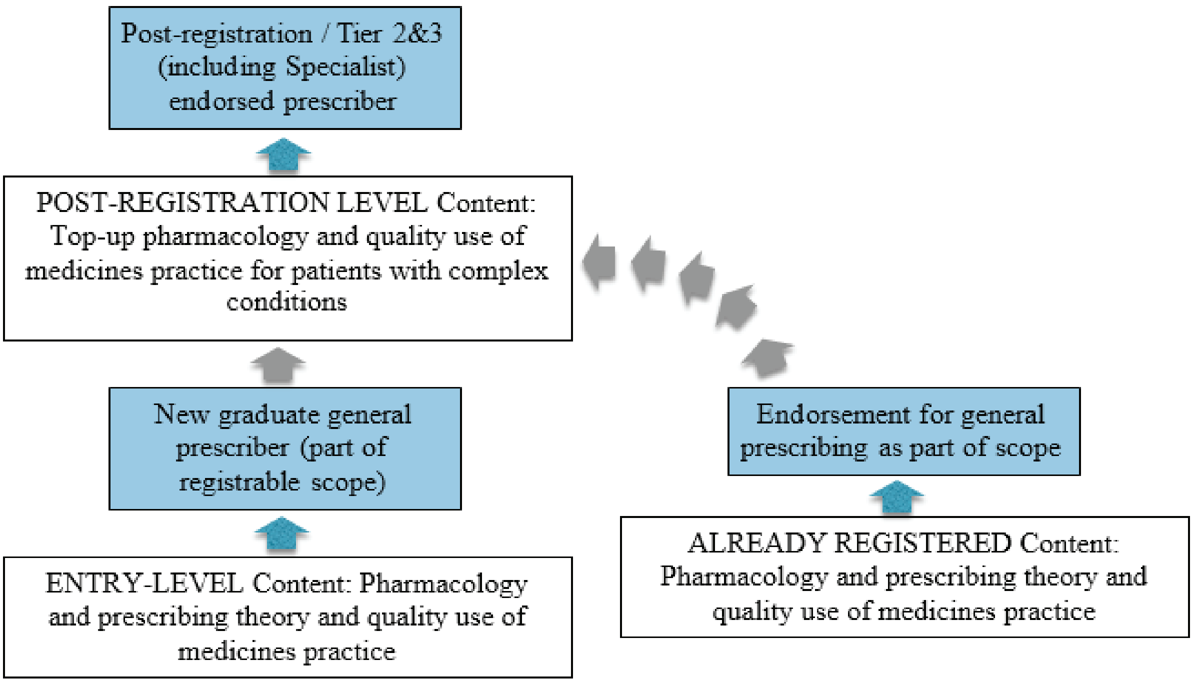

Figure 1: Proposed physiotherapy prescriber education pathway

be for de-prescribing especially in the context of an immobile and/or isolated, chronically-diseased ageing population where poly-pharmacy exists. This editorial does not intend to make a case either for or against such a role but makes the observation that prescribing literacy and competency is imperative for both prescribing and de-prescribing.

The inclusion of the higher education sector in planning curricula that meet the profession's needs as well as the broader healthcare and regulatory requirements is vital. As Australia moves towards physiotherapist prescribing, the profession does so with the knowledge that numerous other matters are being discussed and developed nationally such as a tool for assessment of health professional competence to prescribe, development of new accreditation standards for prescribing education, and a potential inter-professional approach to prescribing curricula. Each of these elements has implications either for Trans-Tasman agreements currently in place or for future use if non-medical prescribing becomes a part of New Zealand physiotherapy practice. Thus the close Trans-Tasman ties enjoyed by our profession will continue to remain relevant and important.

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Physical therapies in 19th century Aotearoa/New Zealand: Part 3 – Rotorua Spa and discussion

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ABSTRACT

This is the final paper reporting on a historiographic study of physical therapies in 19th century Aotearoa/New Zealand. Here we focus on the development of the Rotorua Spa in the final decades of the 19th century and follow the methodological framework of the first two papers by exploring the physical therapies and practitioners that were associated with the spa. The paper examines how the spa also represents the embodiment of changing attitudes towards Māori, the role of central government, and the value of centrally organised healthcare. The second half of the paper provides a discussion of the main questions raised by the study, and considers the role that luxury and surplus may have played in the development of physical therapies in 19th century Aotearoa/New Zealand.

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Key words: Rotorua, Spa, Physical therapy, Aotearoa/New Zealand, Balneology, Luxury, Surplus

INTRODUCTION

This paper is the third to report on a study undertaken to examine why it appears that the physical therapies (massage and manipulation, electrotherapy, hydrotherapy and remedial exercise), were some of the most popular therapies in Europe and North America during the 19th century, but were almost completely absent from Aotearoa/New Zealand before 1900. In the paper, we explore the development of the first organised centre for physical therapies in Rotorua in the last decades of the 19th century. Although the spa would not be formally opened until 1908, plans to exploit the Thermal Springs region's abundant natural resources were in place long before the Te Arawa tribe were coerced into becoming tenants on their own lands in November 1880. We look at the people who were instrumental in developing Rotorua along with the three other government-run spas at Hanmer Springs, Te Aroha and Waiwera, and consider what their actions reveal about people's attitudes towards the physical therapies. Throughout the literature, it is evident that little attention was paid to the therapies themselves. As in Europe and North America, where spas had become phenomenally popular among the leisured classes, the emphasis was on the myriad ways in which it was possible to 'take the waters,' and the properties of the water itself were considered paramount. In images from the time, it is the way in which the water is delivered (through drinking, plunging, spraying, douching, etc.) that is important. Often the physical therapeutic practices and practitioners themselves are entirely subsidiary. The exception to this is the balneologist, who played an increasingly important role in defining the culture of the spa. This was nowhere truer than at Rotorua, where the government ran a decade-long campaign to find the right 'medical man' who could be the face of the new spa. We consider how these changes relate both to traditional Māori cultural practices, and also to the atomistic, fiercely individual political and social context within which the Rotorua Spa was developing. We conclude the paper with a broad discussion of the role that luxury and surplus may have played in defining the physical therapies in Aotearoa/New Zealand in the 19th century.

In the first two papers in this series, we argued that physical therapies were practised by Māori long before colonisation, but that these practices fell into decline after 1860 and the New Zealand Wars. In the second paper we showed that colonists adopted a pattern of settlement that emphasised autonomy and independence at the expense of strong social bonds and organised centres of population. As a consequence, formal health care services, and specifically the physical therapies, were almost entirely absent from the Aotearoa/New Zealand landscape in the 19th century. If a person suffered a serious injury – as was often the case in the gold fields, timber yards and farms throughout the country – there was no opportunity for physical assessment, rehabilitation or treatment. The physical therapists that did offer therapeutic services often did so by working across a range of sectors and offering a range of services. It is likely that many offered services without registering their business or obtaining any formal qualifications.

The exception to this was at Rotorua where, for the first time, the country's government saw value in formalising the provision of physical therapies, not only to the broader public, but also to overseas visitors, who might bring with them valuable investment. The development of the spa represents evidence of a sea-change in attitudes towards the role that government might play in Aotearoa/New Zealand, and points towards the highly interventional policies of the Liberal government that came into power in 1891 under Premier John Ballance, and would remain in power until 1912. During this time, government policy turned on its head and laid the foundations for the radical welfarist policies that would shape the country for the next 60 years. This change in attitudes would lead to the training of physiotherapists beginning in Dunedin in 1913; the deployment of masseurs to front-line service in World War I; the development of post-war rehabilitation, and advances in the management of medical and surgical care of victims of influenza, polio and tuberculosis; the incorporation of physiotherapy into the welfare state formalised by the first Labour government of 1935; and ultimately the formalisation of the profession in the 1949 *Physiotherapy Act*, which gave the profession protection of title and protected access to patients within the public health system. It is hard to imagine that any of these changes would have been possible without the particular opportunities to showcase the physical therapies that the Rotorua Spa offered. So even though the spa itself did not formally open until 1908, the efforts to establish a centre of physical therapy in Rotorua prior to 1900 are significant in defining what was to follow. To begin with then, we will trace a broad timeline of events leading to 1900 and the creation of the world's first Department of Tourist and Health Resorts,[1] which would take over the management of the 'Hot Lake District' and attempt to turn the spa into a world-leading centre for physical therapies.

A BRIEF HISTORY OF THE ROTORUA SPA BEFORE 1900

Like many of the areas in the North and South Island where geothermal water erupted, Rotorua and its surrounding environs had been widely used by Māori long before travellers began exploring Aotearoa/New Zealand's hinterland in the early 19th century. The Te Arawa tribe had long held prestige and authority over the western Bay of Plenty region, including its lands, people, hot springs, fisheries, flora and fauna. Initially opposing Te Tiriti o Waitangi, the tribe came to believe that an alliance with the crown in the 1860s would hold the best protection for their rawa (ancestral assets). Many Te Arawa men fought on the government's side during the Aotearoa/New Zealand wars, but this did not prevent legislation that turned most of their assets into crown property after the end of the war in 1872.[2]

The antecedents to the acquisition of valuable Te Arawa land can be seen much earlier, however, in the early journals, reports and diaries of colonial missionaries and travellers through the Rotorua region after 1840 (Anon, n.d.; Blomfield, n.d.; Corkill, 1888; Gisborne, n.d.; Hill, n.d.; Hoschetter, 1863; Inglis, n.d.; Johnson, 1847; Tiffen, n.d.). Accounts of Māori using the waters for cooking and washing, and the water's remarkable healing properties, began to appear in regional newspapers (McGauran, 1862), and soon the region around Rotorua with the biggest concentration of thermal springs began to be promoted as the 'Hot Lake District,' after its English counterpart. The natural wonders that were the Pink and White Terraces (Otukapuarangi and Te Tarata) drew tourists from all over the world, particularly after Prince Albert's visit in 1870. In 1874, one year after stepping down as Premier, William Fox toured the region and bathed in 'the thermal waters of Orakei-Korako and felt as if he were in 'paradise.' The warm water covered his body with 'an exquisite varnish . . . as smooth as velvet' and made him feel the most polished person in the world' (McLure, 2004, p. 1). Fox was charmed by the beauty of the Terraces, but feared that they would be blighted by tourism. He realised that 'wealth … could be earned from the construction of a sanatorium in the region and the crowds who could be lured there', but '[t]orn between the potential earnings and the risks of exploiting nature, he returned home and urged the government to take on the roles of developer and protector of this landscape' (McLure, 2004, pp. 1-2).

Visits from notable writers like Anthony Trollope and Mark Twain only enhanced the appeal of the region, now becoming more easily accessible after the end of the New Zealand Wars. Combined with the growing popularity of European and North American spa centres, some began to see the advantages of the country as a tourist destination. The Union Steam Ship Company began offering luxury tours of Australasia after the Suez Canal was opened in 1869, and travel times from England were reduced from between three and six months to just seven weeks.

Conscious of the need to control the land surrounding Aotearoa/New Zealand's abundant hot springs, the parliament of 1881 passed the *Thermal Springs District Act* to 'to codify the process it had already begun in Rotorua, legislating on the principle of reserving thermal districts for the use of the nation (*Thermal Springs District Act,* 1881, p. 14).' Within a year of the act, bathing pavilions began to emerge on Rotorua's best spa sites. In 1885, the Blue Baths ('the largest natural swimming bath in the Southern Hemisphere') and a 12-bed hospital (or sanatorium) were opened by writer George Sala.[3] The baths included single sex facilities: a 'boon' for women (McLure, 2004, p. 17). The first formal medical appointment was also made to

[1] To be entirely accurate, the Department of Tourist and Health Resorts was created in 1901. Although one year after the end of the 19th century, we will use this as a landmark date because it concludes one part of the trajectory begun in 1870 with Prince Albert's visit to the Pink and White Terraces, and growing interest in exploiting the region's resources.

[2] The 1865 *Native Land Act* created individual land titles that were easier to acquire and sell, effectively breaking apart collective governship of land common to Māori. Much land was simply stolen, while other areas were acquired by sharp trading, with pākehā taking advantage of conflict and uncertainty to drive a wedge even between Māori families (Binney 2009).

[3] The hospital built in 1886 was destroyed by fire in 1888 and replaced by a larger 21 bed sanatorium, with the government stipulating that 'the patient shall be able to show that his case is one likely to be benefited by the use of the baths, and that he is unable to pay the usual hotel or boarding-house charges'(*Mineral Waters of New Zealand* 1892). The 'tarrif' to stay in the hospital was approximately £1 per head per week. Patients were allowed to remain for three months with a second period possible if needed. The Official Yearbook of New Zealand from 1892 reported that 'A low tariff of this kind will enable the Charitable Aid Boards of the country to send up for treatment a class of patients who would not otherwise be able to avail themselves of the springs, and at the same time will in no way interfere with the private enterprise of hotel and boarding-house proprietors' (*Mineral Waters of New Zealand* 1892).

accompany the new sanatorium and spa. Dr Alfred Ginders was employed as medical superintendent, and served from 1885 to 1899.

Between 1885 and 1891, Ginders published a range of different reports on the thermal springs district, including hints on cases that might benefit from spa treatment, accounts of leprosy among Māori, and statistics on the various other thermal springs in Aotearoa/New Zealand, including Hanmer Springs (Ginders, 1885, 1889, 1890a, 1890b, 1891, 1892). Ginders helped establish a range of baths centred around Sulphur Point, moving vast loads of topsoil from more fertile areas of land to create what would later become the Government Gardens (Werry, 2011, p. 19). Ginders' work concentrated on taming the various fumaroles, ngawha and boiling mud pools, and creating artificially controlled environments that he assumed would be more palatable to overseas travellers and tourists.

The untamed and abundant nature of the Hot Lakes was nowhere more apparent than at Whakarewarewa, an area adjacent to the main Rotorua Spa site controlled by the hapu (sub-tribe) Ngāti Whakaue, who were coerced into selling some 157 acres of land to the crown, whilst retaining a foothold on 58 acres, which they subsequently made available 'to tourists who seem never tired of watching the peculiar customs and manners of the "Māori at Home"' (McLure, 2004, pp. 19-20).

Soon after the 1886 Tarawera eruptions, the government appointed French engineer Camille Malfroy to work as Resident Engineer at the spa. Malfroy had worked for some years designing hydraulic pumps in the West Coast goldfields, and used his experience to develop some world-leading innovations in the control and management of geysers. Malfroy studied the behaviour of the geysers in Rotorua and began to realise that their unpredictability was a function of atmospheric pressure rather than the direction of the wind, as had previously been thought. Experimenting with cold water injected into the head of the geyser tube, he was able to command the geyser's eruption almost at will, boasting in 1893 that he could command the massive Puhutu geyser at Whakarewarewa 'for eminent visitors at a few hours' notice' (2004).[4] Malfroy agitated with others for the government to take a more scientific approach to spa management, arguing that it was the method by which the water was applied, as much as the water itself, that was important; an argument that echoed John Johnson's belief fifty years earlier that it was probably 'their uniform heat [that] is the most active agent in the cure' (Johnson, 1847). Malfroy died prematurely in January 1897 from complications associated with pulmonary tuberculosis, but not before it had been decided that a European trained 'medical man' was now needed to develop the spa further and consolidate it as a world-leading centre for the physical therapies.

THE SEARCH FOR COMPETENT MEDICAL MEN

Some time before the Minister for the Education Department, Thomas Mackenzie, advised the Hon. William Pember Reeves (Minister of Labour) that the government should appoint 'a more up-to-date medical man at the Rotorua Sanatorium in the interests of suffering humanity (Parlimentary Gossip, 1895),' it had come to be believed that Alfred Ginders had been an efficient officer and Camille Malfroy an ingenious engineer, but that 'a medical man who is an expert respecting medicinal springs, should be obtained from Europe.' 'If this were done' it was argued, 'it would increase the utility of what was one of the colony's greatest assets' (Parlimentary Gossip, 1895). Camille Malfroy had himself been arguing that 'we have long recognised the desirability of having a thoroughly competent masseur established here. The difficulty has been to secure the services of a man who has had the necessary training and experience (Mollinghead 1894).' But he believed that 'This want has now been met, as Mr. H. Roth resides at Rotorua, during the summer months, with the sanction of the Government, and treats those at the Priest's Bath Pavilion, who desire his services' (1894). Herman Roth was not a trained doctor, however, and his prestige as a mere masseur was not in line with the government's aspirations.

Much of the delay in finding the right European expert lay in the government's laissez-faire approach to regulation, which had allowed the spa to develop in a piecemeal fashion, lacking the necessary commitment and leadership to fully realise its potential. A report by Inspector-General of Asylums and Hospitals, Dr Duncan MacGregor, highlighted the fact that the spa was only equipped for people who could not afford better private facilities and was unsuited to more affluent tourists. MacGregor argued that 'entirely new arrangements must be made to meet in a comprehensive and systematic way the needs of the rapidly increasing invalid visitors' (Dr MacGregor's Report, 1896). MacGregor pushed to develop the bathing facilities first, followed by the appointment of an 'experienced and specially skilled medical expert in balneology' and a female attendant (Dr MacGregor's Report, 1896).

The government responded by offering Dr Karl Grube – head physician at the springs in Neuenahr in Prussia – an initial salary of £500, but a contract could not be agreed, and ministers had to accept the necessity of raising the salary to £800 if they were going to attract a suitable candidate.[5] The *New Zealand Herald* reported that the man appointed 'must be not only a highly-trained specialist, thoroughly acquainted with the character of the different spas in Europe, but a man of such high reputation in European circles that his reports on our mineral waters will at once command attention,' and that 'It is in England and on the Continent of Europe, and in America, that we want our mineral

[4] Upset with his tampering with natural forces, local Māori tampered with Malfroy's plumbing at the Pohutu geyser in their turn while he represented Aotearoa/New Zealand at the 1890 Paris Exhibition, restoring the geyser's unpredictability (2004, p. 21).

[5] It is worth noting that at the same time, the job of NZ Inspector of Prisons was being offered for £700 per annum; the Secretary of Agriculture £550; The Commander of the Forces £700, and his staff officers £300. So an £800 annual salary for a government balneologist was a considerable national appointment and worth approximately $150,000 today (source: http://www.rbnz.govt.nz/monetary_policy/inflation_calculator/) ("The Estimates," 1898).

waters made known, and to do that we must pay the necessary figure' (Notes and Comments, 1898). The paper argued that it 'would be money well spent, and would be more than recouped to the colony by the expenditure of the class of invalids and tourists that would be found making use of our sanatoria' (Notes and Comments, 1898).

In 1900, there were fewer than 4,000 annual overseas visitors to Aotearoa/New Zealand, however (Bassett, 1998, p. 112), and only a handful of the country's residents had experienced the pleasures of European spas, so the decision to invest heavily in Rotorua was a bold one. Added to this, internal travel within Aotearoa/New Zealand was arduous, and there were few facilities available for tourists. This did not prevent ministers under Richard Seddon's reformist Liberal government from dreaming of a spa centre that would be the envy of the world. Principal among these ministers was Joseph Ward who was instrumental in the search for a European balneologist. It was Ward who, in his first term as Premier in 1901, created the world's first Ministry of Health and Tourism and became the British Empire's first Minister of Public Health. Ward 'convinced himself of Rotorua's curative powers, and he and his wife became devotees, never missing an opportunity to visit the region (Bassett,1998, p. 113). It was Ward who finally appointed Dr Arthur Wohlmann as Government Balneologist in 1902 (Johnson, 1990). Born in Hertford, England in 1867, Wohlmann was 35 years old when he was brought to Rotorua, having graduated from Guy's Hospital in 1891, and having worked at the Royal Mineral Water Hospital in Bath, England since 1894. Wohlmann has been credited with bringing a much-valued scientific approach to the study of Aotearoa/New Zealand's spas.[6] He published a number of books on the mineral compositions of Aotearoa/New Zealand's many natural spas, most notably *The mineral waters and spas of New Zealand (Wohlmann, 1907)*. In this book Wohlmann describes 'Accessory' physical treatments: massage, electrical treatment, medical gymnastics, light and heat. Massage, he argues;

> *constitutes one of the most important—perhaps the most important—forms of accessory treatment. In the Government spas true massage is given by prescription, and under medical direction only, thus eliminating that element of quackery that appears to be so all-pervading where massage is in question (1907, p. 30).*

Wohlmann's innovations, however, came mostly after 1900 with the formal development of the Rotorua Spa. Prior to Wohlmann's arrival, most of the 'medical' treatments of patients at the spa were conducted by masseurs, most notably Hermann Roth. Roth arrived in Aotearoa/New Zealand in 1893 and was appointed masseur at the government sanatorium in the following year. In 1895 he is reported in the *New Zealand Herald* as having made arrangements 'for the erection of a private hospital at Rotorua, suitable for the accommodation and special treatment of invalids, where assistants—both male and female—will be in attendance, and a masseuse for ladies' ("Local and General News", 1895). A few weeks later, the newspaper reported that the opening of the railway line from Auckland had had an immediate effect on the popularity of the spa, with 'All the hotels and boarding-houses…taxed to their utmost, in fact visitors have difficulty at times to secure accommodation, even by putting up with beds in billiard-rooms and tents.'

> *The Sanatorium Hospital, too, is full, not one vacant bed… The bath returns for the last month show better than ever, thus December 1894: Number taken 2890: amount, £56 5s 9d; 1893, number taken, 1608 amount, £34 4s 6d. Increase, 1282, £22 1s 3d. The above figures only refer to the Priest, Rachel, and Blue baths ("Country News", 1895).*[7]

Details of Roth's practices are sketchy, but it is known that he may have ventured into cosmetic medicine as well as more conventional physical therapies. In 1896, for instance, the editor of the Auckland-based newspaper the *Observer* suggests contacting Herman Roth in response to a health problem raised by a correspondent from Cambridge in the Waikato, because 'He has made the removal of superfluous hairs on the face a special study, and he guarantees a permanent cure' ("Our Letter Box", 1896). Beyond this, we can infer some details of his massage practices from the services available at the spa.

The original site of the government spa had been a series of small natural pools on the west side of Lake Rotorua in an area originally known as Oruawhata, and later Sulphur Point. The first two pools developed for commercial activity were the Madam Rachel Baths, named after a London cosmetician who claimed that the silicated water could 'make the plain pretty…make the beautiful exquisite, and…make the age of golden youth return' (Rockel, 1986, p. 20). A pool further south originally called Te Pupunitanga came to be known as the Priest's Bath after a priest from Tauranga (60km to the north of Rotorua) had reportedly been cured of crippling arthritis after a period spent bathing in the pool. Other pools were named after local settlers or for their specific properties, like the Coffee Pot Pool in which the bathers hung from a rope suspended between manuka trees to immerse themselves in its thick brown mud (Rockel,1986, p. 21).

In the 1880s small awnings covered most of the pools, but there were only dressing 'boxes' for people to change in. There were no showers to remove the residue after bathing, which became a significant issue after bathing in the Priest's Bath, since its main constituent chemical was sulphuric acid. In 1885, a small wooden bathhouse was built over the Oruawhata spring and called the Blue Bath, and this offered women-only bathing for a few hours each week. In the following year, Camille Malfroy coordinated the construction of the first proper building over

[6] Arthur Wolhmann served with the New Zealand Medical Corps as principal Medical Officer of the King George V Military Hospital, Rotorua and was subsequently awarded an OBE for his services. Unfortunately, it appears he was never entirely accepted in New Zealand and had to change his surname to Herbert in 1917 because of anti-German sentiment mistakenly associated with his name.

[7] £56 in December 1894 would be equivalent to $10,400 today (source: http://www.rbnz.govt.nz/monetary_policy/inflation_calculator/). Based on the spa's stated throughput, this would equate to an income of $3.60 per visitor to the spa's three main baths. No breakdown of costs for specific physical therapies are given.

the Priest's Bath, incorporating a wooden clock and wooden nails that would not corrode in the acrid steam rising from the pool. A further building was constructed closer to the sanatorium grounds in 1896 called the Postmaster's Bath. This needed to be open to the air because it emanated so much hydrogen sulphide (1986). what does this refer to?

In the *Official Yearbook of New Zealand* published in 1892, Alfred Ginders describes some of the conditions commonly treated at the spa. Having established that hot water was no cure for '[a]dvanced phthisis [pulmonary tuberculosis], chronic Bright's disease [kidney disease], spinal caries [decay], and psoas abscess' (*Mineral Waters of New Zealand*, 1892), Ginders argued that incapacity, severe pain or the difficulties of accessing the spa by coach before the completion of the railway line, need not be deterrents: 'We have many instances on record of patients who, on arrival, required the aid of crutches, or to be actually carried to the bath, and yet went away enjoying the full use of their limbs' (*Mineral Waters of New Zealand,* 1892). Ginders was admirably conservative about the ability of the hot pools to regenerate nerve tissue in severe paralysis, and restore joints deformed by osteoarthritis and rheumatism; '[s]uch cases may improve in general health, gain weight, and lose pain, but there the improvement ends' (*Mineral Waters of New Zealand,* 1892).

Common to the practice of many physicians of the time, accounts of successful treatments were used to illustrate the benefits of particular therapies. With today's more critical approach to evidence-based practice it is easy to dismiss illustrative case studies of this sort as untrustworthy, but their use was nonetheless widespread and their implications for the value of particularly conservative therapies like hot water bathing, electrotherapy and massage are interesting. Ginders illustrates a successful case to highlight the virtues of a stay at the spa:

> *C.H., aged forty-nine…Got his first attack twenty years ago—sub-acute rheumatism of the feet. The attacks recurred every winter, each being more severe than the last. The ankles, knees, elbows and hands became affected. For the last nine years he has spent six months of each year in bed. On his arrival at Rotorua his appearance was that of a man of seventy; his hair white, his complexion pale and anæmic, his back bent, liver sluggish, bowels torpid, appetite bad with slight enlargement of knees, elbows, and knuckles. He commenced taking two acid sulphur-baths daily, and during the first month improved wonderfully. [Following an acute relapse]…serious costiveness[8] set in. Having in vain tried other remedies, as a last resource I tried faradism. All serious symptoms at once disappeared. He rapidly gained strength, resumed his bathing, and, after spending three months with us, considered himself in better condition than he had been for ten years (Mineral Waters of New Zealand, 1892).*

Similar cases are reported for the treatment of paralysis, skin diseases and neuralgia. It is likely that Herman Roth and his assistant worked closely with Ginders and the other medical superintendents who operated between the sanatorium and the spa itself, although how their roles overlapped is unclear. In all likelihood, Roth operated under some degree of medical direction, although this would not have been the case in his own private practice in Auckland and Wellington, suggesting that he had some degree of latitude to apply and adjust treatments according to his own observations.

By 1899, plans were in place for an ambitious expansion of the spa, including a new building to be designed by the notable architect B. S. Corbett, decorated in 'the Victorian decorative vernacular of leisured luxury' (Werry, 2011, p. 22), withwooden parquet floors, conservatories, fountains and statuary, Minton tiled rooms and Royal Doulton bathtubs. The image of Rotorua as a therapeutic and leisured resort for a better class of invalid (Notes and Comments, 1898) reached its apotheosis in 1908 with the construction of the new bathhouse. By the time of its completion it had cost £80,000 – 'a vast (and controversial) sum even in an era of bold public works investment' (Werry, 2011, p. 22). Ultimately, it would prove to be a failed investment. By 1918, the spa was losing £20,000 per year, by 1930-31 this had risen to £112,000. The Blue Baths never appear to have made a profit and finally closed in 1982 (Bassett, 1998, p. 115).

Although the Baths have now been partially revived as an exhibition, the question of the role of the physical therapist in the history of the Rotorua Spa remains obscure. Much of the focus of the available literature falls on the facilities and services offered in the 50-year period when the spa was at its most dynamic. Much is known about the politics of the spa; the role taken by its principal medical and administrative leaders; the management and constitution of the waters; and the cultural appropriation of Māori customary rights. Much less is known, however, of the physical therapists and their practices. And so, if Rotorua represents the most concentrated example of physical therapy practice in 19th century Aotearoa/New Zealand, we must conclude that little evidence exists for physical therapies in Aotearoa/New Zealand. How then might we explain this lack, given the popularity of these approaches to health care in Europe and North America in the same period?

DISCUSSION

The physical therapies were some of the most popular and widely used therapies in 19th century Europe and North America (see, for example, the detailed account of 19th century physical therapies in Krusen, 1969). Prior to the discovery of germ theory in the 1880s, many doctors had been physical therapists, routinely using massage and manipulation, electrotherapy, hydrotherapy and remedial gymnastics in their treatments (Ottosson, 2010, 2011). Physical therapies had become popular among the leisured classes, partly as a result of growing anxieties about the pace of life, but also as an expression of one's cultural sophistication and urbane elitism. Only those with surplus time and money, for example, could afford to engage a

8 Meaning constipated, slowness, or being unforthcoming. It can refer to speech and general demeanour as well as bodily functions.

masseur at home. This was, it must be remembered, before a time when physical therapies were widely available through an organised public health system.

In Gilded Age America, physical therapies and dietetics had become a mainstay in the management of conditions like hysteria, nervous exhaustion and neurasthenia (Williams et al., 2004), while other patients with conditions as diverse as sciatica, obesity, talipes, melancholia, anorexia, dropsy and fractures were routinely massaged.[9] Those who could afford it, relieved their weariness by travelling to Bath, Baden-Baden or Aix-les-Bains to spend months 'taking the waters;' sitting in pyretic baths; Bergonie Chairs; or being rejuvenated with galvanic and faradic batteries.

Why then, was so little of this seen in Aotearoa/New Zealand? It is reasonably clear from the available evidence that Māori used physical therapies in much the same way that the settler population knew, but that the ready availability of seemingly free therapeutic resources (such as geothermally-heated water), and the potential to exploit these for profit, proved too seductive for colonialists who were quick to acquire land and establish restrictions around access to services. Progress in developing nation-wide therapeutic services was also extremely slow. War, isolation, and the settlers' fierce individualism may have served to facilitate individual claims to Aotearoa/New Zealand's abundant resources, but it did little to develop a sense of community or build infrastructure that could have been to the betterment of the whole population. Until 1891 and the election of the first Liberal government, little collective enterprise had been considered in Aotearoa/New Zealand, so there were few opportunities for organised health care to become established.

There were few metropolitan centres to sustain physical therapists before 1900, and most people were employed in primary industries (gold mining, timber milling, farming, etc.). Migrants who were skilled ancillary workers were not encouraged, and few opportunities were created (through the building of hospitals or community clinics, etc.) to allow them to prosper. Those that did offer therapeutic services did so as part of a range of other occupations (Matthew Guinan, for instance), or operated across a range of different locales (see, for example, Herman Roth). It would not be until the creation of the four main spa centres, and the concerted shift towards welfarism taken by the Liberal Party after 1891, that the physical therapies would become anything other than an occasional luxury for those who could afford the treatment.

By comparison with attitudes that followed World War I, the thousands of people who were injured in workplace accidents before 1900, or who became ill as a result of community-acquired infection, were expected to fend for themselves or fall back on family and friends. If someone fell down a sinkhole at the Gabriel's Gully goldfields and broke his leg, he would have no formal health care to fall back on, and there would certainly be no post-surgical rehabilitation, paid leave or workplace compensation. These innovations would only come into effect after 1918, around the same time that professions like physiotherapy were becoming registered health professions.

One of the characteristic features of health care in the 20th century was the realisation that many individuals could not adequately prepare for all of life's adversities on their own, and that 'the state' was responsible for causing many social ills. The welfarism pioneered internationally by successive Aotearoa/New Zealand governments after 1891 made it possible for those people who could not otherwise afford physical therapy to obtain it through the public health system. However, no such vision existed prior to 1900. Thus, the answer to the question 'why was there so little evidence of physical therapy in Aotearoa/New Zealand before 1900' may well lie in an agglomeration of all of these cultural, environmental, political and social issues, resulting in the creation of very few opportunities for physical therapy to prosper.

Our data points to the fact that for physical therapy to prosper, it requires either:

1. A culture in which physical therapies are freely available (Māori culture before colonisation);
2. A significant population of people with enough surplus time and money to afford the luxuries of massage, spas, and galvanic baths; or
3. A public health system that can share the burden of cost among the whole population.

Our evidence suggests that without one of these three elements in place, physical therapy remains a relatively marginal social function. This is not to say that people do not engage in physical therapies in their own homes, or in other informal situations, only that we have found that it cannot elevate above these levels without the necessary cultural paradigms identified above.

As Aotearoa/New Zealand and many other developed economies complete the process of dismantling the welfare state and embrace neo-liberal values of individual autonomy and self-sufficiency, it will be interesting to see how these economic, political and social transformations may affect physical therapy practices in the future. For much of the 20th century, physical therapies have been formalised into powerful occupational identities (*physiotherapy* in Anglo-centric countries, *physical therapy* in North America). These professions have received considerable legislative protection and valuable access to the public sector. Millions of patients have received physiotherapy as a result of these ideologically informed structural arrangements. With the demise of the welfare state, it is possible that professions like physiotherapy will find themselves operating in a cultural context not dissimilar to Aotearoa/New Zealand in the 19th century. Here, physical therapy will be available to those who have the surplus time and money to afford it, and those who cannot will have to make do as best they can. Having become a profession that was able to serve the whole community, regardless of ability to pay, physiotherapy might find itself being a profession only able to service a population of what Barsky called the 'worried well' (Barsky, 1988). Moves by physiotherapy programmes internationally to develop graduate

[9] See the work of John Harvey Kellogg – the founder of the Kellogg company – and the work undertaken at the Battle Creek Sanatorium, for instance (Schwarz 2006)

entry programmes and accelerate pathways to specialist status appear to be pre-figuring this shift. How physiotherapy will meet the needs of the vast populations of people with the worst, most complex, co-morbid health and lifestyle problems – characteristically those least able to afford physical therapy – has yet to be addressed by the profession.

LIMITATIONS

There are a number of limitations we should consider in presenting our analysis of these data. Firstly, we are aware that the primary data search concentrated on nationally available archives. No trawl was undertaken of resources available in the regions. This will have limited some of the specificity of the overall project, and certain sites (particularly Hanmer Springs, Te Aroha, Waiwera, and a number of other significant population centres), have been under-represented as a result. Furthermore, the findings represent only a snapshot of the full archive of data available.[10] Isolating back pain and fractures from the full panoply of Māori physical therapies, for example, not only imposes a reductive 'western' taxonomy on what were otherwise embodied and environmentally-connected assemblages of practices, but it also reinforces the idea that the most appropriate measure of validity for Māori healing practices is one that satisfies European and North American cultural norms. This is plainly an unfortunate consequence of the necessity to present historiographic data in a form that can have meaning for a particular readership. It would be useful in future to do further work on the archive and explore different therapeutic practices in a manner that best reflects their individual ideologies and epistemological presuppositions. Finally, much of the data and subsequent reporting is heavily gendered. As with many accounts of 19th century cultural life, men appear as society's principal architects. Women's roles in 19th century Aotearoa/New Zealand are almost entirely absent from formal accounts of practice, legislation, government and social reform. Yet we know that many women were influential healers and therapists, missionaries, nurses, teachers, counsellors, advocates, organisers and activists (Heggie, 2015; Macgregor, 1973). Their relative absence from formal accounts of 19th century Aotearoa/New Zealand mirrors many similar historiographic accounts which tend to privilege white, male, straight, affluent and Eurocentric accounts of events. As two white, male, straight, Eurocentric authors, we are conscious of our privileged position in writing this account and have attempted to be sensitive to it throughout.

CONCLUSION

Over the span of these three papers we have sought to examine the role that the physical therapies played in Aotearoa/New Zealand in the 19th century. Knowing that physical therapies were very popular in Europe and North America and were widely practised by Māori, we wanted to examine why it seemed that massage and manipulation, electrotherapy, hydrotherapy and remedial exercise were largely absent from official accounts of the period. The study explored whether evidence existed of widespread physical therapy practice in 19th century Aotearoa/New Zealand, and concluded that there was little evidence of any significant physical therapy practice undertaken in the century before the physical therapies became organised as the physiotherapy profession. We have speculated that this is because Aotearoa/New Zealand settler systematically marginalised many of the free therapeutic practice of Māori, but offered little to formally replace them, leaving most people to fend for themselves. It was only the introduction of welfarism that followed the election of the Liberal government of 1891 that provided the necessary foundations for the kinds of physical therapies familiar to most readers. With the demise of the welfare state and a return to a neo-liberal emphasis on autonomy and independence, it will be interesting to see whether evidence from Aotearoa/New Zealand in the 19th century can provide valuable insights into the challenges being faced by physiotherapists in the 21st century.

KEY POINTS

1. The development of Rotorua Spa represents the first attempt to provide centrally-organised physical therapy services in Aotearoa/New Zealand.
2. The spa drew on many European and North American influences and embedded colonial values in its design and organisation.
3. Physical therapies were really only available to those with enough surplus time and money to afford them, and as such were slow to develop in Aotearoa/New Zealand prior to 1900.

DISCLOSURES

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Changes in walking levels of people with stroke following discharge from hospital: A pilot study

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ABSTRACT

This study aimed to investigate changes in walking levels of independently mobile individuals following a stroke between the inpatient setting and the home environment, both directly after discharge and in the longer term. Forty-three participants who had a stroke as their primary diagnosis and who could walk 10 metres without the support of another person on discharge from hospital completed the study. The Step-Watch Activity Monitor, six minute walk test, 10 metre walk test, and the Stroke Impact Scale were used to measure outcome. There was a significant increase in number of steps taken per day between 3-14 days and 4-6 months post-discharge ($p=0.0001$). Walking speed, six minute walk test, perceived mobility and perceived ability to perform activities of daily living all had strong positive correlations with average amount of steps at 4-6 months post-discharge from hospital and could therefore be used as predictors of walking level in the longer term. However, step counts are still below those required for health benefits. This suggests it is beneficial for further emphasis to be placed on increasing activity levels for people after stroke, even if they are able to mobilise independently on discharge home.

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Key words: Stroke, Step count, Walking, Community.

INTRODUCTION

Stroke affects approximately 6000 New Zealanders per year (Tobias, Cheung, Carter, Anderson & Feigin, 2007). Although the incidence of stroke is increasing due to an ageing population, mortality is decreasing (Ministry of Health, 2014; Tobias et al., 2007). This means that an increasing number of people are living with the effects of a stroke. Stroke has a physical, psychological and financial impact on both individuals and their communities (Gbiri, Olawale & Isaac, 2015). If current trends continue, there will be 70 million people living with stroke globally by 2030 (Feigin et al., 2014), thus increasing the burden on health care systems and communities. Stroke can reduce a person's quality of life by limiting their ability to participate in home and community life (Carod-Artal, Egido, González & Seijas, 2000; Chen & Rimmer, 2011). Therefore an important goal after stroke is to support people to reintegrate into their community. A factor in achieving this is for people after stroke to have adequate levels of physical activity including the ability to walk in their community (Van Peppen et al., 2004).

It is well documented that activity levels of people after stroke are low not only during inpatient rehabilitation but also after reintegration into the community (Bernhardt, Dewey, Thrift & Donnan 2004; Skarin et al., 2014; West & Bernhardt, 2012). In the inpatient setting, studies have found that patients spend most of their time inactive, alone or in their rooms (Bernhardt et al., 2004; Skarin et al., 2014; West & Bernhardt, 2012). Even after discharge back to community life, people have reduced levels of physical activity after stroke (Field, Gebruers, Sundaram, Nicholson & Mead, 2013; Rand, Eng, Tang, Jeng & Hung 2009; Tudor-Locke et al., 2011). For instance, a recent meta-analysis of studies in 14 different countries (including New Zealand and Australia) showed that people after stroke take an average of 4355.2 steps per day (Field et al., 2013). This is well below the recommended 7000 steps for the older adult population (Tudor-Locke et al., 2011) and mirrors evidence that people participate in 36% less activity after stroke than normative values for community dwelling individuals over the age of 60 (Rand et al., 2009).

Decreased levels of physical activity during hospitalisation result in deconditioning (Billinger et al., 2014), which may contribute to low activity levels at home despite the greater functional demands of a home environment compared to a hospital environment. Although we know that activity levels of people after stroke remain below the recommended levels for maintaining health and quality of life (Billinger et al., 2014; Field et al., 2013), we do not yet have sufficient information about changes in activity levels from discharge to home living, in the shorter and then the longer term. A clear description of changes in activity levels over time will guide rehabilitation goal setting and help create effective and efficient interventions after stroke. The main aim of this study was to investigate changes in walking levels of independently mobile individuals following a stroke between the inpatient setting and the home environment, both directly after discharge and in the longer term.

METHODS

This was a longitudinal observational study which took place between 2013 and 2015 in a large district health board in a metropolitan area of New Zealand. Ethical approval for this study was granted by the University of Otago Human Ethics Committee (13/002).

Recruitment and participants

Hospitalised patients with stroke were recruited from a stroke rehabilitation unit and an acute stroke unit. Individuals were eligible to participate in this study if they were hospitalised with a stroke as their primary diagnosis, could walk 10 metres independently prior to discharge with or without an aid and could apply (or have support to apply) an activity monitor around their ankle for waking hours over three days. Individuals were excluded if they could not walk 10 metres prior to the stroke, were living in a private care facility, were medically unwell or their cognition precluded them from providing informed consent.

Physiotherapists based in the stroke rehabilitation unit and acute stroke unit, and who were not otherwise involved in the study, screened all patients against a recruitment checklist and provided eligible people with an information sheet. People who were interested in participating were met by a member of the research team (BB, RB, ET, also physiotherapists, but not working on these wards), to explain the study further. People provided written informed consent to participate in the study.

Procedures

Demographic data regarding each participant's age, sex and classification/location of stroke were collected at the time of recruitment from patient notes. Ethnicity was collected by self-report. Further information including walking aids, living situation (alone or with others) and an estimation of house size (small, medium or large) was collected by the research team at the time of recruitment.

Primary and secondary outcome measures were completed by the participant's treating physiotherapist during their inpatient stay for participants recruited from the stroke rehabilitation unit (Assessment A) and by community stroke physiotherapists on two home visits after discharge from hospital (Assessments B and C). The first community visit was between 3-14 days after discharge and the second occurred at 4-6 months.

The primary outcome measure used was the Step-Watch Activity Monitor (SAM). The SAM consists of an accelerometer and electronic filter that detects leg movement to determine the amount of steps taken by its wearer. It is worn above the lateral malleolus on either leg. Information from the SAM was downloaded through a docking system to a computer, with no information displayed on the SAM. Therefore, participants were unable to see how many steps they took. The SAM is a valid and reliable measure of steps taken per day in stroke (Mudge & Stott, 2009; Storti et al., 2008). Participants were asked to wear the SAM from waking to going to bed for three days.

The six minute walk test (6MWT), Stroke Impact Scale (SIS) and the 10 metre walk test (10MWT) were used as secondary outcome measures. The 10MWT and 6MWT have been demonstrated as valid and reliable measures of walking ability after stroke (Enright et al., 2003; Flansbjer, Holmbäck, Downham & Lexell, 2005; Kosak & Smith, 2005; Wevers, Kwakkel & van de Port, 2011; Wolf et al., 1999). These measures were selected to provide information on walking speed and endurance. For both outcome measures, assistive devices or orthotics could be used but were recorded and kept consistent from Assessment A through to C. The SIS is a self-rated questionnaire which indicates how stroke has subjectively impacted health and quality of life for the participant. It is a stroke specific, self-reported measure that contains eight domains: strength, hand function, activities of daily living (ADL), mobility, communication, emotion, memory and thinking, and participation, and has been demonstrated to be reliable, valid and sensitive to change (Duncan et al., 1999).

Participants came from either a stroke rehabilitation unit or an acute stroke unit. Those from the stroke rehabilitation unit had three sets of data collected; once in hospital (Assessment A) and twice in the community (Assessments B and C). Participants from the acute stroke unit only had two sets of community data collected (Assessments B and C). No inpatient data could be collected due to insufficient time between consenting to be in the study and being discharged home. Community data were collected at the participant's home, with the 6MWT carried out on the pavement outside the home or in the participant's driveway. This was consistent for Assessments B and C.

Analysis

The distribution of data was examined for normality using the Kolmogorov-Smirnov test (Antonius, 2012). Data were also assessed for homoscedascity and linearity by graphing the data. Wilcoxon signed rank tests with Bonferroni correction were used to examine the difference between steps over the three time periods. A Pearson's correlation analysis was performed to explore the relationship between different components of the SIS or walking speed with average number of steps (Antonius, 2012). Linear regression models were fitted to account for the impact of age on step counts with any predictive measures.

RESULTS

Sixty-four people were identified by the recruitment team for the study from the beginning of 2013 to July 2015. Fifty-one participants consented to participate in the study, but six people withdrew from the study and there were two incomplete data sets. Therefore a total of 43 people completed the study. See Figure 1 for the flow of participants through the study. The mean age of these participants was 75.8 years (SD 7.5). The group characteristics are presented in Table 1. All data were normally distributed except walking speed and mean steps at 3-14 days post-discharge. Assumptions of linearity and homoscedasticity were met with all data. Main results are shown in Table 2.

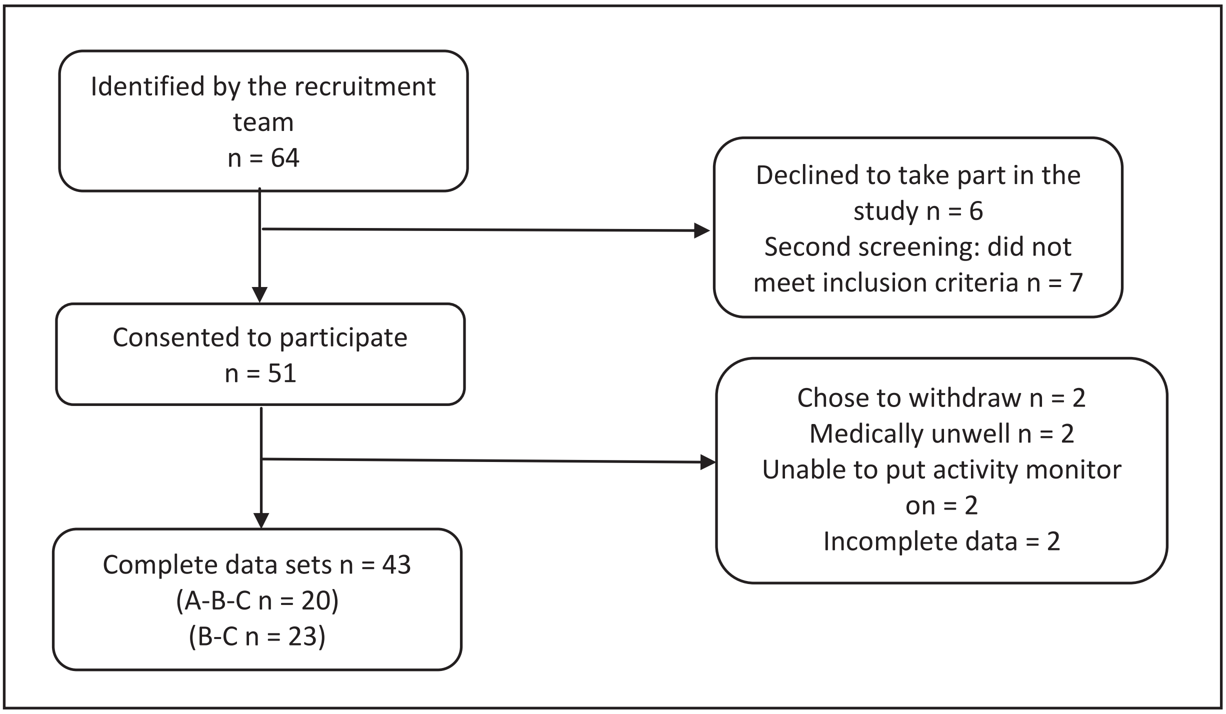

Figure 1. Flow chart outlining study recruitment, dropout and completion.

Table 1: Group characteristics

	n (%)
SEX	
Male	25 (58.1)
Female	18 (41.9)
ETHNICITY	
NZ European	39 (90.7)
Māori	1 (2.3)
Other European	2 (4.7)
Other (Russian)	1 (2.3)
CLASSIFICATION OF STROKE	
PACI	15 (34.9)
LACI	11 (25.6)
POCI	11 (25.6)
ICH	2 (4.7)
Multiple infarcts	1 (2.3)
SIDE OF STROKE	
Left	18 (41.8)
Right	21 (48.8)
Bilateral	4 (9.3)
LIVING ALONE	9 (20)

Notes: PACI, Partial anterior circulatory infarct; LACI, lacunar circulatory infarct; POCI, posterior circulatory infarct; ICH, inter-cerebral haemorrhage.

A Wilcoxon Signed Rank Test revealed a significant increase in number of steps taken (as measured by SAM) between 3-14 days post discharge and 4-6 months post discharge with a medium effect size, ($p=0.0001$). The mean number of steps increased from 2839.5 (SD 1324.9) at 3-14 days to 3665.7 steps (SD 1787.8) at 4-6 months post-discharge. There was also a significant change between inpatient data and 3-14 days post discharge ($p = 0.011$) as well as inpatient data and 4-6 months post discharge ($p=0.0001$), although only 20 participants had been measured for the initial data set (Assessment A).

In addition to step count, walking speed over 10 metres and distance walked in six minutes were also measured. Both 10MWT and 6MWT were found to have a large positive correlation with steps per day at 4-6 months post-discharge ($r=0.59$, $p<0.0001$; $r=0.68$, $p<0.0001$, respectively). Four separate linear regression models were fitted to see if there was an impact of age on the step counts at 4-6 months post-discharge. Results were, however, consistent at all ages. All secondary outcome measures still had an individual significant effect after adjusting for age.

Additionally, relationships between mean number of steps 4-6 months post discharge, and components of the SIS, were investigated using the Pearson correlation coefficient. There was a strong positive correlation between perceived mobility and mean number of steps 4-6 months post-discharge, ($r=0.60$, $p=<0.0001$), with greater perceived mobility being associated with greater number of steps. Similarly, a large correlation ($r=0.57$, $p<0.0001$) was also found with perceived ability to perform activities of daily living and number of steps 4-6 months post discharge. No significant correlations were found between any other relevant categories of the SIS (recovery, mood, strength and community participation) and number of steps 4-6 months post-discharge.

Table 2: Objective outcome measures compared over three time periods

Outcome Measure	Assessment A	Assessment B	Assessment C
Steps count, M (SD)	1996.6 (820.3)	2839.5 (1324.9)	3665.7 (1787.8)
6MWT distance m, M (SD)	233.7 (86.2)	336.6 (150.5)	359.7 (124.5)
10MWT speed m/s, M (SD)	0.80 (0.25)	1.19 (0.53)	1.4 (0.65)

Notes: 6MWT, Six minute walk test; 10MWT, Ten metre walk test; M, Mean; SD, standard deviation.

Ten metre walk test speed and 6MWT distance at 3-14 days post-discharge were assessed as predictors for mean amount of steps taken 4-6 months post-discharge. There was found to be a positive correlation, ($r=0.49$, $p=0.001$ and $r=0.36$, $p=0.019$ respectively) for both variables. A faster 10MWT speed and larger 6MWT distance at 3-14 days post-discharge were found to be associated with a greater amount of steps 4-6 months post-discharge. Furthermore, both the perceived mobility and ADL ability components of the SIS at 3-14 days post-discharge had significant positive correlations with amount of steps 4-6 months post-discharge; $r=0.49$, $p=0.001$ and $r=0.58$, $p<0.0001$ respectively. Thus larger scores in perceived mobility and ADL at 3-14 days post-discharge were associated with a greater amount of steps four months post-discharge. This indicates that all these variables could be used as predictors of daily step count for people post-discharge after stroke.

DISCUSSION

The primary aim of this study was to investigate changes in walking levels of independently mobile individuals following a stroke between the inpatient setting and the home environment, both directly after discharge and in the longer term. Our results showed a significant increase in the number of steps per day between inpatient stay, 3-14 days post discharge and 4-6 months post discharge. In addition, there was a strong positive correlation between 10MWT speed, 6MWT, SIS mobility and SIS ADL scores with steps per day at 4-6 months post discharge. The study also demonstrated that 10MWT speed, 6MWT, SIS mobility and SIS ADL scores directly after discharge could be used as predictors of walking levels in the longer term. Faster 10MWT speeds, increased 6MWT distance, higher SIS mobility and ADL scores at 3-14 days post discharge were correlated with a greater amount of steps 4-6 months post discharge. There was no correlation between other components of the SIS and daily step count, suggesting that SIS domains other than mobility and ADL cannot be used as predictors for walking levels.

Our study supports that of Manns and Baldwin (2009) who conducted a longitudinal observational study investigating differences in step count pre- and post-discharge in a stroke population. Both ours and the study by Manns and Baldwin (2009) had a similar increase in step count, of approximately 800 steps. Although Manns and Baldwin (2009) had a higher initial (5411) and final (6195) step count than in our study, Manns and Baldwin had a younger mean population age by approximately eight years. Similarly Shaughnessy, Michael, Sorkin and Macko (2005) and Moore et al. (2013) investigated walking activity of people after stroke using step count prior to discharge and found that people took 1536 (Shaughnessy et al., 2005) and 3111 (Moore et al., 2013) steps per day. This correlates with our participants who walked an average of 1997 steps per day as inpatients, again illustrating low inpatient activity within the stroke population (Field et al, 2013; Rand et al., 2009; Tudor-Locke et al, 2011). Participants' walking speeds according to the 6MWT and 10MWT were comparable to previously identified speeds in people with chronic stroke of similar age to those in our study (Flandbjer et al., 2005). However comparing our participants' walking speed with established norms for community dwelling older adults, we see that our participants' speeds were below the established norms even at 4-6 months post-discharge from hospital. For instance Steffan, Hacker and Mollinger (2002) found an average 6MWT distance of 499m and a fast 10MWT speed of 1.77m/s for the 70-79 age group. While the mean age of our participants is within this age range, our 4-6 month 6MWT and 10MWT results were below these norms (360m and 1.4 m/s), meaning that our participants with stroke did not reach the expected levels and speed of walking as age matched peers. This may be in part due to participants in our study still being in a sub-acute phase of recovery. However, despite slow walking speeds amongst our participants, the mean walking speed for our participants when inpatients was faster than the suggested speed of 0.66m/s needed to achieve community ambulation (van de Port, Kwakkel & Lindeman, 2008).

Our study has helped to establish how walking activity for people after stroke changes in the early stages following discharge from the inpatient setting. Such knowledge can be used to help guide goal setting in stroke rehabilitation by establishing norms for early post discharge activity levels. Community living demands the ability to mobilise safely and efficiently around the home and into the community, which requires adequate endurance and speed. The increase in 10MWT speed and 6MWT distance found in our study on return home may be explained by the requirement to adapt to these more demanding environments. However, at initial discharge people are likely to have a degree of deconditioning due to reduced activity over the inpatient stay (Bernhardt et al., 2014; West & Bernhardt, 2012). Deconditioning could impair people's ability to undertake functional activities on return home after stroke, limiting their speed of recovery and leading to lower activity levels. Therefore, encouraging people with stroke to be more active in the inpatient environment could lead to a higher number of steps per day at discharge. A higher step count at discharge would lead to a higher step count on return home, and a further increase at 4-6 months post discharge. In particular, targeting people who have low walking speeds after stroke in the inpatient setting or on returning to the community, may better guide rehabilitation effort. However, previous studies have suggested that good outcomes on these standardised walking measures do not necessarily indicate people have resumed community ambulation (Lord, McPherson, McNaughton, Rochester & Weatherall, 2004). Instead self-reported measures have been suggested as more useful indicators for community ambulation (Lord & Rochester, 2005). Given that perceived walking ability and ADLs according to the SIS were strong indicators for step count at 4-6 months post-discharge, it may be that better utilisation of these measures by clinicians could enable more targeted rehabilitation interventions for walking activity. Further research is required to establish specific data ranges for these outcome measures that alert potential 'at risk' people for low walking activity in the longer term after stroke.

People with neurological conditions, including stroke, have been found to need more activity than their unaffected age related peers in order to gain health benefits and prevent secondary comorbidities (Billinger et al., 2014; Gallanagh, Quinn, Alexander & Walters, 2011). Our study showed activity levels of participants were too low to gain health benefits, potentially leading to a cycle of increased comorbidities, further decreased activity and potential for re-hospitalisation. An ageing population and decreasing mortality from stroke will further increase the number of people with stroke potentially entering this cycle, which has the potential to exponentially increase the socioeconomic burden of stroke on the health care system. Therefore, it is imperative that we place more emphasis on increasing physical activity throughout the entire rehabilitation process. For example, in the hospital setting we could increase stimulation for walking activity by offering group activities for motivation (Eng et al., 2003) and encouraging people to be more engaged in rehabilitation activity, such as walking, outside of treatment sessions. In the community, easily accessible stroke specific exercise classes would not only improve activity levels but empower people after stroke and encourage support within a local stroke population. Pedometers or pedometer-like devices could also motivate people after stroke to increase their activity levels as they can independently monitor the progress towards their goals (Tudor-Locke, 2002).

Our study had some limitations. First, this study had a small sample size, particularly relating to inpatient data. This could be due to the strict inclusion criteria coupled with a busy hospital environment which meant not all possible participants were screened and invited into the study. Additionally only a specific cohort, i.e. those who were more physically able, was investigated. Furthermore our data were collected, both on the ward and in the community, by physiotherapists who may have also been a participant's treating physiotherapist. This means there was potential for bias both in terms of assessment by the person collecting the data, and performance of participants who may have wished to 'please' their physiotherapist, thus instituting a potential Hawthorne effect (Jones, 1992). However, the outcome measures chosen for this study have high inter-reliability and validity and are well supported in the literature for use in the stroke population (Duncan et al., 1999; Enright et al., 2003; Flansbjer et al., 2005; Kosak & Smith, 2005; Wevers et al., 2011; Wolf et al., 1999). SAMs are the most reliable movement sensors at low gait speeds and are equal to other pedometers at medium and high gait speeds (Mudge & Stott, 2009; Storti et al., 2008). The SAM also blinded the wearer and assessor to its readings with results being uploaded electronically. Good reliability has been demonstrated for the SAM when worn for three consecutive days (Mudge & Stott, 2008), suggesting that the three days of SAM data would give a valid measure of walking levels. However, the accuracy of SAM relies on the apparatus being applied for all waking hours, thus it is possible steps were not recorded if the SAM was not applied for all waking hours.

This study supports contemporary literature about activity levels of people after stroke in reporting that levels are lower than those required for health benefits. Future research could build on our study by exploring rehabilitation interventions to target ways to increase walking activity especially amongst those people after stroke who can be identified as being of 'high risk' according to predictive outcome measures.

CONCLUSION

Participants increased their number of steps taken per day over the months following discharge from hospital. This increase was predicted by walking speed and perceived function directly after discharge. However step counts are still below those required for health benefits. This suggests it is beneficial for further emphasis to be placed on increasing activity levels for people after stroke, even if they are able to mobilise independently on discharge home.

KEY POINTS

1. After stroke people increased the number of steps they took per day between the inpatient setting and the months after discharge from hospital, but they are still below those required for health benefits.
2. 10MWT speed, 6MWT, SIS mobility and SIS ADL at 3-14 days post-discharge were predictors of the number of steps taken at 4-6 months. This knowledge can help to identify people at risk of low activity.
3. Further emphasis should be placed on increasing activity levels over the entire rehabilitation process to reduce the future burden of stroke.

PERMISSIONS

Ethical approval for this study was granted by the University of Otago Human Ethics Committee (13/002).

DISCLOSURES

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Rotator cuff repair protocols: a survey of current New Zealand practice

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ABSTRACT

Rehabilitation following surgical rotator cuff repair may enable return to pre-injury function. Optimal recovery is facilitated by the use of post-operative protocols that enhance communication between the surgeon and physiotherapist. The purpose of this study was to describe the rotator cuff repair rehabilitation protocols currently used in New Zealand. Orthopaedic surgeons practising in New Zealand were contacted to determine their current rehabilitation protocols. Length of immobilisation and exercise progression following surgical repair were analysed across weekly timeframes from the day of surgery until nine months post-operatively. The response rate was 55% with protocols received from 31 surgeons. Post-surgical rotator cuff protocols currently in use in New Zealand are predominantly determined by weekly time periods which vary from surgeon to surgeon. Immobilisation was most commonly recommended for four to six weeks, pendular exercises were started the week of surgery, active exercises commenced at six weeks, followed by resisted exercises at twelve weeks. Few protocols based the rehabilitation upon tissue quality and size of rotator cuff tear. Level of detail regarding sets and repetitions of exercises also differed between protocols. Variability across protocols was evident regarding the recommended activity level and time period from surgery. Consideration of tissue quality, size of the tear and strength of the repair is recommended to facilitate optimal results.

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Key words: Surgical repair, Tendon, Rehabilitation, Rotator cuff

INTRODUCTION

Rotator cuff tears are a frequent source of shoulder pain, with a prevalence of 25% in people over 60 years, rising to 50% in those over the age of 80 years (Tashjian, 2012; Yamamoto et al., 2010). A recent study in the United States of America (USA) reported that the incidence of rotator cuff repairs has increased by 238% since 1995 (Ensor, Kwon, DiBeneditto, Zuckerman, & Rokito, 2013). This increase may be due to improved imaging techniques, increased availability of surgery and an ageing population, which may lead to further demand for surgery (Ensor et al., 2013). In New Zealand, the total number of rotator cuff repairs in the 2015/2016 financial year was 3,205, with associated surgical and physiotherapy costs borne by the Accident Compensation Corporation (ACC) of $31,125,063 and $1,116,506, respectively (ACC, personal communication, September 7, 2016). In the USA, between 200,000 and 300,000 rotator cuff tears are surgically repaired each year (Colvin, Harrison, Flatow, Egorova, & Moskowitz, 2012), at a cost of between $US10,000 and $US17,000 per surgery (Vitale et al., 2007); total annual expenditure in the USA is estimated at between $US3-12 billion dollars (McElvany, McGoldrick, Gee, Neradilek, & Matsen, 2015). Additional post-surgical rehabilitation costs of approximately $US3,000 per person (Arshi et al., 2015) mean that the total expenditure is considerable.

Rehabilitation following surgical repair can involve significant periods of time, with some protocols providing guidance to therapists for 4 to 6 months, but this can be extended by complications such as tendon non-healing, which varies from 12% to 94% (Boileau et al., 2005; Galatz, Ball, Teefey, Middleton, & Yamaguchi, 2004; Kim et al., 2012; Thigpen et al., 2016). Tendon healing can be affected by various surgical, mechanical and patient specific factors following surgical repair (Mall, Tanaka, Choi, & Paletta, 2014). Patient specific factors associated with decreased healing include large sized tears (>3cm), an increased number of affected tendons (Boileau et al., 2005; Cho & Rhee, 2009; Gulotta et al., 2011; Le, Wu, Lam, & Murrell, 2014), fatty infiltration (Cho & Rhee, 2009; Chung, Kim, Kim, Kim, & Oh, 2013), the extent of tendon retraction (Charousset, Bellaïche, Kalra, & Petrover, 2010; Meyer, Wieser, Farshad, & Gerber, 2012) and the quality of bone stock (Chung, Oh, Gong, Kim, & Kim, 2011). Decreased tendon-to-bone healing has also been associated with increased patient age (Boileau et al., 2005; Cho & Rhee 2009; Gulotta et al., 2011). Excessive load on the tendon in the early post-operative phase has been shown to be detrimental to healing (Sonnabend, Howlett, & Young, 2010; Thomopoulos, Williams, & Soslowsky, 2003). However, non-healing may also result from complete lack of load, as a balance of load is required to promote optimal healing (Galatz et al., 2009). Optimally loading the tendon has been shown to increase fibroblast proliferation, and synthesis and organisation of collagen (Liu, Yang, Al-Shaikh, & Lane, 1995). Early loading of the tendon with passive range of motion (ROM) exercises may not be detrimental to healing in small to medium sized tears (< 3cm) (Keener, Galatz, Stobbs-Cucchi, Patton, & Yamaguchi, 2014; Kim et al., 2012). However, people with larger sized tears (> 3cm) may be prone to an increased re-tear rate with early passive ROM (Lee, Cho, & Rhee, 2012).

Rehabilitation following rotator cuff repair is guided by post-surgical protocols which may recommend a period of immobilisation followed by progressive loading of the tendon through passive, active and resisted exercise (Littlewood et al., 2015). Currently, there are a lack of detailed published guidelines for rehabilitation following rotator cuff repair in New Zealand (Accident Compensation Corporation, 2003). The aim of this study was to describe rotator cuff repair rehabilitation protocols currently used in New Zealand. It was hypothesised that, although there would be variation amongst protocols, they would contain information regarding restrictions on immobilisation, passive and active ROM, and resisted exercises.

METHODS

In order to establish the current protocols available to New Zealand physiotherapists, orthopaedic surgeons with a special interest in shoulder surgery were identified via the New Zealand Orthopaedic Association and contacted for their post-surgical rotator cuff protocols, between May and December 2014. Ethical approval was not required as this study was considered a clinical audit because it did not involve human participants and the protocols received from surgeons were de-identified. In addition, some protocols were publicly available documents. A protocol was defined as any pre-printed formal protocol, website protocol, or a protocol received via email describing the implementation of various treatment modalities at specific times in order to maximise tissue healing and minimise joint stiffness (van der Meijden et al., 2012).

Data from the protocols were extracted individually by two researchers (BH and MO) into a standardised data form, including the length of immobilisation, and the time at which passive, active and resisted exercises were commenced, as well as the duration of these exercises (van der Meijden et al., 2012). Consensus was reached in a single meeting by the researchers if disagreement existed over the protocols.

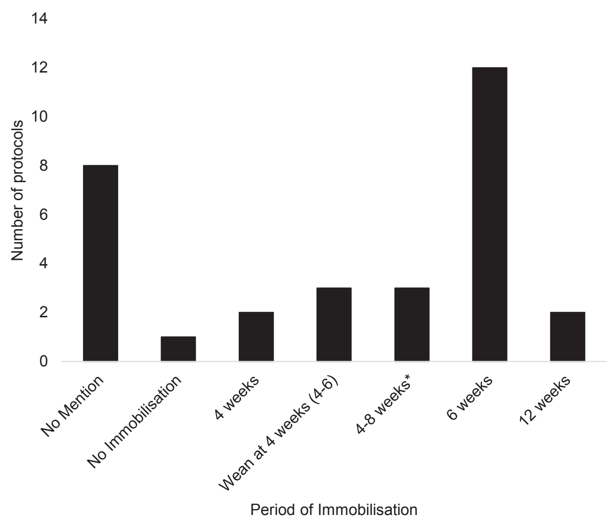
Pendular exercises and self-assisted shoulder flexion are common passive exercises that have been previously reported in a rehabilitation protocol (Millett, Wilcox, O'Holleran, & Warner, 2006) and were chosen to represent the passive phase of rehabilitation. As electromyographic (EMG) activity is low with these exercises, they were considered representative of passive exercise (Dockery, Wright, & LaStayo, 1998; Long et al., 2010; McCann, Wootten, Kadaba, & Bigliani, 1993). Active exercise was defined as "patient-generated movement" whereas resisted exercise was defined as movement undertaken with load applied (Petty, 2014). In instances where return to work/sport, and/or alternative therapies such as aquatherapy or cryotherapy were described in a protocol, these data were also extracted as such forms of therapy have been shown to enhance patient outcomes (Brady, Redfern, Macdougal, & Williams, 2008; Osbahr, Cawley, & Speer, 2002). Data from protocols which reported variation according to the size of the rotator cuff tear, the quality of tissue, or other variables such as the level of pain, were also documented.

RESULTS

Of the 56 surgeons who were contacted for post-surgical protocols, 31 (55%) responded, with protocols received from a wide geographical area throughout New Zealand. Eleven were in printed form, while 18 were written directly to the researchers in an email. One protocol referred to published literature (Millet et al., 2006) and one referred to an independent website (Moon Shoulder Group, 2008).

Immobilisation

Length of immobilisation varied from no immobilisation to twelve weeks. Twelve (39%) protocols recommended immobilisation for 6 weeks (Figure 1), and three (10%) specifically addressed the severity of the tear by requiring immobilisation for 4 weeks in cases of a small tear, and 6 or 8 weeks for a large tear.



* Period of immobilisation between 4 to 8 weeks dependent on tear size

Figure 1: Period of immobilisation recommended following rotator cuff repair (n=31 protocols)

Passive exercise

Pendular exercises were included in 22 (71%) protocols. Eighteen of these (58%) recommended pendular exercises in the first week following surgery (week 0) (Figure 2). One protocol introduced pendular exercises from week 1, another started these at week 2, while two delayed commencement of these exercises until week 4. Only five (16%) indicated the number of repetitions, which varied from two to four times per day. A third of the protocols (29%) did not contain any information on pendular exercises.

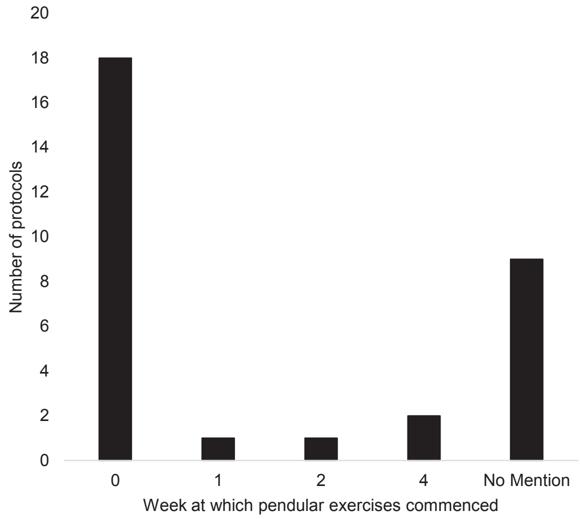


Figure 2: Time of commencement of pendular exercises (n=31 protocols)

Self-assisted shoulder flexion was recommended by 26 (84%) protocols. Two (6%) of these recommended an alternative exercise of table slides instead of supine self-assisted shoulder flexion. Eleven (35%) protocols commenced self-assisted shoulder flexion the week of surgery (week 0) (Figure 3). Seven (23%) restricted the range of shoulder flexion to 90° for a stipulated period of time, varying between 4 to 12 weeks. One protocol limited flexion to 45° until week 3, after which flexion could be increased to 90° until week 6. Four (13%) protocols accounted for tissue quality and size of the tear, by varying the commencement of self-assisted flexion from week 2 to 4 (two protocols) or from week 4 to 6 (two protocols). The two protocols (6%) that recommended table slides commenced this exercise at either week 0, or week 4. Five (16%) protocols made no mention of any passive flexion exercises.

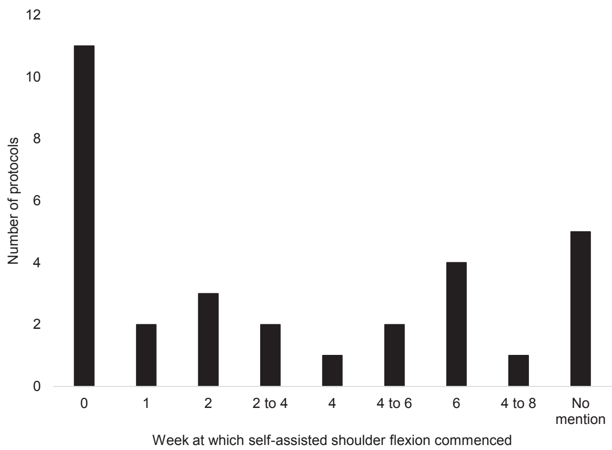
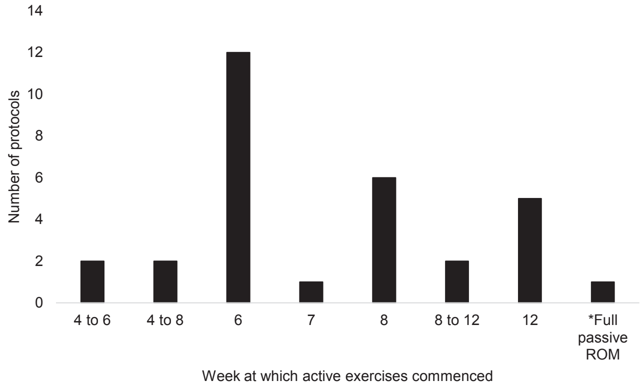


Figure 3: Time of commencement of self-assisted shoulder flexion (n=31 protocols)

Active exercise

All 31 protocols recommended the use of active exercise (Figure 4), commencing with exercises such as active shoulder flexion and light weight waist level activities. Active exercise commenced at week 6 in twelve (39%) protocols, at week 8 in six (19%), and at week 12 in five (16%) protocols. Six (19%) recommended adjusting the commencement of active exercise dependent upon other variables (e.g. size of tear and quality of tissue) at 4 to 6 weeks, 4 to 8 weeks, or 8 to 12 weeks. Active ROM was restricted until full passive ROM was achieved in one protocol.

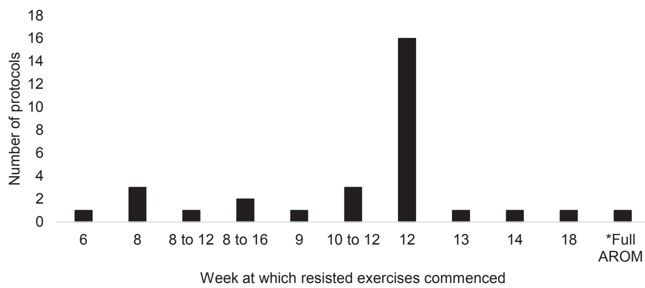


* Active movement commenced when full passive ROM was gained

Figure 4: Time of commencement of active exercises (n=31 protocols)

Resisted exercise

All 31 (100%) protocols recommended resisted exercise during rehabilitation (Figure 5). Sixteen (52%) protocols recommended commencement of resisted exercise at 12 weeks following surgery. Some protocols advised the physiotherapist to delay the commencement of resisted exercises depending on tear size and tissue quality. One (3%) protocol advised commencement from 8 to 12 weeks, two (6%) advised from 8 to 16 weeks and three (10%) advised from 10 to 12 weeks. Five (16%) protocols recommended starting resisted exercises with isometric exercises. Only two (6%) protocols indicated the number of sets and repetitions for strengthening. One recommended resisted dumb-bell exercises three times per week with three to four sets of 10 repetitions. The other recommended three sets of 10 repetitions of Thera-Band® (The Hygenic Corporation, Akron, Ohio) exercises, three times per day.



*Resisted exercises were commenced when full AROM was gained

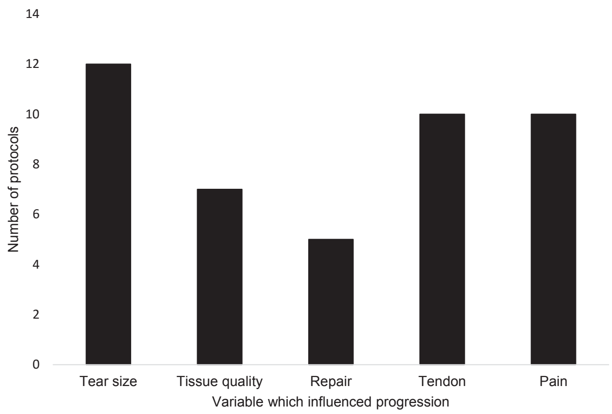
Figure 5: Time of commencement of resisted exercises (n=31 protocols)

Return to work or sport

Time frames for return to work were recommended by three (10%) protocols. Two (6%) suggested return to light work at 3 to 4 months, and heavy work at 6 to 9 months after surgery. One (3%) recommended return to work at 6 months. Return to sport was recommended in four (13%) protocols at various time frames, from 4 to 9 months post-operatively.

Other variables related to rehabilitation

Rehabilitation was altered depending on variables including the size of the tear, quality of the tissue, quality of surgical fixation, presence of pain and whether aquatherapy or cryotherapy was added. The size of the rotator cuff tear was considered in twelve (39%) protocols with progression delayed for large sized tears (Figure 6). Delayed progression of rehabilitation was recommended in seven (23%) protocols when the tissue was of poor quality and in five (16%) when tendon fixation was considered poor. Ten (32%) altered the rehabilitation according to the particular tendon involved, and treatment was varied in 10 (32%) if pain was present. Seven recommended slowing progression to reduce pain, while one advised caution with rapid progression if the patient had minimal pain. Two (6%) documented that ROM exercises be undertaken to the point of pain. Aquatic therapy was proposed as an adjunct in three (10%) protocols, while seven (23%) incorporated cryotherapy into the rehabilitation programme.



* Some protocols included more than one variable

Figure 6: Other variables considered to influence rehabilitation of rotator cuff repairs (n=31 protocols)

DISCUSSION

This study established that a wide variety of rotator cuff post-operative protocols are currently in use throughout New Zealand and highlights the need for further discussion regarding the optimal management following rotator cuff repair. The majority of protocols divided the gradation of rehabilitation into phases, including immobilisation, passive, active and resisted exercises; however, considerable variation was evident in the commencement and definition of these phases. Few protocols considered individual factors such as size of the tear, tissue quality or strength of the fixation.

Immobilisation

Immobilisation following a rotator cuff repair has been shown to increase viscoelastic properties and collagen organisation of the repaired tendon (Parsons et al., 2010; Thomopoulos et al., 2003). In the current study, the length of immobilisation varied across the protocols from no immobilisation to 12 weeks. The majority of protocols recommended immobilisation for 4 to 6 weeks, which is similar to current practice in the United Kingdom (Littlewood & Bateman, 2015). A review of randomised controlled trials, which compared the effect of early versus delayed rehabilitation on outcomes and re-tear rates, showed no adverse effect on outcomes or re-tear rates with early rehabilitation (Littlewood et al., 2015). Some of these studies may have been underpowered however, potentially leading to a Type II error or a false negative result (Littlewood et al., 2015). An optimal balance may be required between some immobilisation to protect the repair and some load to promote healing within the tendon (Galatz et al., 2009). The consensus statement from the American Society of Shoulder and Elbow Therapists (ASSET) on rehabilitation following arthroscopic rotator cuff repair recommends immobilisation for a period of four to six weeks (Thigpen at al., 2016). Both the ASSET consensus statement (Thigpen et al., 2016) and a recent sytematic review (Thomson, Jukes & Lewis, 2016) suggest consideration of tear size and tissue quality to be important, with the latter also advocating a period of immobilisation for four to six weeks for a large tear.

Passive exercise

The current study found that in general pendular exercises were initiated up to 4 weeks post-operatively. Small pendular exercises (20cm in diameter) performed in a position of trunk flexion generate less than 10% maximal voluntary contraction (MVC) of supraspinatus, whereas large, incorrectly performed pendular exercises can generate more than 15% of MVC of supraspinatus (Long et al., 2010). The ASSET consensus statement recommends protected passive ROM during the first 6 weeks after rotator cuff repair of small to medium sized tears (< 4cm), with EMG activity of 15% (Thigpen et al., 2016). Previous studies have defined passive exercise as below 20% MVC (Ellsworth, Mullaney, Nicholas, McHugh, & Tyler, 2004; Smith et al., 2006), below 10% MVC (Uhl, Muir, & Lawson, 2010), or below 5% MVC (Dockery et al., 1998).

The use of self-assisted shoulder flexion was initiated between 0-8 weeks post-operatively. As demonstrated in EMG studies, self-assisted shoulder flexion involves less supraspinatus activity than reciprocal pulleys; however, it has a higher level of muscle activity than pendular exercises (Dockery et al., 1998; Gurney et al., 2016; Murphy, McDermott, Petersen, Johnson, & Baxter, 2013). Many protocols did not identify the specific passive exercises to be used in rehabilitation yet therapists should be aware of the variability in EMG activity across passive exercises for individual muscles (Gurney et al., 2016).

Active exercise

Some of the protocols (39%) reported commencement of active exercise at 6 weeks following rotator cuff repair, but this is slightly later than current practice in the United Kingdom where active exercises commence between 4 to 6 weeks (Littlewood & Bateman, 2015). The strength of the repaired tendon is likely to only be up to 30% of normal at 6 weeks post-operatively and therefore unlikely to be able to withstand large loads or repetitive loading (Gerber, Schneeberger, Perren, & Nyffeler, 1999; Thigpen et al., 2016). Removal of an immobilisation sling necessitates active movement (Gurney et al., 2016). Few protocols provided examples of specific active exercises. The ASSET consensus statement recommends light muscle activities at chest level or below (Thigpen et al., 2016).

Resisted exercise

Over 50% (16/31) of protocols implemented resisted exercises at 12 weeks post-operatively. This is in agreement with a study on primates which found an increased number of Sharpey fibres connecting tendon to bone at 12 weeks following rotator cuff repair (Sonnabend et al., 2010). In animal studies, the strength of the repair is between 29% and 50% at 12 weeks (Gerber et al., 1999; Thigpen et al., 2016). The consensus statement by ASSET recommends progressing to strengthening from 12 weeks and to start with light strengthening when pain is well controlled (<2/10 on a numeric pain rating scale) and sufficient passive ROM has been achieved (Thigpen et al., 2016). Some protocols started a resistance programme with isometric exercises; however, care is needed as maximal isometric exercise may load the tendon more than isotonic exercise (Thigpen et al., 2016). Pain free exercise at low levels of MVC can provide a mechanical stimulus for mechanotransduction (Khan & Scott, 2009) and the progressive loading of tissue results in collagen deposition and increased tensile strength of the tendon (Lin, Cardenas, & Soslowsky, 2004). While few protocols indicated the number of sets and repetitions for strengthening, the two protocols that did provide specific guidelines varied from performing resisted exercises three times per week, to three times per day. As improvement in strength is dependent on the type of exercise intensity and frequency prescribed (Kraemer & Ratamess, 2004), further detail regarding the volume of resisted exercises may enhance patient outcome. Additionally, the volume of load should be individualised dependent on patient goals, and other variables such as the quality of tissue.

Cryotherapy and aquatic therapy

Seven (23%) protocols recommended the use of cryotherapy. The benefit of pain relief from cryotherapy has been demonstrated post-operatively following shoulder surgery (Osbahr et al., 2002; Singh, Osbahr, Holovacs, Cawley, & Speer, 2001; Speer, Warren, & Horowitz, 1996). However no difference in pain relief has been found between a commercial compressive cryotherapy device compared to a standard ice wrap (Kraeutler, Reynolds, Long, & McCarty, 2015). Only three (10%) protocols included aquatic therapy, which has been shown to increase ROM following rotator cuff repair (Brady et al., 2008). Aquatic therapy also produces less muscle activity with shoulder elevation when performed slowly compared to dry land exercise (Kelly, Roskin, Kirkendall, & Speer, 2000). Slow speed aquatherapy for ROM is recommended from 3 to 6 weeks by ASSET and cryotherapy is recommended for pain relief from the first day post-operatively (Thigpen et al., 2016).

Other variables

Less than 40% of the protocols considered other factors such as tear size, tissue quality, strength of the fixation or the tendon involved and yet rehabilitation based on these variables has been advocated (Killian & Cavanaugh, 2014; Pabian, Rothschild, & Schwartzberg, 2011; van der Meijden et al., 2012; Thigpen et al., 2016; Thomson et al., 2016). A recent meta-analysis reported that increased re-tear rates were associated with larger tear size, advanced age, and more fatty infiltration (McElvany et al., 2015). Few of the protocols left the progression of rehabilitation to the discretion of the therapist, and none reported informing the therapist of the tear size, type of repair, or degree of fatty infiltration. Given that these variables are significantly associated with re-tear rates following rotator cuff repair, communication regarding these variables may allow therapists to optimise individual progression to achieve better outcomes.

Ten (32%) protocols considered pain during rehabilitation with most of these suggesting adjustment (slowing down) in cases of excessive pain. Only one protocol suggested that minimal pain may be detrimental, with the temptation for the patient to progress too quickly and risk re-tear. Patients who have a rapid early improvement in clinical outcome and/or are less compliant with their rehabilitation are at greater risk of re-tear (Ahmad, Haber, & Bokor, 2015). Further research into individualised rehabilitation programmes, based upon such factors as size of tear, location, quality of fixation, tissue quality, and general health is warranted (Boileau et al., 2005; Killian & Cavanaugh, 2014; Murphy et al., 2013; Thigpen et al., 2016; Thomson et al., 2016; van der Meijden et al., 2012).

Study limitations

A limitation of this study was the 55% response rate from the surgeons who were approached to participate. While this study replicated the information currently available to New Zealand therapists by extracting data from each protocol, the use of a standardised questionnaire completed by participating surgeons may have provided more detail regarding surgical protocols (e.g. sets and repetitions of exercises). In addition, collecting data from different modes such as email, printed protocols and website information may have resulted in a variation in the level of detail provided. Future research could also investigate therapist adherence to protocol implementation or therapist interpretation of the information contained in protocols.

CONCLUSION

Variability is evident amongst the protocols currently in use in New Zealand, but some similarities across protocols alongside comparisons with international studies can be used to guide therapeutic rehabilitation following rotator cuff repair. The majority of protocols recommend immobilisation of the shoulder following a repair for 4 to 6 weeks. Passive exercises (or exercises that produce low-levels of muscle activity as determined with EMG) commence between 0-8 weeks and most protocols progress to active exercises between 6 and 8 weeks. The majority of protocols recommend starting resisted exercises at 12 weeks which is when the tendon may be sufficiently healed to start exercise against resistance. Communication from the surgeon to the therapist regarding tear size, tissue quality and strength of fixation may reduce the risk of re-tear following surgery. Further investigation into the optimisation of rehabilitation based upon individual patient factors may result in more timely return to full function, following a rotator cuff repair.

KEY POINTS

1. This study adds to current knowledge about rotator cuff repair protocols by identifying the variability across protocols currently in use in New Zealand.
2. Most protocols recommended immobilisation for four to six weeks, followed by passive and active exercises, with commencement of resisted strengthening at twelve weeks.
3. Identification and communication of variables which impact on rehabilitation following surgical repair, such as tear size, degree of fatty infiltration, and type of repair, could enhance outcomes for individuals following rotator cuff repair.
4. Future research could investigate the benefit of an individually tailored rehabilitation programme.

DISCLOSURES

No conflicts of interest have been identified for this research.

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A systematic review of the effects of perturbation training on preventing falls.

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ABSTRACT

Falls cause injury or death in healthy but frail older people. The efficacy of conventional falls prevention training for healthy older people may be sub-optimal, and perturbation training, a new approach that trains reflexive control of postural stability, has been evaluated in several trials. One systematic review of this new approach exists, but it included people with neurological diagnoses. The current systematic review aimed to evaluate if perturbation training can reduce falls in healthy frail older people and healthy young people. Included studies had to compare perturbation training to a control, in terms of falls incidence. Three separate protocols were devised for studies using different ages and falls outcomes. Sixteen eligible papers were found, comprising 849 participants. Perturbation training may be effective compared to no treatment in reducing laboratory-induced falls in older and younger people. Benefits may occur quickly, can be long-lived, and are generalisable. However, the efficacy of perturbation training in reducing community falls incidence in frail older people is uncertain. In all studies the quality of evidence is low to very low, and further rigorous research is required.

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Key Words: Falls, Falling, Perturbation, Trip, Slip, Prevention.

INTRODUCTION

Approximately one third of older people experience at least one fall per year (Shapiro & Melzer, 2010). Of these, about half will suffer two or more falls annually (Masud & Morris, 2001). Approximately 5% of falls lead to fractures (Masud & Morris, 2001; Rubenstein & Josephson, 2006), 20% of which are hip fractures (Masud & Morris, 2001) that carry a high probability of mortality (Rubenstein & Josephson, 2006).

During the last 30 years, conventional approaches to reducing falls in the healthy but frail older population have involved strength and power training of the lower extremities in combination with balance re-education. Unfortunately, published data have not shown a consistent benefit for such approaches (Orr, Raymond & Fiatarone, 2008). Although such methods may be able to reduce the incidence of falling compared to no treatment, there are still many people who fall despite these measures (Grabiner, Crenshaw, Hurt, Rosenblatt & Troy, 2014).

Part of the reason for the limited efficacy may be that conventional therapy tends to focus on training in a relatively stable standing position. This is at odds with the fact that after a trip or slip, which may be initiating factors in 60% (Blake et al.,1988; Luukinen, Herala, Koski, Honkanen, Laippala & Kivela, 2000) of all accidental falls, the person is rapidly moved into a far less stable posture before there is time for compensatory muscle activity to begin (Grabiner et al., 2014). Conventional methods may also not train the specific muscle synergies at sufficiently high velocities (Pijnappels, Bobbert & Van Dieen, 2005). In addition, the postural responses and recovery strategies triggered by a slip or trip are reflexive, and thus may not be specifically trained by voluntary exercise. Finally, conventional methods may not train 'feedforward' mechanisms of stability control. Theories of feedforward stability control suggest that the central nervous system (CNS) forms representations of stable limits of centre of gravity (COG) excursion relative to the base of support. These allow proactive adjustments to the velocity and trajectory of the COG during movement to decrease the likelihood that these limits will be crossed. This should reduce the probability of balance loss and the need for reactive responses (Pai & Iqbal 1999; Pai, Wening, Runtz, Iqbal & Pavol, 2003). In addition, even if balance loss does occur, such prior COG adjustments may allow successful reactive responses to be more easily achieved (Pai & Bhatt 2007). Only exposure to sudden unexpected shifts in the COG may refine CNS representation of safe COG limits, and thus improve the feedforward mechanism of stability (Pai et al., 2003).

This has led some researchers and clinicians to consider the efficacy of 'perturbation' training, which involves unexpected external perturbations during walking (Shapiro & Melzer, 2010) that mimic environmental slips and trips. Such training should develop feedforward mechanisms of stability control (Pai et al., 2003), as well as specifically training the rapid reactions required after a slip or trip has begun (Bhatt & Pai 2009a; Grabiner, Bareither, Gatts, Marone & Troy, 2012; Lurie, Zagaria, Pidgeon, Forman & Spratt, 2013).

Over the past 10 years much research has been published concerning perturbation training. This can be split into three main categories. The first concerns the effects of perturbation training on the incidence of community falls (those occurring in the natural setting) in older people (Lurie et al., 2013; Maki et al., 2013; Mansfield, Peters, Liu & Maki, 2010; Pai, Bhatt, Yang & Wang, 2014a; Rosenblatt, Marone & Grabiner, 2013).

The second category looks at the effects of perturbation training on the ability of older people to resist a simulated slip or trip in the laboratory (Grabiner et al., 2012; Parijat & Lockhart, 2012; Bhatt, Yang & Pai, 2012). This is clearly different from observing the effects on community falls, as the laboratory participants are 'primed' for the possibility of a fall and more completely focussed on the task, which may reduce the tendency to fall, supported by empirical evidence in older women (Pater, Rosenblatt & Grabiner, 2015). Moreover, the nature of simulated trips and slips in the laboratory may differ from perturbations encountered in the community. Nevertheless, Pai, Wang, Espy & Bhatt (2010a) have shown an association between the propensity to fall in the laboratory and the tendency to fall in the community, and so such studies may provide useful indirect evidence that can support evidence from the first category of research.

The third category concerns the effects of perturbation training on young healthy adults (Bhatt & Pai 2009a; Bhatt & Pai 2009b; Bhatt, Wang, Yang & Pai, 2013; Lee, Bhatt & Pai, 2016; Liu, Bhatt & Pai, 2016; Wang, Bhatt, Yang & Pai, 2011; Yang, Bart & Pai, 2013, Yang, Wang & Pai, 2014). Although the key aim of this review is to inform prevention of falls in older people, for whom falls are both prevalent and dangerous (Rubenstein & Josephson, 2006), data from younger people are also of relevance. Although younger people have greater strength and power, there is evidence that young and older people may respond to perturbation training at a similar rate (Pavol, Runtz, Edwards & Pai, 2002) and in a similar way (Pavol, Runtz & Pai, 2004). Furthermore, studies in younger people tend to experiment with different parameters of training, such as intensity and duration, and so conclusions from these may be used to inform training parameters in older adults. Inclusion of data on young people will therefore be of potential benefit to facilitate development of optimal treatment and research strategies aimed at reducing falls in older people.

Only one relevant systematic review currently exists. Mansfield, Wong, Bryce, Knorr & Patterson (2015) conducted a systematic review of eight randomised controlled trials (RCTs), evaluating the effectiveness of perturbation training in reducing community falls in older people. These authors showed a relative risk of falling of 0.71 (95% CIs: 0.52 to 0.96) if perturbation training was used, in comparison to other approaches. However, four of the RCTs comprised participants with neurological or orthopaedic diagnoses, and meta-analyses were not stratified or sub-grouped for such differing populations. It is possible that the meta-analysis may have overestimated the pooled magnitude of benefit, in relation to what might be expected in healthy frail older people, because the results in those with neurological conditions more strongly favoured perturbation training. Furthermore, an important recent RCT (Pai et al., 2014a) was not included. In contrast, the current review will be limited to healthy older and younger participants without diagnoses (such as stroke or amputation) that could be the cause of falling, because the tendency to respond to perturbation training and the underlying mechanism of postural instability are probably linked. This tallies with the views of Gillespie, Robertson, Gillespie, Sherrington, Gates, Clemson & Lamb (2012), who restricted their Cochrane meta-analysis on conventional fall prevention strategies to healthy frail older adults on the basis that people with neurological or other diagnosed conditions are likely to respond differently from frail healthy older adults.

The current systematic review contains three separate systematic review questions, each conforming to one of the three categories of research described above. These are:

1. Does perturbation training reduce community falls incidence compared to standard falls prevention treatment in healthy older people who are fallers or at risk of falling?
2. Does perturbation training reduce laboratory falls incidence compared to standard falls prevention treatment in healthy older people who are fallers or at risk of falling?
3. Does perturbation training reduce laboratory falls incidence compared to a comparison treatment in young healthy people?

METHODS

Study selection

The three protocols (Table 1) corresponding to the three review questions were developed by the authors through consensus. This was based on an initial survey of the literature, and discussion with clinicians who use perturbation training as part of their clinical practice. The following sections detail the protocol.

The protocols are also located online at: http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016039911 The online protocol was submitted after the initial searches had taken place, as a result of administrative delays.

Types of participants

For the two review questions looking at older people having 1) community falls or 2) laboratory falls, studies comprising adults with a mean age of >65 years were included, on the basis that falls begin to become much more prevalent after this age (Shapiro & Melzer, 2010). If studies comprised adults with a mean age between 55 and 65 years then these were included, but with a reduction in quality rating to reflect the 'indirectness' of such evidence to the specific review questions ('indirectness' refers to any departure in terms of the study PICO to the review protocol, and is explained fully in the 'quality assessment' section). Similarly, at least 50% of participants in a study needed to either have a history of at least one fall in the past year or be deemed at risk of falls by any appropriate criteria provided by study authors. If either of these conditions was not met then the study would again receive a reduction in quality rating. Participants had to be healthy (albeit frail) and studies were excluded if any participants had diagnosed conditions such as stroke or amputation that could cause falling. For the third research question, involving laboratory falls in younger people, any studies comprising healthy adults aged <55 years were included.

Types of intervention
For all three research questions, interventions had to comprise perturbation training, where sudden and unexpected anteroposterior or mediolateral forces were imposed on a treadmill, or on a walkway with moveable plates. Perturbation training could be given alone, or in combination with standard or other treatments.

Types of comparator
The key methodological criterion for inclusion was that studies had to have a comparator group. Any comparator was acceptable, non-active or active, as any comparator would help to eliminate intervening variables such as the placebo effect, practice effects or natural history effects as contributors to changes in the outcome. For the first and second research questions, the comparator would ideally be standard falls prevention treatment (such as lower limb strengthening and dynamic balance training), to permit interpretations of perturbation training efficacy compared to best available practice. If a non-standard treatment was used for the control group then a reduction in quality rating was applied for indirectness. For the third research question the comparator could be any treatment because established falls prevention treatments do not exist in young healthy people.

Types of outcome
For the first review question, the outcome was community falls, defined by the existence or not of at least one fall occurring outside the laboratory setting within a clearly defined time interval. For the second and third questions, the outcome was a laboratory-induced fall 'in harness', defined as a loss of balance during the laboratory falls test that exceeded a study-specified load on the safety harness load cell, or that caused an unambiguously unrecoverable loss of balance.

Types of study
For all three research questions randomised trials were preferred, but non-randomised trials were allowed, even though these would tend to have greater selection bias. Longitudinal observational approaches, such as prospective or retrospective cohort studies, or case-control studies, were not excluded as such studies would still enable some degree of causality to be established between training method and falls incidence. Cross-sectional studies were excluded as they would be unable to provide any evidence of causality.

Search
The search strategy was aimed at all three protocols. This aimed for maximal sensitivity at the expense of specificity by avoiding 'AND' terms. The key words were: *trip, trips, tripping, slip, slips, slipping, perturbation, perturbations, "perturbation-based balance training", platform, treadmill, "agility training", "dynamic balance training"* all linked by the term 'OR'. The databases used (in order of succession) were PubMed, EBSCOHost CINAHL, and EBSCOHost SportDiscus, and the last search date was 13/11/2016. All searches were limited to peer-reviewed journals and 'English' to facilitate retrieval and extraction of data. For PubMed, the search was also limited to 'controlled clinical trials' and 'humans', whilst for CINAHL the additional limiters were 'clinical trials' and 'humans'. For SportDiscus the limiters were 'academic journals' and 'articles'. The differing limiters used across databases were due to the differing limiters available within each database. No date limits were set as reviewers were uncertain of the time when perturbation training may have begun to be evaluated. Abstract selection was carried out by both authors and decisions on inclusion were based on consensus.

Data extraction and management
Data from the included papers were extracted onto pre-formatted forms by both authors independently, detailing study design, population, sample characteristics, intervention, comparator, results, conflicts of interest, risk of bias and indirectness. Consensus was used to decide on the final content of forms.

Synthesis of findings
For each of the three separate review questions, findings were synthesised from two or more studies, using fixed effects meta-analysis, when the population, interventions, comparators and outcomes (PICO) of studies were sufficiently similar to enable meaningful and useful pooling of results. If the PICO of different studies was sufficiently dissimilar to allow meta-analysis then a narrative synthesis was carried out. Where available, intention to treat data were used.

Stratification and sub-grouping
Stratification of studies prior to the meta-analysis was carried out as needed, according to the protocols (Table 1), on the grounds that the stratifying variables denoted plausible biological grounds to expect different results within each stratum. After subsequent stratified or non-stratified pooling of studies, further sub-grouping according to *a priori* strategies outlined in the protocols (Table 1) was carried out if serious heterogeneity was observed, shown by an I^2>50%. If more than one sub-grouping strategy was listed in the protocol, then each sub-grouping strategy was used in order of priority, until heterogeneity was resolved, shown by heterogeneity being reduced to I^2<50% in all sub-groups. At this point results were reported for each sub-group separately, and the lower priority sub-grouping strategies were not used. If all sub-grouping strategies failed to resolve heterogeneity then no sub-grouping was carried out, and a random effects model was adopted to allow for the likelihood of a distribution of populations. Since the outcome of falling was a binary outcome, risk ratios (RR) were used where possible but Peto odds ratios were used if there was a low event rate in one of the groups. ReviewManager 5.3 © was used for meta-analyses.

Quality assessment
Quality assessment was performed according to the GRADE approach (Schünemann et al., 2006), and comprised the following:

1. Risk of bias
Each study was appraised for the risk of selection, performance, detection, attrition and outcome reporting bias for the chosen outcome. Based on these criteria, the overall risk of bias for each study was deemed *very serious* (score of -2), *serious* (-1) or *not serious* (0), based on a reasoned estimation of the overall effects of such bias. This was assessed for each study separately and

then a weighted average of bias scores for the chosen outcome across all studies in the meta-analysis was calculated using the meta-analysis weightings (which were based on precision). If a meta-analysis had not been undertaken then a simple average of quality ratings would be given.

2. Indirectness

This concerned any discrepancies between the PICO of the systematic review question (Table 1) and the PICO of each included study. Indirectness was deemed *very serious* (-2), *serious* (-1) *or not serious* (0) for each study separately, depending on the number of discrepancies. An overall score for the outcome across all studies was then calculated (as for risk of bias).

Table 1: Protocol for the 3 research questions

<table>
<tr><td>Review questions</td><td>Does perturbation training reduce community falls incidence more than standard falls prevention treatment in healthy older people who are fallers or at risk of falling?</td><td>Does perturbation training reduce laboratory falls incidence more than a comparison treatment in healthy older people who are fallers or at risk of falling?</td><td>Does perturbation training reduce laboratory falls incidence more than a comparison treatment in young healthy people?</td></tr>
<tr><td>Population</td><td colspan="2">• Older people aged 65 years upwards
• Healthy - free from or any diagnosed condition that could lead to falls (e.g. stroke, amputation, total hip replacement, balance disorders)
• Either deemed at risk of falling (frail) or single/frequent fallers.
Reduce quality rating of studies in terms of ‘indirectness’
• If mean age was aged <65 but > 55 years
• if >50% of participants were not fallers or were not deemed at risk of falling</td><td>Young people (aged <55 years). These need to be healthy and not frail or fallers.</td></tr>
<tr><td>Intervention</td><td colspan="3">• Perturbation (slip/trip) training on treadmill or on a walkway with moveable plates
Exclude any slip/trip training done on slippery surfaces
Can be combined with or without standard falls prevention training</td></tr>
<tr><td>Comparator</td><td colspan="2">• Standard falls prevention training
• Downgrade for indirectness if any other control intervention is used</td><td>• Any control intervention</td></tr>
<tr><td>Outcomes</td><td>Community falls frequency</td><td colspan="2">“Falls in harness” on laboratory walkway or treadmill platform.</td></tr>
<tr><td>Study types</td><td colspan="3">Any randomised or non-randomised study which uses one or more comparison groups.</td></tr>
<tr><td>Strata*/sub-groups**</td><td>Stratify by
+/- inclusion of standard training with intervention
Sub-group by
• Comparator type
• Single fallers/frequent fallers
• Age (<80 vs >80)</td><td>Sub-group by Comparator type</td><td>Sub-group by Comparator type</td></tr>
<tr><td>Analysis plan</td><td colspan="3">Meta-analysis if appropriate.</td></tr>
<tr><td>Search plan</td><td colspan="3">Pubmed, EBSCOHost CINAHL, EBSCOHost SportDiscus; key words: trip, trips, tripping, slip, slips, slipping, perturbation, perturbations, “perturbation-based balance training”, platform, treadmill, “agility training”, “dynamic balance training”</td></tr>
</table>

*Strata denote categories for separate analyses/synthesis which are fixed *a priori*. Strata interact – thus 2 binary strata will lead to 4 sub-strata.
**Sub-groups denote categories for analysis/synthesis that are conditional upon statistical heterogeneity [I^2 > 50%] in meta-analysis. Sub-groups do not interact – each is examined separately

3. Inconsistency

If the outcome meta-analysis I^2 was <50% then a rating of non-serious inconsistency (score of 0) was given. If the outcome meta-analysis I^2 was ≥50% but <75% then a rating of serious inconsistency (score of -1) was given, and if the outcome meta-analysis I^2 was ≥75% then a rating of very serious inconsistency (score of -2) was given. Note that if sub-grouping managed to reduce heterogeneity then the results for each sub-group would be appraised as separate outcomes, each rated as having no serious inconsistency. If no meta-analysis had been undertaken then the level of inconsistency was determined based on an estimate of the differing effects.

4. Imprecision

Imprecision was based on the spread of the 95% confidence intervals (CI) of the pooled effect across arbitrary but established thresholds of clinical importance for the outcome. If the confidence intervals crossed the thresholds of a 25% reduction in risk and a 25% increase in risk (risk ratios [RR] of 0.75 and 1.25, and, by default, odds ratios [OR] of the same value) then a rating of very serious imprecision (score of -2) was given. If the confidence intervals crossed just one threshold then a rating of serious imprecision (score of -1) was given. If no thresholds were crossed by the confidence intervals then a rating of no serious imprecision (score of 0) was given. If no meta-analysis had been undertaken then the level of imprecision was determined based on an estimate of the separate effects.

Overall score

Scores from the four quality aspects were summed. If the overall score was -3 or less, then a rating of very low quality was given, if the overall score was -2 a rating of low quality was given, if the overall score was -1 then a moderate quality rating was assigned and if the overall score was 0 then a rating of high quality was given (Schünemann et al., 2006). These gradings were used to guide interpretation of results.

Since only one outcome (incidence of falling) is used in this review, if a study did not include this outcome then it would not be included. However excluded studies were perused to see if any had been excluded solely for the lack of a falls outcome. The plan was to evaluate such studies to assess if the falls outcome had been deliberately left out because it may have contradicted other outcomes or the favoured hypothesis. Assessment of possible publication bias was conducted using a funnel plot where meta-analyses had been undertaken with a minimum of 10 studies (Higgins & Green, 2011).

RESULTS

Included and excluded studies

The PubMed search yielded 5138 articles, from which 42 were obtained for further analysis. Subsequently, the CINAHL search yielded 790 articles, from which 2 previously unseen articles were obtained for further analysis. Finally, the SportDiscus search yielded 13,310 articles, which were deemed too many for preliminary selection. Hence for this search the original search strategy was combined with 'fall or stability or balance' using the AND operator. This reduced the yield to 1935 articles, from which 5 further articles were obtained for further analysis. Perusal of reference lists in retrieved papers yielded four extra articles, and these were also obtained for more detailed reading. Of these 53 articles, 16 met the inclusion criteria of any of the 3 protocols (Table 1) and were included in the review (Figure 1). Reasons for the exclusion of the other 37 articles are given in Table 2.

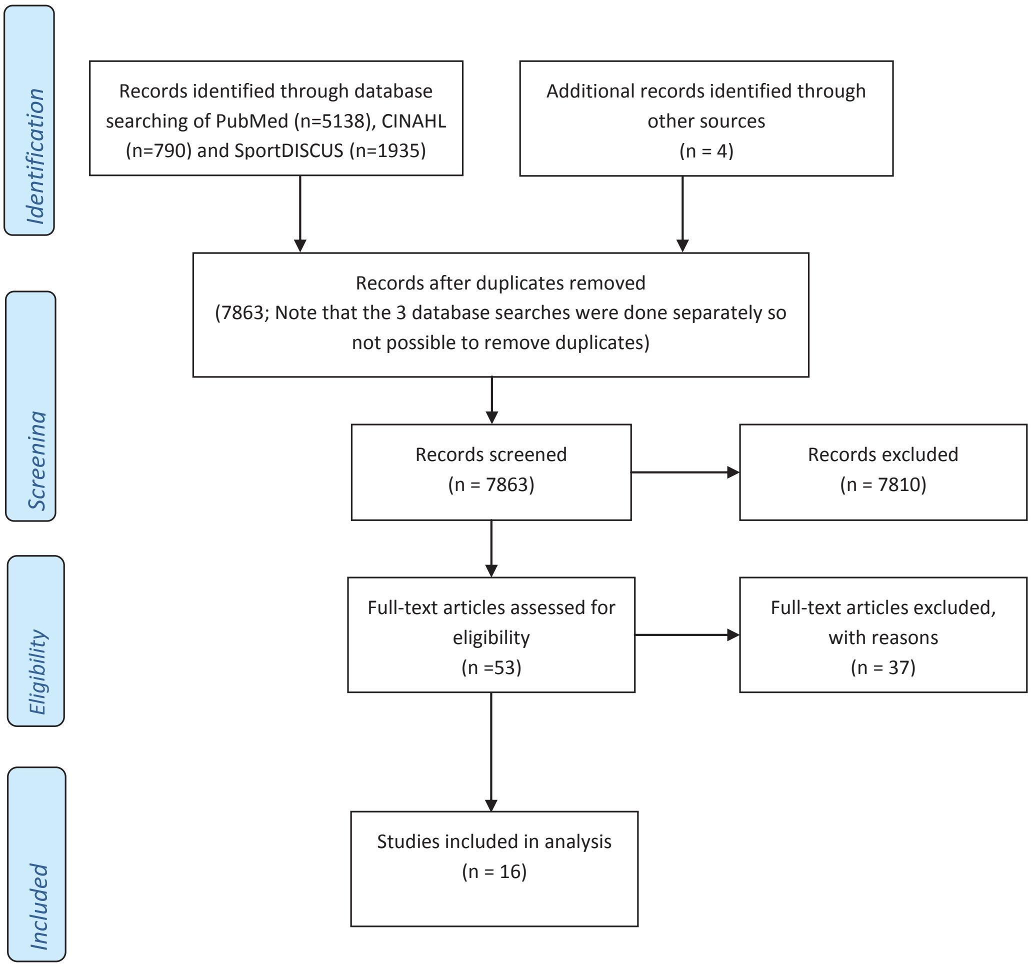

Figure 1: PRISMA Study Flow Diagram

Table 2: Excluded studies list

Study	Reason for exclusion
Bhatt & Pai, 2008	No control group
Bhatt et al., 2011	No control group
Bieryla et al., 2007	No falls data
Cham & Redfern 2001	Descriptive kinematic study
Dijkstra et al.,2015	No control group
Grabiner et al., 2014	Review
Han & Yang, 2015	Did not relate to perturbation training
Kim & Lockhart, 2010	Did not relate to perturbation training
Kojima et al., 2008	No control group
Kurz et al., 2016	No falls data
Lee et al., 2013	Did not relate to perturbation training
Lesinki et al., 2015	Review with no falls outcomes
Liu & Kim, 2012	No control group
McIlroy & Maki, 1996	No control group
Melzer & Oddison, 2013	No falls data
Oddsson et al., 2004	No control group
Pai et al., 2010b	No control group
Pai & Bhatt, 2007	Review
Pai et al., 2014b	No control group
Parijat et al., 2015a	Virtual reality study
Parijat et al., 2015b	Virtual reality study
Patel & Bhatt, 2015	No control group
Pater et al., 2015	No control group
Pavol et al., 2002	No control group
Pavol et al., 2004	No control group
Rossi et al., 2013	No falls outcomes
Sakai et al., 2008	No falls outcomes or control group
Sessoms et al., 2014	Participants were post amputation
Shapiro & Melzer, 2010	Descriptive account of the perturbation device
Shimada et al., 2004	50% had diagnoses such as Parkinson's disease.
Shirota et al., 2014	Descriptive kinematic study
Sohn & Kim, 2015	Did not relate to perturbation training
Yang et al., 2011	No control group
Yang et al., 2009	No control group
Yang et al., 2012	Descriptive kinematic study
Yang & Pai,2013	No control group
Yang & Pai, 2011	Not evaluating interventions

1. Does perturbation training reduce community falls risk compared to standard falls prevention treatment in healthy older people who are fallers or at risk of falling?

Studies included

Five relevant studies (Lurie et al., 2013; Maki et al., 2013; Mansfield et al., 2010; Pai et al., 2014a; Rosenblatt et al., 2013) comprising 484 participants were found. Mean ages in the studies ranged from 65 to over 80 years, but mean ages were not always documented. Mansfield et al. (2010) contained >50% of fallers in the study, but no other studies were documented to contain >50% of fallers. Lurie et al. (2013) stated that participants were recruited as they were at risk of falling, but criteria were not described, and 'risk of falling' status was unclear in all other papers. These issues contributed to the serious/very serious risks of 'indirectness' described below.

For three studies (Maki et al., 2013; Mansfield et al., 2010; Rosenblatt et al., 2013) data on the numbers falling at follow up were not available in the published papers. However the systematic review by Mansfield et al. (2015) published the numbers falling in these studies, derived from communication with the study authors, and it is these falls data that have been included in the meta-analysis. Detailed study characteristics are given in Table 3.

Table 3: Characteristics of the studies for review question 1. All participants were protected by a harness during training

Study name and type	Sample characteristics	Intervention	Comparator	Outcome measure	Risk of bias	Indirectness
Lurie et al., 2013 RCT	64 healthy adults at risk of falls. Mean age c80 years. 50% female in perturbation group and 67% female in standard PT group.	Standard physiotherapy (see right) with addition of treadmill perturbation training. Trips or slips were applied, with magnitude of disturbances depending on patient ability. Parameters left to the discretion of the PT.	Standard physiotherapy comprising patient-specific strengthening, flexibility and dynamic balance exercises. Some given in clinic and some as home exercises. Parameters left to the discretion of the PT.	All-cause community falls, evaluated retrospectively by a 3 month phone call.	Very serious. No assessor blinding, and possible attrition and detection bias.	Serious. No information on baseline fallers / risk of falling.
Pai et al., 2014a RCT	212 adults aged 73.6 years. Baseline rates of community falling (for previous 12 months): 34% of intervention group; control: 39%.	24 unexpected slip perturbations while walking over a moving platform in a single session.	One unexpected slip perturbation while walking over the moving platform.	All cause community falls at 12 month follow up. Over the year falls were recorded in a falls diary, and a researcher would call each participant at 6-week intervals to obtain the diary details, and if a fall had occurred the participant would be interviewed.	Very serious. No allocation concealment, and no assessor blinding.	Very serious. <50% fallers, no information on risk of falling, and comparator not standard training.
Maki et al., 2013 Pilot RCT	8 aged 79-89 in perturbation group, and 69-86 in control group.	Perturbation training, done for 30 minutes, 3 times per week over 6 weeks.	Training of rapid volitional stepping and reaching movements.	Community falls. The data are derived from Mansfield et al., (2015), the authors of which had contacted Maki and colleagues for the falls data.	Very serious. No allocation concealment, and no assessor blinding.	Very serious. <50% fallers, no information on risk of falling, and comparator not standard training.
Rosenblatt et al., 2013 Pseudo-randomised	170 women of mean age 65. Baseline falls history: 38.8% in control group and 37.8% in perturbation group.	Four one hour sessions comprising large trip perturbations on a treadmill over 2 weeks.	No training	Community falls, collected via postcards or emails every 2 weeks for one year. The data for number of all-cause fallers per group was derived from Mansfield et al., (2015).	Very serious. Pseudo random alternate allocation, no assessor blinding and likely attrition bias.	Very serious. <50% fallers, no information on risk of falling, and comparator not standard training.

Study name and type	Sample characteristics	Intervention	Comparator	Outcome measure	Risk of bias	Indirectness
Mansfield et al., 2010 RCT	30 adults (aged 64-80 years). 23/30 had experienced at least one fall in the past 5 years.	6 week perturbation-based balance training program, conducted on a motion platform that could move in 4 different directions. At least 24 perturbations were related to stepping and at least 24 were related to grasping tasks.	6 week control program involving flexibility (2 days per week) and relaxation training (1 day per week).	Community falls. The data for number of all-cause fallers per group was derived from Mansfield et al., (2015).	Very serious. No allocation concealment, and no assessor blinding.	Very serious. <50% fallers, no information on risk of falling, and comparator not standard training.

Effects

The studies were stratified (as per protocol) into two groups according to whether studies had combined the perturbation training with standard training (Figure 2) or not. The study by Lurie et al. (2013), as the only study to have combined perturbation and standard training, was therefore analysed in a separate stratum. No serious heterogeneity was observed in either stratum, so sub-grouping was not carried out. Fixed effects meta-analysis showed uncertain effects for perturbation training in both strata. Relative to the comparator, in the stratum where perturbation training was combined with standard training there was a RR (95% CI) for falls of 0.62 (0.20 to 1.89), and in the stratum where perturbation training was given alone there was a RR (95% CI) for falls of 0.89 (0.70 to 1.12) (Figure 2).

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Fixed, 95% CI
7.1.2 Perturbation and standard training				
Lurie 2013	-0.4762	0.567	100.0%	0.62 [0.20, 1.89]
Subtotal (95% CI)			**100.0%**	**0.62 [0.20, 1.89]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 0.84 (P = 0.40)				
7.1.3 Perturbation alone				
Maki 2008	-0.4055	0.5774	4.3%	0.67 [0.21, 2.07]
Mansfield 2010	0.1586	0.5664	4.5%	1.17 [0.39, 3.56]
Pai 2014	-0.6757	0.3017	15.9%	0.51 [0.28, 0.92]
Rosenblatt 2013	-0.0027	0.1388	75.2%	1.00 [0.76, 1.31]
Subtotal (95% CI)			**100.0%**	**0.89 [0.70, 1.12]**
Heterogeneity: Chi² = 4.59, df = 3 (P = 0.20); I² = 35%				
Test for overall effect: Z = 1.00 (P = 0.32)				
Test for subgroup differences: Chi² = 0.38, df = 1 (P = 0.54), I² = 0%				

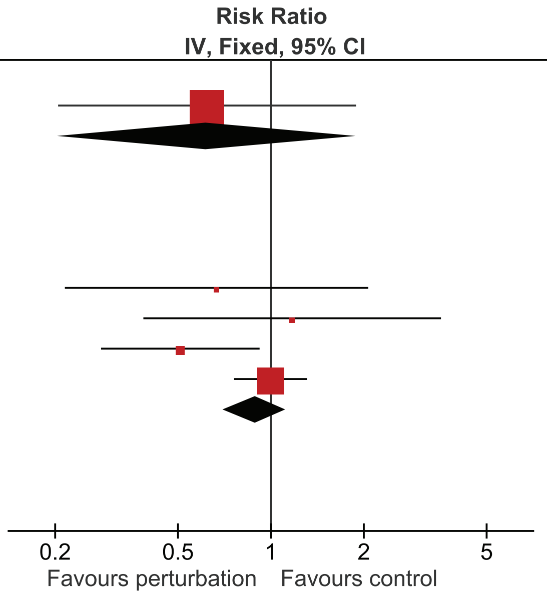

Figure 2: Forest plot for the effects of perturbation training compared to control on falls risk. The analysis was stratified by inclusion of standardised training with perturbation training or not. A generic inverse variance method has been used as the results by Lurie et al. 2013, adjusted for baseline falls incidence, were only available as a risk ratio.

Quality

Quality of the falls outcome in the perturbation-only stratum was deemed very low. This was due to very serious risk of bias, very serious indirectness and very serious imprecision across studies. Quality was also very low in the perturbation and standard training stratum for the same reasons, although indirectness was deemed serious rather than very serious. Details of all these quality issues are provided in Table 3 and the footnotes to Table 7.

2. Does perturbation training reduce laboratory falls risk compared to a comparison treatment in healthy older people who are fallers or at risk of falling?

Studies included

Three relevant studies were found, comprising 145 participants. Two (Grabiner et al., 2012; Parijat et al., 2012) compared the effects of perturbation training to no treatment, and one (Bhatt et al., 2012) compared the effects of perturbation training with a single extra 'top-up' treatment 3 months later to perturbation training without the 'top-up' treatment. Mean ages were above 70 years in both Parijat et al. (2012) and Bhatt et al. (2012), but in Grabiner et al. (2012) the control group had a mean age of <65 years. No study provided any evidence that the participants were fallers or were at risk of falling. Study details are given in Table 4.

Table 4: Characteristics of the studies for review question 2. All participants were protected by a harness during training

Study name and type	Sample characteristics	Intervention	Comparator	Outcome measure	Risk of bias	Indirectness
Parijat et al., 2012 RCT	24 adults aged 72.7 years, 12 of whom were female. At baseline all participants were exposed to a slip on a slippery surface: 5/12 fell in intervention group and 6/12 fell in control group.	Two weeks later, the intervention group experienced 12 simulated slips on a slippery moving force plate embedded on a 15m walkway. The slip trials were interspersed over 24 trials to reduce participant prediction of slips.	The control group had only normal walking trials, but the group were brought to the lab to maintain comparability.	One day post-training, the single slip test performed at baseline was repeated.	Very serious. No allocation concealment, and no assessor blinding.	Very serious. <50% fallers, no information on risk of falling, and comparator not standard training.
Grabiner et al., 2012 Pseudo-randomised	66 women aged 65.9 years (intervention) and 58.8 years (control).	Mean 142.5 perturbations in total over 4 weeks. The perturbations, made with the participant in a standing position, were exerted by a treadmill giving a sudden forward motion (simulating a trip). Magnitude varied according to participant performance.	No treatment	Existence of a fall, defined as loss of stability requiring 'unambiguous' harness protection, after a single mechanically induced trip on a walkway, undertaken about one week post training.	Very serious. Quasi-randomised with alternate allocation, no assessor blinding and probable attrition bias.	Very serious. <50% fallers, no information on risk of falling, comparator not standard training and control group aged 55-65 years.

Study name and type	Sample characteristics	Intervention	Comparator	Outcome measure	Risk of bias	Indirectness
Bhatt et al., 2012 RCT	Forty-eight adults aged 72.3 years. 35% had experienced prior community falls.	24 single session slip perturbations combined with an ancillary session of a single slip perturbation 3 months later. Slips during ambulation were induced by 2 moveable platforms placed on a 7m walkway.	The same 24 single session slip perturbations, without ancillary session.	At 6 months, the risk of falling was determined by the response to a single slip perturbation, with a fall defined as a slip where >30% body weight was detected by the harness load cell.	Very serious. No allocation concealment, and no assessor blinding.	Very serious. <50% fallers, no information on risk of falling, and comparator not standard training.

Effects

In the meta-analysis comprising the results of Grabiner et al. (2012) and Parijat et al. (2012), the pooled effect favouring perturbation training was statistically and clinically significant, with a Peto OR (95% CI) for falls of 0.18 (0.05 to 0.63) (Figure 3). Bhatt et al. (2012) did not provide clear data on falls rates, and so their data could not be included in the meta-analysis, but the authors stated that the difference in falls rates between groups was non-significant (p=0.5). The different effects may relate to the very active comparator used in Bhatt et al. (2012), which did not differ greatly from the intervention, in contrast to the inactive control treatments in the other two studies. It is worth noting that the risk ratio in both studies in the meta-analysis was similar despite Grabiner et al. (2012) employing trips as the training and testing perturbation, with Parijat et al. (2012) using slips instead.

Study or Subgroup	Perturbation Events	Perturbation Total	Control Events	Control Total	Weight	Peto Odds Ratio Peto, Fixed, 95% CI
Grabiner 2012	1	22	8	30	73.0%	0.22 [0.05, 0.93]
Parijat 2012	0	12	3	12	27.0%	0.11 [0.01, 1.19]
Total (95% CI)		**34**		**42**	**100.0%**	**0.18 [0.05, 0.63]**
Total events	1		11			

Heterogeneity: Chi² = 0.23, df = 1 (P = 0.63); I² = 0%
Test for overall effect: Z = 2.70 (P = 0.007)

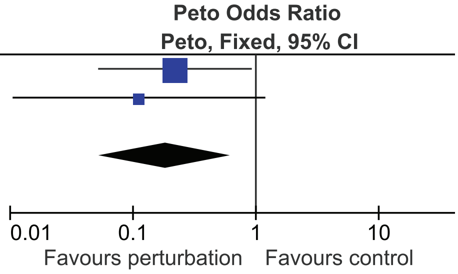

Figure 3: Forest plot for the effects of trip perturbation training compared to no perturbation training on odds of slip-induced laboratory falls in older participants

Quality

Quality of the falls outcomes in the meta-analysis was deemed very low. This was due to very serious risk of bias, and very serious indirectness. Quality was also very low for the single non-meta-analysed study (Bhatt et al., 2012) for the same reasons, as well as very serious imprecision suggested by the p value of 0.5. Details of all these quality issues are provided in Table 4 and the footnotes to Table 7.

3. Does perturbation training reduce laboratory falls risk compared to a comparison treatment in young healthy people?

Included studies

Eight eligible studies were found (Bhatt & Pai, 2009a; Bhatt & Pai, 2009b; Bhatt et al., 2013; Lee et al., 2016; Liu et al., 2016; Wang et al., 2011; Yang et al., 2013; Yang et al., 2014). All studies had ages that complied with the protocol, and all participants were healthy non-fallers. Six compared slip perturbation training to no treatment (Bhatt & Pai, 2009b; Bhatt & Pai, 2013; Lee et al., 2016; Wang et al., 2011; Yang et al., 2013; Yang et al., 2014) (Table 5) and two compared permutations of different intensities and/or frequencies of perturbation training to each other (Bhatt & Pai, 2009b; Liu et al., 2016) (Table 6). These two categories of study are described separately below.

Effects for training versus no training

With the exception of Bhatt et al. (2013) these studies all showed a point estimate indicating a benefit for perturbation training and the pooled effect was statistically significant [RR for laboratory-induced falling for perturbation training versus no training 0.17 (95% CI: 0.06 to 0.49)] (Figure 4). This effect could also be considered to be clinically important.

Study or Subgroup	Perturbation Events	Perturbation Total	Control Events	Control Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Bhatt 2009b	0	8	3	8	16.9%	0.14 [0.01, 2.39]
Bhatt 2013	0	16	0	16		Not estimable
Lee 2016	1	24	3	12	19.3%	0.17 [0.02, 1.44]
Wang 2011	0	20	6	23	29.3%	0.09 [0.01, 1.47]
Yang 2013	0	17	4	17	21.7%	0.11 [0.01, 1.92]
Yang 2014	2	24	2	12	12.9%	0.50 [0.08, 3.13]
Total (95% CI)		**109**		**88**	**100.0%**	**0.17 [0.06, 0.49]**
Total events	3		18			

Heterogeneity: Chi² = 1.64, df = 4 (P = 0.80); I² = 0%
Test for overall effect: Z = 3.28 (P = 0.001)

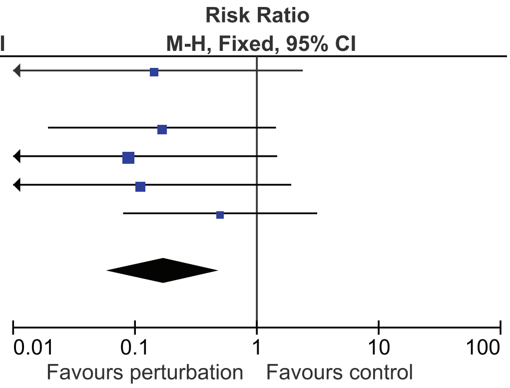

Figure 4: Forest plot for the effects of perturbation training compared to no perturbation training on risk of laboratory falls in young participants. For the trials where two perturbation lengths were tested, the 12 and 18 cm perturbation length results have been summated.

The pooled effect included summation of intervention falls rates in each of the two studies (Lee at al., 2016; Yang et al., 2014) where two perturbation lengths of 12cm and 18cm were tested against no treatment. Perturbation length did not appear to have a clear effect on falls rates, with the 12cm and 18cm perturbation length intervention groups each having 1/12 falls in the Yang et al. (2014) study, while the Lee et al. (2016) study demonstrated 1/12 falls in the 12cm group and 0/12 falls in the 18cm group.

It is important to note that in the Wang et al. (2011) study, two non-responders (defined by an inability to show any adaptive response during the training slips) in the intervention group were excluded from their analysis, thus increasing the risk of attrition bias. We performed a sensitivity analysis re-including these two participants, and their imputed values are based on the assumption that these would have fallen on the walking slip test. This imputation gave a more conservative pooled effect than otherwise [RR: 0.25 (95% CIs: 0.1 to 0.6)] but did not make an appreciable difference.

The lack of any effect in the Bhatt et al. (2013) study may be partially explained by its use of a simulated trip via the use of a physical obstacle, rather than a trip or slip induced by a treadmill or moving plates. Special glasses were used to prevent participants seeing the obstacle.

Yang et al. (2013) also considered another hypothesis – the effects of treadmill perturbation training versus overground perturbation training. The control group were subsequently given 24 induced slips on an over-ground walkway with moveable plates, and no falls were seen in either the treadmill or overground perturbation groups on a final over-ground slip test, initially suggesting treatment effects were similar. However there was a large difference in baseline falls (treadmill: 8/17; walkway: 4/17) indicating that the improvement might have been better for the treadmill training group.

Effects for intensity and frequency of training

In the study by Bhatt et al. (2009a) there was a significant difference between groups in incidence of backward balance loss at 4 months (p=0.04) with the greatest difference seen between the high intensity/high frequency group (lowest incidence of balance loss) and the low intensity/low frequency group (highest incidence of balance loss). In the Liu et al. (2016) study, 1/9 fell in the low intensity group, but none fell in the other three groups. These results weakly support the hypothesis that more intense training may be more beneficial in reducing falls.

Quality

Results for both the meta-analysis and the narrative analysis were graded as low quality (Tables 5 - 7). This was due to very serious risk of bias, largely due to selection and performance bias in most included studies.

Table 5: Characteristics of studies for review question 3 that compared perturbation training to no treatment. All participants were protected by a harness

Study name and type	Sample characteristics	Intervention	Comparator	Outcome measure	Risk of bias	Indirectness
Bhatt & Pai, 2009b RCT	16 young healthy subjects aged 26 years.	Repeated-slip training on a moveable platform set in a 7m walkway. 37 walking trials, including 24 trials where a slip was induced by the moveable plates. The participants were unaware of when slips would occur. All slips were on the right side.	No treatment	The ability to retain balance was tested on an oily floor surface. This occurred immediately after training. A single trial was used. Falls were defined as average force on the safety harness exceeding 4.5% body weight over any 1 second period after the slip onset.	Very serious. No allocation concealment. No assessor blinding.	None.
Bhatt et al., 2013 RCT	32 adults (26 women), aged 26 years.	Slip training including 8 slip perturbations simulated by a moveable platform set in a 7m walkway.	No treatment	An in-harness fall during a single trip induced during walking via a physical obstacle (the participants did not know when it would occur). This occurred immediately after training.	Very serious. No allocation concealment. No assessor blinding.	None.
Yang et al., 2013 Non-randomised	34 adults (16 female), aged 25.8 years.	15-20 forward slip-like perturbations during treadmill walking. The intensity of perturbations was adjusted to performance.	No treatment	As above	Very serious. Non random allocation with large baseline group discrepancies. No assessor blinding.	None.
Yang et al., 2014 Non-randomised	24 adults aged 24.9 years. 23/36 female.	Two intervention groups given perturbation training. 7 perturbations were applied using a 7m walkway with 2 moveable platforms over 18 trials. One group had 12cm slip perturbations while the other had 18cm slip perturbations.	No treatment	Balance loss was tested using an overground walking test where a 150 cm slip was given by moveable plates on a 7m walkway at a random trial. This occurred immediately after training.	Very serious. Non random allocation with large baseline group discrepancies. No assessor blinding.	None.

Study name and type	Sample characteristics	Intervention	Comparator	Outcome measure	Risk of bias	Indirectness
Lee et al., 2016 Non randomised	24 young adults aged 26.7 years, 18/24 female.	Two groups given perturbation training on treadmill. 7 forward slip-like perturbations applied during treadmill walking over 12 trials. One group had perturbations giving a slip distance of 12cm whilst the other had perturbations giving a slip distance of 18cm.	No treatment	As above	Very serious. Non random allocation with large baseline group discrepancies. No assessor blinding.	None.
Wang et al., 2011 Non randomised	43 young adults (26 women), aged 26 years.	With the participant sitting in a custom built chair a perturbation was applied on moving from sit to stand, by a pair of moveable plates. Participants performed 28 sit-stands, containing 14 slip perturbations.	No treatment	A fall (defined as >30% body weight detected by harness load cell) during a novel slip during walking on the walkway with two moveable plates was the outcome.	Very serious. Non-random allocation with large baseline group discrepancies. No assessor blinding.	None.

Table 6: Characteristics of studies for review question 3 that compared different intensities/frequencies of perturbation training. All participants were protected by a harness

Study name and type	Sample characteristics	Interventions to be compared	Outcome measure	Risk of bias	Indirectness
Bhatt & Pai, 2009a RCT	49 healthy young subjects (26 years).	Four groups experienced varying parameters of perturbations induced by moveable plates on a walkway. Slips were provided by moveable plates set in a 7m walkway, and participants were unaware of when a slip would occur. • High intensity, high frequency perturbation training - 24 slips on an initial session and 3 ancillary single slip training sessions. • High intensity, low frequency perturbation training - 24 slips on an initial session as above, but with no ancillary single slip training sessions. • Low intensity, high frequency perturbation training - a single slip on an initial session and 3 ancillary single slip training sessions. • Low intensity, low frequency perturbation training - a single slip on an initial session as above, but with no ancillary single slip training sessions.	Four months after the initial session participants were tested with a single slip test on the walkway. Falls were defined by 'backward balance loss' (where the contralateral leg lands behind the slipping heel).	Very serious. No allocation concealment. No assessor blinding.	None.
Liu et al., 2016 RCT	36 healthy young people of mean age 24.8 years	Four groups experienced varying parameters of perturbations induced by a treadmill. • High intensity group where 24 slips were experienced at an acceleration of 12 ms^{-2} • Low intensity group where 24 slips were experienced at an acceleration of 6 ms^{-2} • Increasing intensity group where perturbation accelerations increased from 6 ms-2 to 12 ms^{-2} over 18 perturbations and then from 6 ms^{-2} to 12 ms^{-2} over the final 6 perturbations. • Decreasing intensity group where perturbation accelerations decreased from 12 ms^{-2} to 6 ms^{-2} over 18 perturbations and then from 12 ms^{-2} to 6 ms^{-2} over the final 6 permutations.	In the same session, all subjects then walked down a 7m walkway and were given a single slip perturbation provided by moving plates. The definition of a fall was not provided.	Very serious. No allocation concealment. No assessor blinding.	None.

Table 7: Grade table summarising the quality of evidence for all questions

Number of studies (number of participants)	Risk of bias	Indirectness	Imprecision	Inconsistency	Outcome reporting bias	Publication bias	Grade
Community falls for perturbation combined with standard training vs standard training in older people							
1 (64)	Very serious[1]	Serious[2]	Very serious[3]	No serious inconsistency	None suspected	Unable to detect as <10 studies	Very low
Community falls for perturbation training vs non-standard training in older people							
4 (420)	Very serious[4]	Very serious[5]	Very serious[3]	No serious inconsistency	None suspected	Unable to detect as <10 studies	Very low
Laboratory falls for perturbation training vs no training in older people							
2 (97)	Very serious[6]	Very serious[7]	No serious imprecision	No serious inconsistency	None suspected	Unable to detect as <10 studies	Very low
Laboratory falls for perturbation training vs no training in older people (not meta-analysed)							
1 (48)	Very serious[8]	Very serious[9]	Very serious[10]	No serious inconsistency	None suspected	Unable to detect as <10 studies	Very low
Laboratory falls for perturbation training vs no training in younger people							
6 (199)	Very serious[11]	No serious indirectness	No serious imprecision	No serious inconsistency	None suspected	Unable to detect as <10 studies	Low
Laboratory falls for perturbation training vs no training in younger people - intensity and frequency effects (not meta-analysed)							
2 (85)	Very serious[12]	No serious indirectness	No serious imprecision	No serious inconsistency	None suspected	Unable to detect as <10 studies	Low

[1] In the Lurie et al. (2013) study, there was no assessor blinding as well as likely attrition bias due to the exclusion from follow up and analysis of 5 subjects in the intervention group who did not attend for treatment.

[2] Less than 50% participants were fallers at baseline in Lurie et al. (2013). The authors stated that participants were referred because they were at risk of falling but the criteria are unclear.

[3] 95% CIs crossed both 0.75 and 1.25 thresholds

[4] Rosenblatt et al. (2013) used a pseudo-random alternate allocation approach, whilst none of the other randomised studies except Mansfield et al. (2010) used allocation concealment or had assessor blinding, and most had some degree of attrition bias and performance bias.

[5] No studies used standard physiotherapy approaches as the comparator. Only Mansfield et al. (2010) had clear documentation that >50% of participants were fallers, and data concerning the extent to which participants in the other studies were deemed at risk of falling was unclear.

[6] No reporting of allocation concealment in the Parijat and Lockhart (2012) study and a pseudo-randomisation procedure in the Grabiner et al. (2012) study. In addition, neither study ensured assessor blinding. Attrition bias likely in Grabiner et al. (2012)

[7] The outcome also had very serious indirectness as the mean age was <65 (but >55) in the Grabiner et al. (2012) study, the comparators were non-standard treatment for both Parijat et al. (2012) and Grabiner et al. (2012), and there was no documentation in either study that the participants were fallers or at risk of falling.

[8] No reporting of allocation concealment or assessor blinding, and potential attrition bias.

[9] Comparator was no treatment and there was no documentation that the participants were fallers or at risk of falling.

[10] p=0.5 in study

[11] In the two randomised studies (Bhatt and Pai 2009b, 2013) neither reported allocation concealment, whilst in the non-randomised studies (Yang et al. 2013; Yang et al. 2014; Lee et al., 2016; Wang et al., 2011) the method of allocation was unclear. Furthermore, assessor blinding was not reported in any study. In Wang at al. (2011) two people in the perturbation group were excluded from analysis when it was likely they would have fallen had they not been excluded.

[12] No reports of allocation concealment or assessor blinding in either study. In the Bhatt et al. (2009a) study attrition rates differed between groups, but this is unlikely to have related to outcome (these being a healthy sample) so attrition bias risk was probably low.

DISCUSSION

Our two meta-analyses relating to laboratory-induced falls in older and younger people clearly demonstrate that perturbation training has fall-prevention benefits compared to no treatment. The strong effect of perturbation training on falls in a laboratory setting appears to be similar between young and old, with both age groups demonstrating an approximately 6-fold decrease in laboratory falls frequency after perturbation training compared to no training. This is a qualitative impression as no direct age comparisons were conducted, but does agree with a study showing that older participants respond just as well to perturbation training as younger people (Pavol et al., 2002). This suggests that the mechanisms through which perturbation training exerts its benefits are not significantly attenuated by age. In particular the shift in reliance generated by perturbation training from reactive strategies towards a combination of feedforward and reactive strategies may be of particular advantage to older people. This is because feedforward strategies may be less affected by ageing effects on muscle power than the rapid 'emergency' movements involved in feedback responses.

In contrast, our other meta-analysis concerning the effects of perturbation training on community falls in older people suggests a more modest efficacy, with point-estimates of risk reductions of around 30% compared to the comparison treatment. Importantly there is considerable uncertainty about the true effect, indicating the possibility that no benefits may exist at all. The modest effect might relate to training specificity: it is intuitive that perturbation training conducted using laboratory equipment is more likely to promote recovery from falls induced on the same equipment than recovery from falls induced in the community. However some evidence (Bhatt & Pai, 2009a; Grabiner et al., 2012; Wang et al., 2011) suggests that the effects of perturbation training are generalisable to different contexts, and thus specificity may not necessarily be of prime importance. The relatively lower efficacy of perturbation training in the community falls studies might also relate to the fact that participants were generally older and frailer than those in the laboratory studies. For such participants, the low strength and power associated with frailty may be the limiting factor governing the ability to recover from a perturbation, rather than feedforward or reflexive stability control components, which are more amenable to perturbation training. However our inconclusive pooled results do not necessarily indicate that perturbation training is ineffective in preventing community falls. The quality of the meta-analysis for community falls was limited by the methodology and size of included studies, as well as the low number of eligible studies, which prevents a less ambiguous interpretation of findings. Further high quality trials may permit future meta-analyses to provide more certain results.

Only one study (Lurie et al., 2013) has evaluated the effects of perturbation training (combined with standard approaches) on community falls in older people, using standard best-practice falls prevention strategies as the comparator. Use of such a gold standard comparator is essential before it can be suggested that a combined perturbation training strategy is a new best-practice approach. The evidence from that single study was limited by the study not being adequately powered, and also by serious risks of attrition bias and detection bias. However, it weakly suggested that a combined perturbation approach might have some benefits over established methods. This reinforces the need for further work.

If perturbation training does have clinical efficacy, then one of the particular benefits of perturbation training may be its relatively rapid action (Pai et al., 2010b; Pai & Bhatt, 2007). Although limited evidence in younger people (Bhatt & Pai, 2009a; Liu et al., 2016) shows that more intense and frequent training may lead to even greater beneficial effects, the effects from just one session alone seem to be clinically important (Bhatt & Pai, 2009b; Bhatt et al., 2013; Grabiner et al., 2012; Lee et al., 2016; Pai et al., 2014a; Parijat et al. 2012; Wang et al., 2011; Yang et al., 2013; Yang et al., 2014). This rapid effect may be possible because this training may exert effects via immediate changes in CNS representation of the stable limits of the position of the centre of mass (Pai & Bhatt, 2007). It has also been suggested (Pai et al., 2014a) that the speed of such learning may be augmented by the fear induced by a training-induced (though harness-protected) fall, in accordance with animal studies showing that fear accelerates the development of adaptive synaptic pathways (Sacchetti, Scelfo, Tempia & Strata, 2004). In contrast, established approaches, which rely partially on the development of strength and power, may require several weeks of training for the neuromuscular adaptations to occur, and there are consequently likely to be greater problems with patient compliance and higher costs. Even if perturbation training is combined with standard approaches, as it probably should be given that the causes of falls are multifactorial, then the rapid benefits may still be beneficial. This is because any improvements in the proactive and reflexive aspects of postural stability may confer enough overall improvement (and perhaps confidence) to motivate continued standard training.

Another claim of the literature has been that the benefits of a single session of perturbation training may be relatively long-lived. Pai & Bhatt (2007) have discussed how updating of the stable limits of the COG, as part of a feedforward mechanism, may involve cortical and sub-cortical influences which might therefore be associated with longer-term memories. Accordingly, Bhatt et al. (2012) showed that both a single session of training and a single session combined with an ancillary session 3 months later led to continued gains at 6 months in younger people. Pai et al. (2014b) have also shown benefits lasting for up to 12 months in older people. However these results (which are not included in the main body of this systematic review) could be spurious as they were uncontrolled within-group gains, and thus prone to influence by intervening effects. No study has evaluated long-term outcomes using a control group and so it is still unclear if a single session is effective in leading to sustained benefits.

This systematic review has included data from younger people on the grounds that such studies are more likely to experiment with the parameters of training. However, there is currently insufficient evidence to allow definitive guidelines on the optimal parameters. The limited evidence suggests that slip perturbations of 12 cm length are probably sufficient (Lee et al., 2016; Yang et al., 2014), and that more frequent and/or intense sessions may be more effective (Bhatt et al., 2009; Liu et al., 2016). In addition, treadmill-induced perturbations may be slightly more effective than perturbations induced by shifting plates on a walkway (Yang et al., 2013), as well as being more practical, but this is far from clear.

Most of the evidence concerns training in the form of predominantly slip-type perturbations. However, it is known that real-world perturbations can be both slips and trips. So far only two studies (Grabiner et al., 2012; Rosenblatt et al., 2013) have estimated the effects of trip-like perturbation training on falls in older people. It is unknown if slip or trip training is superior and although the laboratory falls evidence in this review suggests each may have similar benefits (Grabiner et al., 2012; Parijat et al., 2012), this evidence is only in terms of how trip training protects against trip-induced falls and how slip-training protects against slip-induced falls. What remains to be seen is how well trip training relates to resistance to slips, and vice versa. Bhatt et al. (2013) attempted to establish the effects of slip training on resistance to trip-induced falls, but no falls were recorded in either intervention or control groups, making conclusions difficult.

It has been theorised that combining slip and trip training may actually be counter-productive because slip and trip training involve opposite stimuli – slip training promoting backward corrections due to the posterior rotation induced by the anterior slip perturbation, and trip training promoting forward corrections due to the anterior rotation induced by the posterior trip perturbation (Bhatt et al., 2013). However, in an extension to their comparative study, Bhatt et al. (2013) also showed that mixing approaches in the perturbation group did not adversely affect measures of stability. The authors concluded that the CNS was able to develop a generalised and adaptable movement strategy. This concurs with other findings. For example, in the Bhatt & Pai (2009b) study the slip perturbations trained on the treadmill transferred to reduced fall rates on a slippery floor. In the Wang et al. (2011) work, perturbations given during a sit-to-stand task transferred to greater falls resistance during walking. Similarly, in the study by Grabiner et al. (2012) perturbations provoked in standing appeared to carry over to protection of falls occurring during walking. Hence it is likely that trip training may carry over to protection from slips and vice versa. This generalisability is important as falls may occur in many different contexts, and perturbation training cannot hope to mimic all of them.

There are two main threats to a review capturing all the available data: 1) actual studies not being found by the search, and 2) failure of researchers to report relevant results or publish their data at all. In terms of the first threat, this systematic review used three databases, alongside cross-referencing, which make us confident that we have surveyed all the relevant literature. In terms of the second threat, we have no evidence to suggest there was any outcome-reporting bias or publication bias, although the latter was not possible to evaluate rigorously due to a small number of studies. One strength of this study was the use of two researchers to sift, extract and appraise all data. For the initial three sifts (Kappa scores: 0.83, 0.67 and 0.57 respectively) any papers selected by either author were automatically sought for further examination for maximum sensitivity. For the final selection of included papers and decisions on GRADE ratings, consensus was used where initial disagreement occurred (Kappa 0.78 and 0.57 respectively), and all were resolved to the satisfaction of both reviewers.

Ultimately, perturbation training is unlikely to be the ‘magic bullet’. Even if reflex responses to perturbations are optimised these may not prevent falling in response to trips or slips if failing sensory systems or reduced muscle strength and power are the limiting factor. Furthermore, it has been estimated that 40% of falls are not related to slips or trips (Luukinen et al., 2000), so perturbation training may have limited effects on these. The ideal approach is therefore likely to involve a variety of approaches, based on detailed patient assessment.

CONCLUSION

The evidence that perturbation training has benefits over conventional approaches is unclear. Laboratory studies provide some evidence that perturbation training may have a place in falls prevention and further research is needed to confirm this. Perturbation training may exert effects after one session, but greater frequency and intensity of training may further increase effects.

KEY POINTS

1. Perturbation training is effective in reducing *laboratory-induced* falls in healthy young and older people,
2. Perturbation training may have rapid effects on reducing *laboratory-induced* falls, but the duration of effect is unclear.
3. Despite this, the efficacy of perturbation training in reducing *community falls* in healthy older people is uncertain, and further adequately powered and rigorous research is required before resources should be uncritically devoted to such an approach.

DISCLOSURES

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Are people with whiplash-associated neck pain different from people with nonspecific neck pain?

Anstey, R., Kongsted, A., Kamper, S., & Hancock, M.J. (2016). Journal of Orthopaedic & Sports Physical Therapy, 46 (10), 894-901. doi:10.2519/jospt.2016.6588.

OBJECTIVE

To determine whether individuals with whiplash-associated neck pain (WAD) are different from individuals with non-specific neck pain (NSNP) upon presentation to secondary care and at long-term follow-up.

METHODS

A secondary analysis was performed on a prospective cohort study of people presenting to a Danish outpatient spinal clinic following unsatisfactory recovery from primary care management. Participants included those on the registry who had: (i) a primary complaint of persistent neck pain, (ii) recorded a response regarding past experience of whiplash trauma, and (iii) complete data sets for baseline and at least one of six or 12 month follow-up measures. Baseline clinical characteristics including pain intensity, pain frequency, previous episodes, neck disability, general health, anxiety, depression, expectations of recovery, dizziness, memory difficulties and morning stiffness were assessed at initial consultation using self-report questionnaires. Long-term follow-up measures comprised pain intensity (Numerical Pain Rating Scale (NPRS)) and neck disability (Neck Disability Index (NDI)) assessed at six and/or 12 months post-initial presentation. Mean WAD and NSNP baseline characteristics were compared descriptively and with hypothesis testing as appropriate to data distribution. Linear mixed modelling was performed to identify between-group differences in follow-up measures.

RESULTS

In total, 2578 participants with a mean age of 48.8 (SD 13.2) years and median neck pain duration of 10.5 (IQR 4.1-32.6) were included in the study. Of these, 488 (19%) and 2090 (81%) were classified with WAD and NSNP, respectively. The WAD group demonstrated greater symptom severity at baseline as evidenced by often small but statistically significant between-group differences in all measures ($p<.006$) except pain frequency ($p=.09$). Large between-group differences were evident in memory difficulties (WAD=68%, NSNP=36%, $p<.001$) and dizziness measures (WAD=67%, NSNP=45%, $p<.001$). Between-group differences increased significantly at long-term follow-up ($p<.001$), with the NSNP group demonstrating a 1.64 point greater improvement in NPRS and 11% greater reduction in NDI score compared to the WAD group. Study drop-out was substantial with only 1093 (42%) participants contributing data to follow-up outcomes.

CONCLUSION

Individuals presenting to secondary care with persistent WAD experience greater symptom severity and poorer long-term outcomes than those with NSNP.

COMMENTARY

Whilst quantifying the clinical characteristics of people with neck pain is not new, the head-to-head comparison of individuals with persistent WAD and NSNP provided by this study is unique, and helps establish whether these groups are clinically distinct. The results indicate that people with WAD experience significantly higher levels of pain, disability and associated clinical characteristics than those with NSNP. Although many between-group differences were not clinically significant, more frequent signs of functional, sensory, psychological, and cognitive impairments in the WAD group may reflect greater need for multi-domain assessment and management. For example, higher rates of anxiety and depression serve as a reminder that evaluation of psychological symptoms is important in this population. Use of measures such as the Impact of Events or Depression Anxiety Stress Scales are recommended to assist physiotherapists in identifying people with psychological symptoms, prompt referral to a general practitioner or clinical psychologist, or informing the decision to monitor those with milder symptoms (Motor Accident Authority, 2014). The presence of dizziness in 67% of WAD participants is also notable due to its association with poor recovery and indicators of sensorimotor dysfunction (Treleaven, Jull, & Sterling, 2003). Assessment of dizziness can therefore provide physiotherapists with prognostic information, as well as prompting investigation of other sensorimotor functions (e.g. cervical kinaesthetic sense and head-eye movement control), which may lead to the selection of more efficacious impairment-targeted interventions (e.g. head relocation and eye-head coordination exercises).

Over the course of secondary management, individuals with WAD improved significantly less than their NSNP counterparts. Whilst substantial drop-outs and an absence of intervention details limit the interpretation of these findings, minimal improvement in the WAD group is consistent with results of treatment trials that demonstrate difficulties in changing the clinical course of chronic WAD. It remains uncertain how clinicians should communicate unfavourable prognostic information in this context, since this might compound negative expectations and influence outcome (i.e. via the nocebo effect). Conversely, providing inaccurate expectations or information that is inconsistent to that provided by other practitioners can result in distrust of health providers and reduced willingness to seek future treatment. Instead, it may be reasonable to indicate that symptomatic improvement is likely, but may be smaller, and occur more gradually than what is expected in other conditions. Further, recent evidence suggests that benefits normally achieved through positive treatment expectation can be harnessed without deception, by educating patients about established links between mind and body (Carvalho et al., 2016). Given the current study demonstrated that people with WAD have less favourable expectations, such education might be particularly important in this group.

It should be noted that the results of this study do not infer that every individual with WAD will experience severe symptoms or an unfavourable outcome. Recovery from WAD is widely acknowledged as heterogeneous. As such, early identification of prognosis can facilitate the provision of reassurance and concerted management of people who are likely to make a rapid recovery, whilst enabling greater allocation of resources towards more detailed assessment and management of those who may not. To detect those with a less favourable prognosis, Australian WAD management guidelines recommend identifying those with high initial pain intensity, high disability, and low expectations of recovery (Motor Accident Authority, 2014). Application of a validated clinical prediction rule (Ritchie, Hendrikz, Jull, Elliott, & Sterling, 2015) to complement these indicators may further enhance certainty in prognostic decision-making.

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