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Feasibility of a physiotherapist-supervised walking program with telephone coaching to increase physical activity following acquired brain injury

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ABSTRACT

Background. Physical activity has health benefits for adults with acquired brain injury, but it is a challenge to increase physical activity during inpatient rehabilitation. The objectives of this pilot study were to determine whether a physiotherapy-supervised inpatient walking program was feasible and able to improve physical activity and sedentary behaviour in the short and medium term. **Methods.** Adults with acquired brain injury receiving inpatient rehabilitation undertook twice-weekly supervised walks plus behavioural therapy for 4 weeks. Feasibility was measured via recruitment, participation and drop out rates, adverse events and intervention delivery costs. Physical activity and sedentary behaviour were measured with an activPAL. Assessments were conducted at baseline, post-intervention and 3–6 months post-intervention. **Results.** The program was safe to deliver (no adverse events), recruitment rate was 55% (16/29) and the participation rate for eligible individuals was high (14/19, 74%). However, the program had a high drop out rate (7/16, 44%) and physical activity and sedentary behaviour did not significantly change during the 4-week intervention. Costs were AU$427.71/participant. Physical activity and sedentary behaviour did improve 3–6 months after the intervention (vs baseline, on average: +3913 steps per day, 95% CI: 671, 7156). **Conclusion.** This pilot study demonstrated a supervised physiotherapy walking program is safe and feasible to recruit in an inpatient setting. However, drop out during the study was high and behaviour change did not occur. More work is required to boost physical activity during sub-acute rehabilitation for acquired brain injury.

Keywords: behavioural therapy, brain injury, hospital rehabilitation, physical activity, physiotherapy, sedentary behaviour, self-management, walking.

Introduction

Acquired brain injury (ABI) is defined as a brain injury that occurs after birth, caused by trauma (traumatic brain injury (TBI)), stroke, tumours, infection, hypoxia or substance misuse (Teasell *et al.* 2007; Turner-Stokes *et al.* 2015). This is a condition that affects many Australians. In 2020, more than 445,087 Australians were dealing with the consequences of a stroke (Deloitte Access Economics 2020). Across 2015–2020, 16,350 Australians were hospitalised with a moderate to severe TBI (O'Reilly *et al.* 2023). The consequences of ABI are complex and often result in significant restrictions on an individual's ability to participate fully in daily tasks, employment and physical activity. Their rehabilitation needs may encompass physical, communicative, behavioural, psychosocial and environmental concerns (Turner-Stokes *et al.* 2015).

Physical activity guidelines recommend that all adults, including those living with a disability, should participate in 150–300 min of moderate intensity or 75–150 min of vigorous intensity aerobic physical activity per week (or a combination of both); muscle strengthening exercises on 2 or more days per week; reduce their time spent sitting and break up long periods of sitting (World Health Organization 2020; Department of

Health 2021). In adults with ABI, however, this is often difficult to achieve, with a multitude of physical deficits (Basford *et al.* 2003), cognitive deficits (Slovarp *et al.* 2012), psychosocial changes (Hart *et al.* 2011) and fatigue (Chaudhuri and Behan 2004; Guggisberg *et al.* 2020) negatively impacting participation in physical activity (Hamilton *et al.* 2016; Fini *et al.* 2017; Ramsey *et al.* 2018) and resulting in high levels of sedentary time (sitting or lying with low energy expenditure, ≤1.5 metabolic equivalents (METS)) (Tremblay *et al.* 2017). Being physically inactive predisposes adults with ABI to experiencing poorer long-term health outcomes and prolonged disability, along with an increased risk of developing subsequent health issues including stroke (Hartmann *et al.* 2001; Burke *et al.* 2013), depression (Zgaljardic *et al.* 2015; Shi *et al.* 2017) and dementia (Li *et al.* 2016; Kuzma *et al.* 2018). As participation in regular physical activity is an important factor in maintaining health and wellbeing and reducing the risks of these secondary complications (Hoffman *et al.* 2010; Moore *et al.* 2015; D'Isabella *et al.* 2017), there is a need to improve and maintain physical activity levels in adults with ABI and reduce their sedentary time.

Previous studies have explored engaging adults with ABI in physical activity programs, using a variety of supportive tools and in different settings. Driver and colleagues (2023) implemented a 12-month educational diabetes prevention program, supported by a wrist-worn activity tracker to promote physical activity, for community-dwelling adults with TBI in the United States. Participants in the intervention group lost more weight than the control group who received a general health education group program. Bellon and colleagues (2015) progressively increased the step count goal for adults with TBI using a pedometer over 12 weeks and found their walking program to significantly reduce depression and stress when compared to education about nutrition (control group). Quality of life improved for sub-acute stroke survivors after a 9-month group physical activity program conducted within a seniors community centre (Lund *et al.* 2012). These programs employed physical activity as a component of their interventions, but did not measure physical activity as an outcome. One such program that did measure physical activity delivered a group education program (1 h, twice per week) to adults with a brain injury undertaking outpatient rehabilitation (Driver and Woolsey 2016). This education was designed to teach social and behavioural strategies, so that participants could adopt and maintain physical activity within a healthy lifestyle (Driver *et al.* 2012*b*). Participants did improve their (self-reported) physical activity levels as a result of the program. This evidence is promising, but also serves to highlight that translating the effect of physical activity programs into increased free-living physical activity is still a challenge.

Initiating and maintaining a physically active lifestyle is a significant challenge for healthy adults (Kelly *et al.* 2016; Australian Institute of Health and Welfare 2018); adults with ABI may face even greater challenges due to the nature of their injury (Driver *et al.* 2012*a*). An important aspect of maintaining an active lifestyle is having positive thoughts and beliefs about physical activity. Previous research suggests that behavioural therapy (changing thoughts and beliefs, and thus behaviours) can improve self-confidence to exercise in adults with ABI (Bell *et al.* 2005; Driver *et al.* 2012*b*). Behavioural therapy can be delivered in person or via telephone to adults with ABI to treat conditions such as depression (Fann *et al.* 2015; Kirkness *et al.* 2017). Behaviour change programs delivered via telephone have been shown to increase physical activity levels in adult patients of an ambulatory care clinic (Barrett *et al.* 2018). Thus, promoting self-confidence to exercise in adults with ABI could be achieved via telephone coaching, and might contribute to increasing their levels of physical activity.

It is common for adults with ABI who are hospitalised to receive an initial period of intensive rehabilitation within a hospital inpatient setting, with ongoing community-based follow up in specialised outpatient clinics after discharge (Turner-Stokes *et al.* 2015; Stroke Foundation 2023). During inpatient rehabilitation, many patients achieve a level of functional mobility, meaning that they can engage in walking as a form of physical activity. Walking as a regular form of physical activity has many known health benefits in free living adult populations and certain neurological populations (Halabchi *et al.* 2017; Jones *et al.* 2021). Prior studies have implemented physical activity programs with adults in the sub-acute and chronic phase post-ABI (Lund *et al.* 2012; Bellon *et al.* 2015; Driver *et al.* 2023). There is a need to explore the feasibility of such programs for the inpatient rehabilitation setting, as patients in these settings are physically inactive (Kunkel *et al.* 2015). Therefore, we designed a 4-week, hospital-based, supervised walking program complimented with behavioural therapy including telephone coaching in order to increase physical activity and decrease sedentary behaviour of patients with brain injury.

Pilot studies are a sub-set of feasibility studies, in that researchers are seeking to determine whether something can be done (a feasibility study) as well conducting some part of a future study on a smaller scale (a pilot study) (Eldridge *et al.* 2016). According to Thabane and colleagues (2010), there are four concepts to assess within a pilot study, related to a larger future study: the process, resources, management and treatment response. We had three objectives for this pilot study that addressed the process, resources and treatment response concepts. The first objective was to determine the recruitment rate, participation rate, drop out rate (process), adverse events (treatment response) and associated cost (resources) of the intervention. The second objective was to explore if the intervention had an effect (treatment response) on physical activity and sedentary behaviour primarily, and health-related quality of life, exercise self-efficacy and fatigue secondarily, in the short term (immediately after the 4-week intervention) and in the medium term (3 months after the intervention). The third objective was to explore feedback from participants

with ABI, their caregivers and physiotherapy staff involved in the walking program concerning the acceptability of and satisfaction with the assessment and intervention components of the program (process).

Materials and methods

Study design and setting

This pilot study with one group of participants was conducted at Princess Alexandra Hospital in 2019–2020; specifically, the Brain Injury Rehabilitation Unit, which is the 26-bed specialist multidisciplinary inpatient rehabilitation unit for people with brain injury in Queensland and northern New South Wales, Australia. This study was approved by Metro South Health (HREC/2019/QMS/48750) and The University of Queensland (2019/HE001243) Ethics Committees. Written informed consent was obtained from each participant. A corresponding hypothesis was not set for objective 2 (treatment response) as a formal power calculation was not done and any results from hypothesis testing in pilot studies are recommended to be treated with caution (Lancaster *et al.* 2004).

Participants

Eligible participants were adults (18 years and older) with a history of ABI; current inpatients of the Brain Injury Rehabilitation Unit; able to safely mobilise outdoors continuously for at least 10 min (±walking aid, ±stand by assistance only) at a minimum step rate of 80 steps per minute; able to follow three stage commands and provide informed consent. People were excluded from the study if they had other medical conditions that limited walking or made walking unsafe; had ABI-associated behavioural concerns or a mental health condition that limited constructive group engagement; had a cognitive impairment or insufficient English that impaired provision of informed consent; or were likely to discharge from the unit within 2 weeks of admission. The participants' treating physiotherapists, and medical team if required, were consulted to establish eligibility.

Caregivers or family members of participants with ABI and physiotherapy staff delivering the intervention were also invited to formally consent as research participants in order to provide feedback about the program. Caregivers were eligible to participate if they were within the social support network of a participant with ABI, as nominated by that participant. Physiotherapy staff were eligible to participate if they worked within the brain injury clinical team at Princess Alexandra Hospital and had actively supervised participants in at least one walking session.

Sample size

A sample size of 20 individuals with ABI was considered practical for this study, allowing for potential participant drop out (Julious 2005; Sim and Lewis 2012) as well as being feasible to achieve with predicted patient flow through the Brain Injury Rehabilitation Unit.

Procedures

Treating physiotherapists within the Brain Injury Rehabilitation Unit referred patients who they identified would benefit from the program and broadly met eligibility criteria to the first author (physiotherapy clinician) or the senior author (physiotherapy researcher) for formal screening and recruitment. Baseline data collection included 7 days of continuous accelerometer wear and completion of clinical and patient-reported outcome measures (Supplementary material S1). The 4-week intervention period commenced after the 7-day activity monitoring. The post-intervention assessment occurred as shortly after the intervention completion as possible (i.e. at the next hospital visit). The medium-term follow up assessment was planned to occur at 3 months after intervention completion, at the next most convenient hospital outpatient appointment. Caregivers of participants were identified in the last 1–2 weeks of the intervention period for their associated participant and were consented to provide feedback via written questionnaire about the program, not to actively be involved in the walking sessions. Staff involved with the study provided feedback via anonymous online questionnaire at the end of the study period.

Intervention

All participants received the intervention, which had two components: a supervised walking program twice a week and a weekly behavioural therapy program delivered by a trained physiotherapist. This was in addition to usual care provided within the rehabilitation unit.

The participants undertook two supervised walking sessions per week for 4 weeks in small groups of up to six. Each session was supervised by one physiotherapist and either a physiotherapy assistant or final year physiotherapy student. The walking session consisted of a 5-min warm up, 30-min walk on a pre-specified walking route around the hospital campus, and a 5-min cool down. Music with a tempo of 80 beats per minute was played to keep participants walking at a pace considered to be of moderate intensity for other neurological populations (Manns and Baldwin 2009; Billinger *et al.* 2014) to achieve a physiological effect.

The behavioural therapy component was designed by following the steps to design a behaviour change intervention advocated by Michie *et al.* (2011, 2014): understand the behaviour, identify intervention options and identify content and implementation options. Behaviour occurs as a result of capability, opportunity and motivation. We identified intervention functions (e.g. education, training, enablement) and their corresponding behaviour change techniques (e.g. information, demonstration of the behaviour, goal setting) to

influence capability, opportunity or motivation. An in-person one-on-one initial education session of 20–30 min duration was delivered to the participant (and their caregivers, if available) by a physiotherapist trained in goal setting (Prescott *et al.* 2015) and motivational interviewing principles (Medley and Powell 2010). The purpose of this session was to facilitate discussion of the participant's beliefs, expectations and concerns around physical activity, and commence goal setting toward physical activity targets. An A4-sized paper copy of a presentation was used as a tool in the education session, meaning the education session was semi-scripted. Either individual face-to-face or telephone coaching (depending on inpatient vs outpatient status) was then delivered once per week. During these coaching sessions, participants were facilitated to set goals that increased their total physical activity each week, working towards the adult physical activity recommendations of 30 min of moderate intensity physical activity per day for 5 days per week (Department of Health 2021) by Week 4. However, as the intervention was tailored to each participant, participants were not forced to achieve this recommended amount by Week 4. If a participant was discharged before completing the program, they were facilitated via these coaching telephone calls to continue twice-weekly community walking sessions equivalent to the hospital-based sessions. The goal setting diary and weekly coaching phone call were used to support engagement, and a family member or friend was encouraged to supervise the sessions if available, although was not mandated.

At the start of the intervention, participants also received a generic physical activity brochure; an activity diary to plan, record and reflect on physical activity levels; a pedometer to use as a goal setting tool; and a hat, water bottle and sunscreen.

Outcome measures

Feasibility data included recording the number of eligible patients screened and recruited, along with participant drop out. The recruitment rate was defined as the consented participants as a percentage of participants screened. The participation rate was defined as the number of participants who commenced the intervention as a percentage of those eligible. Participants who were uncontactable after discharge as well as participants who formally withdrew were considered to have dropped out.

To contribute to feasibility data, staff conducting the supervised walking sessions were instructed to ask all participants how they felt after the previous walking session (e.g. to identify any musculoskeletal injuries associated with the walking session), and to make a record in the medical chart and in the research record of any adverse events (e.g. mechanical fall) that may have occurred during the supervised walking sessions. The treating medical team was also to be notified of any adverse events arising from the walking sessions. Costs of implementing the program were determined by the recording of staff time spent screening, recruiting, collecting data and delivering the walking program; and by recording the use of equipment and consumables.

Physical activity and sedentary behaviour were captured by the activPAL4 accelerometer (PAL Technologies Ltd, Glasgow, UK). This device has been found to be a valid and reliable measure of physical activity and sedentary behaviour in healthy adults and neurological populations (Ryan *et al.* 2006; Lamont 2013; Mahendran *et al.* 2016). For each monitoring period, participants were asked to wear the device for 7 continuous days, affixed to the right thigh via a hypoallergenic dressing. Time points for waking, sleeping and device removal >15 min were recorded by the participants in a paper-based diary. Days were regarded as invalid if >4 h of non-wear occurred. All participants with ≥ 1 day of valid data were included in analyses. Outcomes derived from this device included step count, stepping time, upright time, standing time, sitting time, primary lying and secondary lying, metabolic equivalents per hour (MET/h), and number and duration of sitting bouts. Primary lying is the longest bout of lying of ≥ 60 min (i.e. night time sleep) and secondary lying is any other time spent lying for ≥ 60 min (e.g. daytime nap, lying on the couch) (PAL Technologies 2021). Physical activity was then further classified by intensity as either light or moderate-vigorous (Lyden *et al.* 2017). This range of variables was used in order to fully describe the concepts of physical activity and sedentary behaviour.

Health-related quality of life was measured with the EuroQol-5 Dimensions (EQ-5D) questionnaire. A utility score was calculated, anchored at 0 for poor health and 1 for perfect health (Herdman *et al.* 2011). The visual analogue scale (VAS) component of the EQ-5D was also used, where respondents reported their perceived health status with a grade ranging from 0 (worst possible) to 100 (best possible) (Herdman *et al.* 2011). In people undergoing rehabilitation after stroke, the minimal clinically importance difference (MCID) has been reported as 0.10 for the EQ-5D Utility score, and 8.61 for the EQ-VAS (Chen *et al.* 2016).

In addition to the EQ-5D, the Short Form-36 (SF-36) was also used to measure health-related quality of life (Ware and Sherbourne 1992). The SF-36 has eight sub-scales, each of which is scored on a 0–100 scale with a higher score denoting a more favourable health state (Ware and Sherbourne 1992). An MCID of eight points has been reported across healthy and neurological populations (Norman *et al.* 2003).

The Self-efficacy for Exercise Scale (Resnick and Jenkins 2000) was also utilised to measure the individual's beliefs in their ability to continue exercising across nine different situations covering environmental, physical and psychosocial barriers to exercise. The total score is a sum of the question scores, ranging between 0 and 90, with a higher score indicating greater self-efficacy for exercise (Resnick and Jenkins 2000). The MCID value has not been established for this outcome measure.

The Modified Fatigue Impact Scale (MFIS) was used to measure fatigue and the impact it has on daily function (Schiehser *et al.* 2015). In this scale, items are aggregated into three subscales: physical (0–36), cognitive (0–40) and psychosocial (0–8), which can also be represented as a total score (0–84). Higher scores indicating a greater impact of fatigue (Schiehser *et al.* 2015). Studies in people with multiple sclerosis have reported an MCID of four points (Rooney *et al.* 2019).

Acceptability and satisfaction with aspects of the walking program were captured via two 5-point Likert scales anchored with 0 being 'not at all acceptable/satisfied' up to 5 being 'very acceptable/satisfied'. The questions were individualised to participants with ABI, caregivers and staff.

In order to characterise the cohort, data concerning sociodemographics (age, gender, country of birth, language spoken at home, education, marital status, residence) were collected from participants at baseline via a paper-based questionnaire. Health data (time since injury, initial Glasgow Coma Scale, type of brain injury) were extracted from the medical chart by the first author. All participants had their height and weight measured at baseline by the first author or senior author, in order to calculate body mass index. Level-ground gait performance was measured at baseline as an additional descriptor of the cohort (not outcome). Gait was evaluated by completing a 12-m walk over an instrumented GAITRite walkway (GAITRite® CIR Systems Inc., USA). GAITRite® instrumentation has been shown to have high reliability capturing spatio-temporal gait characteristics (Batey *et al.* 2003). The variables velocity, step count, step time and step length were processed by the GAITRite® software. Participants completed three walks along the walkway, and the results of the three walks were averaged.

Statistical analyses

Statistical analysis was performed using SPSS (ver. 25, IBM Corp, Armonk, NY, USA) and STATA (vSE 17.0, StataCorp LLC, College Station, TX, USA) and statistical significance was set at $\alpha = 0.05$. Summary statistics (mean, standard deviation, frequency, percentage) were produced to describe the participant cohort. A comparison between characteristics of those who remained in the study versus those who withdrew was conducted using the Independent *t*-test (parametric) and Mann Whitney *U* test (non-parametric) for continuous data, and Pearson's Chi-squared or Fisher's exact test for categorical variables. For the first objective, feasibility data were presented descriptively. The total cost of the pilot intervention and the cost per participant were calculated using the known hourly rates for physiotherapists (level HP3.4) and physiotherapy assistants (level OO3.4) within Queensland Health applicable to 2020, plus facility usage fees and on-costs. For the second objective, data obtained from the activPAL4 activity monitors were batch processed and analysed using the activPAL software PALanalysis (v8.10.3.8). These data were also processed and analysed using MATLAB software (ver. R2017b) to provide intensity of physical activity (light, moderate-vigorous intensity). To explore the second objective, the Shapiro-Wilk test was used to test for assumption of normality, with paired *T*-Test or Wilcoxon Signed Rank tests being used to calculate mean differences (with 95% confidence intervals) between (i) baseline to 4-weeks, and (ii) baseline to long-term follow up. Partial eta-squared values (partial η^2) were used as a measure of effect size and calculated using repeated measures analysis of variance. These effect sizes were interpreted as a small (0.01), medium (0.06) or large (0.14) effect (Richardson 2011). This analysis for the second objective applied to the variables of physical activity and sedentary behaviour, as well as SF-36, EQ. 05D, Self-Efficacy for Exercise Scale and MFIS. Missing data were not replaced. For the third objective, acceptability and satisfaction results were tabulated and presented as a frequency count.

Results

Interruptions to study procedures

Recruitment commenced in April 2019. Research activity was paused in September 2019 due to unforeseen staff redeployment out of the Brain Injury Rehabilitation Unit and did not resume until July 2020 due to the health system's response to the COVID-19 pandemic in the first half of 2020 (group treatment sessions were suspended). Research activity and participant recruitment continued from July 2020 until November 2020. Another aspect of the hospital's response to COVID-19 during 2020 was to shift from in-person outpatient clinical appointments to telehealth clinical appointments. Consequently, some of our participants did not return to the hospital for in-person testing post-intervention (if they had been discharged during their 4-week walking program) or at the 3-month medium term follow up assessment timepoint. The general unease in the community due to COVID also made it harder to reach existing participants and arrange even remote data collection. As a result, some of the 3-month follow up appointments were conducted up to 6 months after the end of the intervention. To reflect this change, this medium term follow up time point will be referred to as 3–6 months post-intervention through the remainder of the present study. Accelerometer data and patient-reported outcomes were measured remotely under these circumstances if participants agreed.

Feasibility – recruitment rate and drop out rate

During the accumulative 11 months of active research activity, 29 inpatients were identified by clinical staff as potentially eligible. When formal eligibility screening was conducted, 19/29 (66%) were eligible, and 16 patients

Table 1. Participant recruitment.

Recruitment	*n* (%)
Participants referred for screening	29 (100%)
Participants eligible for recruitment	19 (65%)
Consented to recruitment (recruitment rate)	16 (55%)
Declined to participate	3 (10%)
Commenced intervention (participation rate)	14 of 19 (74%)
Participants interested in participating but excluded due to not meeting eligibility criteria	10 (35%)
Failure to emerge from post-traumatic amnesia, thus being unable to provide informed consent	3
Discharge date from rehabilitation unit unexpectedly brought forward, shortening length of stay to <2 weeks	4
Onset of new medical condition making it unsafe to perform intervention	2
Deterioration in acquired brain injury associated behaviour, making it unsafe to participate in group setting	1

went on to consent to participate. This resulted in a recruitment rate of 16/29 (55%). Table 1 presents the reasons for ineligibility for $n = 10$ patients. The main reason for ineligibility ($n = 4$) was too short a duration in inpatient treatment, followed by having post-traumatic amnesia ($n = 3$). Fig. 1 presents the flow of participants through the study. The 16 participants who consented to the project were reduced to 14 by the start of the intervention because two participants withdrew during the baseline activPAL testing period of 7 days ($n = 1$ change of mind, $n = 1$ unexpected early discharge). This resulted in a participation rate of 14/19 (74%). A further three participants dropped out during the intervention period because of: a change to their exercise ability due to surgical complications ($n = 1$); failure to respond to telephone coaching calls ($n = 1$); and withdrawing from the research project at the same time as discharging against medical advice ($n = 1$). This resulted in 11 participants completing the intervention. Two participants were unable to be contacted for post-intervention assessment. Therefore, the drop out rate was 7/16 (44%). The same nine participants were assessed post-intervention and at medium-term follow up (3–6 months post-intervention). There were incomplete data at each time point, mostly activPAL data, missing due to researcher error (see Fig. 1).

Of the 14 who commenced the intervention, six discharged home from hospital prior to completing the last 2 weeks of the intervention. These participants continued their walking in the community and received their weekly coaching and behavioural therapy via telephone. Additionally, the rolling nature of the program meant that on rare occasions, the walking sessions at the hospital were conducted with only one participant.

Participant characteristics

The characteristics of participants who consented ($n = 16$) are presented in Table 2. Participants were predominantly male ($n = 11$, 69%), with a mean (s.d.) age of 36 (12) years and a mean (s.d.) BMI in the overweight range (26.0 (5.5) kg/m^2). The age range was 18–56 years. The most frequent cause of brain injury was trauma ($n = 5$, 31%) or cerebral haemorrhage of non-traumatic origin ($n = 5$, 31%). These participants had a mean (s.d.) first documented Glasgow Coma Scale of 9 (5) indicating a moderately severe brain injury (Teasdale and Jennett 1974), with mean (s.d.) length of time of 38 (21) days between date of injury and study recruitment.

Due to the considerable drop out rate (44%), characteristics were then compared between the participants who were retained in the study ($n = 9$, 56%) and those who withdrew ($n = 7$, 44%). Those who withdrew were significantly younger (mean (s.d.) 28.7 (6.5) vs 42.1 (12.3); $P = 0.02$), and were significantly more likely to reside within the greater Brisbane area (86% vs 33%) (see Table 2).

Feasibility – safety and cost

When asked, no adverse events were reported by participants to the physiotherapists, and no adverse events occurred during the supervised walking sessions. The cost per participant was AU$427.71. Intervention costs and research costs are outlined in Supplementary material S2.

Physical activity and sedentary behaviour outcomes

Summary data for measures of physical activity and sedentary behaviour are presented in Table 3 and Fig. 2*a*–*c*. The available data demonstrated no change to physical activity or sedentary behaviour across the intervention period ($n = 6$, post-intervention vs baseline). The number of available data sets for analysis was small, and results should be interpreted with caution. In comparing medium-term follow up (3–6 months post-intervention) with baseline, there were a total of $n = 8$ datasets available for analysis – still a small number to be interpreted with caution. When comparing medium-term follow up (3–6 months post-intervention) with baseline, on average, participants took an extra 3913 steps per day (95% CI 671, 7156; $P = 0.03$) and spent an extra 52 min stepping (95% CI 9, 96; $P = 0.03$). On average, participants sat for a total of 213 min less each day (95% CI −341, −85; $P < 0.01$). Time spent in light and moderate-vigorous physical activity or in primary lying and secondary lying were not significantly different at either follow up. Large effect sizes (partial $\eta^2 > 0.14$) were identified for all of the physical activity and sedentary behaviour outcomes, with the exception of primary and secondary lying time.

Participants who withdrew after baseline spent significantly less time sitting (mean, s.d.) (427, 150 min) than the

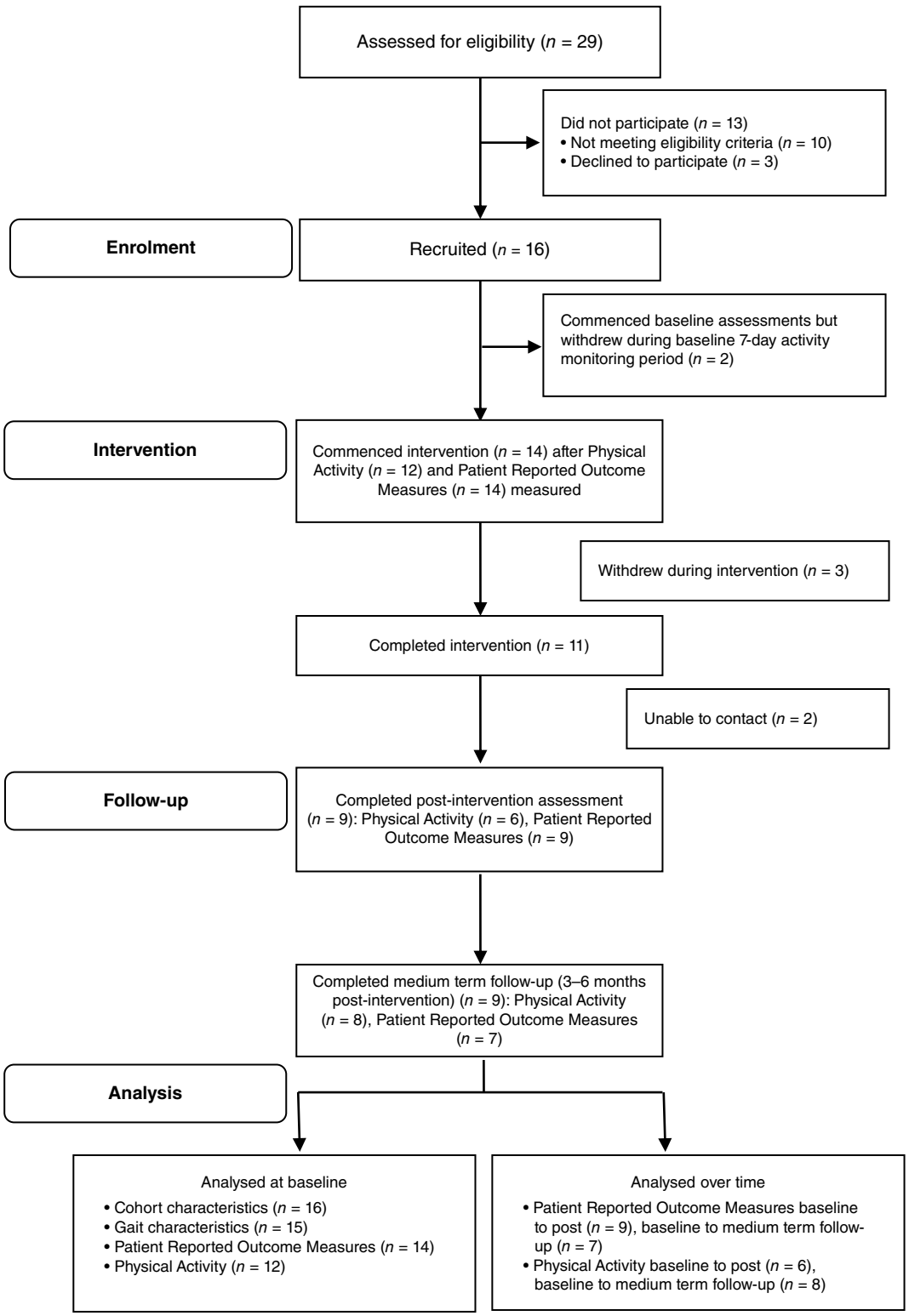

Fig. 1. Flow diagram of patients through the study.

retained cohort (650, 109 min; $P = 0.01$), however spent significantly more time in primary lying (784, 250 min) compared to the retained cohort (536, 71 min; $P = 0.01$). Further comparisons of physical activity measures between the retained and withdrawn cohorts are depicted in Supplementary material S3.

Table 2. Characteristics of the whole recruited cohort (*n* = 16), those retained in the study (*n* = 9) and those who dropped out (*n* = 7).

Characteristics	Recruited cohort (*n* = 16)	Retained cohort (*n* = 9)	Dropped out (*n* = 7)
	Mean (s.d.) or *n* (%)	Mean (s.d.) or *n* (%)	Mean (s.d.) or *n* (%)
Age (years)	36.3 (12.0)	**42.1 (12.3)**	**28.7 (6.5)**
Gender (male)	11 (68.8%)	5 (56%)	6 (86%)
Height (m)	1.74 (0.1)	1.70 (0.1)	1.78 (0.1)
Weight (kg)	78.4 (19.2)	75.6 (14.6)	82.1 (24.7)
Body mass index (kg/m^2)	26.0 (5.5)	26.0 (4.6)	26.1 (6.9)
Country of birth			
Australia	12 (75%)	7 (78%)	5 (71%)
China	1 (6%)	0 (0%)	1 (14%)
England	1 (6%)	1 (11%)	0 (0%)
New Zealand	1 (6%)	1 (11%)	0 (0%)
South Africa	1 (6%)	0 (0%)	1 (14%)
Language spoken at home		2 (22%)	2 (29%)
English	15 (94%)		
Chinese	1 (6%)	9 (100%)	6 (86%)
Highest educational level achieved			
Certificate I–IV	2 (13%)	1 (11%)	1 (14%)
Secondary education	13 (81%)	7 (78%)	6 (86%)
Primary education	1 (6%)	1 (11%)	0 (0%)
Marital status			
Married or de facto	6 (38%)	4 (44%)	2 (29%)
Never married	6 (38%)	3 (33%)	3 (43%)
Divorced	3 (19%)	2 (22%)	1 (14%)
Widowed	1 (6%)	0 (0%)	1 (14%)
Residential address within greater Brisbane (yes)	9 (56%)	3 (33%)	6 (86%)
Time since injury (days between injury and consent)	38 (21)	36 (22)	41 (22)
Initial Glasgow Coma Scale	9 (5)	9 (5)	10 (5)
Category of brain injury			
Traumatic	5 (31%)	4 (44%)	1 (14%)
Haemorrhage	5 (31%)	2 (22%)	3 (43%)
Hypoxic	3 (19%)	2 (22%)	1 (14%)
Surgical resection of tumour	2 (13%)	1 (11%)	1 (14%)
Abscess	1 (6%)	0	1 (14%)
Gait characteristics[A]			
Velocity (cm/s)	112.0 (12.0)	114.2 (13.7)	108.8 (9.2)
Step count (*n*)	8.6 (1.1)	8.5 (1.0)	8.8 (1.3)
Cadence (steps/min)	108.7 (8)	110.3 (7.9)	106.3 (8.4)
Step time – left (s)	0.55 (0.04)	0.54 (0.04)	0.56 (0.04)

(*Continued on next page*)

Table 2. (*Continued*)

Characteristics	Recruited cohort (*n* = 16)	Retained cohort (*n* = 9)	Dropped out (*n* = 7)
	Mean (s.d.) or *n* (%)	Mean (s.d.) or *n* (%)	Mean (s.d.) or *n* (%)
Step time – right (s)	0.56 (0.04)	0.55 (0.04)	0.57 (0.04)
Step length – left (cm)	61.3 (5.5)	62.0 (5.9)	60.2 (5.2)
Step length – right (cm)	62.2 (5.5)	61.9 (6.4)	62.7 (5.7)

Bold data indicates a significant difference ($P < 0.05$) present between retained vs dropped out.
[A]Baseline gait data are reported for $n = 15$.

Self-reported quality of life, exercise self-efficacy and fatigue

Summary data for patient-reported outcome measures are presented in Table 4 and Supplementary material S4. At the post-intervention assessment, a statistically significant improvement of 14.4 points was observed for the energy/fatigue (vitality) subscale of the SF-36 (95% CI 5.0, 23.7, $P = 0.008$). Clinically significant improvements were observed across multiple domains of the SF-36 ($+ \geq 8$ points) and MFIS (-17 points) scales during the intervention period, and multiple sub-sections of the EQ-5D, SF36 and MFIS at long-term follow up, however none of these changes were statistically significant. Exercise self-efficacy scores were not statistically significantly different across the study at either timepoint. Large effect sizes (partial $\eta^2 > 0.14$) were identified for five of the eight sub-scales of the SF-36, the EQ-5D VAS and the MFIS total score.

Acceptability and satisfaction

Seven participants completed the feedback forms, and the results are presented in Supplementary material S5. In summary, all participants found the walking program, coaching and the combination of the two either mostly or very acceptable, and mostly or very satisfactory. Four staff members (two physiotherapists and two physiotherapy assistants) completed the feedback forms (see Supplementary material S6). All staff found the walking program and telephone coaching to be very acceptable (100%) and were very satisfied (100%). Of the two caregivers who were approached to provide feedback, neither consented to do so.

Discussion

This physical activity program with behavioural coaching for adults with ABI, delivered in an inpatient care setting, was found to be safe and feasible to recruit to (55% recruitment rate; 74% of those eligible commenced the intervention). However, physical activity and sedentary behaviour did not change during the intervention period and the cost per participant was high at AU$427.71 per participant given the lack of behaviour change. Encouragingly, participants were found to be more physically active and less sedentary at the medium-term follow up; however, it is unclear how much this can be attributed to the intervention given the lack of control group. In contrast, there were clinically significant improvements in measures of quality of life and fatigue at both post-intervention and medium term. Very high levels of acceptability and satisfaction were reported by both staff and participants; however, the carers' perspectives were unable to be ascertained. In summary, this combined walking program with concurrent behavioural therapy was found to be feasible to recruit, safe and acceptable. However, the potential impact on physical activity remains unclear.

Study feasibility was greatly influenced by the flow of patients through the unit. Length of stay within the Brain Injury Rehabilitation Unit varies greatly between patients because admission is guided by the patient's goals, rate of progress and supports available on discharge, rather than being a standardised fixed length of time. Admission duration for higher functioning patients is often much shorter than for those with more severe impairments and restricted function. Given this environment, recruiting 16 of 29 eligible, specifically highly mobile, patients to this program was considered a positive outcome by our research team. The nature of the intervention in the present study meant that our target participants were already highly mobile and had intact basic cognition. As such, these individuals tended to progress quickly through their rehabilitation, and many transitioned home from hospital sooner than originally expected when they were first admitted to the unit. This affected recruitment rates in the study, as we excluded patients who were planned to have short admissions, and our retention of participants – one participant had an unexpected early discharge between consenting to the study and baseline testing. Participants who dropped out were more likely to be younger than those who remained in the study. It is possible that younger patients (in their 20s and 30s) are more likely to move quickly through inpatient rehabilitation than older patients, perhaps due to fewer comorbidities or more robust social support networks in the community (e.g. parents). A fully telehealth program or a program delivered as a part of their outreach outpatient

Table 3. Physical activity and sedentary behaviour results at baseline, post-intervention and medium-term follow up (3–6 months post-intervention).

Outcome measures	Baseline (*n* = 12)	Post-intervention (*n* = 6)	3–6 months post-intervention (*n* = 9)	Post-intervention vs baseline (*n* = 6)	3–6 months post-intervention vs baseline (*n* = 8)	Partial η^2 (effect size) for time
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean difference (95% CI)	Mean difference (95% CI)	
Total number of steps/day	5331 (2793)	4682 (1664)	9355 (3338)	-551 (-5187, 4084)	**3913 (670, 7156)**	0.36
Total stepping time (min/day)	71 (40)	64 (23)	124 (45)	-5 (-70, 60)	**52 (9, 96)**	0.36
Upright time (min/day)	199 (96)	194 (86)	369 (148)	3 (-169, 174)	**163 (31, 294)**	0.42
Standing time (min/day)	128 (59)	130 (66)	246 (113)	8 (-103, 118)	**111 (15, 206)**	0.26
Sitting time (min/day)	576 (160)	582 (112)	437 (164)	-66 (-187, 56)	**-213 (-341, -85)**	0.40
Primary lying time (min/day)	619 (187)	620 (174)	561 (162)	93 (-102, 288)	29 (-81, 138)	0.10
Secondary lying time (min/day)	46 (50)	44 (67)	64 (85)	-30 (-110, 50)	13 (-51, 76)	0.09
Activity score (MET.h/day)	32 (1)	32 (1)	34 (1)	0 (-2, 2)	**2 (0, 3)**	0.42
Number of sitting bouts >30 min/day	4.3 (2.5)	3.8 (1.7)	2.4 (1.8)	-1.8 (-4.3, 0.6)	**-2.5 (-5.0, -0.0)**	0.36
Number of sitting bouts >60 min/day	0.8 (0.6)	0.8 (1.7)	0.1 (0.3)	-0.2 (-1.0, 0.6)	**-0.8 (-1.3, -0.2)**	0.48
Time spent in sitting bouts >30 min (min/day	256 (126)	222 (96)	131 (87)	-97 (-204, 10)	**-149 (-261, -37)**	0.48
Time spent in sitting bouts >60 min (min/day)	105 (58)	85 (47)	39 (24)	-47 (-101, 7)	**-74 (-128, -20)**	0.52
Time spent in light physical activity (min/day)	29 (21)	34 (11)	49 (21)[B]	n/a[A]	n/a[A]	0.37
Time spent in moderate-vigorous physical activity (min/day)	39 (20)	38 (12)	63 (28)[B]	2 (-26, 30)	15 (-33, 3)	0.34

Bold data indicates a significant ($P < 0.05$) mean difference. n/a, not applicable.
[A]The non-parametric test was used to analyse these non-normally distributed data, therefore mean difference was not calculated.
[B]The 3–6 month follow up cohort for Time spent in light physical activity and Time spent in moderate-vigorous physical activity are reported for *n* = 8.

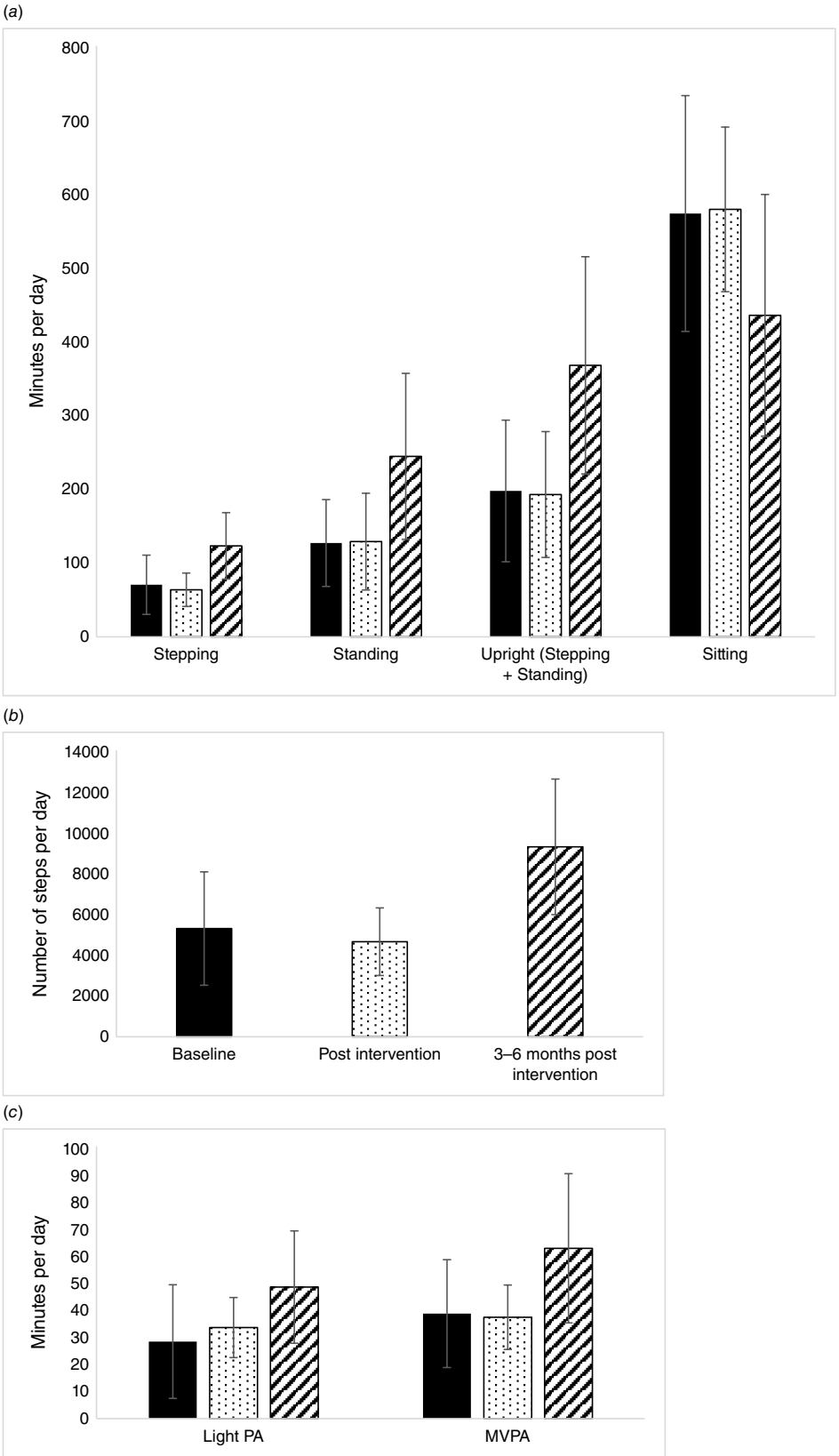

Fig. 2. Physical activity and sedentary behaviour outcomes at baseline (solid), post-intervention (dots) and medium-term follow up (3–6 months post-intervention) (stripes). Error bars represent standard deviation. (*a*) Average time spent stepping, standing, upright (combination of stepping and standing) and sitting, minutes per day. (*b*) Average steps per day. (*c*) Average time spent in light vs moderate-vigorous intensity physical activity (MVPA), minutes per day.

Table 4. Health-related quality of life, fatigue and self-efficacy for exercise results at baseline, post-intervention and medium-term follow up (3–6 months post-intervention).

Self-reported outcome measures	Baseline (*n* = 14)	Post-intervention (*n* = 9)	3–6 months pest-intervention (*n* = 7)	Post-intervention vs baseline (*n* = 9)	3–6 months post-intervention vs baseline (*n*= 7)	Partial η^2 (effect size) for time
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean difference (95% CI)	Mean difference (95% CI)	
EQ-5D						
Utility	0.88 (0.08)	0.89 (0.11)	0.91 (0.13)	n/a[A]	n/a[A]	0.09
VAS	74.3 (15.3)	78.9 (22.0)	86.0 (11.4)	6.7 (-6.2, 19.5)	11.7 (-7.6, 31.0)	0.19
SF-36						
Physical functioning	67.5 (23.1)	76.9 (20.6)	87.2 (16.7)	16.3 (-4.4, 37.0)	25.8 (-7.0, 58.6)	0.35
Role limitations due to physical health	22.0 (32.5)	40.6 (40.0)	50.0 (47.9)	33.3 (-2.2, 68.8)	41.7 (-11.2, 94.5)	0.26
Role limitations due to emotional problems	42.9 (42.2)	58.3 (38.8)	61.9 (48.8)	12.5 (-34.5, 59.5)	23.8 (-44.5, 92.1)	0.08
Energy/fatigue (vitality)	48.6 (20.0)	61.3 (19.2)	56.4 (20.8)	**14.4 (5.0, 23.7)**	12.9 (-5.2, 30.9)	0.30
Emotional wellbeing	66.6 (14.9)	70.0 (17.0)	66.3 (17.9)	8.0 (-8.5, 24.5)	4.0 (-16.3, 24.3)	0.10
Social functioning	54.5 (23.8)	67.19 (26.67)	60.71 (24.40)	18.75 (-9.2, 46.7)	14.29 (-24.3, 52.9)	0.18
Pain	58.8 (20.3)	66.88 (22.35)	75 (23.40)	14.38 (-8.8, 37.6)	19.64 (-8.6, 47.9)	0.28
General health	63.6 (14.5)	63.75 (20.13)	70.71 (12.72)	-0.63 (-12.3, 11.1)	5.00 (-9.6, 19.6)	0.03
MFIS						
Physical subscale	5.3 (3.0)	4.4 (2.5)	4.1 (2.9)	-1.1 (-3.9, 1.7)	-1.6 (-4.3)	
Cognitive subscale	10.6 (6.0)	8.8 (4.9)	8.3 (5.8)	-2.3 (-7.9, 3.4)	-3.1 (-8.7, 2.4)	
Psychosocial subscale	15.9 (9.0)	13.1 (7.3)	12.4 (8.7)	-3.4 (-11.8, 5.0)	-4.7 (-13.0, 3.6)	
Total score (/84)	66.9 (28.9)	52.4 (11.6)	52.3 (25.3)	-17.0 (-36.4, 2.4)	-20.1 (-45.5, 5.2)	0.29
Self-efficacy for exercise						
Total score (/90)	55.4 (24.8)	56.8 (22.5)	65.0 (19.0)	1.3 (-29.5, 32.0)	13.0 (-21.4, 47.4)	0.10

Bold data indicates a significant ($P < 0.05$) mean difference.
EQ-5D, Euro Qol 5 Dimensions; SF-36, Short Form 36; MFIS, Modified Fatigue Impact Scale; n/a, not applicable.
[A]The non-parametric test was used to analyse these non-normally distributed data, therefore mean difference was not calculated.

services may be better suited to addressing physical activity and sedentary behaviour with such younger patients.

The cost analysis provides useful information for implementing a walking program within a rehabilitation program. Costs were high at AU$427.71per participant for no demonstrable return on investment in physical activity or sedentary behaviour; however, formal comparison of costs and benefits was not possible in this study design. Previous economic analyses have identified that programs with exercise as a core intervention are cost effective for improving mobility outcomes and decreasing falls in elderly adults and neurological populations such as Parkinson's disease (Davis *et al.* 2010; Farag *et al.* 2015, 2016). However, in this context, a larger study with a comparison group would be required to explore the cost-effectiveness of this particular intervention.

The combined walking and behaviour change program was developed by clinicians and clinician-scientists in response to a perceived need to better foster physical activity levels and exercise self-efficacy in adults with ABI, particularly during inpatient rehabilitation. However, there were no changes in physical activity and sedentary behaviour during this intervention period. It is possible that the supervised sessions were unable to overcome the environmental influence on sedentary behaviour – the Brain Injury Rehabilitation Unit is a locked ward that patients cannot freely come and go from. It is also possible that patients were not yet cognitively ready for such a program. Driver and colleagues used this observation as justification for piloting their health promotion program with adults in an outpatient, transitional rehabilitation program for adults with TBI (Driver *et al.* 2013).

Our study found a significant increase in levels of physical activity at medium-term follow up (3–6 months post-intervention). This may be explained in part by the fact that

community-dwelling adults have more potential opportunities for participating in physical activity than those residing in hospital rehabilitation settings (Ramsey *et al.* 2021). This is consistent with research in people with stroke who were observed to spend less time sitting and more time standing and walking in their homes following discharge compared with the last week of their hospital stay (Simpson *et al.* 2018). Another potential explanation is the task-specific practice of ambulating within real-life physical environments that our participants received in the walking sessions. This element of the program is in line with task-specific rehabilitation principles (Shumway-Cook and Woollacott 2017) and may have had a flow on effect to post-discharge community-based physical activity. Another explanation, and an acknowledged limitation of the study, is the data loss across the study, meaning participants included in analyses at post-intervention may not have been the participants included in analyses at follow up.

Strengths and limitations

This study has some strengths but several significant weaknesses that need to be acknowledged. As a feasibility study, several outcomes relevant to future larger studies and to clinical implementation were monitored, including recruitment rate, patient and staff satisfaction, adverse events, and costs. The use of device-based measures of physical activity and sedentary behaviour is a strength, as the reliability of self-reported measures of physical activity could be impacted by cognitive changes in adults with ABI. Using device-based measures in this study is part of the growing trend for such monitoring in hospital patients (Fazio *et al.* 2020).

The study setting was a specialised neurorehabilitation unit with experienced clinical staff associated with intervention delivery; however, this may limit the generalisability of findings to other more generalised hospital wards. There is risk of bias present in the recording of adverse events by intervention staff, who may have an interest in the intervention being considered safe. The timeframe in which the study was carried out did not occur as originally planned due to the COVID-19 pandemic. Inpatient flow through the Brain Injury Rehabilitation Unit was reduced compared with pre-COVID expectations and follow up appointments with the treating clinical team were rescheduled to telehealth, leading to slower than expected recruitment rates and a small sample size. The slow pace of recruitment also meant that on some occasions, only one participant was walking with two staff (or one staff and one student). The absence of peers may have affected how participants felt about the study and their ongoing participation. The gender, age and body mass index of participants were consistent with the usual patient population in our unit; however, the proportion of participants with TBI (vs non-TBI) in the study was lower than what is normally encountered in the unit. Findings may not be generalisable to all forms of ABI. For those who were able to commence the intervention but were discharged home prior to completing it, they continued to engage in walking and coaching via telephone. As these walking sessions were not supervised, true compliance rates are unknown, and this may have influenced study findings.

Critically, data loss and drop out rate mean the results must be interpreted with caution as there is significant potential for bias, particularly of the physical activity and sedentary behaviour outcomes. A power calculation was not performed in the context of this pilot study. Finally, there was no control group, meaning that these findings must be interpreted with care. Future randomised controlled trials may be planned on the output from this feasibility study to better understand the potential effectiveness of the intervention over standard care.

Conclusions

Participants within a specialist inpatient rehabilitation unit for adults with ABI engaged in a 4-week program of twice-weekly supervised walking sessions with behaviour change counselling. This pilot study demonstrated that while the program was safe, the drop out rate was high and behaviour change did not occur. More work is required to boost physical activity during sub-acute rehabilitation for ABI.

Supplementary material

Supplementary material is available online.

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