STAIR NEGOTIATION AS A REHABILITATION INTERVENTION FOR ENHANCING RECOVERY FOLLOWING TOTAL HIP AND KNEE REPLACEMENT SURGERY

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ABSTRACT

Background: Total hip replacement (THR) and total knee replacements (TKR) are common orthopaedic procedures. However, an optimal programme for post-operative rehabilitation has yet to be established. Stair negotiation is a challenging, habitual task, regularly used as a post-operative functional outcome measure; yet as a physical rehabilitation intervention it appears to be rarely used.

Aim: The review purpose was to investigate the effectiveness of stair climbing as a rehabilitation intervention for THR and TKR patients.

Methods: MEDLINE, PsycINFO, Science Citation Index, CINAHL, SPORTDiscus, and the Cochrane Database of Systematic Reviews were searched. The systematic review targeted studies using stair negotiation as a rehabilitation intervention. Randomised and non-randomised controlled trials, pilot studies, and case studies were included; systematic reviews and meta-analyses were excluded.

Results: Of 650 articles identified, ten studies were eligible for review. A predefined data table to extract information from selected studies was used. Of the ten identified reports, two prehabilitation and eight rehabilitation studies included stair negotiation exercises as part of multi-modal physical interventions. Outcome measures were classified as: functional self-reported, perceptual, psychological and those relating to quality of life.

Conclusion: Studies were methodologically heterogeneous and typically lacked adequate control groups. It was not possible to determine the impact of stair negotiation exercise on the positive outcomes of interventions. Stair negotiation warrants further investigation as a rehabilitation activity.

KEYWORDS stair climbing; knee arthroplasty; hip arthroplasty; physical function; rehabilitation.

INTRODUCTION

Over 205,000 people had hip and knee replacement surgery in England in 2014 (National Joint Registry, 2014) and due to the increasing lifespan of the population, the number of patients requiring these operations is rising (Learmonth et al., 2007).

To enhance the benefits of total hip (THR) and knee replacement (TKR), rehabilitation is necessary to i) recover musculoskeletal strength and physical fitness, and ii) improve post-operative mobility for independence and quality of life. As the burden on health care increases, appropriate and affordable rehabilitation programs, specific to the patient's activities of daily living (ADL), are essential. For example, mobility interventions that capitalise on the built-environment of the delivery location (i.e., hospital and/or day centre settings), so that improvements can be translated in to home-based settings (i.e. in the patients' home and community-based environments). Stair negotiation, going up and down a flight of stairs with, or without assistance (Van Iersel et al., 2002), is a primary functional requirement for inpatient hospital discharge. Centre-based interventions also facilitate early rehabilitation and adherence to higher training intensity (Lemmey & Okoro, 2013), both of which may promote faster functional recovery and shorter hospital admissions after hip (Oldmeadow et al., 2006) or knee joint surgery (Khan et al., 2008).

Standard physiotherapy care often fails to correct post-operative impairments in physical function from bed-rest and surgery deconditioning for THR patients (Lemmey & Okoro, 2013). Immediate, post-operative care commonly entails a combination of weight-bearing, bed, and functional exercises, but not progressive resistance training (Okoro et al., 2013). These inpatient exercises benefit from centre-based, physiotherapist supervision and specialised equipment; however unlike stair negotiation, they may not sufficiently challenge lower-limb strength, postural stability and sensorimotor abilities.

Stair climbing is a requirement for discharge, requiring sufficient leg strength (Costigan et al., 2002), lower-limb joint range of motion (Nadeau et al., 2003; Riener et al., 2002) and medio-lateral postural stability (Nadeau et al., 2003; Protopapadaki et al., 2007) to raise the body up to the above step. In comparison to healthy adults, total hip arthroplasty patients display impaired gait mechanics during stair climbing (Lamontagne et al., 2011), as a result of weak abductor muscles (Perron et al., 2000) and reduced hip extension motion (Queen et al., 2013). Conversely, walking down stairs requires the body to be moved forwards, and downwards, in single-limb support to contact the step below. This involves high postural instability (Zachazewski et al., 1993), and therefore sufficient neuromuscular control to ensure the swinging, contralateral limb safely clears the two step-edges, and is then placed accurately on the following step (Muhaidat et al., 2011).

Osteoarthritis is the most common reason for THR (Felson et al., 2000) and TKR (Guccione et al., 1994; Weinstein et al., 2013), and presents a functional limitation for level and stair walking. Accordingly, level walking and unaided stair negotiation are used as physical performance outcomes to assess patient functional mobility following THR and TKR (Dobson et al., 2012; Kennedy et al., 2005; Mizner et al., 2011; Stratford et al., 2006). Stair negotiation poses a greater level of task demand, when compared to walking and chair rising (Jette et al., 2003). For more demanding tasks, such as stair climbing, older women (70-79 years) with lower functional mobility (4 m walk and sit-to-stand tests) are differentially slowed (Weiss et al., 2007). Furthermore, difficulties in performing stair climbing begin to develop in midlife (43 and 53 years) (Wloch et al., 2016). Therefore, rehabilitation interventions should be demanding enough to allow individual progression, as well as promote physiological (cardiovascular) and functional (balance, strength and co-ordination) adaptation from midlife onwards. An inability to independently walk and negotiate stairs not only affects confidence and increases fall risk, but also requires greater healthcare assistance and influences quality of life. Recovery from joint replacement surgery is often managed by home-based, multi-modal exercise interventions (Mangione et al., 2005; Tsauo et al., 2005), yet stair negotiation provides a limited contribution in these programs and has not been examined in rehabilitation programmes.

As stair negotiation represents a functional outcome measure (Unver et al., 2015; van Iersel et al., 2002) and ADL high on the hierarchy of task demand (Jette et al., 2003), improvements would be expected to translate to less challenging, mobility and ambulatory tasks encountered in daily-life (such as transfers, standing up and walking) (Carr & Shepherd, 1998; Liao et al., 2015).

To our knowledge, the use of stair negotiation within multi-modal rehabilitation interventions varies widely with post-operative, THR and TKR patients. The aim of this review was to identify how stair negotiation is used as a rehabilitation intervention to improve performance outcomes, post-operative THR and TKR surgery. The secondary aim was to identify the utility of stair negotiation as prehabilitation; although less common, stair negotiation is used to pre-condition. We aimed to minimise bias by limiting our search to high-quality, peer-reviewed evidence, and where appropriate include only randomised control trials.

METHODS

Eligibility criteria

This systematic review targeted studies using stair negotiation as a physical rehabilitation intervention following THR and TKR. Also included were prehabilitation (pre-operative conditioning) studies and exercise training studies, incorporating stair climbing and/or stair descent. Stair negotiation refers to both walking up, and down stairs; whereas, stair climbing only walking up, and stair descent only walking down stairs. These terms are referred to henceforth.

Inclusion criteria were: studies comparing physical rehabilitation interventions involving stair negotiation, with other types of care (including standard physiotherapy, health education and water therapy, or no intervention).

Exclusion criteria were: studies involving stair negotiation as an outcome measure, but not as an intervention; multimodal interventions, without stair negotiation; prospective cohort and observation studies (involving biomechanical assessment). The Cochrane Database of Systematic Reviews was searched to identify relevant literature for screening, but systematic reviews and meta-analyses were not eligible for review (see Figure 1).

Outcome measures

Where possible, eligible studies had to include health outcomes considering: i) functional recovery (e.g., 6 min walk time), ii) self-reported recovery (e.g., the Oxford hip score), iii) self-perceived pain (e.g., the visual analogue scale (VAS)), and iv) life quality indexes (e.g., Assessment of Quality of Life (AQoL)).

Data sources and searches

This systematic review used a computerised literature search using the Physiotherapy Evidence Database (PEDro), the Cochrane Database of Systematic Reviews and the mySearch Database (Bournemouth University), which included: MEDLINE, PsycINFO, Science Citation Index, CINAHL and SPORTDiscus. The strategy searched publications from January 1^{st} 2000, to October 22^{nd} 2015, and was limited to peer-reviewed, English language, academic journals. The medical subject headings (MeSH) and related terms in Table 1 were used to identify words in the title or abstract for the systematic search strategy.

<<< INSERT TABLE 1 HERE >>>

All relevant randomised and non-randomised controlled trials, pilot studies, and case studies were included; systematic reviews, meta-analyses, dissertations, editorials, abstracts, books, government and technical reports, and guideline statements were excluded. Subsequent search results were exported to a database in EndNoteWeb (Thomson Reuters Corp, New York, http://www.myendnoteweb.com/EndNoteWeb.html). A second, independent reviewer performed the search strategy to check for accuracy and rigor using the Peer Review of Electronic Search Strategies (PRESS) Checklist (McGowan et al., 2010).

Study selection

Two reviewers (JG and TW) performed the literature search separately, screening study titles and abstracts to determine those eligible for inclusion. Next, the same pair independently reviewed possibly eligible articles, to make a final decision whether to include or exclude. When the reviewers disagreed upon study inclusion, an independent reviewer (TI) was consulted.

Data extraction and quality assessment

Eligible studies were examined by the lead reviewer (JG), who used a predefined data extraction table to extract data from the selected studies. This table included information on the: follow-up period, surgical operation, number of patients recruited (and adhering), patient age, control group, intervention (including details of stair negotiation exercises), and reported outcomes measures. When an article failed to include this information in detail, the authors were contacted. The second reviewer (TW) then independently checked the completed data extraction table against the included articles. Edits or comments from the second reviewer were made with the 'Track Changes' feature on Microsoft Word (Microsoft Corporation, Redmond, Washington) and amended by the lead reviewer. Methodological quality was determined independently by each reviewer (JG and TW) using the PEDro scale. The 11 item scale is used to critically appraise randomised controlled trials (van Leeuwen et al., 2014); each study is scored out of 10 (item one indicates external validity), with a score of six the threshold for a high-quality study.

Data synthesis and analysis

The outcome measures considered in this systematic review were classified as functional, self-reported (i.e., perceived recovery), perceptual (i.e., pain), psychological and those relating to quality of life. Our evidence was synthesised with all outcome classifications reported in each respective study, as well as whether specific outcome measures changed during the post-operative follow-up period. Our primary interest concerned outcomes measures of functional ability, these included performance in: stair negotiation, walking tests, the 6 min walk test (6MWT), the timed up-and-go test (TUG), the sit-to-stand test, and lower-limb range of motion (ROM) and strength. Self-reported measures included: the Oxford hip score, the Western Ontario and McMasters University Osteoarthritis Index (WOMAC) and VAS scores, (perceptual measure); the Arthritis Self-Efficacy scale, (psychological measure); and the AQoL, (quality of life measure). This review conforms to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009).

RESULTS

Study selection

Our study search and inclusion processes are displayed in Figure 1. The search retrieved 752 articles, of which, 102 duplicates were removed and 650 were screened for eligibility. Thirty three articles were then full-text screened, a number of these were: i) studies without stair negotiation as part of the intervention, ii) post-operative observational studies (spatiotemporal, kinematic and kinetic changes), iii) involved prosthesis, artificial devices or assistive-technology and, iv) systematic reviews. Ten studies remained for further review.

<<< INSERT FIGURE 1 HERE >>>

Study quality and characteristics

Table 2 displays the PEDro scale appraisal for selected studies. Of the ten identified studies, the interventions, locations, involvement of stair negotiation and follow-up periods varied widely. Therefore, studies were classified as either: prehabilitation, rehabilitation (inpatient) and rehabilitation (after discharge) (Table 3). Of these, nine were randomised control trials and one a case report. Eight studies stated that a primary diagnosis of osteoarthritis at the operative joint was responsible for the joint replacement. Three trials used an intervention targeting the hip joint (one prehabilitation study, two rehabilitation studies) and seven trials used an intervention targeting the knee joint (one prehabilitation study, six rehabilitation studies). Five studies were centre-based (two prehabilitation, three rehabilitation), four ward-based and one home-based (the case report). The follow-up assessment periods ranged from 17 days to 15 months for hip replacement, and from 7 days to 12 months for knee replacement. In all cases, stair negotiation was supervised and formed part of a multimodal prehabilitation or rehabilitation regimen. For example, Galea et al (2008) used 45 min exercise sessions, allocating only 5 min to climbing and descending a three-step stair. Sessions ranged from 45 to 70 min in duration, and one study (Swank et al., 2011) used step-ups (forward and lateral) in preference to stair negotiation. Exercise progressions included speed (Bruun-Olsen et al., 2013), repetition and step height (Swank et al., 2011). The performance outcomes following each intervention are presented in Table 3. The studies were in insufficient number and clinical homogeneity to justify a meta-analysis.

<<< INSERT TABLE 2 HERE >>>

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Evidence summary for stair negotiation as an orthopaedic rehabilitation intervention

The prehabilitation studies (Swank et al., 2011; Vukomanovic et al., 2008) demonstrated improved functional mobility, including standing, walking and stair negotiation abilities pre-operatively (Swank et al., 2011), 3 days post-operatively and upon discharge (Vukomanovic et al., 2008). Vukomanovic and colleagues (2008) randomised patients awaiting primary THR surgery to i) short-term, prehabilitation (education (one physiotherapist-led session) and physical therapy exercises (two physiotherapist-led sessions) including, bed transfers, standing, walking with crutches, sitting on chair, aided stair negotiation), or ii) no prehabilitation. The same physical therapy exercises were then provided to both groups from day one, post-operative. Participants in the prehabilitation group were able to chair transfer (between-group mean change:

1.05 days; P = 0.006) and perform unaided stair negotiation (between-group mean change: 1.67 days; P = 0.002) earlier than the control group. Upon discharge, the prehabilitation group could negotiate stairs unaided (.0001), whereas the control group could not. However, ROM and self-reported measures were similar upon discharge.

For rehabilitation, Galea et al. (2008) randomised post-operative THR patients to 8 weeks of either: centre-based exercises (two, 45 min sessions per week; exercise progression), or home-based exercises (received illustrated exercise guide; no exercise progression). Both groups received an initial, 3 week program, involving transfers, walking and stair negotiation. Thereafter, the 8 week intervention included three-step, stair negotiation, which was progressed in the centre-based group by speed and/or repetition. Both groups improved physical function, gait measures and AQoL (Table 3), with the centre-based group reducing step time, and time in stance and double-support time (P = 0.05). Albeit positive outcomes, the intervention effects are difficult to determine as there was no non-exercise control group and the cohort of each group was small (centre-based group, *n* = 11; home-based group, *n* = 12).

Similarly, Harmer et al. (2009) randomised 2 weeks post-operative TKR patients into either: land-based, or water-based exercise groups (twice weekly for 6 weeks). The land-based intervention was delivered in a hospital gym and included five-step stair climbing and stationary, stepping-machine exercise. Both groups improved: 6MWT distance (group mean change: 201 m [95% CI = 184, 218 m]; P = 0.0001), stair climbing power (group mean change: 91 watts [95% CI = 81, 101 watts]; P = 0.0001), VAS soreness (group mean change: -3.2 points [95% CI = 2.7, 3.8 points]; P = 0.0001), knee flexion ROM (group mean change: 24° [95% CI = 21, 27°]; P =

0.0001) and WOMAC scores, up to 26 weeks post-operative. Elsewhere, Kramer et al. (2003) found no difference between clinic- and home-based rehabilitation for TKR patients on timed stair negotiation, 6MWT distance, pain, and knee flexibility at 12 and 52 weeks. Both rehabilitation groups were instructed to perform home exercises (three times daily, from 2 to 12 weeks post-operative), which included stair climbing.

Kauppila and colleagues (2010) had all patients receive daily standard physiotherapy care, with an intervention group undergoing an additional 10 day multimodal exercise program, 2 to 4 months post-operative TKR (Table 3). Initial, ward-based physiotherapy care comprised of transfers, gait training, and stair climbing from 0 to 2 months, which were instructed to be performed daily from discharge. In both groups stair nine-step stair ascent ($P < 0.001$) and descent ($P < 0.001$) times improved.

Bruun-Olsen et al. (2013) provided standard physiotherapy care to TKR patients for 2 to 4 weeks, patients were then provided either: 6 weeks of walking-skills training or continued physiotherapy care (control group). Both groups underwent twelve, 70 min small-group sessions, whereas walking skills training included 5 min of five-step stair climbing at different speeds and heights. The walking-skills group showed greater improvements in 6MWT ($P = 0.004$), self-reported physical function ($P = 0.008$) and self-efficacy ($P = 0.03$) scores immediately post-intervention, and 6MWT ($P = 0.02$) 9 months post-intervention. This was one of the few studies in which both the experimental and control (comparison) group did not both receive a training intervention, involving stair negotiation. Additive to that no study has used an intervention involving solely stair negotiation training, the specific influence of stepping and/or stair negotiation exercise on functional recovery post-orthopaedic surgery cannot be ascertained.

Liao et al. (2015) used platform or stair climbing in their functional training programme (one of 12 post-warm up activities) for TKR patients, which improved functional reach ($P < 0.01$), single-leg balance, gait speed, TUG, and sit-to-stand ability at 8 and 32 weeks ($P < 0.05$). However, the addition of balance training further improved each outcome measure from baseline.

In the case report (Lesch et al., 2010), seven home-based sessions over a period of 17 days, involving step-by-step stair climbing, improved walking gait pattern on level and during unaided, stair ascent and descent. After the 17 day intervention, the patient's functional hip assessment score (Harris Hip Score) increased (from 51 to 85) at 6 weeks post-operative. Most studies combined a range of exercises stressing: muscle strength, mobility, co-ordination and balance to a lesser or greater extent; yet supported stair negotiation may pose a safe and greater demand, for each of these abilities.

DISCUSSION

Summary of principal findings

Immediate physiotherapy care to improve recovery after THR and TKR requires activities that challenge the patient's functional mobility, physical strength and balance, in a progressive and tolerable manner (Lemmey & Okoro, 2013; Mangione et al., 2005; Okoro et al., 2013). Stair negotiation can safely test these capacities and is a common outcome measure to assess post-operative recovery, yet stair climbing is rarely included formally in physical rehabilitation exercises. We aimed to identify how stair negotiation is used as a prehabilitation and rehabilitation intervention to improve functional outcomes, after THR and TKR surgery.

Our review has identified that very few physical rehabilitation interventions exist that involve stair negotiation as a means of recovering physical function in THR and TKR patients. Few of these studies provided stair negotiation and/or stepping exercise to only one experimental group. Existing physical interventions therefore vary in: experimental design (use of control groups), exercise training (mode, activities, duration and volume), time of implementation, and follow-up periods. In addition, the specific impact of stair negotiation on the recovery of physical functions cannot be determined. Two studies using stair negotiation in a prehabilitation intervention demonstrated improved functional mobility both pre- (Swank et al., 2011) and post-operatively (Vukomanovic et al., 2008), when compared to standard care. No intervention used stair negotiation as i) a major component of, or ii) the sole exercise, in post-operative rehabilitation. This is surprising given that stair ascent and descent are functional requirements for patients returning to normal domestic and occupational activities. Owing to study heterogeneity and stair negotiation having not been used as a stand-alone activity, it was not possible to determine the impact of stair negotiation exercise on the recovery of physical function in THR and TKR patients. For these reasons a meta-analysis was not performed, and as such, the reader should be cautious when generalising from the results. There is a paucity of data evidencing the potential positive effects of stair negotiation on the recovery of physical function post-TKR and THR. As outcome measures, there seems little benefit in assessing level walking alongside stair negotiation with TKR patients (Crosbie et al., 2010). In this respect, the same may apply for exercise interventions. This review highlights that the effect of stair negotiation exercise on improving the recovery of functional outcomes for THR and TKR patients is not clear and warrants further investigation.

Walking up and down stairs presents a safe, but demanding activity that is adopted as a common functional measure to assess post-operative outcomes. It is important for the patient to be able to overcome stairs during their hospital admission, so that they can safely negotiate steps unsupervised in their own home and communities upon discharge. This review has shown that although stair negotiation is used as a common outcome measure after orthopaedic surgery, it is rarely adopted as a rehabilitation intervention, and has not been as a sole intervention. This is surprising given that stair climbing i) is an ADL, ii) presents a cost-effective, no equipment required intervention, and iii) poses greater functional challenge than other daily activities. Stair negotiation is an ADL high on the hierarchy of task demand (Jette et al., 2003), therefore one would expect potential improvements in strength, mobility and balance to translate on to simpler activities, such as transfers, standing and walking. We do not advocate the omission of lower demand exercises, such as standing and walking, from post-operative exercise interventions. But stair negotiation is a prerequisite for patient discharge and may present as a single exercise that may remove the need for large, burdensome multimodal exercise interventions.

In a case report with a THR patient (Lesch et al., 2010), reciprocal stair climbing 4 days after surgery was found to restore level walking and unaided stair climbing ability after only 17 days. Sessions were supervised and home-based (also involving body-weight resistance, balance and stretching exercises); therefore it is tempting to hypothesise that similar improvements may be achieved from a ward-based setting. Stair climbing is functional and presents high postural and proprioceptive demands, and more so stair descent, when an individual must lower their centre of mass to the step below. What remains to be seen is whether an intervention focused upon stair negotiation could enhance short- and long-term function for ADLs in individuals after orthopaedic surgery. Future studies examining stair negotiation to promote improved recovery should aim to assess functional and self-reported outcomes over more prolonged periods, particularly with regard to fall risk and quality of life.

Strengths and limitations

This review adopted a comprehensive search strategy that received agreement from a second independent reviewer to reduce error and bias. In addition, explicit study inclusion and exclusion criteria were established prior the commencing the search strategy by the two primary reviewers, to identify all relevant publications. The methodology used was standardised, and prior to the review all reviewers were familiar with the study aims, conducting systematic reviews and PRISMA guidelines. The PRISMA guidelines support reviewers in conducting and reporting systematic reviews and meta-analyses; all reviewers had previously used the PRISMA process (see Figure 1). This review also has limitations; these include studies restricted to English language (although most randomised controlled trials are published in English) and publication date before January 2000, and the use of only one independent reviewer.

Conclusion

This review has highlighted an exercise intervention that may be used to improve recovery from THR and TKR, but to date, has not been implemented as a sole intervention. Stair negotiation is a cost-effective, functional and adaptable activity; that has previously been limited to use as an outcome measure and as part of multimodal exercise regimens. Little evidence currently exists regarding the effect that supervised stair negotiation exercise has on the short- and long-term functional, self-reported and psychological outcomes of THR, or total TKR patients. This includes stair climbing exercise delivered in: the hospital ward, the home and the gym, as well as initial physiotherapy care delivered as a stand-alone, not multimodal rehabilitation activity. Stair negotiation as an exercise to improve recovery post-THR and TKR must first be deemed feasible, before potential effectiveness can be determined. Future research is required to determine i) the individual effect of stair negotiation, ii) the safety and practicality of such intervention, and iii) how potential functional improvements translate on to more simple outcome measures (i.e., transfers, standing and walking).

TABLE AND FIGURE LEGENDS

Tables

Table 1. Search strategy (Medical subject headings (MeSH) and related terms)

Table 2. Methodological quality of selected studies

Table 3. Characteristics of included studies, incorporating stair negotiation within their rehabilitation interventions

Figures

Figure 1. The process of article identification and selection, according to PRISMA guidelines

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