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Sedentary behaviour and physical activity patterns in adults with traumatic limb fracture

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A B S T R A C T

Objective: To describe patterns of sedentary behaviour and physical activity in adults two weeks post-hospital discharge following an upper or lower limb fracture, and identify associated predictive factors. Design: Observational study. Setting: Level 1 Trauma Centre. Participants: Adults aged 18–69 years with an isolated upper (UL) or lower (LL) limb fracture. Main Outcome Measures: Sitting time and steps measured via a triaxial accelerometer and inclinometer-based device (activPAL) (anterior thigh); and moderate-intensity physical activity (MPA) measured via triaxial accelerometer (ActiGraph) (hip) for ten days. Results: Of 83 participants, 63% were men and 55% had sustained LL fractures; mean (SD) age was 41 (14) years. Participants sat for a mean (SD) of 11.07 (1.89) h/day, took a median (IQR) of 1575 (618–3445) steps/day and had only 5.22 (1.50–20.78) mins/day of MPA. Multivariable regression analyses showed participants with LL fracture, had increased adjusted mean sitting time of 2.5 h/day relative to UL fracture ($\beta = 2.5$ hours, $p < 0.001$). For each day since surgery/injury there was reduced adjusted mean sitting time of 4 mins/day ($\beta = -0.06$ hours, $p = 0.048$). LL fracture was associated with 80% fewer steps/day (Ratio of Geometric Means (RGM) = 0.20, $p < 0.001$) and 89% less MPA (RGM = 0.11, $p < 0.001$) relative to UL fracture. Older age was associated with 59–62% less MPA relative to the youngest participants (RGM = 0.38–0.41, $p = 0.01$). There was no association between the predictive variables sex, BMI and pre-injury physical activity and any outcome. Conclusions: At two weeks post-hospital discharge, participants were engaged in high amounts of sitting and were physically inactive. Injury location was the strongest predictor of outcome, indicating that patients with LL fracture are most in need of encouragement to reduce sitting time and gradually increase activity, within the bounds of clinical safety.

Keywords: sitting; orthopaedic; injury; trauma; recovery

1. Background

Fractures are the most common form of hospitalised trauma in every age group [1], contributing the largest proportion of hospitalisations from injuries sustained at work [2], on the road [3], or while playing sport [4]. It is estimated that one in every two men and three women will experience a traumatic fracture before the age of 65, most commonly as a result of falls and road crashes [1,5]. Many people experience ongoing pain and activity restrictions following fracture, and almost one third of adults with a lower limb fracture fail to return to work 12 months post-injury [6,7]. The resulting healthcare and productivity costs, have been estimated at \$9,800 to \$23,100 USD per working-age adult in the six months following a single limb fracture [8].

During recovery from fracture, mobility restrictions, pain, fatigue, or medication side-effects may cause an initial reduction in physical activity (i.e. bodily movement produced by skeletal muscle resulting in energy expenditure [9]), and an increase in sedentary behaviour (i.e. waking behaviour characterized by low energy expenditure while sitting, reclining or lying [10]) [11,12]. In the short term, this change in behaviour can lead to impaired glucose control and fat metabolism [13,14], precipitate a decline in physical capacity (e.g. muscle strength and cardiovascular fitness), lead to a loss of bone density, and potential re-fracture [15–17]. Other factors may also influence post-injury activity behaviour, such as fear-avoidance, loss of motivation or loss of routine [18]. These limitations may persist in the long-term such that, even after bony injuries are healed and physical capacity has returned, the diminished activity behaviours can become ingrained [19].

There is mounting evidence that long-term physical inactivity (i.e. failure to meet Physical Activity Guidelines) and also sedentary behaviour (e.g. high levels of sitting) are related to all-cause mortality, cancer, heart disease and type 2 diabetes [20,21]. There is also preliminary evidence of a heightened prevalence of chronic disease in people who have experienced serious injury [22], and a six-fold increase in mortality risk two years following major trauma [23]. One hypothesis for this is that a dramatic change in patients' activity levels can precipitate certain risk factors for chronic disease, such as hyperlipidaemia and hypertension [22].

Recent systematic reviews on this topic have demonstrated that orthopaedic injury does have an impact on physical activity levels and sedentary behavior [11,12]. However, previous studies have either relied on self-reported physical activity measures (e.g. the International Physical Activity Questionnaire (IPAQ) or the Community Healthy Activities Model Program for Seniors (CHAMPS) Physical Activity Questionnaire) which are susceptible to over-reporting [24,25], have focused solely on hip fracture in older adults, failed to include pre-injury measures of activity, or not included the measurement of sedentary behavior [11]. At present, despite the potential for broader adverse health outcomes following fracture in working-age adults, there are no objective data capturing activity levels and patterns of sitting time within this high-risk group [11]. These data are needed to provide a more accurate and unbiased understanding of post-fracture activity levels and to better identify associated factors.

The aims of this study were to describe patterns of sedentary behaviour and physical activity in working-age adults two-weeks post hospital discharge following an upper or lower limb fracture, and to identify factors associated with these patterns.

2. Methods

2.1. Participants

All patients aged 18–69 years admitted to a major trauma centre with a new isolated upper limb (UL) or lower limb (LL) fracture (confirmed by X-Ray), a hospital length of stay >24 hours and home discharge, were eligible for inclusion. Patients with a pathological fracture related to metastatic disease, cognitive deficits or a language other than English were excluded. Ethical approval was obtained from the Alfred Health and Monash University human research ethics committees. All participants were recruited during their inpatient stay and provided written informed consent before participating in the study. The rights of participants were protected.

2.2. Procedures

Data collection commenced approximately two weeks post-hospital discharge when participants returned to the hospital for their outpatient review. Participants completed a questionnaire pertaining to their demographics, self-reported height and weight, self-reported physical activity for the week preceding injury (IPAQ, Short Form (SF) [26]) and current weight-bearing status. During the appointment, each participant received two activity monitors, waterproof adhesive patches, an activity log, and a postage-paid satchel for returning the devices to investigators. Details of participants' injury and surgical management were obtained from hospital medical records. Time spent sitting was collected using the validated activPAL3™, a triaxial accelerometer and inclinometer-based device (PAL Technologies Limited, Glasgow, UK) [27]. Step count was collected using the activPAL based on evidence of the activPAL's accuracy across a wide range of walking speeds, including slow speeds and when using gait aids [28–30]. The monitor was secured to the anterior thigh (uninjured limb for LL fracture patients) [29] with a waterproof patch and worn continuously (24 hour/day) for 10 days following the outpatient appointment. Physical activity was measured using an ActiGraph GTX3+ triaxial accelerometer (ActiGraph LLC, Pensacola, FL, USA) during the same 10 day period [31]. Data were sampled at 30Hz and counts per minute (cpm) were determined using ActiGraph's proprietary software, ActiLife (Version 6.13.3). Participants used a diary to report their sleep/wake times as well as whether devices were removed for more than 15 minutes during the day. This information was used to verify non-wear/sleep time [32].

2.3. Data processing

Monitor data were processed in SAS™ 9.3 (SAS Institute Inc., Cary, NC, USA). The algorithm outlined by Winkler et al. [32] was used to determine sleep/non wear bouts for ActivPAL data. To allow for potentially very low activity levels in this population, the "any one activity that accounts for >95% of waking wear time" condition described by Winkler et al. [32] was removed from consideration and the threshold for invalid days was lowered from 500 to 100 steps/day. For ActiGraph data, valid days were determined using the Choi algorithm [33]. For each day of data collection, heat maps of data were visually inspected for any potential classification errors (e.g. sleep time as waking time). Finally, any potential errors were checked against the patient diaries and the most plausible classification chosen and applied [34]. Where participants had at least four valid days (with ≥600 minutes of waking wear time/day) [35], total daily sitting time (hours/day), percentage of the day spent sitting (sitting time/total waking time), steps (n), and moderate- (1952 cpm–5724 cpm) (MPA) and vigorous-intensity (≥5725 cpm) physical activity (VPA) (mins/day) were calculated and then averaged across all valid days [36]. Accelerometry cut points were deemed appropriate for the pre-injury health status and age range of our participants (i.e. healthy adults, aged 18–69 years) [36].

2.4. Statistical analysis

Characteristics of the sample and activity data were summarised descriptively using frequencies and percentages for categorical data, and means and standard deviations (SD) for continuous data or medians and interquartile ranges (IQR) if data were skewed. Age followed a bimodal distribution and was subsequently categorised. Body mass index (BMI) was calculated as weight (kg)/height (m2), and categorised according to accepted cut points [37]. Pre-injury physical activity data was reported as low, moderate and high, in accordance with IPAQ-SF scoring protocols [26].

Separate multivariable linear regression models were fitted for the three main outcomes: (I) sitting time; (ii) steps; and (iii) MPA. Based on previous literature, the potential predictive variables included were age, sex, UL vs. LL fracture, BMI, pre-injury physical activity, and days elapsed since surgery (or from injury where fracture was non-operatively managed) to the start of activity monitoring [38–40]. Variables showing a significant ($p < 0.25$) association on preliminary univariate analyses, in addition to those deemed clinically important (age and sex), were entered into each model [41]. Non-significant variables were identified using Wald tests, and were removed from the model individually in a backward stepwise approach ($p < 0.05$) [41]. The reduced models were compared with the initial model using likelihood ratio tests and the remaining variable coefficients assessed to ensure that they had not substantially changed, indicating potential confounding. This process was repeated until a parsimonious final model was achieved. Variables excluded from the initial model were then included to ensure that important variables had not been missed. Residual plots were inspected to evaluate model assumptions (i.e. normal distribution of residuals and equal variances) [42]. As steps and MPA outcomes were not normally distributed, a log transformation was used with the effect estimated as a ratio of geometric means (RGM) [43]. With age, BMI and pre-injury physical activity treated as three-level categorical variables, the estimated models used 9 degrees of freedom. Thus, a sample size of 72 would allow for 8 subjects per variable (SPV), well exceeding the minimum SPV required for accurate estimation of regression coefficients, confidence intervals and adjusted R2 values [44]. All analyses were performed using Stata Version 15 (StataCorp LLC, college Station, TX, USA).

3. Results

Out of the 120 participants recruited, 83 returned valid activPAL data (n = 78) and/or valid Actigraph data (n = 77) and were included in the final analysis. For activPAL data, 125 invalid days (i.e. <600 mins waking wear time and/or <100 steps per day) were removed from analysis leaving 706 valid days. For ActiGraph data, 176 invalid days (<600 mins waking wear time) were removed, leaving 699 valid days. There were no significant differences in demographics between included and non-included participants (Table S1 of Supplementary). There were a range of reasons for non-inclusion, such as loss of interest in participating (n = 14), ineligibility (n = 11), non-attendance at outpatient appointment (n = 8) and <4 valid days (n = 4).

For included participants, the mean (SD) time from surgery (or from injury for those managed non-operatively, n = 10) to the start of activity monitoring was 17 (5) days (Table 1). Most participants were men (63%), almost half (43%) were aged 18-34 years (mean (SD) age 41 (14) years) and over half (51%) were overweight or obese (BMI median (IQR): 25 (22–28)). Of the 46 participants with lower limb fractures (55%), most were non-weight bearing on the affected limb (65%), and mostly using crutches to ambulate. Twenty-eight percent of all participants had ankle fractures, with forearm/wrist fractures the next most common (18%). Most participants (63%) reported a high level of physical activity in the week preceding injury.

Table 1. Characteristics of included participants (n = 83).

Characteristic	n (%)
Male	52 (62.7)
Age group (years)	
18–34	36 (43.4)
35–49	21 (25.3)
50–69	26 (31.3)
Injury group	
Upper limb fracture	37 (44.6)
Lower limb fracture	46 (55.4)
Non weight bearing	30 (65.2)
Partial weight bearing/weight bearing as tolerated*	16 (34.8)
Fracture type	
Ankle	23 (27.7)
Forearm/wrist	15 (18.1)
AC/Scapula/clavicle	11 (13.3)
Tibia/fibula	10 (12.0)
Humerus	8 (9.6)
Foot	6 (7.2)
Patella	4 (4.8)
Elbow	3 (3.6)
Hip	3 (3.6)
Body mass index categories	
Normal or underweight (<25 kg/m^2)	41 (49.4)
Overweight (≥25 kg/m^2–<30 kg/m^2)	31 (37.4)
Obese (≥30 kg/m^2)	11 (13.3)
Pre-injury physical activity (IPAQ-SF category)	
Low	7 (8.4)
Moderate	24 (28.9)
High	52 (62.7)
Days since fracture/surgery (mean, SD)	
To activPAL start	16.7 (5.0)
To actigraph start	16.5 (4.3)

Continued on next page

*Note: Non-weight bearing: patient is not permitted to bear any weight on the affected limb (i.e. must use crutches to hop on the unaffected limb); partial weight-bearing: patient is allowed to bear some weight on the affected limb (i.e. must use crutches to walk); weight bearing as tolerated: patient is allowed to bear as much weight on the limb as they can tolerate (i.e. can walk with or without crutches). AC: acromioclavicular joint.

The mean (SD) sitting time was 11.07 (1.89) hours per day with participants spending 41%–98% of their waking hours sitting (median 79%) (Figure 1 and Table S2 of Supplementary). Participants with lower limb fractures spent more time sitting than those with upper limb fractures. Overall, participants took a median (IQR) of 1575 (618–3445) steps per day, but participants with lower limb fractures, took only 647 (344–1140) steps per day. Participants overall spent only 5.22 (1.50–20.78) minutes per day engaging in moderate intensity physical activity, while for those with lower limb fractures this was less than 2 minutes per day (Figure 1 and Table S2 of Supplementary). No vigorous-intensity physical activity was recorded for 78% of participants and the remainder recorded very low values (<3 mins). Therefore this variable was not further examined.

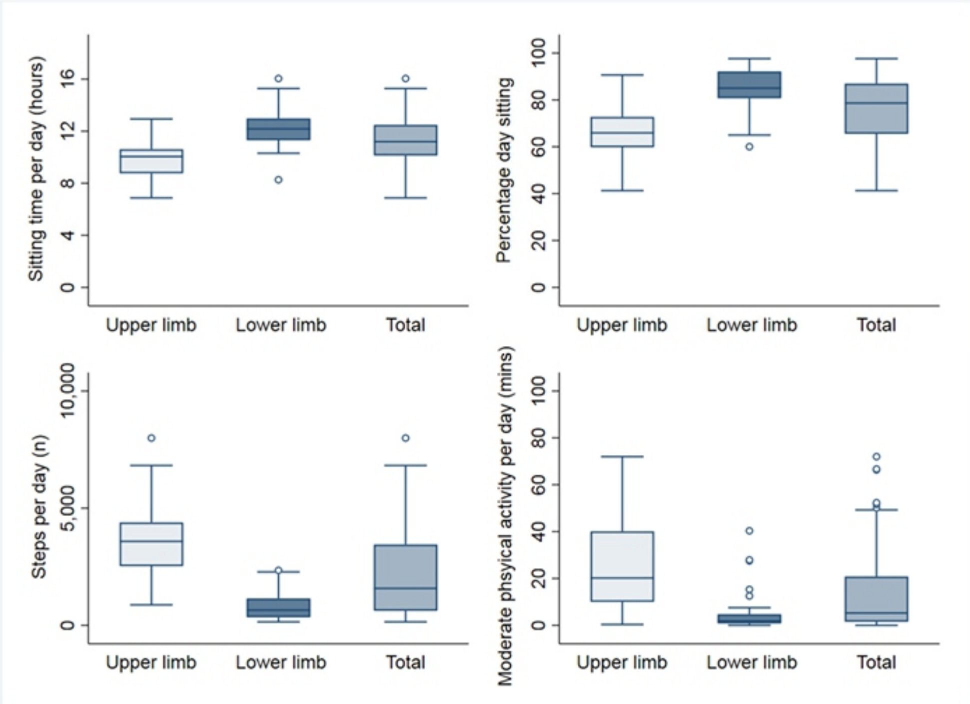

Figure 1. Sitting time and physical activity patterns of study population.

Multivariable regression analyses showed that for participants with LL fracture, there was an increase in adjusted mean sitting time of 2.5 hours per day relative to participants with UL fracture (β = 2.5 hours, p < 0.001), while for each day since surgery/injury there was a reduction in adjusted mean sitting time of approximately four minutes per day (β = −0.06 hours, p = 0.048; Table 2). These variables accounted for 44% of the variance in sitting time (adjusted R2). Lower limb fracture was associated with 80% fewer steps per day relative to UL fracture (RGM = 0.20, p < 0.001), accounting for 60% of the variance. Finally, LL fracture was associated with 89% less time spent in MPA relative to UL fracture (RGM = 0.11, p <0.001), and older age was associated with 59-62% less time spent in MPA relative to participants in the youngest age group (RGM = 0.38–0.41, p = 0.01), accounting for 44% of the variance. There was no association between the predictive variables sex, BMI and pre-injury physical activity and any outcome (p > 0.05 for all).

Table 2. Multivariable analysis for independent predictors of sitting time, steps and moderate-intensity physical activity.

	Sitting time (hours/day) (n = 78)		Steps (n/day) (n = 78)		Moderate-intensity physical activity (mins/day) (n = 77)*	
	β (95% CI)	p	RGM (95% CI)	p	RGM (95% CI)	p
Age group						
18-34	–	–	–	–	Ref	0.01
35-49					0.38 (0.18, 0.79)	
50-69					0.41 (0.20, 0.82)	

Injury group						
Upper Limb	Ref	<0.001	Ref	<0.001	Ref	<0.001
Lower Limb	2.50 (1.86, 3.14)		0.20 (0.15, 0.27)		0.11 (0.06, 0.20)	
Days since fracture/surgery	−0.06 (−0.13, −0.001)	0.048	–	–	–	–

*Note: Missing data n = 1 (0 mins moderate physical activity recorded). β: beta coefficient; CI: confidence interval; RGM: ratio of geometric means.

4. Discussion

In this study we aimed to characterise patterns of sitting time and physical activity in adults following isolated limb fracture, and to identify factors associated with these patterns. Approximately two weeks post-hospital discharge, the working-age adults included in the current study were engaged in high amounts of sitting time, took few steps and engaged in little physical activity. Compared to participants with UL fractures, participants with LL fractures spent more time sitting, took fewer steps and were less physically active. Older participants also had lower levels of physical activity. As expected, participants spent less time sitting as time passed following surgery or injury. Relative to population norms, our participants were highly sedentary. The US National Health and Nutrition Examination Survey (NHANES) reported mean daily sedentary time (accelerometry <100 cpm) in 6329 adults aged 20–85 years of up to 9.3 hours/day [45]. This upper limit, recorded in the oldest adults (70–85 years), was similar to sitting time for patients in our study with upper limb fractures, which is striking considering the much younger age of our participants. Notably, participants in our study with LL fractures recorded almost three hours per day more sitting time than this upper limit.

Our participants also took very few steps relative to population values. Participants in the Australian-based Tasped study (n = 2576, mean age 59 years) recorded, via pedometers, an average of 7774–8925 steps per day [46]. Our overall median step count was substantially lower (~1500 steps per day) and was <700 steps per day in participants with LL fractures. For MPA, participants with upper limb fracture compared favourably with women of a similar age from the NHANES study, who recorded approximately 15 to 20 minutes of MPA per day (Actigraph 2020–5999 cpm) [47]. However, participants in our study with LL fractures recorded substantially less daily MPA than even the least active NHANES participants (women aged 70+ years), who recorded approximately 5 mins/day of MPA.

Previous studies of device-measured activity in older adults with hip fractures have also demonstrated high levels of sedentary time (up to 99% of the day) [38,48] minimal steps (as few as 36 steps/day) [48] and limited MPA (as little as 1.8 mins/day) [38,40], both in the early stage of recovery [48] and up to six months post fracture [38]. However, adolescents with LL fracture, have been shown to undertake over 20 minutes of MPA within the first month post-injury, suggesting a significant effect of age, and possibly physical health on post-injury physical activity [39].

Notably, patients' pre-injury physical activity levels were not associated with post-injury activity levels, suggesting that, regardless of patients' motivation to be active, or previous exercise habits, it is the injuries themselves, and the mobility restrictions that they cause, that are the main barrier to activity. This is supported by our finding that patients with LL fractures were significantly less active than those with UL fracture, and indicates that patients with more physically limiting injuries, such as tibial fractures, may need more education from clinicians in the early stage of recovery, particularly in relation to breaking up prolonged bouts of sitting. However, considering that people with UL fractures also recorded high levels of sitting time and few steps, there are other factors, such as pain, fatigue, medication side-effects or impaired haemodynamics that may contribute to inactivity following fracture [48] Patients with both upper and LL fractures spent less time sitting as time passed, suggesting that some of these factors may be less influential as patients recover. While we did not collect data on mobility, pre-injury function or pain as potential correlates of physical activity and sitting time, these would be valuable to monitor in future research. We do not yet know the long-term impact of this acute reduction in patients' activity levels.

However, there is evidence that lack of daily physical activity and high volumes of sedentary time, even for just a few weeks, can have an immediate impact on physical function and overall health. In healthy, previously active young adults, less than three weeks of bed rest was sufficient to cause significant muscle wasting and weakness [15]. In middle-aged adults substantial reductions in cardiovascular capacity have occurred after as little as 10 days of bed rest [16]. In both healthy and clinical populations, uninterrupted bouts of sitting are detrimental to glucose control, fat metabolism and blood pressure, which are all associated with chronic diseases such as diabetes and stroke [49]. Furthermore, while necessary for bone healing in some patients, immobility following fracture significantly reduces bone density which is known to increase the risk of future fracture [17].

Future research should investigate whether these changes are avoidable with early intervention. For example, for patients who are unable to walk without supervision, breaking up sitting time with regular standing breaks could provide a feasible alternative. Such interruptions to prolonged sitting, even for as little as one minute, have been shown to have positive effects on cardio-metabolic health markers, such as BMI and waist circumference in general and clinical populations [49]. For patients using gait aids, who have difficulty walking long distances, short bursts of ambulation are a safe and viable option. These light activity bouts can have important cardio-metabolic effects, including lowered blood glucose and insulin, and reductions in blood triglycerides [50,51]. In the long-term, these simple interventions may even reduce the risk of chronic diseases such as type 2 diabetes and heart disease [20].

As demonstrated in previous physical activity research, there is the potential for sampling bias towards those with an interest in, or high levels of, physical activity [52]. Considering that the majority of our participants reported high levels of pre-injury physical activity, this is likely to be the case in the current study. However, this may also indicate that physical inactivity and high volumes of sitting are even higher in the wider orthopaedic population. Another limitation is that the Actigraph has not previously been validated for measurement of physical activity in the fracture population and further methodological research is needed in this population. However, we did use the activPAL rather than Actigraph to measure steps, which has been shown to have higher accuracy at slow walking speeds and when using gait aids [29]. It is also a limitation that certain activities commonly performed by patients recovering from fractures, such as swimming and stationary cycling, were not able to be measured with our devices. Finally, there is evidence of only fair agreement between self-reported and device-measured physical activity levels in patients with fractures, calling into question the accuracy of patients' pre-injury physical activity levels [25]. However, there are currently few feasible options for capturing device-based pre-injury physical activity levels. Despite these limitations there were numerous strengths to our study, including the large sample size for studies of this kind, device-based measurement of physical activity and sitting time via gold-standard measures and investigation of a population not previously studied.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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Putting psychology into telerehabilitation: Coping planning as an example for how to integrate behavior change techniques into clinical practice

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ABSTRACT

Background: Behavioral interventions based on psychological theory can facilitate continued recovery after discharge from cardiac or orthopedic rehabilitation. For example, health professionals can encourage patients to engage in coping planning to support the maintenance of physical activity. Telephone-based interviews or web-based interventions are two promising delivery modes to provide such after-care services from a distance (telerehabilitation). However, previous evaluations of such behavioral interventions lack a detailed description of the specific content, and its connection to psychosocial antecedents and health outcomes. Therefore, the primary aim of this study was to (i) describe the content of user-specified coping plans. Second, we aimed to identify (ii) coping plan characteristics associated with health outcomes post-rehabilitation and (iii) sociodemographic and psychosocial variables associated with coping plan characteristics. Methods: This was a secondary analysis from a larger behavioral intervention study, using remote delivery modes, within orthopedic and cardiac rehabilitation. Two raters evaluated the content, quality and number of coping plans from 231 participants. Physical activity and quality of life (health outcomes) were measured via self-reports at the end of rehabilitation and six months after discharge. We used linear regression analyses to examine the relationship between plan characteristics and health outcomes. Results: Content analyses of participants' coping plans emphasized that physical barriers such as pain or other health limitations presented major obstacles for engagement in physical activity postrehabilitation. The most frequently identified external barriers to physical activity were workload, family obligations or bad weather. There was a statistically significant difference in quality of life and physical activity for participants who formulated highly instrumental coping plans (higher quality of life and activity) compared with participants with coping plans of lower quality (lower quality of life and activity). The number of plans (quantity) was not related with outcomes. Conclusion: Generating coping plans can be a useful theory-based approach for inclusion in telerehabilitation to facilitate the maintenance of physical activity and quality of life. It is important to encourage adults and older adults to engage in coping planning and, specifically, to formulate strategies that support tenacious plan pursuit.

Keywords: behavior change theory; coping planning; physical activity; intervention fidelity; rehabilitation after-care; plan content; number of plans

1. Introduction

Health behavior management is essential for preventing and managing chronic diseases such as coronary heart disease or after musculoskeletal trauma [1]. In particular, engaging in regular physical activity is an important element throughout the rehabilitation process, including post-discharge [2]. Clinical interventions that incorporate psychosocial factors and adopt a guiding behavior change theory can facilitate continued physical activity after discharge [2,3]. For example, health care professionals can prompt rehabilitation patients to identify barriers interfering with their postrehabilitation physical activity plans (e.g., physical discomfort) and encourage them to develop effective strategies [4,5]. Using this example of coping planning, the present study aims to illustrate how telerehabilitation may benefit from using psychological behavior change theory to optimize post-rehabilitation care.

1.1. Telerehabilitation meets health psychology: Implementing theory-based principles of behavior change to maintain rehabilitation outcomes

Theory of behavior change may be useful for guiding the development and evaluation of rehabilitation interventions [6–8]. In particular, theories on behavior maintenance such as the health action process approach (HAPA; [9]) or Rothman's framework of behavioral maintenance [10], may guide interventions aimed to engage individuals in sustained health behavior beyond supervised treatment. In a review, Kwasnicka et al. [11] identified coping with behavioral barriers as one of the key psychological processes to explain maintenance of health-related behaviors. Coping plans are a key component of the HAPA and refer to self-regulatory strategies consisting of two components: The anticipated barrier and the approach to overcome it. Coping plans are assumed to help individuals create a mental link between the anticipated barrier (e.g., bad weather) and suitable behavioral strategies (e.g., exercise indoors) thereby inhibiting distractions and decreasing the likelihood of relapse (e.g., [2,4]). As an effective strategy, individuals may vary their initial plan in terms of situational cues (e.g., different time, context) or in terms of their behavioral response (e.g., different type of physical activity). Following an if-then structure (i.e., if barrier x, then response y), coping plans can be understood as implementation intentions [12]. Coping planning, the actual use of coping plans as a self-regulatory strategy, is an alterable variable and can be easily communicated [13].

In rehabilitation, for instance, coping planning can be implemented without the need of face-to-face contact with health care professionals. With the guidance of an interactive web-based program, individuals can initially brainstorm potential barriers to home-based physical activity and enter them in a web-based form. In a second step, individuals may choose those barriers that are most meaningful for them. Finally, they can be encouraged to generate and write down effective strategies, either self-identified or selected from a list, to cope with their barriers. In a web-based environment, strategy development can be easily supported by providing tailored examples (e.g., tailored to gender, age, medical indication etc.). Alternatively, health professionals can assist patients to formulate coping plans via means of computer-assisted telephone interviews, or telephone calls.

1.2. Evaluating coping planning interventions in rehabilitation care: What matters about coping plans?

Previous research yielded mixed findings regarding the efficacy of interventions using coping planning as a behavior change technique (BCT; [14]). Results of one systematic review [15] and one meta-analysis among non-clinical samples of older and younger adults [16], respectively, indicated that the inclusion of coping planning (in combination with other techniques) was associated with lower levels of both self-efficacy and physical activity in comparison to interventions that did not use coping planning. Similarly, intervention research on environmental behavior showed that complex interventions including coping planning may have adverse effects [17,18]. Conversely, a systematic review of randomized controlled trials that tested coping planning as a separate intervention module [19] found that the efficacy of interventions highly varied depending on the level of support provided during the formulation of coping plans. Higher level of support (e.g., telephone-assisted coping planning among older adults [20]; face-to-face, interviewer-assisted coping planning among middle-aged rehabilitation patients, [2]) resulted in a higher number of coping plans, and sustained physical activity [2,4,20] compared to self-administered coping planning.

Previous research (see e.g., [12]) on coping planning interventions is frequently based upon the implicit assumption that participants identify personally meaningful barriers and effective strategies to cope with those barriers. Although coping planning is usually implemented in a consistent manner (e.g., using written material or standardized interview), the content, quality and number of coping plans may highly vary. In other words, although the fidelity of intervention delivery may be very high, individuals may highly differ in how they receive a coping planning intervention [21] and how they enact coping planning skills in daily life [22], with the potential to affect health outcomes. Other evidence highlights that among middle-aged adults a larger number of coping plans was associated with larger improvement in physical activity [23]. However, the content of behavior change techniques (BCTs) such as coping planning (e.g., type of barriers and type of strategies) has rarely been considered in evaluations, and especially within rehabilitation interventions [24]. To further develop and improve the efficacy of theory-based interventions, and specifically coping planning interventions, it is crucial to consider intervention content.

To close this research gap, the first aim of this study was to describe the content of physical activity-related coping plans generated at two different time points during recovery from a cardiac or orthopaedic health condition. To do so, this study investigated user-specified coping plans that participants generated as part of a self-administered, web-based task at the end of rehabilitation (early recovery phase) and a subsequent computer-assisted telephone interview with a trained research assistant six weeks after rehabilitation (late recovery phase). As depicted in Figure 1, this study focussed on two different coping plan components: the barriers that participants anticipated would hinder them to engage in their intended behavior (i.e., if-part of coping plan) and the strategies that participants generated to overcome their barriers (i.e., then-part of coping plan). Besides plan content, we considered the number of coping plans (quantity) as an indicator of how individuals received the intervention. Our second aim was to examine the extent to which plan content and quantity contributed to subsequent health outcomes (i.e., physical activity and quality of life).

The third aim of this study was to identify relevant psychosocial (e.g., self-efficacy, outcome expectancies, intention) and socio-demographic correlates (e.g., age, medical condition: orthopaedic vs. cardiac) of those coping plan characteristics that were linked to health-related rehabilitation outcomes. Finally, we explored whether there would be differences in coping plan content depending on the phase of recovery (early phase: at the end of rehabilitation, late recovery phase: 6 weeks after rehabilitation). The present study presents secondary analyses of an existing data set based on a larger behavioural rehabilitation intervention. Coping planning was only one of the BCTs used in the intervention, and the initial study did not evaluate the content of this single intervention module. Therefore, the present study further examines the characteristics, antecedents and consequences of coping plans for engagement in physical activity after cardiac or orthopaedic rehabilitation.

2. Materials and methods

2.1. Study context, research design and participants

This current study includes secondary analyses of data from a larger intervention trial [25,26] with 1,166 adults who participated in a medical rehabilitation program. Specifically, the FaBA study tested the effect of a psychological, computer-based delivery system on cardiac and orthopaedic patients' health and physical activity. Participants were German-speaking adults, aged ≥18 years, who were prescribed physical activity after discharge from rehabilitation. We provide details of participant recruitment elsewhere (blinded for review). For the present analyses, we only considered participants randomized to the intervention group, because participants randomized to the control group received standard rehabilitation treatment without any additional support for behavior change (i.e., no coping planning).

Briefly, 630 participants in the intervention group completed in-person, interviewer-assisted measurement sessions at the beginning of rehabilitation (Baseline, T0) via trained research assistants. Just prior to discharge from rehabilitation (Time 1, T1) 449 participants completed the web-based intervention including the coping planning module. We excluded participants from the present analyses were if they did not form any plans or only formed incomplete plans at T1 (i.e., specified a barrier but no strategy across all three plans). For the present analyses, 618 coping plans from 231 participants were considered for subsequent content analyses. Of these, 184 participants participated in the follow-up computer-assisted telephone interviews six weeks after discharge from rehabilitation (Time 2, T2). There were 158 participants who completed the 6-months follow-up (Time 3, T3) and were included in the longitudinal analyses. The Ethics Commission of the German Association of Psychology (DGPs) granted ethics approval for this study.

Participants received (i) usual clinical care, and (ii) access to a computer (T0, T1) and a telephone-based (T2) intervention aimed at promoting physical activity-related, self-regulatory strategies; self-efficacy, habit formation as well as behavior and health status. The present analyses focused on the coping planning module of the intervention. At the end of rehabilitation (T1, early recovery phase), participants could form up to three coping plans as part of the self-administered, web-based task. Initially, participants listed up to six barriers that might hinder their engagement in physical activity after discharge from rehabilitation. If participants did not fill in any barriers during the initial brain storming session, they were redirected to a page that prompted them to consider potential barriers to physical activity. For example, the webpage provided an image of a wristwatch (e.g., time as a barrier). Guided by the computer system, participants then selected their three most important self-generated barriers.

For each of the identified barriers, participants generated a coping strategy (see Appendix A for screenshots of the barrier identification process). To support participants with the generation of effective strategies, the web-based system provided up to seven examples of useful strategies (e.g., mobilization of social support, visualization of goal, setting priorities). Participants could choose to skip the examples and directly proceed with entering their own plans. A trained research assistant was also present to assist participants in case of technical or content-related questions, and provided participants with a printed take-away summary of their plans. During the computer-assisted telephone interview (late recovery phase) six weeks after discharge (T2), participants could form up to two coping plans. In contrast to the self-administered task at T1, trained research assistants encouraged participants to think about particular barriers experienced since discharge (e.g., at work, at home). Following this, the interviewer guided participants to formulate specific strategies to overcome their most important barriers. Six months after discharge (T3), trained research assistants contacted participants via telephone to fill in another self-report questionnaire.

3. Measures

3.1. Behavior and quality of life (dependent variables)

Physical activity at baseline and at T3 was measured with a modified version of the Godin Leisure-Time Exercise Questionnaire [27,28]. Participants indicated how many sessions per week and how long per session, they performed vigorous and moderate physical activity. Health-related quality of life at T3 was measured with an adapted German version of the first item of the SF-8 (Short Form-8 Health Survey; [29]), "How would you rate your general health?" Responses were given on a 6-point scale from "very bad" (1) to "excellent" (6).

3.2. Predictors of coping plan characteristics (independent variables)

Intention to engage in regular physical activity after discharge was assessed at the end of participants' stay at the rehabilitation center (T1) using three items that asked participants to rate how much they intended to engage in mild, moderate, and vigorous physical activity [30]. The items started with *"I intend to perform the following activities at least three [two] days per week for 40 [20] minutes..." (a) "...strenuous (heart beats rapidly, sweating) physical activities;" (b) "...moderate (not exhausting, light perspiration) physical activities;" and (c) "...light (minimal effort, no perspiration) physical activity."* Possible responses were on a 6-point scale from *"not at all true" (1) to "absolutely true"*(6). *Self-efficacy* to engage in regular physical activity after discharge was assessed at T1 with four items [28]. The item stem *"I am certain that I can be active on a regular basis..."* was followed by (a) *"...even if I have to motivate myself", (b) "...even if it is difficult",* (c) *"...even if it takes some time until it becomes a routine",* and (d) *"...even if I need several attempts until I am successful."* Possible responses were on a 6-point scale from *"not at all true"*(1) to *"absolutely true"* (6). *Positive outcome expectancies* were assessed at T1 with a scale adapted from [9]. The stem *"If I was physically active I would expect that..."* was followed by five positive outcomes: (1) *"...it will have a positive impact on my health",* (2)*"...I will feel better afterwards",* (3) *"...I will feel more flexible afterwards",* (4) *"...it will have a positive impact on my appearance",* (5) *"...I will get to know other people." Response categories ranged from "I totally disagree" (1) to "I totally agree"* (6). *Coping planning was measured at T1 with two items, for example "For the next month, I have already planned what to do if something interferes with my plans"* [4]. We assessed sex, age, and medical condition (orthopaedic vs. cardiac), and measured *severity of illness* with one item asking participants to what degree their illness interfered with their usual activities (e.g., work, leisure time, household). Possible responses were on a 6-point scale from “strong impairment” (1) to “no impairment at all” (6). We operationalized participants’ engagement in the self-administered coping planning module as the number of strategy examples that participants clicked on during the intervention.

3.3. Coping plan characteristics

We used the Framework Method to analyse coping plan content [31]. One author (LF) and one independent rater (M.Sc. Psychology) individually familiarized themselves with participants’ entries and developed a conceptual model with codes for each of the plan components. After coding the first few coping plans, raters compared their results, and agreed on a set of codes to apply to all subsequent coping plans. Each of the predefined plan categories (e.g., barriers) was further subdivided (e.g., physical barriers, barriers related to mood). Based on this working analytical framework, both raters independently coded coping plans generating a matrix in an Excel spreadsheet. The raters discussed the spreadsheets, compared and agreed upon coding allocations.

To measure the degree to which a coping strategy would help participants to engage in postdischarge physical activities, two independent raters assessed the instrumentality of coping plans. Raters assessed each coping plan strategy on a multiple-point scale, ranging from 4 “very instrumental” to 1 “obstructive”. Higher values indicated that a coping strategy supported the tenacious pursuit of the originally intended physical activity (e.g., make physical activity a priority) whereas lower values referred to strategies that were obstructive to plan pursuit (e.g., “I can’t do anything”). The coding manual can be found at the end of this manuscript (see Table 4) and Appendix C. Inter-rater agreement was moderate (Cohen’s $k = 0.71$). Raters solved disagreements through discussions.

Each rater calculated the number of generated coping plans independently, and confirmed the total amount with the other rater. Coping plans were only counted if participants specified a valid barrier and a strategy (i.e., one credit each). Since participants were encouraged to formulate up to three coping plans as part of the self-administered intervention module, the number of plans could range from zero to three. During the telephone interview, participants could generate up to two coping plans. Accordingly, the number of coping plans of the telephone interview could range from zero to two. The inter-rater reliability was very high (Cohen’s $k = 0.92$). Disagreement between raters was resolved by discussion.

3.4. Statistical analysis

We used counts and proportions for categorical variables (sex, medical condition) and means and standard deviations for continuous variables. We conducted drop-out analyses to compare participants who remained in the study with those who did not complete T3 using t-tests for continuous and $\chi 2$-tests for categorical measures. To assess zero-order associations between all variables in the model (see Figure 1) we computed Pearson’s correlation coefficients. To test the association between coping plan characteristics and health outcomes (i.e., quality of life and physical activity; see right side of Figure 1), we performed step-wise linear regression analyses. We only included a predictor in the regression model if it was significantly associated with physical activity and/or quality of life. To identify relevant psychosocial and socio-demographic correlates of coping plan characteristics (see left side of Figure 1), we ran step-wise linear regression analyses. We used SPSS V24 for all analyses (IBM Corp, Armonk, New York). Data missing at random (<10% on all variables) were imputed using the Expectation Maximization algorithm [32] in SPSS, as it has proven more robust than regression imputation [33].

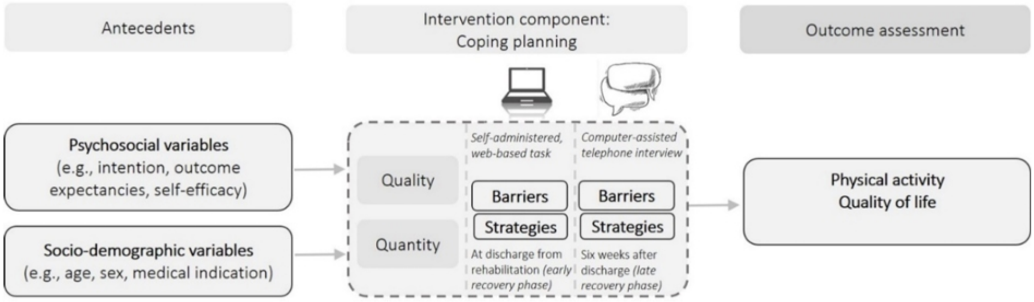

Figure 1. Conceptual model of this study.

4. Results

4.1. Preliminary findings and drop-out analyses

The mean age of the longitudinal sample was 50.45 years (SD = 8.96; range 21–77 years). More than half of all participants were women (59.5%). Most participants had an orthopedic injury or chronic condition, or a previous orthopedic surgery (84.8%). Regarding covariates and psychosocial predictor variables (i.e., intentions, self-efficacy, outcome expectancies, coping planning) there were no significant differences between participants who dropped out and those who remained in the study. Participants who completed the 6-months follow-up, however, were older (M = 50.45, SD = 8.91) than those participants who dropped out of the study (M = 42.79, SD = 9.6). In addition, participants who remained in the study initially generated more complete coping plans at T1 (M = 2.70, SD = 0.61) than those who dropped out (M = 2.35, SD = 1.01).

4.2. Content analysis: Coping plans

To describe the generated barriers, we rated 618 coping plans from 231 participants (T1, early recovery phase). We also coded 263 coping plans of 184 individuals who took part in the computerassisted telephone interview (T2, late recovery phase). Another goal of the content analyses was to describe which type of strategies participants intended to use to cope with barriers, and are presented below.

4.2.1. Barriers: Which barriers prevent participants from engaging in physical activities after discharge?

During the *self-administered web-based task at the end of rehabilitation participants reported physical barriers (e.g., pain), barriers related to a lack of motivation and volition* (e.g., “inertia”)*, barriers related to mood and stress regulation* (e.g., stressed, feeling exhausted) as well as*external barriers* (e.g., work load, bad weather, lack of money). Figure 2a depicts the percentage of type of barriers by recovery phase. Across all coping plans (n = 618), participants most frequently referred to external barriers (54.21%), followed by physical barriers (22.65%) and barriers related to a lack of motivation and/or volition (15.21%). Participants most frequently identified “weather” or “work” as an external barrier. With regard to physical barriers, participants identified “pain” and “disease” as meaningful barriers. Only a small proportion of participants identified problems with mood or stress regulation as a barrier for physical activity (7.93%, see Figure 2a).

During the telephone interviews six weeks after discharge from rehabilitation (T2), the ranking of the reported barriers remained the same: As illustrated in Figure 2b, external barriers ranked first as the most frequently mentioned barrier (64.26%), followed by physical barriers (21.29%) and barriers related to motivational and/or volitional deficits (9.51%). For external barriers, most participants experienced work-related problems (e.g., shift work, long working hours) as a major barrier for their intended physical activities. Similar to the web-based task, participants rarely referred to mood or stress as a barrier to engaging in physical activity (4.49%, see Figure 2a).

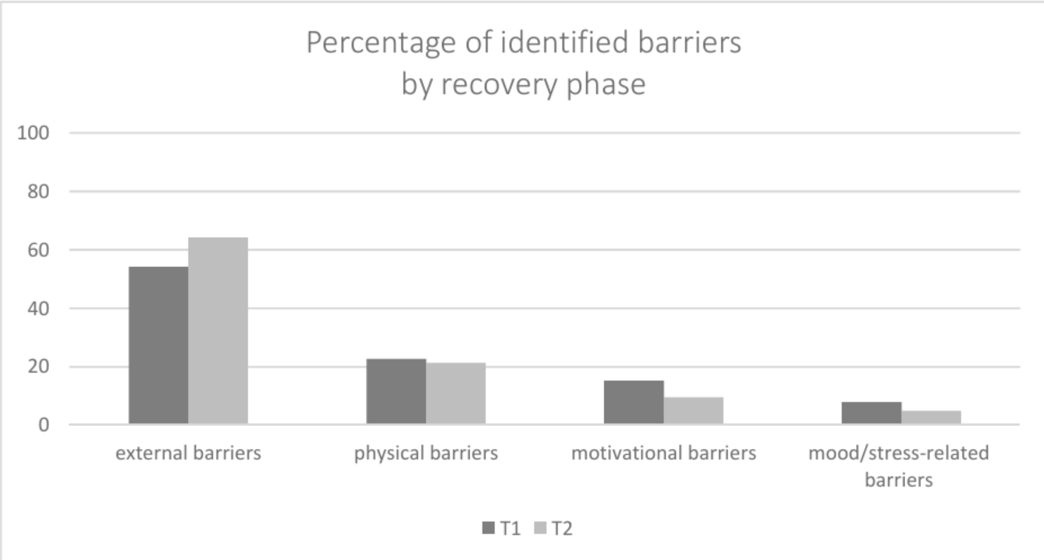

Figure 2a. Types of barriers generated during early (T1, at discharge, n = 231, n = 618 plans) and late (T2, six weeks, n = 184, n = 263 plans) recovery phase. Note: Percentages only add up add up to 100% within each measurement point.

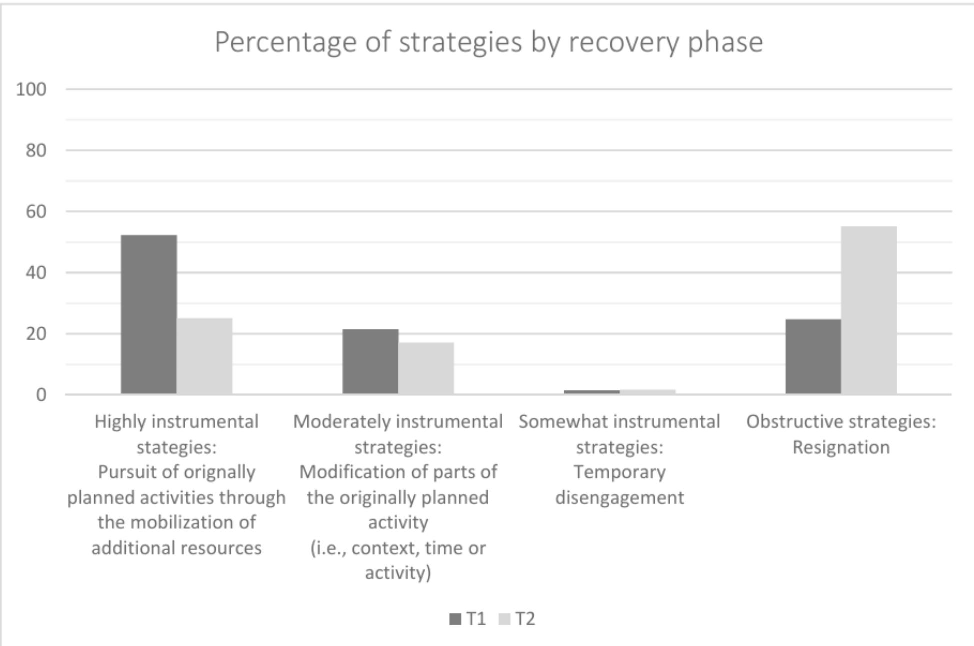

Figure 2b. Types of strategies generated during early (T1, at discharge, n = 231, n = 618 plans) and late (T2, six weeks, n = 184, n = 263 plans) recovery phase; Note: Percentages only add up add up to 100% within each measurement point.

4.2.2. Strategies: Which type of strategies do participants generate to overcome barriers related to post-rehabilitation physical activity?

At T1, participants most frequently formulated a coping strategy that involved the mobilization of resources to tenaciously pursue the planned post-rehabilitation physical activity (52.27%; e.g., visualization of goal). They frequently referred to a cognitive strategy (e.g., pull oneself together, better time management), followed by preventive behavioral strategies (e.g., change work schedule, put on raincoat). Besides the mobilization of resources, participants mentioned coping with a barrier by modifying aspects of their intended activity (21.52%), rather than trying to modify the barrier. To compensate e.g., a missed physical activity opportunity due to a visiting friend or high work load, participants frequently reported that they modified the following aspects: (i) the time of their planned activity, (ii) the behavior itself (e.g., different exercise, lower intensity level) or (iii) the location of activity (e.g., indoors instead of outdoors). Just over one quarter of all generated strategies involved a temporary disengagement from the intended physical activities (e.g., "wait until I have less pain") or simply the conviction that nothing can be done (e.g., "I cannot do anything about this", "I don't know", "nothing").

In contrast to the early recovery phase (T1), the reported strategies at T2 were different. As depicted in Figure 2b, participants most frequently mentioned that they could not do anything about a barrier (57.79%). Only 25.10% of all reported coping strategies involved the mobilization of cognitive, social or behavioral resources to pursue the physical activities as originally planned. Similar to the self-administered task, even nearly one fifth all generated strategies (17.11%) included an adjustment of the originally intended physical activity in terms of type of physical activity or context (e.g., time, location, see Figure 2b).

4.3. Quantitative analyses

4.3.1. Plan quantity and instrumentality

At T1 coping plan generation, 73.2% of respondents (n = 175) formed three complete coping plans, 15.5% had two complete plans, 7.9% of participants generated one complete coping plan, and 3.4% filled in no coping plan. Participants' completion rate declined from plan 1 to plan 3. On average, each participant filled in 2.67 (SD = 0.62) complete coping plans at T1 (median = 3 plans). Approximately one quarter (n = 59) of participants looked at one example of coping strategies; only 5.6% of participants clicked through all seven examples of coping strategies. Thus, engagement in the coping planning task beyond the formulation of coping plans was low to moderate. During the late recovery phase (T2), only 31.5% (n = 58) of participants generated two complete coping plans. There were just over one third (n = 71) of participants who generated one complete coping plan and 29.9% of participants did not generate any complete plan. Participants reported a median of one complete coping plan. For the instrumentality of coping plans, participants' coping plans at T1 were rated as highly instrumental (M = 3.10, SD = 0.90). The instrumentality of the coping strategies generated at T2 was rated as moderately instrumental (M = 1.90, SD = 0.99).

4.3.2. Prediction of rehabilitation health outcomes

Table 3 presents the results of the stepwise linear regression analysis predicting health-related quality of life (left-hand side) and physical activity (right-hand side). To reach a parsimonious model we only included those variables in the prediction models that were significantly associated with either physical activity or quality of life. Zero-order correlations of all variables included in the conceptual model (Figure 1) can be found in Tables 1 and 2. Number of plans at T1, and the number and instrumentality of coping plans at T2 were not related to quality of life and physical activity. To test, however, whether instrumentality of plans (T1) would predict health-related outcomes over and above plan quantity, we included number of plans into the regression model (in its own block, see Step 2 in Table 3). As summarized in Table 3, the third model (using all predictors of the stepwise regression model) showed that instrumentality of coping plans generated at T1 was positively linked to quality of life reported six months after rehabilitation (T3) even when controlled for the number of coping plans. The addition of instrumentality of plans in Step 3 lead to a significant increase in R2 (see Table 3). Of the covariates, coping planning was positively linked to quality of life while severity of illness and age were negatively linked to quality of life.

Next, we analyzed the association between coping plan characteristics and self-reported physical activity. Model 3 in Table 3 shows that instrumentality of coping plans at T1 was positively linked to physical activity at T3. This was the case when controlling for number of coping plans as well as the covariates of which baseline physical activity and coping planning (T1) were positively linked to post-rehabilitation physical activity (T3). The addition of instrumentality of plans in Step 3 lead to a significant increase in R2 (see Table 3). Results from a regression analysis using dummy variables for the instrumentality variable did not substantially differ from the original model (see Appendix B).

4.3.3. Psychosocial and socio-demographic correlates of plan quality

To predict instrumentality of coping plans at T1 in n = 231 individuals, we entered those predictors into the linear regression model that showed a significant zero-order correlation with plan instrumentality (see Table 2). Regression analyses revealed that outcome expectancies were positively linked with plan instrumentality (ß = 0.12, p = 0.03). In addition, women tended to generate more instrumental coping plans compared with men (ß = 0.18, p = 0.01). Overall, the model accounted for 5% of the variance in plan instrumentality.

Table 1. Inter-correlations between quality of life, physical activity and physical activity-specific social cognitions in n = 158 rehabilitation patients.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Sex												
2. Age	−0.15*											
3. Medical condition	-	0.19**										
4. Severity of illness T1	0.02	−0.11	−0.31**									
5. Baseline physical activity	−0.03	−0.17*	−0.11	0.07								
6. Baseline quality of life	0.04	−0.01	−0.09	−0.25**	0.05							
7. Coping planning T2	0.07	0.01	−0.01	0.08	0.15*	0.07						
8. Number of coping plans T1	0.22**	−0.08	−0.04	0.03	−0.04	0.11	0.01					
9. Number of coping plans T2	0.10	−0.05	−0.01	−0.06	−0.08	0.01	0.06	0.07				
10. Instrumentality of coping plans T1	0.17*	−0.08	−0.01	−0.05	−0.13	0.10	−0.02	0.41**	0.07			
11. Instrumentality of coping plans T2	0.17*	−0.12	−0.07	−0.06	0.01	0.01	−0.02	0.13*	0.67**	0.20**		
12. Physical activity T3	−0.01	−0.04	−0.13*	0.09	0.32**	0.12	0.22**	−0.02	−0.01	0.14*	0.05	
13. Subjective health T3	0.09	−0.19*	0.03	−0.18*	−0.01	0.18*	0.13*	−0.07	0.14	0.16*	0.13	0.19*

Note: *p < 0.05; **p < 0.01; Sex was coded 0 = male, 1 = female; Medical condition was coded 0 = orthopedic condition; 1 = cardiac condition.

Table 2. Inter-correlations between plan content, psychosocial variables and sociodemographic variables in n = 231 individuals.

	1	2	3	4	5	6	7	8	9
1. Sex									
2. Age	−0.15*								
3. Medical condition	-	0.19**							
4. Severity of illness	0.03	−0.22	−0.31**						
5. Baseline physical activity	−0.04	−0.17*	−0.13*	0.06					
6. Intentions	0.09	−0.15*	−0.07	−0.01	0.17*				
7. Outcome expectancies	0.07	−0.18**	−0.22**	0.04	0.15*	0.22**			
8. Self-efficacy	0.02	−0.04	−0.09	−0.01	0.20**	0.35**	0.56**		
9. Engagement	0.12*	0.09	−0.09	0.05	−0.08	−0.07	0.05	0.06	
10. Instrumentality of coping plans T1	0.16*	−0.08	−0.01	−0.07	0.03	0.04	0.12*	−0.07	0.11

Continued on next page

Note: *p < 0.05; **p < 0.01; Sex was coded 0 = male, 1 = female; Medical condition was coded 0 = orthopedic condition; 1 = cardiac condition; engagement = number of strategy examples viewed on during the intervention.

Table 3. Linear regression results: Plan quantity and quality as predictors (T1) of post-rehabilitation quality of life and physical activity (T3) in n = 158 rehabilitation patients.

	Quality of life T3						Physical activity T3					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	β^1	p	β^1	p	β^1	p	β^1	p	β^1	p	β^1	p
Age	−0.18	0.03	−0.18	0.03	−0.18	0.03	-	-	-	-	-	-
Medical condition	-	-	-	-	-	-	−0.11	0.17	−0.13	0.14	−0.13	0.11
Severity of illness	−0.15	0.04	−0.14	0.04	−0.13	0.04	-	-	-	-	-	-
Baseline physical activity	−0.05	0.54	−0.06	0.43	−0.04	0.64	0.28	0.01	0.28	0.01	0.30	0.01
Baseline quality of life	0.12	0.15	0.13	0.12	0.13	0.12	-	-	-	-	-	-
Coping planning T1	0.14	0.07	0.14	0.07	0.13	0.07	0.16	0.03	0.16	0.03	0.16	0.03
Number of coping plans T1	-	-	−0.07	0.38	0.07	0.15	-	-	0.02	0.81	0.03	0.29
Instrumentality of coping plans T1	-	-	-	-	0.19	0.03	-	-	-	-	0.23	0.01
R^2	0.10			0.11		0.14		0.14		0.14		0.18

1 standardized coefficients; medical condition was coded 0 = orthopedic condition; 1= cardiac condition.

Table 4. Coding scheme for instrumentality ratings of coping plan strategies.

Instrumentality score	obstructive (= 1)	somewhat instrumental (= 2)	moderately instrumental (= 3)	Highly instrumental (= 4)
	to adhering to the planned physical activities after discharge from rehabilitation			
	- strategy that does not support the planned physical activity at all (*e.g., read a book*) - when the answer does not refer to a strategy (*e.g., weekend*) - when participants did not fill in anything *(e.g., xx or left the field blank)* - when participants entered that they don't know what to do about a barrier *(e.g., I have no idea what to do; there is little I can do)* - when participants explicitly stated that nothing can be done about a barrier *(e.g., you can't do anything about it)*	- strategy that only supports the planned activity in the long-term *(e.g., find a new sports partner)* - strategy which implies a temporary disengagement from the planned activity *(e.g., wait until the pain is gone)*	- strategy that immediately supports the pursuit of the intended activity, but only parts of the planned physical activity: When strategy includes a modification of the original plan in terms of (i) context (e.g., location, time) and/or (ii) activity itself (e.g., type or intensity) *(e.g., I exercise indoors instead of outdoors, I make smaller exercises, I exercise at the weekend)*	- strategy which prevents that a barrier hinders a person from engaging in the planned activity: Strategies that immediately and fully support the pursuit of the originally planned physical activity through the mobilization of (i) cognitive *(e.g., visualize my goal, make physical activity my priority, think positively)* and/or (ii) social resources *(e.g., ask friend to exercise together)* and/or facilitating (iii) behavioral efforts *(e.g., appropriate clothes, change work schedule)*

5. Discussion

This study aimed to comprehensively describe characteristics of coping plans for physical activity generated by patients undergoing cardiac and orthopedic rehabilitation within a larger behavioral intervention. We chose the BCT of coping planning as an example of how to integrate psychological behavior change theory into clinical practice. To support the maintenance of rehabilitation health outcomes (i.e., physical activity and quality of life) beyond treatment, individuals of the present study received access to two subsequent coping planning modules, which were embedded within a self-administered, web-based task (early recovery) and a computer-based telephone interview (late recovery). Besides the description of intervention content, we aimed to examine whether coping plan characteristics such as quantity and instrumentality mattered for subsequent health outcomes. Finally, we aimed to explore whether phase of recovery and other psychosocial and socio-demographic variables would make a difference for coping plan content.

5.1. Coping plan content: Hanging in and letting go in the pursuit of post-rehabilitation physical activity

Content analyses of coping plans of both intervention modules provided insights into the types of barriers and strategies individuals formulated. Meaningful barriers included obstacles in participants' perceived social or physical environment (external) rather than barriers that related to problems with motivation or mood regulation (internal). Similar to previous research among patients in rehabilitation [34], individuals most frequently identified external barriers such as work and family obligations as well as weather (e.g., rain or heat) as obstacles to their physical activity. Analyses further emphasized that physical barriers such as pain or other health limitations (e.g., unexpected cold or flu) presented a major barrier for participants. External and physical barriers were both highly prevalent: when individuals had already spent some weeks at home, they identified even more external issues than at the end of rehabilitation. It may be possible that participants refrained from open disclosure of their internal barriers (such as inertia), preferring to state external causes of inaction to preserve a positive image of themselves. Such a self-serving bias is very common [35].

Coping strategies were categorized under three general themes: participants either (1) planned to tenaciously pursue their intended physical activities despite the occurrence of a barrier, (2) planned to temporarily disengage from their intended activities until the barrier disappeared or (3) were convinced that there would be no alternative course of action to cope with a barrier. At discharge from rehabilitation (early recovery), most participants planned to tenaciously pursue their goals by mobilizing reserve capacities (e.g., visualize goal, set priorities) and increase compensatory efforts. To compensate, e.g. a missed opportunity to exercise, some participants planned to modify their intended physical activity (e.g., type, intensity) or the context of the behavior (e.g., timing, location). In other words, individuals planned to transform their circumstances (e.g., put on raincoat, change work schedule) in accordance with their personal preferences. These strategies may be understood as a form of assimilative coping [36,37]. Engagement in assimilative coping has been shown to be adaptive for successful health goal pursuit and quality of life, particularly among younger and middle-aged adults [38]. An alternative to assimilative coping is accommodative coping [38]. Accommodative coping consists in adjusting personal goals to a given situation (e.g., by letting go of the original goal). The concept of accommodative coping aligns well with theme 3 of our content analysis of coping strategies ("temporary disengagement and resignation"; see Figure 2b). In the context of coping planning, an accommodative strategy may be not to exercise when pain is present. In other words, a person tries to cope with a barrier (e.g., pain) by temporarily disengaging from the original plan to be physically active. In contrast to assimilative efforts, accommodative coping strategies may be less beneficial for relapse prevention after treatment—but this would have to be tested empirically in the future. In sum, despite standardized instructions of the coping planning modules, the content of plans highly varied between participants. The fact that some individuals generated coping strategies that might even promote relapses (e.g., plan to disengage from goal; complete resignation) emphasize the value of considering intervention content. The latter type of coping plans should be of particular interest for future coping planning interventions (e.g., automatically detect and address these plans during an intervention).

5.2. Predicting health outcomes: Which coping plan characteristics matter?

The present findings extend the conceptual framework of coping planning interventions by emphasizing the importance of the quality of plans in the intervention: In general, the higher the instrumentality of the plans, the more likely participants were to maintain their physical activity and quality of life. Instrumentality ratings were based on the content of the coping plans, with higher levels of instrumentality reflecting a higher level of commitment to directly cope with an identified barrier to behavior engagement. In the present sample, participants who planned to engage in assimilative coping strategies appeared to be more likely to have a higher quality of life and remain physically active. In contrast to previous findings [23], forming multiple plans was not associated with continued behavior engagement. Wiedemann et al. [23] argued that a rich repertoire of strategies to overcome action barriers should rather facilitate the uptake and maintenance of physical activity. Our findings, however, suggest that, when tested concurrently, the instrumentality of plans seems to be more relevant to behavior maintenance and quality of life than the number of plans. Taken together, the present findings highlight that plan content matters and should be considered when evaluating behavioral interventions. Intervention developers should encourage participants to engage in coping planning and, specifically, to formulate strategies that support tenacious plan pursuit.

5.3. Correlates of coping plan quality

Women's plans had higher instrumentality than plans created by men. It is possible that women tend to respond with higher compliance to the demands of interviewers and web-based requests. Future research might want to examine this possibility along with an assessment of sex differences in conscientiousness. Instrumentality may also be a function of outcome expectancies—expecting positive consequences from engaging in physical activity was positively linked to coping plan instrumentality.

5.4. Strengths and limitations of the study

This study has many strengths such as, it is theory-based, uses a large longitudinal dataset, and it examines the role of coping planning in a fine-grained manner by looking at detailed plan characteristics. Coping planning as a mental simulation represents a proximal antecedent of behavioral maintenance, but there has not been much research on the content of the actual plans, which has been the focus of the present study. Identifying how people create and enact a coping planning intervention (e.g., generate plans in terms of frequency and instrumentality) has valuable insights for developing future clinical interventions. However, we acknowledge limitations that need to be addressed in subsequent research. For example, the quality ratings were performed post-hoc and participants were not randomized to different intervention instructions (e.g., instruction to generate strategies that support the tenacious pursuit of the originally planned activity vs. strategies that allow more flexibility). However, the time lag of six months between the completion of the coping planning module and the measurement of health outcomes support the hypothesized associations. In addition, the evaluation of the coping planning module was limited to aggregated health outcomes. Future studies may use more detailed, plan-specific outcome measures [39] assessing, for example, whether participants encountered an anticipated barrier and enacted the planned coping strategy.

6. Conclusions

Remote delivery of rehabilitation (e.g., telerehabilitation, mhealth) can benefit from using behavior change theories to facilitate maintenance of target behaviors such as physical activity. It is important to identify a parsimonious set of psychological constructs, one of them being coping planning, which can be easily implemented with technology. Reporting of behavioral interventions needs to improve, for example by including a description of intervention content and its link to theory-based psychosocial and behavioral outcomes. Analyzing how individuals receive and enact specific BCTs can be one option to assess and ensure intervention fidelity [22]. This may be particularly relevant for BCTs that use self-management strategies rather than simply looking at or listening to advice (e.g., behavioral instruction). Coping with behavioral barriers is only one psychological process to promote maintenance [11]: It is important to consider other theory-based mechanisms (e.g., habit formation) for integration into remote delivery of rehabilitation.

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Conflict of interest

The authors declare no conflict of interest.

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Older adults’ activity on a geriatric hospital unit: A behavioral mapping study

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A B S T R A C T

Background: Systematic reviews highlight a preponderance of prolonged sedentary behavior in the hospital setting, with possible consequences for patients’ health and mobility. To date, most of the published literature in this field focus on the hospital experience for older adults with dementia or stroke. Few data describe hospital activity patterns in specialized geriatric units for frail older adults, who are already at risk of spending prolonged periods of time sitting. Yet, promoting older adults’ activity throughout hospitalization, when possible, is an avenue for exploration to identify opportunities to encourage more daily functional activities, and minimize the risk of post-hospital syndrome. Methods: This was a two-part observational study to describe (1) the hospital indoor environment and (2) patients’ activity patterns (using behavioral mapping) within public areas of two hospital units. One combined-trained physiotherapist and occupational therapistrecorded information on indoor environmental features for two acute geriatric hospital units, such as potential opportunities for sitting and walking (i.e., handrails, chairs, benches, etc.), and identified obstacles which may impede activity (i.e., food or laundry carts in hallways, etc.). The observer also systematically scanned these units every 15 minutes (8 am to 4 pm) over two days/unit (one weekday and one weekend day) using standard behavioral mapping methods. There were three to four observation stations identified on each unit to count the number of people who were present, distinguish their role (patient, visitor), approximate age, gender, and body position or activity (sitting, standing, walking). We did not enter patients’ rooms. We described units’ indoor environment, and observed activity for each unit. We used Chi square tests to compare differences in observations between units, day of the week, and gender. Results: For both units there were similar indoor environmental features, with the exception of the floorplans, number of beds, minor differences in flooring materials, and an additional destination room (two lounges attached to one unit). Both units had ite items such as laundry carts against walls in hallways, blocking handrails, when present. We observed between 46–86% (average 60%) of admitted patients in the public areas of hospital units, with variability depending on unit and day: More than half of the observations were of patients sitting. Approximately 20% of patients were observed more than once: This included five women and seven men. There were significant associations for gender and observations on weekdays (men > women; Chi square = 17.01, $p < 0.0001$), and weekend days (women > men; Chi square = 6.11, $p = 0.013$). There were more visitor observations on Unit 2. Conclusions: These exploratory findings are an opportunity to, generate hypotheses for future testing, and act as a starting point to collaborate with front line clinicians to highlight the indoor environment's role in promoting activity, and develop future strategies to safely introduce more activity into the acute care setting for older adults.

Keywords: behavioural mapping; built environment; hospital; mobility; older adults; sedentary behavior

1. Introduction

Sedentary behavior with low levels of physical activity is ubiquitous in the hospital or rehabilitation setting [1–3]. Sedentary behavior includes activities of low energy expenditure occurring in a seated, lying or reclined position (e.g., sitting or watching television) [4,5], while physical activity encompasses a wide range of energy-expending actions, such as activities of daily living, household tasks, work-related activity, or exercise [6]. These concepts are distinct and may impact health outcomes via different mechanisms [7]. While bed rest was traditionally prescribed for recovery, recent evidence demonstrates that prolonged periods of reduced movement may lead to several adverse health outcomes in older adults, such as substantial loss of muscle mass [8], and increased frailty [9,10]. Alternatively, better health outcomes may be gained with early mobilization during recovery: Literature from intensive care and other hospital settings suggest that early mobilization may prevent muscle atrophy [11], improve future functional outcomes [11], and support falls prevention [12]. Equally important to early mobilization, is to consistently break up prolonged periods of daily sedentary behavior throughout the recovery period.

Several factors may contribute to high periods of sedentary time for patients [13]: Reduced access to resources, falls-risk liabilities, patient perspectives, low staff-patient ratios, and physical aspects of the hospital environment. In particular, the indoor (built) environment can promote or hinder physical activity. In a recent Australian study, there were no statistical differences in sedentary behavior for two groups of patients: adults recovering from a stroke or adults recovering from an acute myocardial infarction despite their different (potential) capacities [14]. This study suggests environmental factors (beyond person-level factors) may also contribute to behavior [14], and warrants further investigation.

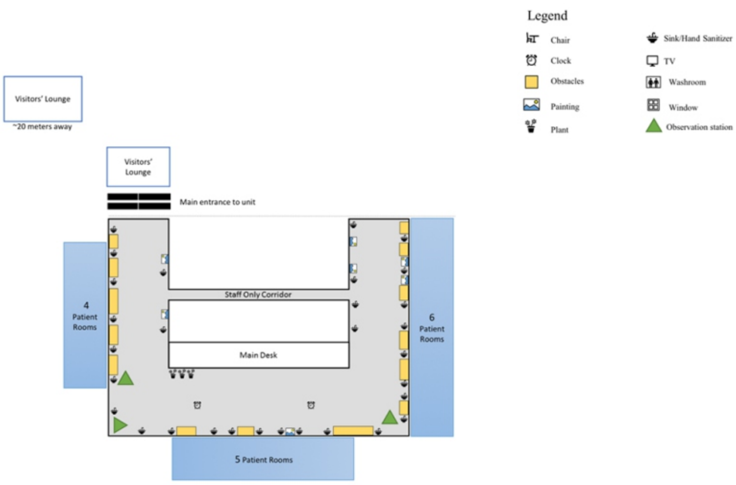
There are several studies describing the hospital indoor environment and person-level activity using behavioral mapping, an environmental scanning method used to systematically record and compare behaviors across time and locations [15]. An advantage of behavioral mapping is the ability to detect a lower threshold of activity, which can sometimes be missed due to the known limitations with pedometers and accelerometers for people with slow walking (gait) speed [16]. Further, behavioral mapping can provide important contextual information for activity [17]. However, most current behavioral mapping studies are limited to inpatients with dementia [15,17] or after stroke [18–23]. Few studies, if any, relate to older adults admitted to an acute care of the elderly (ACE) hospital unit [24,25]. These ACE units were "developed to disrupt the [unavoidable] trajectory of functional decline of geriatric patients who are admitted to acute hospital wards." [25] page 219.

The ACE unit incorporates five key components—patient-centered, frequent medical review, early rehabilitation, environment, and enhanced discharge planning—to minimize the risk of older adults' functional decline during an acute hospital admission [26,27]. Although rehabilitation is key to mitigate limited activity due to an acute illness, one or two therapy sessions/day leaves ample opportunity for prolonged sitting (and possibly provides an opportunity to reverse the benefits of therapy). Specifically, despite the many positive attributes of an ACE unit, it is also important to recognize the need for breaking up prolonged sitting with periods of light activity over the day (if possible). Light physical activity (e.g., activities of daily living, household tasks) provides health benefits [28–32], and may be perceived as more attainable, especially for an older adult who is hospitalized. The indoor environment may support older adults to be active in general [33], via destination rooms and or clear hallways with handrails, and benches or chairs for rest stops, for example. We wanted to understand these factors in an already enriched hospital (ACE) unit for older adults.

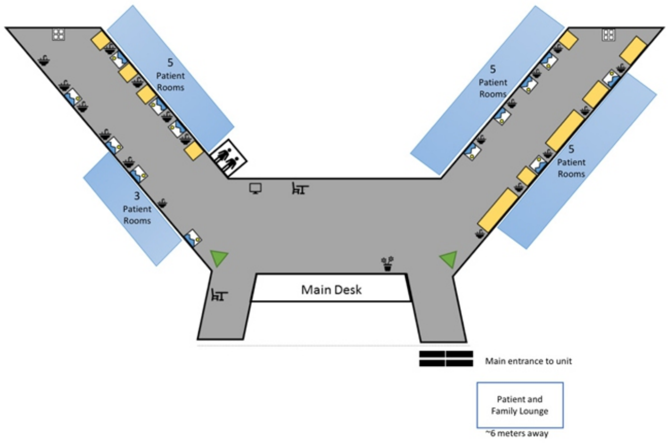
Our aim was to describe the indoor environment of geriatric hospital units, and patients' and visitors' behavior. Specifically, we used an environmental scan and behavioral mapping to characterize two ACE units to describe the, physical, therapeutic, and social opportunities for older adult inpatient mobility outside their hospital rooms. This contextual knowledge was an essential first step to understand older patients' activity patterns in the acute care setting, and is a foundation to develop interventions to maximize mobility recovery in older adults admitted to hospital.

2. Methods

This was an observational inquiry of two inpatient units within a teaching hospital in Vancouver, Canada. We included two ACE units with patients (60 years and older). We also obtained minimal information on unit occupancy (number of patients, age and gender) during the data collection period. Please see Figure 1 for a visual description of both units. We documented the indoor environment and the behavior of patients and visitors (e.g., caregivers, friends, relatives). We used two data collection methods: First, we conducted an environmental scan to describe the indoor features and opportunities for movement in the unit, and second, we used behavioral mapping to describe the actions of people within unit environments during weekdays and weekends. We recognize the difference between gender and sex [34], however in this manuscript, we use gender-based terms, as we do not know the contribution of gender ("socially constructed roles") or sex (biology) [34] for older adults' observed mobility whilst hospitalized. This study was approved by the university and hospital research ethics boards, and data were collected in September and October 2017.



(a) Unit 1



(b) Unit 2

Figure 1. Illustration of two hospital units with environmental features.

2.1. Indoor environmental scan

We conducted an environmental scan of the two units to determine overall design and other key features that may (or may not) encourage physical activity. Specifically, we were interested in collecting information on environmental features that support or hinder safe physical activity, such as access to chairs, benches, and corridors with handrails [35], the color and texture of the floor material [36], noise and lighting [37,38]. The same observer scanned each ward and recorded the environmental features, such as permanent structures (e.g., windows and bathrooms), and more transient items such as portable laundry carts. The observer recorded the information based on a checklist we created to assess the unit design, guided by the Evidence-Based Design conceptual framework [39]. In addition, the observer drew a map of each unit, and indicated the location of permanent and portable items.

2.2. Patient and visitor observations

Behavioral mapping is an observational research method to systematically record behavior within a specific environment [40]. We used standard methods [40] to observe activity every 15 minutes on each unit for two days (one week day/unit and one weekend/unit) from 8 am to 4 pm (except at 12 noon when we only recorded two sessions during lunch time). We specifically chose to look at weekend days as some hospitals generally have less therapy available on weekends. One trained observer, a combined-trained physiotherapist and occupational therapist, conducted the behavioral mapping over the four days. The observer moved in a predetermined pattern throughout each unit (in the public access areas only). Working with hospital staff, we identified two or three places on the unit (called "stations"), and one station in lounges, where the observer stopped for 5–10 seconds four times an hour for data collection. The identified lounges were immediately adjacent, but outside of the hospital units. During the observation period, the observer counted the number of patients and visitors (distinguished their role and posture/activity, and estimated the age and gender of patients) if they were in public areas of each unit (that is, the observer did not enter any rooms) to respect patient privacy. During the observation days, the observer also collected information on noise and lighting, because of the potential negative impact on patients' and staff's health and safety [37,38].

2.3. Analysis

We describe the units (based on the environmental scan of the indoor environment), use frequencies (and percentages) to record the sum of people and activity over each hour in two units, and differentiate between week days and weekend days. One trained research assistant entered data, and reviewed it on multiple occasions for accuracy. We created summary tables, and met with hospital staff to discuss and situate our findings within the context of the hospital unit (member checking). We used the actual number and gender of patients admitted to hospital units on the observational days as the denominator for some calculations. We used Chi square tests to explore associations for observed number of patients (based on the total number of patients admitted) and (I) women and men for overall observations, (ii) women and men for weekdays, and (iii) women and men for weekend days. We conservatively applied a Bonferroni correction to account for multiple testing ($p = 0.05$/three analyses), and considered $p < 0.017$ as significant. We used SPSS Version 23 (IBM, Armonk, New York) for data description and analyses.

3. Results

We completed the environmental scan and behavioral mapping protocol as planned. Tables 1 and 2 provide an overview of the units' environment features. The units differed in their floorplans, number of beds (23 vs 28), and an additional visitor lounge in Unit 2. Both units had a number of obstacles along the corridors and few handrails; but they also had pictures, plants and furniture placed outside hospital rooms (Figure 1). Flooring material differed in their color and design: Unit 1 had light colored floor materials perceived to better distinguish between the floor and adjacent items. Overall, lighting was sufficient, and there were moderate to low levels of noise observed in both units throughout the day (Table 2).

During the data collection period there were 22 patients (Wednesday) and 23 patients (Saturday) admitted on Unit 1, and 28 patients admitted on both days (Thursday and Sunday) for Unit 2. In Tables 2 and 3, we provide a summary of patient and visitor observations. There was consistency between observed and actual patient numbers, gender and age groups, with only one patient misclassified as younger than their actual age. Sitting was noted in 61% of the patients' observations. There was an equal distribution of upright and sitting postures for three days; the exception was a weekend day with considerably more observed sitting. There were more observations in Unit 1, but more visitor observations in Unit 2 (94 vs 134), especially on the weekend.

Table 3 provides a detailed description of observations by unit. In Unit 1 (weekday), there were 42 observations from 19 patients: This included five patients (one woman and four men) who were observed more than once (four patients had five or less observations, and one patient > five observations). For this same unit on the weekend day (23 observations from 14 patients), there were three participants observed (two women and one man) more than once (one patient < five observations, and two patients > five observations). In Unit 2, there was only one patient (woman) observed twice on the weekday (14 observations from 13 patients). For this same unit on the weekend day (38 observations from 14 patients), there were three patients (one woman and two men) observed multiple times (one patient < five observations, and two patients > five observations). In sum, for the patients observed in the public areas of the units, 24% of the patients in Unit 1 had more than one observation, compared with just 15% of patients in Unit 2 (overall average 20%). For all admitted patients, 10% of women (5/48) and 13% of men (7/53) had multiple observations.

There were no significant associations for women's and men's overall observations (Chi square = 1.04, p = 0.31). However, men were more commonly observed outside their rooms on weekdays, and the reverse effect was recorded for women's observations on the weekends. Specifically, there were significant associations for gender and observations on weekdays (men > women; Chi square = 17.01, p < 0.0001), and weekend days (women > men; Chi square = 6.11, p = 0.013).

Table 1. Description of the hospital unit environmental features for the two hospital units, in the public areas only.

Environmental feature	Unit 1	Unit 2
Physical description	Unit: Rectangle-shaped with three corridors with rooms; there were machines and other items (blood pressure machine, charts, linen, etc.) pushed up against the side of one wall for each corridor. There was one chair in the corridor. Lounge 1 (large): Rectangle-shaped room with a television, two sofas, two chairs, and a table. Lounge 2 (small): Square-shaped room with two sofas and a table Airy, open concept design	Unit: V-shaped unit with two long corridors and windows at each end; there were machines and other items (blood pressure machine, charts, linen, etc.), pushed up against the side of one wall for each corridor. Across from the nursing station desk there was a television, a table and two chairs, and a table with three chairs. Lounge: Rectangle-shaped room with television, books and bookcase, information pamphlets, five small tables, piano, and 11 chairs Older traditional hospital design, a bit darker lighting
Bathrooms	Two: Corridor and near lounge	Two: Corridor and near lounge
Destination rooms on unit	None, lounges adjacent unit	None, lounge adjacent unit
Dining room for patients	No	No
Family support features (e.g., lounge, access to washrooms)	Two lounges (large and small) and access to bathroom	Large lounge with plants and a piano, and access to bathroom
Flooring type	Linoleum, light color and easy to distinguish objects	Linoleum, dark speckled flooring
Gardens and plants	Three plants in the corridor, garden visible outside	One plant on the desk, and six in the lounge; outside green space visible
Handrails	Not on unit or lounge	In corridors, but not in the lounge
Items on walls or ceilings	Paintings in corridors and lounge, a lot of messaging on the walls about patient care and hand washing	Paintings in corridors and lounge, a lot of messaging on the walls about patient care and hand washing
Televisions	Lounge only	Corridors and lounge
Temperature	Good in the corridor but lower in the lounge	Good in the corridor but lower in the lounge
Wayfinding	Signage available for reception, bathrooms, hand washing sinks and sanitizers, but not for consumer services, stairs or elevators	Signage available for reception, bathrooms and hand sanitizers, but not for hand washing sinks, consumer services, stairs or elevators
Windows	Windows only in lounge with views of parking, trees and street	Windows at the end of each corridor and in lounge with views of parking, trees and street

Table 2. Perception of unit's noise level (1–10 scale: 1 is silence and 10 is extremely loud) and lighting (1 is sufficient, 2 is dim lighting): These data were averaged over four observations/hour (except the 12:00 noon data collection period were there were only two observations/hour, and the 16:00 data collection period where only one observation was made). The table also includes the total number of visitor and patient observations/hour. Each unit was observed on two separate days: Once on a weekday and the second time on a weekend day.

		Unit 1				Unit 2			
				Observations				Observations	
	Time	Noise	Light	Visitor	Patient	Noise	Light	Visitor	Patient
WEEKDAY	8:00	2	1	1	5	2	1	5	0
	9:00	3	1	0	6	3	1	3	1
	10:00	3	1	11	7	2	1	3	2
	11:00	3	1	15	7	3	1	11	3
	12:00	5	1	8	2	3	1	5	2
	13:00	3	1	8	5	3	1	8	4
	14:00	3	1	3	4	2	1	6	1
	15:00	3	1	2	5	3	1	18	1
	16:00	2	1	0	1	4	1	4	0
	Total observations			48	42			63	14
				Observations				Observations	
	Time	Noise	Light	Visitor	Patient	Noise	Light	Visitor	Patient
WEEKEND	8:00	2	1	0	6	2	2	5	0
	9:00	2	1	4	5	4	2	7	3
	10:00	2	1	5	3	3	1	9	11
	11:00	4	1	15	3	4	1	9	8
	12:00	2	1	1	0	3	1	6	4
	13:00	2	1	0	0	2	1	22	6
	14:00	2	1	8	5	2	1	6	2
	15:00	2	1	11	1	2	2	7	3
	16:00	2	1	2	0	3	2	0	1
	Total observations			46	23			71	38

Table 3. More detailed information on the older adults admitted and observed on the hospital units. The table highlights the overall daily observations of patients by unit and by day. It also describes the age and gender of patients observed on the unit, and the percentage of admitted patients observed outside of their rooms on the unit.

	Day 1 (Wednesday)	Day 3 (Saturday)	Day 2 (Thursday)	Day 4 (Sunday)
	Unit 1	Unit 1	Unit 2	Unit 2
Number of observations/day	42	23	14	38
Upright	22	11	7	6
Sitting	20	12	7	32
Patients admitted on unit	22	23	28	28
Women	9	10	16	13
Men	13	13	12	15
Age < 65 years	2	3	2	1
Age > 65 years	20	20	26	27
Patients observed on unit	19 (86%)	14 (61%)	13 (46%)	14 (50%)
Women	6 (67%)	10 (100%)	3 (19%)	7 (54%)
Men	13 (100%)	4 (31%)	10 (83%)	7 (47%)
Age < 65 years	3	1	0	0
Age > 65 years	16	13	13	14

4. Discussion

Sedentary behaviors, such as prolonged sitting, lying or reclining, use very little energy expenditure [4,5], and are ever-present throughout the hospital phase and subsequent recovery period [1,2]. Studies indicate hospitalization can lead to the development of disability and loss of autonomy [41], and may mediate a change in residence upon discharge. Here, we describe the indoor environment for two ACE units with features that encourage more activity such as, low to moderate noise levels, adequate lighting, good esthetics (windows, pictures and plants), hallways for walking with rest stops (chairs), and destination rooms (visitor lounges). However, few handrails and the presence of items against walls in the hallways (perceived obstacles) were potential barriers to patients' mobility outside their rooms. Based on the behavioral mapping exercise, we observed about 60% of patients admitted to the ACE units left their room on at least one occasion, with 20% of patients with multiple observations. Sitting was noted in more than half of the observations. However, we recognize that patients may have engaged in routine rehabilitation (in their room or therapy department). Our work extends the literature to highlight an interesting finding related to gender and activity patterns. We observed significantly more older men outside their rooms during weekdays, and more older women outside their rooms on the weekend days: Concurrently, we recorded more visitor observations on the weekend. To our knowledge, our study is the first to observe activity patterns (using behavioral mapping) on an ACE unit, thus it is difficult to put our results into perspective. That is, older adults admitted to an ACE unit are generally considered frail, thus observing more than half of patients in the public areas of the units is encouraging. A laudable goal is to optimize physical activity for all older adults in the acute hospital setting, to avoid the cycle of prolonged sedentary behavior that can be difficult to change once discharged home. Therefore, these results serve as a baseline, and generate hypotheses for future testing to optimize the hospital experience for older adults.

The exploratory work presented here is an important first step to work collaboratively with key stakeholders. Behavioral mapping is a unique approach to provide contextual information on patients' mobility in the hospital setting. As there are few, if any, studies using behavioral mapping conducted within ACE units, we do not know if more patient observations lead to better health outcomes. However, other studies underscore that early [42–44] (and frequent) daily movement can be beneficial. The approach presented here provides a person-centered way to develop and test interventions to encourage safe mobility on the hospital unit and circumvent the post-hospital syndrome, a multifactorial phenomenon negatively impacting health and recovery [45]. As aptly stated by Professor Krumholz, "The hospitalization should not only address the urgencies of the acute illness, but also seek to promote health actively by strengthening patients and contributing to their physiological reserve." [45] page 3. Hospital policies are generally developed for the health and safety of patients and staff. Although there has been a recent call to re-evaluate patients' activity in hospital vs. the risk of falls [13], there is an urgent need for solutions that promote mobility while minimizing harm. This is an important goal that would benefit from further clarification with empirical evidence.

Early mobilization is essential, however it is equally important to balance activity with restorative breaks, and develop skills, strategies and confidence with new or evolving mobility and health status. Technology advances could assist this change in focus by providing staff with real-time monitoring of patients' daily movement patterns [46]. Reduced self-efficacy (resulting from hospitalization) and or an increased fear of falling [47,48] may result in older adults' hesitancy to mobilize. Support for activity and developing good health habits could begin through modeling within the hospital setting, while patients are still supervised by health care staff. It does not seem to be enough to "tell" people to be active once they are home. This can be an opportunity to develop positive health habits for longer term adoption outside of the hospital setting. Ultimately, the hospital experience is a complex, multi-dimensional issue that we need to better understand from different perspectives: Patients' families, hospital staff and policy makers. This comprehensive approach with a person-centered lens is ideal to develop and test possible solutions to minimize the risk for iatrogenic development of mobility disability and support in-hospital harm reduction.

We noted an interesting finding in our study: Older men were observed more in the unit during the weekdays and older women during the weekends. We do not know why this may have occurred but speculate that it may be a result of gender-based behaviors, the presence of family members (visitors), or by chance. It is possible that older men took a more traditional approach to the hospital admission and "worked" on their recovery during the weekdays: Older men (compared with older women) generally engage in more higher intensity physical activity [49]. Alternatively, maybe older men engaged in steps to gain back some control [50] (through exercise) when confronted with an acute hospital admission. Interestingly, based on our previous work at the same hospital, we noted there were more men who fell, compared with women [51] during a hospital admission: we do not know why they fell, but it is possible that older men may be at greater exposure for falls due to walking outside hospital rooms. There is other literature with similar observations for men in hospital [52,53]. Conversely, there were slightly more visitors observed on the weekend, which may have encouraged women to leave their rooms. In a similar study by Prakash and colleagues [54], they noted that patients with stroke were more active (in hospital) when family was present, although there were no gender differences reported. We stopped data collection at 4 pm, so do not know whether visitors, such as family members, may have supported older women to leave their rooms on weekday evenings. These preliminary data generate hypothesis for future studies to disentangle the role of gender (if any) in the recovery period.

To address the current state of prolonged sedentary behavior in the hospital setting requires understanding factors at multiple levels: person, practitioner, policy and environment. The built environment is emerging as a key factor to support older adults' outdoor physical activity [55,56], but, in general, less is known about older adults' physical activity and the indoor (home) setting [33]. Similar principles may apply to hospital settings, thus we used a framework to guide our research [39] and conducted an environmental scan of the hospital units. We noted several challenges within units which may account for patients' reduced activity. For example, handrails were missing on Unit 1, and for both units there were obstacles in the hallways, and no destination rooms within the unit (e.g., central dining room, small gym). In addition, we observed fewer patients in Unit 2; here the floor plan was more traditional, and flooring was darker (and possibly creating obstacles for older patients with low vision). These features may or may not have contributed to our findings, and it remains uncertain as there are no publications on barriers to activity in ACE units. Activity is most likely influenced by the interaction of the person within the physical and social environment. Within the stroke literature, Rosbergen and colleagues explored the effect of an "enriched environment" on activity for older adults with stroke [57–59]. In this controlled pre-post pilot study, they noted an increase in patients' activity, with no significant difference in adverse events compared with a control group [58]. This study is informative to guide future interventions for patients, staff, and hospital culture and policies.

We acknowledge the following limitations with this study. First, we only collected data in the public areas of the hospital units and are not able to account for activity participants engaged in within their room, or areas of the hospital outside of the unit. In particular, some ACE units have cycle ergometers for use in patient rooms. Second, we only collected data during the day for a few days, and cannot comment on any physical activity during the evenings. Nonetheless, we have detailed observations of patients' daily routines outside their rooms and can provide context to their patterns. Third, we observed low numbers of participants, and this may or may not represent typical behavior for older patients admitted to ACE units. Further, we do not have information on the health status of the patients on each unit, thus these factors could explain the observations (or lack thereof). We also did not use a direct measurement (e.g., accelerometry) of patients' activity patterns. However, given the low level of patients' observed physical activity, there is the possibility of missing data (due to slow gait speed) with accelerometry [60]. Conversely, in this study, an experienced physiotherapist-occupational therapist collected all data reducing the risk of missed activity. Finally, we do not know if the observed behaviors in hospital were associated with health outcomes post-discharge, but collectively, this valuable information is hypothesis-generating for our next research phase.

In conclusion, we describe the indoor environment for two ACE units, with features that can encourage mobility, but also noted potential barriers, such as few handrails, and obstacles in the hallways. We also describe older adults' physical activity patterns in the acute hospital units during a recent admission. We noted variability in observations (based on day and unit) for patients outside of their rooms, and sitting was observed over half of the time. Emerging evidence supports early activity, but to date, many older adults engage in prolonged periods of sedentary behavior as a hospital inpatient. A recent international consensus on older adults and sedentary behavior [61] includes a recommendation for more research to reduce prolonged sitting during hospitalization. Our exploratory data is a beginning to advance the field and supports our next phase, the co-creation of safe and person-centered policies on inpatient mobilization.

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Conflict of interest

All authors have no conflict of interest to disclose.

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Role of mushrooms in gestational diabetes mellitus

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ABSTRACT

Many studies have shown that plant-based diets and Mediterranean diets can lower the risk of development of gestational diabetes mellitus. Plants have been the main source of medicines since ancient times. Despite tremendous advances in medicinal chemistry, synthetic drugs have not provided cures to many diseases due to their adverse side effects or diminution in response after prolonged use. Medicinal mushrooms have been used traditionally as an anti-diabetic food for centuries especially in countries such as China, Japan, India and Korea. These are source of natural bioactive compounds. The bioactive constituents are polysaccharides, proteins, dietary fibres, lectins, lactones, alkaloids, terpenoids, sterols and phenolic compounds which have various health benefits. This review will focus on recent examples of diverse types of mushrooms that have been validated by scientific evaluation as having promising activity for the prevention and/or treatment of gestational diabetes mellitus. Dietary components and plant-derived molecules can be used in the future to complement current treatment strategies for gestational diabetes mellitus.

Keywords: Gestational diabetes mellitus; medicinal mushrooms; polysaccharides; dietary fibres; phenolic compounds; anti-diabetic food

1. Introduction

Gestational diabetes is a form of hyperglycemia. It is a common metabolic disorder during pregnancy. According to 'World Health Organization' (WHO), gestational diabetes is defined as hyperglycaemia that is first recognised during pregnancy and is observed to precedes to type 2 diabetes in up to one third of women later in life [1]. Series of endocrine, metabolic and vascular changes take place during pregnancy to fulfil the demand of energy and nutrient needs of the foetus. GDM develops when pancreatic β-cell is not sufficient to compensate for the decreased insulin sensitivity and due to which there is increase in post-prandial free fatty acids, hepatic glucose production, insulin resistance and glucose production [2]. Although, glucose homeostasis is restored after delivery but there is high risk of development of type 2 diabetes mellitus in future. Gestational diabetes indicates the underlying frequency of type 2 diabetes for any ethnic and population group with incidences rising globally needing huge health care and economic costs [3].

GDM is clearly a major public health issue internationally, especially among those of non-European descent and data from previous studies also revealed that GDM was more prevalent in women with family history of diabetes, women who were obese and parous [4].

2. Pathophysiology

During pregnancy, there is an increase in oestrogen and progestin concentration which further leads to decrease fasting glucose, delay in gastric emptying and increase in appetite. Tissue sensitivity to insulin decreases as gestation progresses and therefore, post-prandial glucose concentration increases. To counteract this, pancreatic β-cell of the mother have to increase insulin secretion to regulate glucose concentrations and GDM females are unable to produce sufficient insulin (Figure 1). Insulin resistance is also caused by defects in receptors of insulin -signalling cascade. The down-regulation of insulin receptor substrate-1 (IRS-1) decreases insulin-mediated glucose uptake in skeletal muscles. Genetic variations have also been associated with greater risk of developing gestational diabetes (Figure 2) [5].

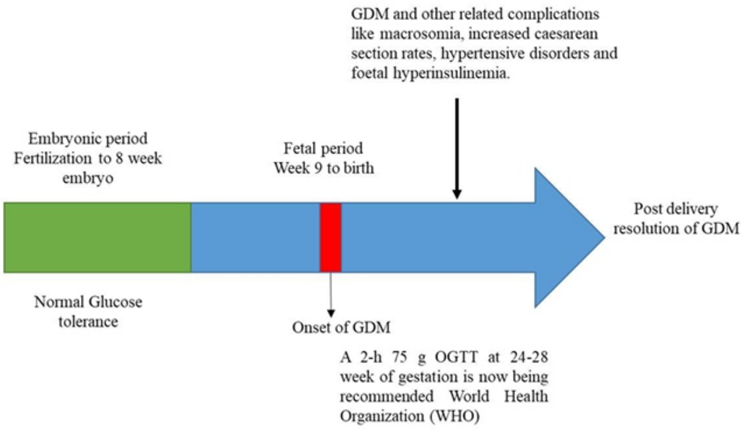

Figure 1. Onset of GDM in pregnant females.

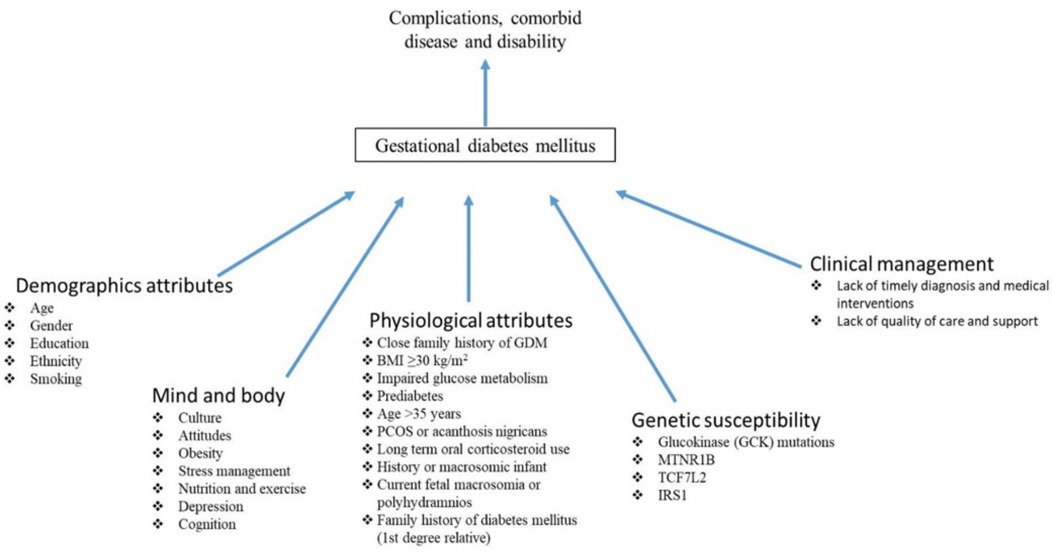

Figure 2. Factors which increase the onset of GDM in females.

3. Management of gestational diabetes mellitus

Blood glucose monitoring is very important to manage GDM. Diet and nutrition must be carefully monitored, and exercise can effectively regulate the blood glucose concentrations and can reduce the risks of complications for a mother as well as her baby due to hyperglycaemia [5]. Maintaining healthy body weight, abstinence from cigarette smoking, restricting refined sugars and Trans fats, consumption of low glycaemic foods, soluble fibres and calorie restriction are the preventive measures in blood glucose regulation [6].

Plants have been used historically for medicinal purposes worldwide. Plants are the rich sources of fibres, vitamins, minerals and phytonutrients and have shown beneficial effects in management of diabetes, cardiovascular disorders, obesity and some cancers [7]. In recent years, mushrooms and seaweeds have gained an interest of many researchers and now they have moved on to explore mushrooms to control and manage post-prandial hyperglycemia [8]. Mushrooms have been used in Traditional Chinese Medicine (TCM) and as functional foods in nutraceuticals for their anti-diabetic and anti-obesity effects [9]. The worldwide mushroom industry has grown, and rate of consumption has been increased at a rapid rate since the late 1990s [10].

Mushrooms have been part of culinary culture across the globe and have been valued for their unique flavor. More than 2000 mushroom species exist in nature but only 25 species have been accepted as food [11]. Eighty five percent of the world's mushroom supply is from five main genera such as Agaricus (A. bisporus and A. brasilensis) contributing 30% world's cultivated mushrooms. Pleurotus, second one with 5 to 6 cultivated species, constitutes about 27% of world's output and then Lentinula edodes (Shiitake) contributes 17%, whereas Auricularia and Flammulina constitute for only 6% and 5% respectively [10].

Mushrooms belong to phylum Basidiomycota and order, Agaricales. They have a fruiting body composed of a stipe (stalk), pileus (cap) and lamellae (gills) and mycelium, the root absorbs the nutrients [12]. Gymnopilus edulis seaweed is potential glucosidase enzyme inhibitor, Lenitus edodes, Ganoderma lucidum have shown to possess anti-diabetic effects in various studies [13]. Several beneficial nutritional effects of mushrooms have been identified (Figure 3) [14].

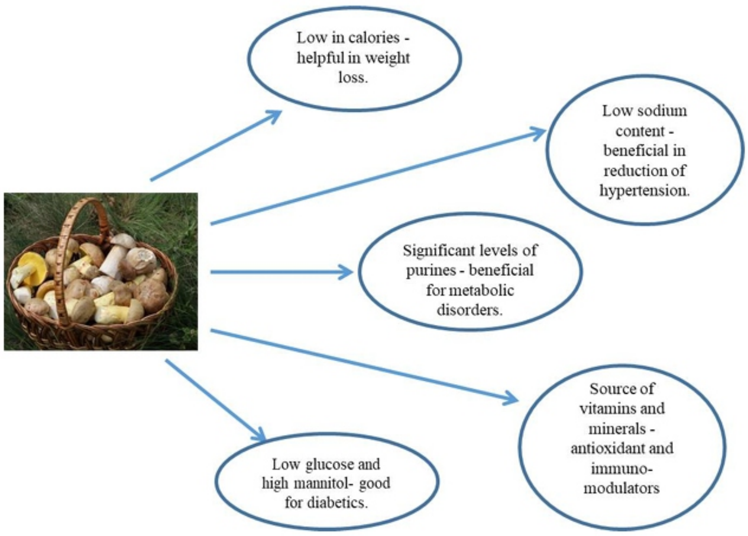

Figure 3. Nutritional effects of mushrooms.

The aim of this article is to review the relevant literature on use of different mushrooms in managing diabetes and gestational diabetes mellitus.

4. Medicinal mushrooms with potential anti-diabetic activities

4.1. Ganoderma lucidum (Lingzhi/Reishi)

Ganoderma lucidum belongs to the family Ganodermaceae which is widely used for longevity and health promotion. It is commonly known as 'Ligzhi' in China and 'Reishi' in Japan. The bioactive compounds are polysaccharides, β-glucans, lectins, organic germanium, phenols, steroids, amino acids, lignins, mycins and vitamins. Ganoderma is considered as golden medicinal fungus [15]. Ganoderma lucidum is often combined with another mushroom, Cordyceps sinensis which is thought to increase potency of Ganoderma lucidum [16].

4.2. Lentinus edodes (Shiitake mushrooms)

Shiitake mushrooms have been used to treat common cold for hundreds of years. These mushrooms contain high fibre, high levels of β-glucans, proteins, lipids, carbohydrates, minerals, vitamin B1, B2 and C, ergosterol, lectins and lentinans. Studies have shown that shiitake mushrooms could alleviate the damage of pancreatic β-cells, promote insulin synthesis and lower plasma glucose levels. An ex-polymer of L. edodes reduced plasma glucose and increased insulin synthesis in streptozotocin-induced diabetic rats compared to normal rats [8].

4.3. Ophiocordyceps sinensis

Ophiocordyceps earlier known as Cordyceps sinensis has been used historically as a medicinal mushroom. It has only been found growing at high altitudes in Qinghai-Tibetan plateau and due to high demand and declining harvest, this has become the one of the most expensive mushrooms used in oriental medicine. This mushroom is only found in co-habitation with larvae of an insect, needs rarefied atmosphere, mineral rich soil and low temperature which makes artificial cultivation challenging. Cordyceps has a unique profile of secondary metabolites and thus, considered as world's most costly medicinal mushroom [17]. Various animal and human studies have shown antihyperglycemic, anti-atherosclerotic, anti-hypertensive, antioxidant and cholesterol lowering effects of Cordyceps sinensis [16].

4.4. Agaricus blazei Murill

ABM is native to Brazil and widely grown in Japan. This mushroom is traditionally believed to fight physical and emotional stress, stimulate immune system, manage diabetes, cholesterol, digestive issues. Ergosterols, lignins and polysaccharides are the main bioactive constituents [18]. The polysaccharides, α-glucans, β-glucans have been shown to possess immune-modulatory and anti-mutagenic activity in both in-vitro as well as in-vivo studies [8]. The natural polysaccharides of this mushroom have shown to be effective in regulating diabetes by the mechanisms given below [19].

(a) Elevation of plasma insulin and decrease of pancreatic glucagon
(b) Increase in insulin sensitivity and improvement of insulin resistance
(c) Inhibition of α-glucosidase enzyme
(d) Increase of hepatic glycogen and inhibition of sugar dysplasia
(e) Increased use of glucose from peripheral tissues
(f) Scavenging free radicals and lipid peroxidation

4.5. Grifola frondosa

Grifola frondosa, also known as Maitake mushrooms has varied medicinal properties and is popular in Korea, China and Japan. Chinese people have been consuming Maitake mushrooms for hundreds of years for it's enticing taste. These mushrooms possess anti-tumour, immune-regulatory, anti-diabetic, beneficial effects against hepatitis and HIV/AIDS [20].

4.6. Pleurotus pulmonarius (Grey Oyster Mushroom)

This type of mushroom is an excellent anti-diabetic food. It contains polysaccharides, vitamins and minerals, dietary fibres and rich in essential amino acids. Oyster mushroom is consumed all over the world due to its high nutritive value and flavour. It can be cultivated within wide-range of temperatures and possess wide range of health benefits [21].

4.7. Antrodia cinnanomea

This mushroom is native to Taiwan with various medicinal properties. This has mainly used to treat diarrhoea, abdominal pain, hypertension, cancer and toxicities caused by various foods and drugs [11].

4.8. Panellus serotinus (Mukitake)

This mushroom is the most delicious edible mushroom in Japan. This mushroom has found be very beneficial for liver and helps to prevent the development of non-alcoholic fatty liver disease [11].

4.9. Auricularia auricular

Auricularia species are widely cultivated in China, Taiwan, Thailand, Philippines, Indonesia, Malaysia [10]. Most species of Auricularia are edible and possess medicinal properties. A. polytricha (Woodear mushrooms) and A. auricula-judae (black fungus) are anti-tumour, anti-coagulant and cholesterol lowering, A.auricula-judae has also shown hypoglycemic properties [11].

4.10.Flammulina velutipes

This mushroom is traditionally used for soups in China. Bioactive constituents are dietary fibre and polysaccharides. Flammulina is hypoglycemic, cholesterol lowering and anti-oxidant [11].

5. Hypoglycemic effects of mushrooms

There have been numerous investigations conducted on rats to understand effect of different variety of medicinal mushrooms on underlying biomarkers of diabetes; some of these studies are summarized in Table 1. All these studies have either used polysaccharides, protein complexes, or compounds extracted from fruiting bodies, cultured mycelium, or cultured broth of medicinal mushrooms. This section includes most of the medicinal mushrooms that have been investigated for their potential in Diabetes along with the demonstrated mechanism of action. The medicinal mushroom extracts are invaluable source of a variety of:

(1) enzymes such as laccase, superoxide dismutase, glucose oxidase, peroxidase;

(2) polysaccharides such as β-D-glucans, glucuronoxylomannan;
(3) lectins, glucoproteins, proteins, polysaccharide-protein complexes,
(4) lipopolysaccharides,
(5) terpenoids, alkaloids, sterols, phenolic substances, metal chelating agents [19].

These components have been demonstrated to target various deranged carbohydrate metabolic pathways thereby lowering blood glucose and insulin concentrations in type 2 diabetics as shown in Table 2 and 1. Efforts are currently underway to quantify these compounds for their therapeutic usage in diabetes and other conditions.

Table 1. Summary of some experiments on rats to demonstrate hypoglycaemic effects of medicinal mushrooms (MM).

Type of medicinal mushroom	Form of mushroom	Dose	Result	Possible mechanisms
Agaricus brasiliensis and *Ganoderma lucidum* [22]	Mycelia powder	1 g/kg for 14 days	MM extracts reduced complications in microcirculation induced by hyperglycaemia via promotion of ion homeostasis and structural and functional states of erythrocyte membranes.	Influenced physiological balance of process of sialylation and desialylation, regulated ion charge on the surface membrane of red blood cells, normalized aggregation properties, and elevated the structural recovery of oligosaccharide chains of erythrocyte membrane surface glycoconjugates.
Lentinus edodes (*Agaricomycetes*) [23]	Lyophilized and reconstituted	Doses of 100 or 200 mg/kg/d of lyophilized and reconstituted *L. edodes* for 19 days of gestation	Reduced glucose in plasma, urea, triglycerides, and aspartate aminotransferase.	Improved liver function and stabilized insulin response.
Maitake -*Grifola frondosa* (Higher Basidiomycetes) [24]	Fermented mycelia, broth, or mycelia plus broth	1 g/kg-per day for two weeks	Hyperglycaemia and cell mediated inflammation was reduced.	Decreased inflammation by downregulating IFN-γ IL-4, and IL-6 IL-4 as well as significantly improved the productions of tumor-necrosis factor-α.
Cracked-Cap-Phellinus rimosus (Higher Basidiomycetes) [25]	Extract	*P. rimosus* (50 and 250 mg/kg) and glibenclamide (0.65 mg/kg) for 30 days	Significant reduction in blood glucose, triacylglycerol, total cholesterol, LDL-cholesterol, and liver function enzymes, and increased serum insulin, liver glycogen, and HDL-cholesterol levels.	Possible insulinogenic and antioxidant mechanisms as improved antioxidant status was observed in pancreas, liver, and kidney tissues with associated fall in thiobarbituric acid- reactive substances.
Agaricus brasiliensis and *Ganoderma lucidum* [26]	Powdered mushrooms	Dose of 1 g/kg body weight	Reduced Oxidative-nitrative stress.	Decreased the activity of the NO synthase, as well as positive corrective action on the L-arginine/NO system and the ratio between p53 and Bcl-2 proteins in white blood cells, as well as on apoptotic index reduction.
Pleurotus ostreatus and *P. cystidiosus* [27]	Freeze-dried and powdered	Different doses (250, 500, 750, 1000, and 1250 mg/kg/body weight) to normal rats and a single dose of 500mg/kg body wt. to diabetic rats	A single dose significantly ($P < 0.05$) reduced the serum glucose levels in diabetic rats.	Hypoglycaemic action.
Pleurotus florida [28]	Polysaccharide extract	200- and 400-mg/kg doses	Hypocholesterolaemic, anti-inflammatory and hypoglycaemic actions.	Lowered glucose concentrations, serum cholesterol, triglycerides, and urine glucose and ketones. Also caused significant fall in MDA and NO, but enhanced superoxide dismutase, catalase and active glutathione.
Grifola frondosa [29]	α-glucan	300 or 100 mg/kg	Reduced injury to β cells of pancreas, hypoglycaemic and hypocholesterolaemic.	Lowered triglycerides, cholesterol, free fatty acid, improved inflammatory action.
Pleurotus ostreatus [30]	Total polysaccharides extract	100, 200, and 400 mg/kg/d for 4 weeks	Reduced hyperglycemia and hyperlipidemia levels, improved insulin resistance, and increased glycogen storage, reduced the risk of oxidative damage.	Enhanced GSK3 phosphorylation and GLUT4 translocation. Also increased endogenous antioxidants' (superoxide dismutase, catalase, and glutathione peroxidase) activities and decreased MDA.
Coprinus comatus [31]	Polysaccharide fractions (ethanol based)	1000 mg/kg in 12 min and 21 days of injection at the same dosage	Short and long term hypoglycaemic action.	Hypoglycemic activity is possibly mediated via immune stimulation.

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Table 2. Medicinal mushrooms active constituents and pharmacological action.

Name of the mushroom	Active ingredient	Pharmacological action
Agaricus bisporus [32]	Thiamine, ascorbic acid, vitamin D_2 as well as minerals like folates, ergothioneine (ET) and polyphenols	Reduced plasma glucose, significant decrease in triglycerides concentrations, plasma total cholesterol, low density cholesterol
Agrocybe cylindracea [33]	Glucan and heteroglycan	Hypoglycemic activity
Agaricus campestris [34]	Aqueous fruiting body extracts	Insulin releasing and insulin-like activity
Agaricus subrufescens/Agaricus blazei [35–37]	High levels of valuable minerals like potassium, phosphorus, calcium, magnesium and zinc Beta-glucans	Anti-hyperglycemic. Suppressed the increase in HbA1c and oxidative stress
Auricularia auricula [38,39]	Water soluble polysaccharide from fruit body	Lowering plasma glucose and significantly lowered blood urea nitrogen (BUN) and uric acid (UA) in serum, and protein concentration in urine by altering the anti-oxidative system and nuclear factor kappa B-related
Coprinus comatus [40,41]	It is rich in trace elements like vanadium, chromium, zinc, magnesium, copper, iron, and nickel and Comatin an inhibitor of the non-enzymatic glycosylation (NEG) reaction	Helped in lowering the level of blood glucose and improved the glucose tolerance
Cordyceps sinensis [42,43]	It is rich in trace elements like cadmium, lead, arsenic, copper, nickel, silver, chromium, and mercury	Increase serum insulin concentration and decreased serum fructosamine concentration
Ganoderma lucidum [44]	Polysaccharides (Ganoderan A and B, glucans), proteoglycans (*FYGL)*, and triterpenoids	FYGL was able to enhance insulin sensitive and to decrease hepatic glucose output along with the increased level of adipocyte and skeletal muscle glucose disposal
Grifola frondosa [45]	Alpha-glucan (MT-alpha-glucan)	Alpha- glucan was able to increase the insulin sensitivity and ameliorate insulin resistance.
Hericium erinaceus [46,47]	Polysaccharides, oligosaccharide, sterol, fatty acid, erinacine and hericenone,	It was able to reduce the blood glucose levels, liver glycogen content and also able to enhance insulin production.
Inonotus obliquus [48,49]	Polysaccharides and polyphenols	Polysaccharide has shown to inhibit *dipeptidyl peptidase 4* (DPP4) enzymes and induce translocation of GLUT4 receptor
Lentinus edodes [50]	Provitamin D2 (ergosterol), glycogen-like polysaccharides, (1-4)-, (1-6)-D-glucans and exopolysaccharide	Exopolysaccharide has been reported to decrease the plasma glucose level and increased plasma insulin
Pleurotus pulmonaris [51,52]	Profilin-1, glyceraldehyde-3-phosphate dehydrogenase and guanide	Guanide is known to cause exocytosis of insulin containing granules and reduces fasting plasma glucose concentration
Tremella aurantia [53,54]	Acidic polysaccharide	Exhibited hypoglycemic and ameliorated the symptoms of diabetes
Tremella fuciformis [55]	Glucuronoxylomannan and exopolysaccharides	Hypoglycemic activity was attributed to the presence of gluronoxylomannan whereas; insulin sensitivity was enhanced due to the exopolysaccharides reported in the mushroom
Wolfiporia cocos [56,57]	Dehydrotumulosic acid, polyporenic acid C, pachymic acid, dehydrotrametenolic acid, and dehydroeburicoic acid.	Acts as an insulin sensitizer in glucose tolerance tests and reduces hyperglycemia
Wolfiporia extensa [57,58]	Triterpenoids like pachymic acid and polysaccharides.	Reduced postprandial blood glucose levels and enhanced insulin sensitivity

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One of such studies experimented with the mycelia powder extracted from Agaricus brasiliensis and Ganoderma lucidum. The extract was fed to streptozotocin (STZ)-induced diabetic Wistar outbred white male rats. The study demonstrated hypoglycaemic effects when compared to control group as evidenced by lowered blood glucose and glycosylated hemoglobin concentrations [22]. This study also demonstrated that when the mushroom preparations were orally administered at a dose of 1 g/kg for 14 days to diabetic rats, the physiological balance between sialylation and desialylation processes was restored and integrity of erythrocyte membrane surface glycoconjugates strengthened. Thus, mushrooms extract prevented dysregulation of iron homeostasis erythrocyte membranes thereby strengthening them and causing hypoglycemic and anti-anemic action [22]. Another animal experiment tested the polysaccharides and α-glucans extracted from the body of Grifola Frondosa and reported decreased concentrations of fasting plasma glucose, triglycerides, cholesterol and increased serum insulin in diabetic mouse [20]. Another study utilized Maitake mushrooms (Grifola frondosa) and reported lowered blood glucose concentration. The fall in blood glucose may be attributed to Vanadium and an alpha-glucose inhibitor present in this variety of mushrooms. [8]. Vanadium complexes have been demonstrated to have insulin-mimetic as well as insulin potentiation properties [59] as observed in in vivo, animal and human studies. It facilitates regulation of glucose metabolism in diabetics as it plays a pivotal role being a cofactor for enzymes that participate in insulin signalling leading to GLUT4 translocation [60–62].

Further, a study reported reduction in hyperglycaemia induced oxidative-nitrative stress on rats with gestational diabetes [gestational diabetes was induced by streptozotocin (80 mg/kg), administered intraperitoneally] when medicinal mushroom powder was orally administered at a dose of 1 g/kg body weight [26]. Another experiment of daily dose of 100 or 200 mg/kg of lyophilized and reconstituted Lentinus edodes to diabetic rats on 1st to the 19th day of gestation, observed reduced plasma catalase, glucose, urea, triglycerides, and aspartate aminotransferase [23].

Ingestion of mycelia, broth, and mycelia plus broth of Maitake (Grifola frondosa) has also been demonstrated to alleviate the increase in 2 h postprandial blood glucose. The experiments showed significant improvement in innate immunity by modulating levels of inflammatory cytokines such as tumor-necrosis factor-α, macrophages productions of IFN-γ from the T-leukocytes, IL-4, and IL-6 from the monocytes and IL-4 from the T-splenocytes type 2 diabetes mellitus rats [24].

Pleurotus ostreatus and P. cystidiosus ingestion has also been shown to reduce blood glucose level, improved serum lipid profile, liver glycogen, liver function enzymes, and enzymic antioxidants activities in pancreas, liver, and kidney in STZ-induced diabetic rats [27]. Another mushroom Phellinus rimosus has been shown to increase antioxidant status in pancreas, liver, and kidney tissues with concomitant decrease in levels of thiobarbituric acid- reactive substances thus showcasing significant hypoglycemic and hypolipidemic activities that may be related to its insulinogenic and antioxidant effect of medicinal mushrooms [25].

Studies by Huang et al. [63,64] demonstrated that polysaccharides from Pleurotus tuber-regium mushrooms have antihyperglycemic properties and they reduce oxidative stress in diabetic rats that were fed a high fat diet.

Another interesting compound-Ternatin (a highly methylated cyclic heptapeptide) isolated from mushroom Coriolus versicolor was reported to inhibit fat accumulation in 3T3-L1 adipocytes and suppressed the development of hyperglycemia via decreasing the SREBP-1c mRNA level in hepatocytes [65]. Another experimental study was conducted on pregnant rats (diabetes was induced by streptozotocin) in which the effects of reconstituted lyophilized powder and dehydrated mushrooms powder of Agaricus blazei, Ganoderma lucidum or Lentinula edodes at daily dose of 100mg/kg were investigated from gestation day 1 to 19. Mushrooms G. lucidum and L. edodes reduced glucose levels in glycemic curve in response to glucose tolerance test thereby suggesting potential of mushrooms as functional foods in management of diabetes [66].

In a clinical study, oral hypoglycaemic effect of freeze-dried suspensions and powder prepared from Pleurotus ostreatus and Pleurotus cystidiosus on both healthy and type 2 diabetic humans was investigated. A dose of 50mg/kg/body weight was administered to both groups while on a diet control, followed by a glucose load. A significant reduction ($P < 0.05$) in fasting and postprandial serum glucose levels of healthy volunteers and decreased postprandial serum glucose levels and increased the serum insulin levels ($P < 0.05$) of type 2 diabetic patients was observed. The researchers simultaneously conducted animal study to understand the mechanism of action using same dose. The medicinal mushrooms demonstrated possible increased glucokinase activity and insulin secretion that improved the utilization of glucose by peripheral tissues, inhibited glycogen synthase kinase and promoted glycogen synthesis [67].

A clinical study on 71 participants with type 2 diabetes evaluated the safety and efficacy of Ganopoly (polysaccharides extracted from G. lucidum) for 12 weeks at 1800mg thrice a day. Significant decrease in the mean glycosylated haemoglobin (HbA1c) was observed with decrease in post-prandial glucose. The study found Ganopoly to be efficacious and safe in lowering blood glucose concentrations [68]. A double blind, randomised, placebo-controlled trial evaluated the safety and efficacy of Ganoderma lucidum for the treatment of hyperglycemia and cardiovascular risk factors of metabolic syndrome. Ganoderma lucidum extract was used with or without Cordyceps sinensis in dose of 3 grams/day for 16 weeks. Eighty four, 18 years and older participants with type 2 diabetes mellitus and metabolic syndrome were randomised to one of three intervention groups – Ganoderma lucidum, Ganoderma lucidum with Cordyceps sinensis or placebo. The HbA1C and fasting plasma glucose were measured and the results were not found to be clinically significant or statistically significant on hyperglycemia, hypertension, or lipid profile in adults with metabolic syndrome or type 2 diabetes [16]. The effects on metabolic profile could be attributed to the presence of polysaccharides that are mainly classified as β-glucan polymers [owing to β-(1→3) linkages with some β-(1→6) branches along with presence of chitin, mannans, galactans, and xylans]. Pancreas enzymes are not equipped to hydrolyze the β-glucosidic bond, thereby allowing for prebiotics action of glucans that modulates gut microbiota, improves utilization, dietary energy, gene expression and gut permeability. Further polysaccharide glucan content of medicinal mushrooms [69,70]:
(1) Reduces serum glucose and lipoproteins;
(2) Enhances serum insulin;
(3) Improves liver PPAR-α expression and mRNA expression of protein levels;
(4) Provides structural support to pancreatic β-cells;
(5) Antioxidant and anti-inflammatory action.
Thus, medicinal mushrooms may have multiple metabolic actions that may cause improvement in insulin response and glucose homeostasis at cellular levels. It may also reduce underlying inflammation and strengthen epithelial and hepatic cells to prevent damage from any type of diabetes including GDM. However, there is insufficient evidence to draw definitive conclusions about the efficacy of individual medicinal mushrooms for Gestational diabetes unless human randomized trials are completed.

6. Discussion

There is association between gestational diabetes and type 2 diabetes and it has been observed that women who have had gestational diabetes have at least seven-fold risk of developing type 2 diabetes in future compared to those women who have had a normal pregnancy. The risk factors are family history of diabetes, raised body-mass index, increased age, Asian ethnicity [3]. There are currently few clinical studies that have investigated the effects of mushrooms on diabetes or gestational diabetes mellitus in humans. The sample size of these studies was small, all dietary factors were not evaluated for confounding effects, various insulin and glucose control functions were not assessed consistently in all the studies which makes it difficult to formulate guidelines. Furthermore, there is not enough evidence on the dose, dosage form and side-effects of medicinal mushrooms that may be effective for pregnant females. According to American Herbal Products Association Botanical Safety Handbook, both mushrooms Ganoderma lucidum and Cordyceps sinensis are listed as safest drug class (Class 1 Drug) with no known herb-drug interactions. However, there is lack of scientific data on a safety and efficacy of Ganoderma dosage but 1.5 gms to 9 gms of dried extract per day is recommended by Chinese medicine experts [16]. There is immense scope to investigate the duration of supplementation to manage glucose irregularities in females with gestational diabetes. Studies are also required to investigate whether maternal supplementation of medicinal mushrooms influences growth and physiology of infants. There is also lack of consistency of clinical data for long term consumption to demonstrate the efficacy and safety in GDM females and also the quality control and standardisation data for the production of mushroom supplements is needed for its nutraceutical use [70].

7. Conclusion

The current review highlights the potential of medicinal mushroom in management of Gestational diabetes: a disease with serious, long-term consequences for both baby as well as mother. The heterogeneity of the data from animal and human study prevented a statistical analysis/meta-analysis, hence a qualitative review was conducted. GDM is a growing health concern and evidence now suggests that screening, early detection and management can greatly improve outcomes for both baby and a mother. There is no uniformity in the screening and diagnostic methods around the world which leads to underdiagnoses and under management of gestational diabetes.

The present review has shown that polysaccharides, β-glucan, vanadium and other nutrients in mushrooms may address deranged metabolic profile in diabetics thereby improving immune responses, liver and pancreatic enzyme functions and exert prebiotic effect and improve gut permeability. Dietary source is always a popular and economical choice to manage a metabolic disorder in a community. Therefore, future research on mushroom species among humans is required that could assist in testing dosage and form of consumption for better health outcomes among gestational diabetic women.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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Beyond “#endpjparalysis”, tackling sedentary behaviour in health care

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A B S T R A C T

Reducing Sedentary Behaviour after hospitalization starts with reducing sedentary behaviour whilst in hospital. Although we have eradicated immobilisation as a therapeutic tool due to its potent detrimental effects, it is still in systemic use within health care systems and hospitals. Evidence shows that when in hospital, patients spend most of their time sedentary. In this editorial, we explore the determinants of, and a system-based approach to, reducing sedentary behaviour in health care.

Keywords: sitting; physical activity; ageing; inactivity

1. Introduction

Whilst in hospital, a person will spend the vast majority of their day sitting or lying and mostly alone [1]. Sedentary behaviour is defined as spending time sitting, reclining or lying, without expending much energy (<1.5 METs) [2,3]. In hospital, patients can spend 12 hours per day sedentary, often in a long uninterrupted bout of sedentary behaviour sitting near their bed or lying in bed [4]. Prolonged sedentary behaviour has been observed in orthopaedic, geriatric, neurology, rehabilitation and medical wards in hospitals around the world, using a wide variety of physical activity measurement techniques [4–9]. For example, patients with stroke spend only 8% of their day in an upright position in a rehabilitation ward [8] and on a geriatric rehabilitation ward patients were in an upright position for only 70 (± 50) minutes per day, with 70% of this time spent in standing or walking bouts of less than 5 minutes [4]. Sedentary behaviour has profound detrimental effects on physiological processes in a matter of hours [10] and these effects seem to accumulate over time [11]. Spending too much time sedentary is associated with increased risk of chronic disease, hospitalisation and premature death [12].

There is mounting evidence that people who spend time in hospital, because of musculoskeletal injury or other acute or chronic conditions, tend to adopt a much more sedentary lifestyle while in hospital and that this perseveres after discharge [7,13–15]. Upon discharge, people engage in less physical activity and tend to spend more time in sedentary behaviours; this appears to be true even if they have recovered to full functional capacity and are medically stable [15]. Indeed, discharge physical function (assessed using tests such as Timed up and go or gait speed) and fear of falling are better in those who spend more time upright and mobilising whilst in hospital [16].

Too much sedentary time in hospital is likely to contribute to ‗Post-hospital syndrome‘, an acquired condition of vulnerability [17]. This syndrome shows itself in the critical 30-day period after discharge, where up to a fifth of older people have a further hospital admission, often with no link to the previous admission cause. This vulnerability might derive as much from the hospital stay as it does from the lingering effects of the acute illness that precipitated the first admission. It is not acceptable that people are exposed to further health risks if they have to go into hospital. We have long known that bed rest has poor clinical outcomes and we have gradually successfully eradicated it as a treatment modality. We have also long known that movement is essential to recovery and health, even in intensive care units [18]. Despite this, it is undeniable that traditional care in hospital tends to limit movement and enforce sedentary behaviour, perhaps as a result of concerns about falls on the ward, and that this impacts on behaviour and health after discharge. We need to identify and change the practices, processes and systems that condition sedentary behaviour during hospitalization [19–21]. A profound transformation of health care systems and hospitals occurred because of the rise in hospital acquired infection. Today it is time that we also address the iatrogenic (defined as any effect on a person resulting from any activity of one or more healthcare professionals that does not support a goal of the person affected) effect of our health systems on health behaviours.

2. A wicked problem

In 2016, Brian Dolan launched a social media campaign called #endpjparalysis (http://www.endpjparalysis.com). This was the first really sizeable attempt at addressing systemic issues of immobility in hospital and health care. The campaign aims to encourage patients to remove their hospital uniform (pyjamas or ‗pj‘) and wear their day clothes. The idea behind the campaign is that if people get up and get dressed they will get moving and this in turn will prevent complications of being immobile, including chest infections, muscle degeneration and blood clots. In addition, the idea is to enhance dignity, autonomy and shift a person‘s perception from ‗I‘m sick‘ to ‗I‘m getting better‘, possibly also fostering more active behaviour post discharge. This has been a very successful social media campaign (judging by the volume of social media activity), as it has caught the imagination of nurses, allied health professionals and medical staff worldwide. It has raised awareness amongst health care staff and encouraged them to consider how they could encourage people to be more active in hospital. But will this have a real impact on immobility in hospital settings?

There is no doubt that the campaign will change the hospital stay of many individuals, but will #endpjparalysis on its own result in large scale and sustainable systemic change benefiting all patients? Current thinking about the determinants of sedentary behaviour suggests that #endpjparalysis will not be enough. The campaign is built on the premise that the only actors in changing movement behaviour are the patients themselves and the staff, without consideration of other barriers inherent to the health care system and hospitals. For example, patients may need support in mobilisation, but there may not be enough staff available to get patients up regularly due to low staffing levels, or there may be interruptions from staff rounds and shift patterns. Staff may be concerned about falls risk and feel it is safer, or quicker, to move the patient by wheelchair or to bring a commode over, rather than mobilise the patient to the toilet. Organisational risk aversion often takes precedence over function focussed rehabilitation, mobility and promoting physical activity [22,23]. These more upstream determinants are ultimately more powerful at shaping behaviour than the determination of individuals [24]. The idea that health behaviour rests solely on the individual is highly prevalent in a medical model of health care, but evidence clearly points to system-based interventions as being more effective. Perhaps #endpjparalysis is too simplistic. Sedentary behaviour is a ―wicked‖ problem [25,26], simple on the surface but extremely complex in reality, and resistant to resolution. Wicked problems are characterised by the influence of multiple factors all interacting and deeply entangled. How can a patient move more in an environment that people normally sit or lie down in? How can that environment be changed if there are not enough staff or the right insurance policy to do so safely or at least subjectively safely? Another example of a ―wicked‖ problem is obesity. Seemingly simple, all we have to do is eat less and move more, but all our attempts to solve it have failed as it is a complex interplay of issues [27]. One of the main characteristics of such wicked problems is that individuals often feel rapidly powerless to act against them which then leads to inaction. Acting at the system level through the development of localised solutions, co-created with all the stakeholders involved in the running of the system, is often more effective in this situation [28].

In 2015, a consensus of experts produced a map of the determinants of sedentary behaviour called the SOS (System Of Sedentary behaviour) framework to help researchers, practitioners and policy makers come to terms with the complexity of the problem and plan system-based interventions [25].

This evidence based framework (Figure 1), shows that sedentary behaviour is conditioned by six clusters of factors: (1) the physical health and wellbeing of a person; (2) the social and cultural context a person is immersed in; (3) the natural and built environment a person lives in; (4) their psychology and behavioural attributes; (5) political and economic factors, and; (6) the institutional and home setting a person is in.

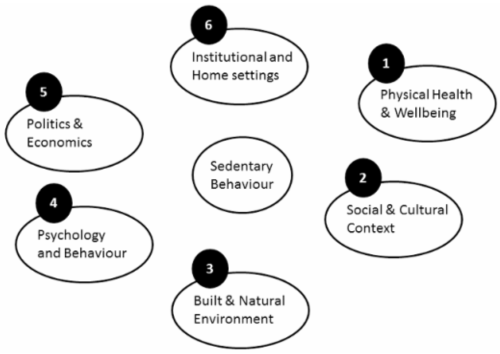

Figure 1. The system of sedentary behaviour framework reproduced from [25].

3. Beyond #endpjparalysis

Recently there has been a drive to decrease sedentary behaviour and increase physical activity in the in-patient setting outside of classic ―therapy time‖. Any change to healthcare delivery must take into consideration local needs and drivers. A ―one size fits all‖ approach is not appropriate. Sites need time to work as a team to review service provision and to identify how appropriate improvement can be made involving all stakeholders on an ongoing basis. Function focussed care is one such example [29]. The Model for Improvement is a recognized model for making this type of improvement in the healthcare setting [30]. Sedentary behaviour in the clinical setting is a complex issue. It is affected by culture, environment, people and operational processes, as can be seen in the fishbone diagram in which the SOS framework is contextualised to hospital settings (Figure 2).

Notwithstanding the importance of site specific planning, some common solutions will be appropriate in many circumstances. Starting with the patient being central to care provision, the patients, families/carers and the multi-disciplinary team (in both acute and community settings) can work in partnership, to ensure the patient‘s transition through the health and social care system is a continuum. Patient and family/carer education that is accessible and brief should be provided with a consistent message provided from all professionals covering the importance and benefits of minimising prolonged periods of sedentary behaviour, along with very specific advice for the individual as how to mobilise, how often, and how a family member/carer can assist with this.

Pivotal to this is having prompt access to mobility assessment and any appropriate aids, in line with any step change in function. Indeed, one recent study showed that length of stay was reduced in patients who had a physiotherapy assessment within 24 hours of admission compared to those who waited longer, and were less likely to be discharged to formal care [31]. Complex cases require timely in-depth assessment, such as that provided by Frailty Teams (https://ihub.scot/frailty-at-the-front-door/).

High quality assessment should lead to care that supports self-management, therefore empowering the individual to have ownership of their own well-being, with patient centred goal setting and action planning that is reinforced by staff on the ward. To support this, patients should have access to well established techniques for management of energy, mood, pain and sleep. Person held care plans, such as My Active Care Plan (https://sedentaryblethering.wordpress.com/2018/05/25/my-active-care-plan/), allow recording, communication, and motivation to support self-management and partnership working.

Rehabilitation should be central to the waking day, not just during specific therapy sessions, thus movement should be encouraged during the daily routine, and as much as possible, keeping to what is normal or would be expected in the home environment. The culture, staffing levels and physical environment of the hospital should be conducive to movement and appropriate to varying levels of patient‘s ability and confidence and be supported by management. The final facet is to ensure we have a resilient workforce that learn from each other by sharing good practice, in an inter- and cross–professional manner, for the best outcome for our patients.

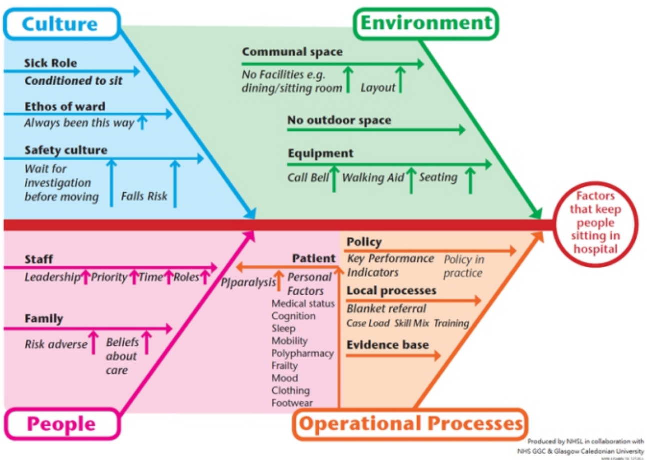

Figure 2. Operationalisation of the SOS framework applied to the problem of sedentary behaviour in hospital. Four clusters of factors; Culture, Environment, People, Operational Process determine sedentary behaviour in hospital. Example of factors for each of the clusters and their relationship are presented.

4. Evaluating the effect of changing practice and getting help from technology

One of the key things in this whole debate, is that there is only limited evidence of the effectiveness of campaigns such as #endpjparalysis on sedentary behaviour, the specific behaviour it is looking to change. Generating this evidence requires effective measurement of sedentary behaviour, but unfortunately it can be tricky to measure in a hospital ward environment.

Direct observation (independent observers watching the participant and recording when they are lying in bed, sitting, standing and walking) is cited as the gold standard measurement of sedentary behaviour in validation studies [32]. However, in the ward, direct observation it is not practical, as it is time-consuming and has ethical issues regarding privacy. Although it may seem a simple solution, getting ward staff to observe participants behaviour might be very difficult to implement. Asking patients to record sedentary time may suffer from underestimation, as self-report of sedentary behaviour in the general population can underestimate sedentary time by up to 4 hours per day [33]. In a ward context, the likelihood of the presence of co-morbidities (e.g. poor memory and cognition) that detrimentally affect known sources of bias in self-report (e.g. recall and perception of time) would exacerbate such errors. Therefore, objective measures of sedentary behaviour are preferable, as they are able to measure continually, in an unobtrusive manner, and provide an un-biased measurement of behaviour.

Body-worn sensors, usually accelerometers, are used to measure physical activity and sedentary behaviour objectively, and wear location (hip, wrist, or thigh) is one of the key characteristics that differentiate between different types of monitor for sedentary behaviour measurement. Accelerometers worn at the hip and wrist actually measure low movement, rather than the posture of sitting. This means that some quiet standing can be misclassified as sedentary behaviour, limiting applicability in the ward [34]. In contrast, monitors worn on the thigh, use thigh inclination to accurately distinguish between the postures of sitting and standing [35]. However, it should be noted that these monitors do not usually distinguish between sleep, lying awake and sitting, and it might be useful to keep a diary of time awake and time in bed. Although it may be tempting to use pedometers, accelerometers or commercially available activity trackers, to count steps taken, without specialised modification [36,37], most of these tools are not effective for very slow walking or shuffling gait, which means step count is not a good outcome measure to use in the ward [38].

Although currently not widely used in hospital settings, recording time spent in a location might serve as a suitable proxy measure to indicate mobility and social interaction. GPS systems do not generally work indoors, but there is potential to use systems such as RFID tags, bluetooth sensors or LED-lights, to log time-stamped location within a building [39]. This does require initial investment to set-up sensors throughout the building, but is easy to run thereafter, so may be suitable for long-term projects in a single hospital.

5. Conclusion

Sedentary behaviour is a systemic and complex problem in the health care system. Interventions targeted solely at changing patient‘s behaviour are unlikely to work. Instead, a system-based solution approach would be advantageous with local health care teams and other stakeholders co-creating sustainable solutions that synergistically target changes in the environment, policy, institutional settings and culture. Recording progress, specifically in terms of measuring sedentary behaviour, is fundamental to achieving effective solutions.

Conflict of interest

The authors declare no conflict of interest.

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