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The physical hospital environment and physical activity: patients' perspectives on barriers, facilitators and preferences after cardiothoracic surgery

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ABSTRACT

Hospital environments often promote sedentary behaviour, despite physical activity being essential for recovery. This study explored patients' perspectives on how the physical hospital environment supports physical activity after cardiothoracic surgery. A cross-sectional survey study was conducted among patients, who underwent elective cardiothoracic surgery, using a self-developed questionnaire. Descriptive statistics ranked barriers, facilitators and potential supportive features, while Spearman correlations explored associations of barriers/facilitators with participant characteristics and hospital factors. Of 221 eligible patients, 106 (48%) responded, with 70% being male, a median age of 65 years and a median hospital stay of seven days. Main barriers included medical devices, while main facilitators included convenient layout, comfortable furniture and information about physical activity. Greater support from healthcare professionals was associated with fewer barriers and more facilitators. The results showed that the physical hospital environment should promote physical activity, with a key role for healthcare professionals to help patients leverage these opportunities.

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KEYWORDS
Enabling design; physical activity; health facility environment; cardiothoracic surgery; environmental psychology; behavioural change

1. Introduction

Hospital environments often promote inactivity and sedentary behaviour, which are common problems during hospitalization (Jasper et al. 2020; Jawad et al. 2022; Meesters et al. 2019) and seem to be inherent to traditional hospital-culture (De Klein, Valkenet, and Veenhof 2021; Koenders et al. 2020; Koenders, Marcellis, et al. 2021; Oliver 2017). Inactivity often leads to functional decline, unnecessary nursing home admissions and higher risk of death (Brown et al. 2016; Ostir et al. 2013; Zisberg et al. 2015). This contrasts with phase 1 cardiac rehabilitation recommendations including early mobilization, exercise therapy and facilitating physical activity (PA) post-surgery (Kachur et al. 2019; Visseren et al. 2021), which are related to higher levels of PA after discharge (Brown et al. 2016). In the Netherlands, around 13,500 adult patients undergo cardiothoracic surgery yearly, with coronary artery bypass grafting (CABG) being the most common (Dutch Heart Registration 2021).

To understand sedentary behaviour and inactivity in the hospital environment, both behavioural (COM-B) and environmental psychology (ecological) models can be used. To support behavioural change of patients, health care professionals (HCPs) need to consider patients' capabilities (C), opportunities (O) and motivation (M) for PA-behaviour (B) (Visseren et al. 2021). The opportunities component in the COM-B model emphasizes the importance of the physical and social environment to provide patients with the opportunity to be more physically active (Michie, Atkins, and West 2014, 59).

The COM-B model (from behavioural psychology) is complementary with the ecological model (environmental psychology), which is more externally and context oriented (van Kasteren, Lewis, and Maeder 2020) (Box 1). Ecological models describe person-environment interactions (Golden and Earp 2012; Sallis et al. 2006; Steg, van den Berg, and de Groot 2013, 6; Stokols 1992) and provide an additional viewpoint on the influence of the setting on PA-behaviour (Humpel, Owen, and Leslie 2002). Behaviour occurs in the interaction between a person's perception – biased by personal characteristics, cognition and experiences – and affordances. Affordances describe what the environment offers or 'affords' (Gibson 2015, 119, 121). Thus, the perception of meaningful functional features in the physical and social environment may lead to certain behaviour (Bélanger and Coolen 2014; Heft 2001, 289; Meagher 2020; Travert, Sidney

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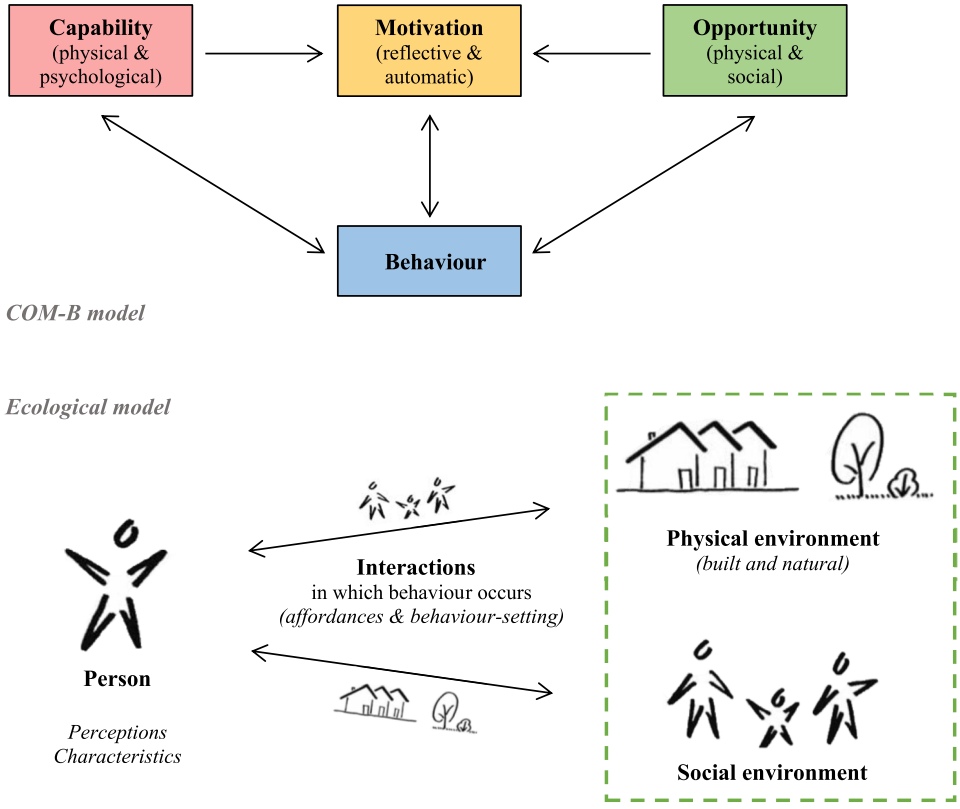
Box 1: The role of the physical environment and the interactions with behaviour explained by the COM-B model and the ecological model according to environmental psychology. Illustration adapted from Michie, Atkins, and West (2014, 62), and van Dorst (2005, 26), with permission.



The *COM-B model* offers a tool to understand complex behaviour and develop interventions for behavioural change, by considering the targeted behaviour in the context of

- Capability: 'the individual's psychological and physical capacity to engage in the activity concerned. It includes having the necessary knowledge and skills'.
- Motivation: 'all those brain processes that energize and direct behavior, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision making'.
- Opportunity: 'all the factors that lie outside the individual that make the behavior possible or prompt it', existing in the social and physical environment (Michie, Atkins, and West 2014, 59).

The *Ecological model*, within the field of environmental psychology, considers how the way a person's behaviour is influenced by their environment, which is closely related to the 'opportunity component' of the COM-B model. The illustration above shows how the interaction between a person and the physical environment itself is influenced by the social environment. In the same way, the physical environment influences the interaction between a person and the social environment. This interaction can be explained by affordances and behaviour-settings (van Dorst 2005, 24–28). Affordances reflect the individual-environment relation ('a bed is a place to rest'). The behaviour setting involves the collective-environment relation of the hospital environment (Bélanger and Coolen 2014; Heft 2001, 299; Meagher 2020; van Dorst 2005, 24–28).

Annerstedt, and Daivadanam 2019; van Dorst 2005, 24–28). In this study, the physical hospital environment is defined as the objective and perceived characteristics of the hospital environment, including the built environment, but also including ambient conditions, resources and devices relevant to PA-behaviour in the hospital setting (Geelen et al. 2021; Sallis et al. 2006; Travert, Sidney Annerstedt, and Daivadanam 2019).

Several studies described the importance of hospital environments that supports PA (Geelen et al. 2021; Geelen et al. 2022; Hesselink et al. 2020; Koenders et al. 2019; Koenders et al. 2020; Koenders, Potkamp-Kloppers, et al. 2021; Mudge, McRae, and Cruickshank 2015; van Delft et al. 2020; Zisberg et al. 2018). A scoping review, on barriers and facilitators for PA-behaviour during hospitalization, identified the physical environment as

the main facilitator (Geelen et al. 2021). Other studies reported beneficial outcomes of PA-facilitating environments, including reduced time spent lying in bed and shorter length of stay (LOS) (Koenders, Potkamp-Kloppers, et al. 2021; Mudge, McRae, and Cruickshank 2015; van Delft et al. 2020).

So far, only one of these studies referred to the ecological model (van Delft et al. 2020). While the other studies explored barriers and facilitators as a basis for their intervention, they did not explicitly investigate the broader scope of the interaction between the patients' behaviour and the attributes of the physical hospital environment. The field of Evidence-Based Design (EBD) has increasingly recognized the importance of the physical hospital environment for diverse patient outcomes across diverse inpatient populations (Elf et al. 2024). However, studies on the potential of the built environment to specifically support patient PA remain scarce across inpatient settings (Annemans, Van Dyck, and Heylighen 2024; Bernhardt et al. 2022). In this respect, research in other physical environments provides relevant insights as spatial concepts can be translated across settings (Davidovici 2021). Systematic reviews (SRs) showed clear correlations between physical environmental attributes – e.g. safety, walkability, access, aesthetics – and PA in urban communities (Barnett et al. 2017; Carlin et al. 2017; Malambo et al. 2016; Rhodes, Zhang, and Zhang 2020; Yarmohammadi et al. 2019). Travert, Sidney Annerstedt, and Daivadanam (2019) reviewed 107 reviews and identified five main categories of perceived environment that facilitate PA: (1) accessibility, (2) safety and security, (3) affordability, (4) desirability and (5) convenience. Additionally, surveys were developed to measure these environmental perceptions in neighbourhoods (Saelens et al. 2003; Spittaels et al. 2010).

This person-environment interaction is further influenced by personal and other contextual factors. Personal characteristics – such as age, gender, body mass index (BMI) – shape how patients perceive environmental attributes for PA (Bora et al. 2024; Kilgour et al. 2024; Tcymbal et al. 2020; Wen et al. 2024) Hospital factors – such as LOS and HCP support similarly influence this perception (Geelen et al. 2021; Hesselink et al. 2020). Reciprocally, changes in PA-behaviour can alter how patients perceive these environmental opportunities (Travert, Sidney Annerstedt, and Daivadanam 2019; Wallmann et al. 2012).

Altogether, insight into specific attributes of the physical hospital environment, and its interaction with patients' behaviour, supports designing and achieving a PA-friendly hospital. The aim of the study is, therefore, first to identify the patients' experienced barriers and facilitators in the hospital environment for PA after cardiothoracic surgery and potential supportive features – ideas of what could support PA. Second, we explore if the factors, gender, age, BMI, LOS and experienced support from HCPs to be physically active are related to experienced barriers and facilitators.

2. Materials and methods

A cross-sectional survey study was conducted within a one-year cohort of patients who underwent open heart surgery at the Department of Cardiothoracic Surgery of the Leiden University Medical Center (LUMC). The LUMC is a tertiary referral centre in the Netherlands providing specialized care for patients undergoing complex cardiac procedures, including coronary artery bypass grafting, valve surgery and aortic surgery. Patients are routinely referred from across the region for surgical treatment and subsequent cardiac rehabilitation. According to the Medical Ethics Committee (MEC) of the LUMC (G21.068), the study did not fall under the Dutch Medical Research Involving Human Subjects Act (WMO).

2.1. Questionnaire development

No questionnaires were available to identify environmental factors that influence PA in a specific environment, such as a hospital setting, from the perspective of patients. Therefore, a survey was developed, following the stepwise procedure for survey development by Portney (Portney 2020, 144) (for a detailed description, see Table 1).

In step one, a literature search (Appendix A) was conducted to identify physical environmental factors that influence PA. Given the extensive research of PA within the physical neighbourhood environment in comparison to research concerning PA within hospital settings, literature from both settings was used. Moreover, it is not uncommon in architectural and urban design to translate one spatial scale to another – i.e. the neighbourhood to the clinical/hospital environment (Davidovici 2021; van Aken 2010; Verhoeven and Habraken 2011). This approach resulted in two sets of items influencing PA. The first set pertained to the neighbourhood-setting – based on seven SRs – and two validated questionnaires (Barnett et al. 2017; Carlin et al. 2017; Malambo et al. 2016; Peters et al. 2020; Rhodes, Saelens, and Sauvage-Mar 2018; Rhodes, Zhang, and Zhang 2020; Saelens et al. 2003; Sawyer et al. 2017; Spittaels et al. 2010; Yarmohammadi et al. 2019). The second set pertained to the hospital setting – based on five articles (Geelen et al. 2021; Koenders et al. 2019; Koenders, Potkamp-Kloppers, et al. 2021; Mudge, McRae, and Cruickshank 2015; van Delft et al. 2020) (Appendix B).

In step two, a set of preliminary items that influence PA was derived from step 1 to fit the hospital setting and corresponding questions were formulated.

In step three, items and corresponding questions from step two were discussed in online one-to-one interviews with experts (two physiotherapists, two nurses and one architect).

In step four, items and questions were revised and then categorized based on the framework from Travert, Sidney Annerstedt, and Daivadanam (2019) (Figure 1). Subsequently, a first version of the questionnaire was drafted, followed by pilot testing among three experts and two patients who underwent open-heart surgery.

In step five, the questionnaire (see Appendix C, informally translated from Dutch) was finalized.

2.2. Questionnaire content, scoring and data collection

Patients were asked to complete an adaptive questionnaire, meaning that certain questions were presented or skipped based on preceding answers. As a result, participants completed between 86 and 116 items depending on their individual response patterns. The estimated completion time was approximately 20–30 min.

Table 1. Survey development and overview of the analysis of survey data.

Steps & approach	Procedure	Outcomes
Step 1 Literature review	Primary search A systematic literature search strategy to identify environmental/neighbourhood factors influencing PA was conducted, using MEDLINE (in PubMed) (a minimum of 5 systematic reviews (SRs) or an equivalent of 20 articles was expected to lead to saturation in obtaining preliminary items). One researcher (LL) performed the electronic searches and conducted the screening of titles and abstracts and selections of studies. Selection was discussed with a senior researcher (JM). Additional search Additional literature on influencing factors on PA during hospitalization was identified through exploratory searches on PubMed, targeted expert recommendations (senior researcher JM) and snowball search of relevant studies. Selection was discussed with a senior researcher (JM). Obtaining the environmental factors influencing PA Researcher LL extracted environmental factors influencing PA from studies of the primary and additional search.	The primary search was conducted in October 2021 and yielded 1378 articles. All eligible systematic reviews (SRs) from the past five years were selected, resulting in seven SRs (Barnett et al. 2017; Carlin et al. 2017; Malambo et al. 2016; Peters et al. 2020; Rhodes, Saelens, and Sauvage-Mar 2018; Rhodes, Zhang, and Zhang 2020; Sawyer et al. 2017; Yarmohammadi et al. 2019) (see appendix A for the search string and flowchart on selection of articles). In addition, two validated questionnaires, mentioned in these SRs, were included: the abbreviated version of the Neighbourhood Environment Walkability Scale' (NEWS-A – the most frequently used tool) and 'Assessing Levels of Physical Activity and Fitness' (ALPHA – a questionnaire suited for the European situation) (Saelens et al. 2003; Spittaels et al. 2010). Additional literature search regarding influencing factors on PA during hospitalization, resulted in the selection of five articles (Geelen et al. 2021; Koenders et al. 2019; Koenders, Potkamp-Kloppers, et al. 2021; Mudge, McRae, and Cruickshank 2015; van Delft et al. 2020). Two sets of factors influencing PA were identified: an initial set of factors pertaining to the neighbourhood setting and an additional set pertaining to the hospital setting. An overview of the obtained factors is presented in Appendix B.
Step 2 Preliminary items of factors influencing PA with corresponding questions	First, a preliminary set of items was identified from factors influencing PA pertaining to the neighbourhood-setting, and subsequently translated to fit the hospital setting. Subsequently, these items were compared to factors influencing PA pertaining to the hospitalization setting, and supplemental items were added. The preliminary set of items was identified, and corresponding questions formulated, by the researcher LL in agreement with the senior researcher JM.	A set of preliminary items and corresponding questions.
Step 3 Review through expert opinion	The items and corresponding questions were discussed in online one-to-one interviews of the researcher LL with experts (two physiotherapists, two nurses and one architect). In preparation for the interview, all experts rated the items with example questions as important, neutral or unimportant. Researcher LL made notes during the interviews.	Feedback and notes of interviews on preliminary items and corresponding questions.
Step 4 Revising items and pilot testing	Revising items Items and questions were revised in agreement with researchers LL and JM. The obtained items were categorized based on the framework from Travert, Sidney Annerstedt, and Daivadanam (2019). The main categories of the items identified for the hospital setting were accessibility; feeling of safety; desirability and convenience (representing perceived characteristics). As shown in Figure 1, these internal physical environment categories correspond to the external physical environment categories (representing objectively measurable characteristics). Pilot testing The first version of the questionnaire was drafted, followed by pilot testing among three experts and two patients who underwent open-heart surgery.	A first version of the questionnaire, including feedback from three experts and two patients.
Step 5 Finalising questionnaire	The questionnaire was finalized by the researcher LL in agreement with the senior researcher JM, taking the recommendations of experts and patients in step 4 into account.	Finalized version of the questionnaire (Appendix C)

Five answering formats were used: numeric or short-text entries, single- and multiple-answer multiple choice; 5-point Likert scale (totally disagree – totally agree) and open text fields.

The questionnaire comprised three main sections. Section 1 (patient and hospitalization characteristics) contained 22–31 items. Sections 2 and 3 comprised statements on barriers, facilitators and supportive features. Items in these two sections were categorized into four environmental scale levels: room (I), ward (II), hospital (III) and immediate surroundings (IV). Section 2 (scale levels I–II) contained 42–54 Likert statements and six open-text fields. Section 3 (scale levels III–IV) contained 10–19 Likert statements and one to two open-text fields. A two-step routing procedure distinguished between participants who were (1) not permitted to leave the ward (e.g. telemetry) and (2) those who were allowed but either did or did not go outside. The questionnaire ended with an open text field for optional remarks.

2.2.1. Patient characteristics and basic characteristics during hospitalization

The following participant characteristics were obtained: age, gender, BMI, smoking, living and employment status and time passed since surgery. In addition, characteristics during hospitalization were collected, including LOS and the number of days until independence in sit-to-stand, walking and climbing chairs – indicating mobility level – as well as experienced support

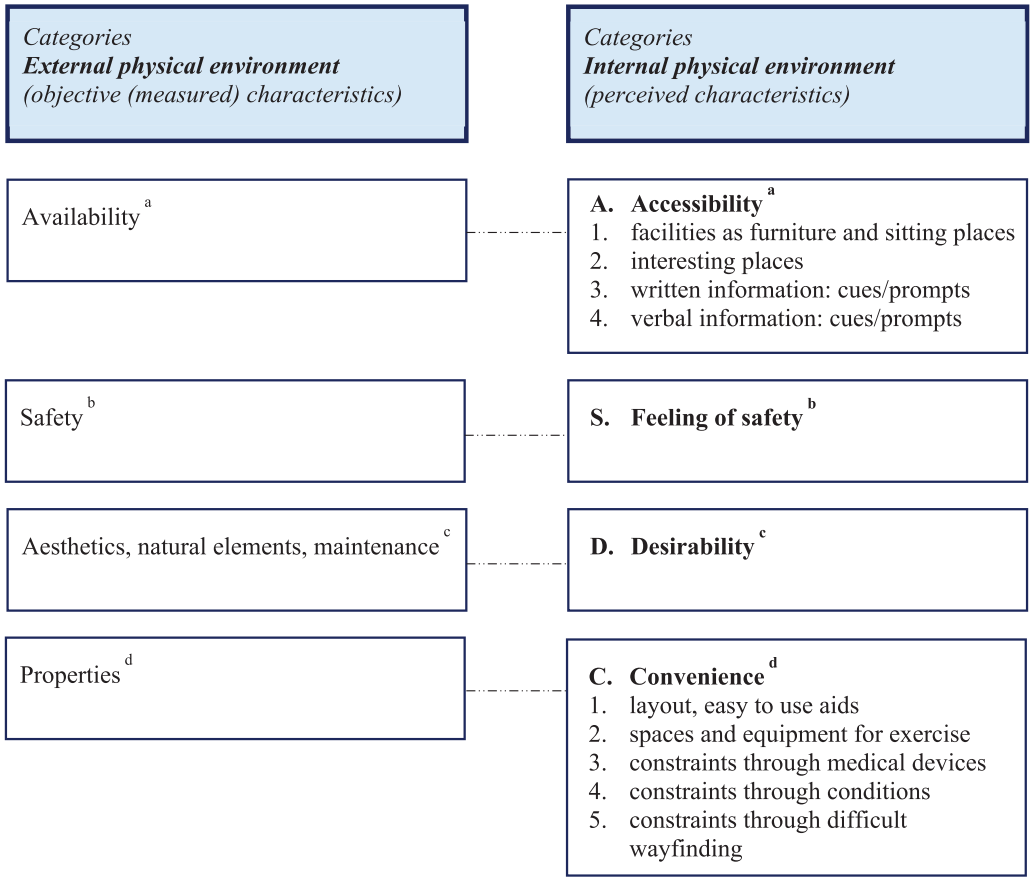


Figure 1. Categories structuring obtained items from the literature.

Notes: Categories are based on the framework of Travert, Sidney Annerstedt, and Daivadanam (2019), adapted to the hospital setting. *External physical environment*, the dimension of the physical environment exogenous to individuals (objective). *Internal physical environment*, the dimension of physical environment describing the way individuals experience the environment (perceived). [a]Availability vs. accessibility: the presence, number and diversity of infrastructure, facilities and equipment vs. the capability to reach the destination. [b]Safety vs. feeling of safety: the interactions with others, infrastructure and facilities vs. feeling of and safety individuals' perception of security and safety. [c]Aesthetics, natural elements, maintenance vs. desirability: strategies used to present the physical environment as appealing and visually pleasant vs. the individuals' appreciation. [d]Properties vs. convenience: (intrinsic) characteristics that define the functioning of an object vs. support being physically active without difficulty.

from HCPs, use of assistive devices, use of medical devices – e.g. chest tube, urine catheter, telemetry – and room-type preference.

2.2.2. Assessing experienced barriers and facilitators

The patients' level of agreement with statements regarding barriers and facilitators of the physical environment was assessed. This included, for example, items regarding feeling safe to walk around, feeling constrained using medical devices, sufficient information (written/illustrated and verbal), convenient layout of the room and ward. Every statement regarding experienced barriers and facilitators was assigned to measure either a barrier or a facilitator. By default, all influencing factors were formulated as a facilitator; unless impossible, then it became a barrier. The 5-Point Likert scale was subsequently reversed for negatively formulated items.

2.2.3. Assessing potential supportive features

Besides assessing the experienced barriers and facilitators, patients could express their level of agreement regarding supportive features for PA, e.g. advice from health professionals to eat meals out of bed, interactive digital games.

2.2.4. Assessing context by open-ended questions

The open-ended questions were used to gain deeper insights into the context and meaning of the participants' responses (O'Cathain and Thomas 2004), regarding aspects such as preference of room type, feelings of safety while moving around and the influence of layout.

All data were collected anonymously using encryption within the electronic data capture system, Castor EDC (Castor 2022).

2.3. Recruitment and selection of participants

A year cohort (March 2021–March 2022) of adult patients who underwent open-heart surgery (e.g. valve replacement, coronary artery bypass grafting (CABG) and/or aortic surgery) at the Department of Cardiothoracic Surgery was eligible to participate in the study. Inclusion criteria were the availability of an e-mail address, sufficient understanding of the Dutch language to understand the questionnaire and returning to their home after hospital discharge. The electronic data capture system, Castor EDC (Castor 2022), was used to send out the invitation letter by email and to obtain informed consent. The invitation letter comprised the study information and the link to the online survey. A first automatic reminder was sent after seven days, and when needed, a second reminder was sent after eighteen days.

Since this study included a convenience sample of all patients who underwent surgery during one year, no formal sample size calculation was performed.

2.4. Data analysis

All data were exported from Castor EDC (Castor 2022). Questionnaires in which at least the questions regarding the barriers and facilitators, and the supportive features at the room and ward scale levels were completed were included in the data analysis. Statistical and qualitative analyses were performed using IBM-SPSS Statistics version 25 and Atlas.ti-22, respectively.

2.4.1. Descriptive statistics – participant characteristics and characteristics during hospitalization

To describe the self-reported participant characteristics, descriptive statistics were performed. Normality of numerical data was determined using the Shapiro-Wilk test, accepting normality with p-values > 0.05. Normally distributed numerical data were described as mean $\pm$ standard deviation (SD), non-normally distributed numerical data as medians (Mdn) with interquartile range (IQR). Ordinal data, including Likert scale responses, were not subjected to normality testing and were summarized using frequencies and percentages, and where applicable, Mdn with IQR.

2.4.2. Frequency distribution: barriers, facilitators, supportive features

The identified experienced barriers, facilitators and supportive features were ranked using a frequency distribution (including percentages). Before analysis, to distinguish between barriers and facilitators, the scores of the 5-point Likert scale statement scores were recoded into three groups: disagree (totally and somewhat disagree), neutral and agree (somewhat and totally agree). These data were handled as ordinal data.

2.4.3. Relations between participant and hospitalization characteristics, barriers and facilitators

Spearman's correlation coefficient (two-tailed) was calculated to explore the relation between the variables age, gender, LOS, experienced support from HCPs, and the subscale barriers and the subscale facilitators, regarding items at the room and ward levels. The two subscales were computed by calculating the mean of the summed scores of the corresponding items. Therefore, the original 5-point Likert scale was used and handled as interval data. Experienced support from HCPs was calculated by the mean of agreement on experienced support from nurses, physiotherapists and physicians together. In the case of incomplete surveys, pairwise deletion of missing values was applied.

2.4.4. Qualitative content analysis – open-ended questions

A qualitative content analysis was performed on data from the open-ended questions (Elo and Kyngas 2008; Vaismoradi, Turunen, and Bondas 2013). The analysis process comprised first, developing a partly structured categorization matrix with a combined deductive – based on the framework from Travert, Sidney Annerstedt, and Daivadanam (2019; see Figure 1) – and inductive approach. Second, content was reviewed and coded according to the matrix. This resulted in conceptual/summary categories as a general description of the research topic.

Coding of all qualitative data was performed by two researchers independently (LL and AM). Summary categories were written by one researcher (LL) and checked by the other (AM). Disagreements in both coding and categorization of all qualitative data were solved through discussion or by consulting a third researcher (JM).

Qualitative data were derived from open-ended survey questions, and all available responses were included; data collection was not iterative. Therefore, the concept of data saturation was not considered.

3. Results

In total, 221 patients were eligible and asked to participate in the survey study, of whom 106 (48%) were included; 103 (97%) respondents completed 100% of the questionnaire.

3.1. Patient characteristics and basic characteristics during hospitalization

Tables 2 and 3 show the participant characteristics of the 106 respondents who underwent open-heart surgery. Of these 106 patients, 69.8% were male; median (Mdn) age (with 1st–3rd quartiles (IQR)) was 65.0 (58.0–72.0) years and the Mdn (IQR) length of stay was 7.0 (6.0–8.0) days. On a 5-point Likert scale rating the support to be physically active (no support – full support; -2.0 to $+2.0$), patients reported a Mdn support by nurses and physiotherapists of $+2.0$ (IQR 1.0–2 and 0.0–2.0, respectively) and by physicians of $+1.0$ (IQR 0.0–2.0).

3.2. Experienced barriers and facilitators for PA in the physical hospital environment

Table 4 shows the ranked items for barriers and facilitators. The main barriers fell within the subcategory 'Constraints by medical devices' (see Figure 1, C3). Chest tubes and urine catheters were perceived as important barriers to being physically active on the ward, with agreement levels of 60.5% and 52.7%, respectively; in the room, these were 48.4 and 44.7%. Conditions (light,

Table 2. Participant characteristics who underwent open-heart surgery.

	Patients *(N = 106)*
Median Age, years (IQR)	65.0 (58.0–72.0)
Male	74 (69.8)
Mean Length, cm (SD) *(n = 105)*	176.1 ± 10.4
Median Weight, kg (IQR)	80.0 (72.0–89.0)
Median BMI, kg/m^2 (IQR) *(n = 105)*	25.7 (23.8–28.3)
Smoking	4 (3.8)
Living alone	19 (17.9)
Paid employment	46 (43.4)
Fully returned to paid employment *(n = 46)*	23 (21.7)
Back to paid employment, number of months after surgery *(n = 38)*	3.0 (2.0–5.0)
Time has passed since surgery	
1–3 months	18 (17)
4–6 months	34 (32.1)
> 6 months	54 (50.9)

Notes: Data are presented as the number of patients (percentages) based on *n = 106*, unless stated otherwise. *IQR* interquartile ranges (1st–3rd quartile Tukey's hinges), *SD* standard deviation, *BMI* body mass index, *m.* metre.

Table 3. Participant characteristics during hospitalization.

	Patients *(N = 106)*
Median LOS, days (IQR)	7.0 (6.0–8.0)
Independent activities no. of days after surgery[a]	
Median Sit to stand, days (IQR) *(n = 98)*	2.0 (2.0–3.0)
Median Walking, days (IQR) *(n = 98)*	3.0 (2.0–4.0)
Median Climbing stairs, days (IQR) *(n = 84)*	5.0 (4.0–6.0)
Used assistive devices[b]	
Rope at the end of the bed	92 (86.8)
Infusion stand	20 (18.9)
Walker	58 (54.7)
No use of assistive devices	2 (1.9)
Used medical devices	
Telemetry	69 (65.1)
Infusion	58 (54.7)
Urine catheter	76 (71.7)
Vacuum-Assisted Closure	3 (2.8)
Chest drain	43 (40.6)
External pacemaker	23 (21.7)
None	7 (6.6)
Experienced support from HCP to be physically active[c]	
Nurse	2 (1–2)
Physiotherapist	2 (0–2)
Physician	1 (0–2)
Preference for room type	
Single room	39 (36.8)
2-person room	20 (18.9)
4-person room	18 (17.0)
No preference	29 (27.4)

Notes: Data are presented as the number of patients (percentages) based on $n = 106$, unless stated otherwise. *IQR* interquartile ranges (1st–3rd quartile Tukey's hinges), *SD* standard deviation, *HCP* health care professional.

[a]Only participants who were able to carry out the activity independent (assistive devices allowed).

[b]Rope is used by patients to pull oneself up, other mentioned assistive devices: shower chair, crutches, wheelchair (mentioned by one different participant each).

[c]Calculated median from 5-point Likert scale of agreement on being stimulated to perform PA: –2 = totally disagree, –1 = somewhat disagree, 0 = neutral, 1 = somewhat agree, 2 = totally agree.

temperature, smell and sound) were not experienced as a major barrier in the room and ward (< 13%). Only a few participants felt unsafe to walk around the room and ward (< 3.8%). Not all participants were allowed to go outside the ward, because they were connected to telemetry. Of the 61.9% (65 out of 105) of participants who were not allowed, 23% would have wanted to. Of the 38.1% of participants who were allowed, 45.0% went. This latter group (17.1% of all participants) reported feeling unsafe and wayfinding as the main barriers (both 33.3%), followed by medical devices (27.8%).

The main facilitators were a convenient layout of the (bath)room and ward, and accessibility to furniture in the room to get out of bed (> 88%). Also, high agreement was found on the accessibility of information about PA, resting possibilities, the convenience of using walking aids and the desirability of a tidy and well-maintained room and ward (> 73%). Little agreement was found on a sufficient exercise equipment (23.6) and an attractive set-up for exercise bikes (12.3%). Only two participants went outside the hospital during their stay.

3.3. Potential supportive features for PA in the physical hospital environment

Table 5 shows the ranked items for supportive features. The main supportive features were the accessibility of a comfortable chair to use during the daytime, and the desirability of an attractive design and well-maintained room (> 83%). Also, information about how to be physically active (> 74%), a convenient training space for exercise bikes or equipment (69%) and a communal room (67%) scored high. A convenient layout and sufficient walking aids were considered as a requirement and therefore not submitted to the questionnaire on supportive features. Supportive features for the room and ward scored higher on agreement than supportive features for the hospital and direct surroundings.

3.4. Relations between participant and hospitalization characteristics, barriers and facilitators

Spearman's correlation analysis (Table 6) showed a significant negative correlation between the factor 'experienced support from HCPs' and the subscale barriers ($r_s = -0.283$, $p = 0.003$), as well as a positive correlation with the subscale facilitators ($r_s = 0.584$, $p < 0.001$), based on data from 106 participants. The factors age, gender, BMI and LOS showed no correlation with these subscales.

3.5. Content analysis open-ended questions

Table 7 shows the key findings of the patients' experiences and an overall concept of the role of the physical hospital environment in PA, based on the content analysis of the open-ended survey questions. A complete and structured overview of the content analysis is presented in Appendix D. In summary, the direct influence of the physical environment was important in providing facilities (e.g. communal room) and adequate space to move around. Although the direct influence of the design on PA was under debate, it could motivate unconsciously. Also, information (written/illustrated and verbal) on how to be physically active was desired. In addition, feeling safe to walk around was related to well-organized, well-lit and spacious layout, the assistive devices, such as a walker and facilities to rest and lean on. In addition to the overall contribution of the physical hospital environment to PA, PA also depended on the support from HCPs, the short length of stay and the focus on recovery as a motivator for PA. This led to the line of argument: 'The direct influence of the physical hospital environment on PA appears modest as the use of the opportunities it offers depends on the support from HCPs, LOS and one's own motivation'.

Barriers, facilitators and ideas for improvement derived from all results are summarized as design recommendations in Figure 2.

4. Discussion

This study examined PA in a hospital setting and identified barriers and facilitators, potential supportive features and relations of barriers and facilitators with participant and hospital characteristics. In our study, several different medical devices were considered the main barriers for PA. The main supportive features were in line with the main experienced facilitators (e.g. furniture in the room to get out of bed; written/illustrated and verbal information on PA, walking aids, handrails and seats to rest) and focused mainly on the level of the room and ward. Moreover, support from HCPs was significantly correlated with barriers (negative correlation) and facilitators (positive) of the physical hospital

Table 4. Experienced barriers and facilitators, ranked in order of agreement.

Items	Cat.	Scale	*n*	A	N	D	
Barriers at room and ward				%	%	%	Agree Neutral Disagree
chest tube as barrier for PA at the ward	C3	II	43	60.5	18.6	20.9	
urine catheter as barrier for PA at the ward	C3	II	76	52.6	21.1	26.3	
chest tube as barrier for PA at the room	C3	I	43	48.8	23.3	27.9	
urine catheter as barrier for PA at the room	C3	I	76	44.7	25.0	30.3	
drip as barrier for PA at the room	C3	I	58	32.8	17.2	50.0	
drip as barrier for PA at the ward	C3	II	58	32.8	13.8	53.4	
external pacemaker as barrier for PA at the room	C3	I	23	30.4	8.7	60.9	
telemetry as barrier for PA at the room	C3	I	69	26.1	11.6	62.3	
external pacemaker as barrier for PA at the ward	C3	II	23	26.1	4.3	69.6	
telemetry as barrier for PA at the ward	C3	II	69	21.7	14.5	63.8	
uncomfortable lighting for PA	C4	II	106	12.3	33.0	54.7	
temperature as barrier for PA	C4	I-II	106	5.7	20.8	73.6	
feeling unsafe to move around ward	S	II	106	3.8	6.6	89.6	
sound as barrier for PA	C4	I-II	106	1.9	20.8	77.4	
smell as barrier for PA	C4	I-II	106	0.9	20.8	78.3	
feeling unsafe to move around room	S	I	106	0.9	7.5	91.5	
vacuum assisted closure as barrier for PA at the ward	C3	II	3	0.0	33.3	66.7	
vacuum assisted closure as barrier for PA at the room	C3	I	3	0.0	33.3	66.7	
Barriers at hospital							
feeling unsafe walking around hospital [a]	S	III	18	33.3	33.3	33.3	
hard to find your way in hospital [a]	C5	III	18	33.3	22.2	44.4	
medical devices as barrier for walking around hospital [a]	C3	III	18	27.8	38.9	33.3	
feeling unsafe walking around hospital [b]	S	III	22	27.3	36.4	36.4	
medical devices as barrier for walking around hospital [b]	C3	III	22	13.6	50.0	36.4	
hard to find your way in hospital [b]	C5	III	22	13.6	45.5	40.9	
Barriers at direct surroundings							
medical devices as barrier for walking in direct surroundings	C3	IV	2	0.0	50.0	50.0	
feeling unsafe going outside hospital	S	IV	2	0.0	0.0	100.0	
Facilitators at room and ward				%	%	%	Agree Neutral Disagree
convenient layout of the ward to move around	C1	II	106	93.4	5.7	0.9	
convenient layout of the bathroom to move around	C1	I	106	90.6	5.7	3.8	
convenient layout of the room to move around	C1	I	106	89.6	7.5	2.8	
presence of furniture (e.g., chair or table) in the room to come out of bed	A1	I	106	88.7	6.6	4.7	
sufficient verbal information about PA by HCP	A4	I-II	106	83.0	9.4	7.5	
sufficient assistive (walking) devices to come out of bed & move around	C1	I-II	106	82.1	15.1	2.8	
tidy and well-maintained room and ward	D	I-II	106	81.1	10.4	8.5	
sufficient information on paper or digitally about PA	A3	I	106	77.4	15.1	7.5	
sufficient possibilities to rest at the ward (e.g., chair, bench, railing)	A1	II	106	73.6	18.9	7.5	
presence of interesting places on the ward (e.g., coffee room, hall, reception)	A2	II	106	62.3	25.5	12.3	
attractive and interesting room and ward (e.g., views, material use, styling)	D	I-II	106	50.0	34.0	16.0	
sufficient exercise equipment to support PA	C2	I-II	106	23.6	43.4	33.0	
attractive set up for exercise bikes	C2	II	106	12.3	47.2	40.6	
Facilitators at hospital							
sufficient knowledge about where to go [a]	A3	III	18	44.4	38.9	16.7	
sufficient knowledge about where to go [b]	A3	III	22	36.4	36.4	27.3	
sufficient knowledge about resting places [b]	A3	III	22	31.8	45.5	22.7	
sufficient knowledge about resting places [a]	A3	III	18	22.2	55.6	22.2	
Facilitators at direct surroundings							
sufficient number of places for resting in direct surroundings hospital	A1	IV	2	100.0	0.0	0.0	
nice places to go to in direct surroundings hospital	A2	IV	2	50.0	50.0	0.0	

Notes: The number of participants differs per question depending on: (1) if participants were allowed to go outside the ward (as long as participants had to use telemetry, they were not allowed); (2) if participants were allowed to go outside the ward and/or the hospital during hospitalization; (3) if participants fully completed the questionnaire. *Cat.* categories of the physical environment (*A* Accessibility, *S* Feeling of safety, *D* Desirability, *C* convenience, see also Figure 1, e.g. C3 corresponds to subcategory 'Constraints through medical devices'), *Scale* Level of scale (I room, II ward, III hospital, IV direct surroundings of hospital), *n* number of participants, *D* disagree, *N* neutral, A agree, *HCP* health care professionals.

[a] A group of patients who went outside the ward.

[b] A group of patients who did not want to go outside the ward but were allowed.

environment, indicating patients experienced fewer barriers and more facilitators when experiencing more support from HCPs. Furthermore, the content analysis of the open-ended questions showed that although the physical hospital environment influences PA, the actual use of the opportunities the environment offers depends on the support from HCPs, LOS and one's own motivation.

4.1. Enabling design

From an Evidence-Based Design (EBD) perspective, hospital environments can be deliberately shaped to promote specific patient behaviours, including PA (Bernhardt et al. 2022; Elf et al. 2024). A qualitative case study in a rehabilitation centre confirmed that built environment features – particularly accessibility, physical barriers, visual connections and spatial familiarity – directly affect whether patients feel safe enough to be physically active (Annemans, Van Dyck, and Heylighen 2024).

Consistent with this EBD perspective, and in line with studies specifically examining PA-behaviour during hospitalization our findings indicate that physical environmental features (e.g. convenient layout, facilities to safely ambulate, rest and explore) play an important role in facilitating PA-behaviour (Geelen et al.

Table 5. Potential supportive features, ranked in order of agreement.

Items	Cat.	Scale	*n*	A	N	D	
Supportive features at room and ward				%	%	%	■Agree ■Neutral ■Disagree
a comfortable chair in the room to use during daytime	A1	I	106	86.8	8.5	4.7	
attractive design, interesting to explore, well-maintained room and ward	D	I-II	106	83.0	15.1	1.9	
advice from health professionals to eat out of bed	A4	I	106	81.1	15.1	3.8	
leaflet before admittance: possible PA hospitalization & illustrated exercises	A3	I-II	106	80.2	14.2	5.7	
leaflet at admittance: possible PA during hospitalization	A3	I-II	106	74.5	19.8	5.7	
leaflet before admittance: importance of PA hospitalization	A3	I-II	106	74.5	21.7	3.8	
handrails in the hallway	A1	II	106	70.8	26.4	2.8	
personal exercise plan (on paper or video)	A3	I-II	106	70.8	24.5	4.7	
several places on the ward to rest (e.g., bench or seats)	A1	II	106	68.9	26.4	4.7	
training space for exercise bike or equipment	C2	II	106	68.9	25.5	5.7	
coffee room with reading table (communal room)	A1	II	106	67.0	28.3	4.7	
leaflet with places to go to at the ward	A3	II	106	65.1	25.5	9.4	
view from window at greenery	D	I-II	106	59.4	33.0	7.5	
pictures/ art on the wall of the ward	D	II	106	51.9	41.5	6.6	
posters at the room with well-illustrated exercises	A3	I	106	50.0	35.8	14.2	
space for interactive videogames to move & virtual bike riding	C2	II	106	43.4	39.6	17.0	
joint lunch in a shared place	A2	II	106	36.8	34.9	28.3	
mobility icons placed on the wall to show mobility level	A3	I	106	35.8	43.4	20.8	
interactive game gathering QR-codes by walking on the ward	C2	II	106	31.1	50.0	18.9	
special walking zones in the hallway	C2	II	106	25.5	52.8	21.7	
Supportive features at hospital				%	%	%	■Agree ■Neutral ■Disagree
training space to perform personal PA schedule	C2	III	103	60.2	33.0	6.8	
a restaurant/ coffee place in the hospital	A2	III	103	52.4	37.9	9.7	
a roof garden on the hospital	A2	III	103	49.5	38.8	11.7	
a hospital map with all facilities	A3	III	103	47.6	41.7	10.7	
a map of the hospital with special walking routes	A3	III	103	45.6	41.7	12.6	
a library in the hospital	A2	III	103	43.7	44.7	11.7	
a shop in the hospital	A2	III	103	38.8	42.7	18.4	
Supportive features at direct surroundings							
well-designed seats in direct surroundings	A1	IV	103	35.9	47.6	16.5	
a shielded space for visits in direct surroundings	A2	IV	103	34.0	44.7	21.4	

Notes: The number of participants can differ per question depending on the full completion of the survey. *Cat.* categories of the physical environment (*A* Accessibility, *S* Feeling of safety, *D* Desirability, *C* convenience, see also Figure 1, e.g. A1 corresponds to subcategory 'Facilities as furniture and sitting places'), *Scale* Level of scale (I room, II ward, III hospital, IV direct surroundings of hospital), *n* number of participants, *D* disagree, *N* neutral, A agree, *bda* before, during and after.

Table 6. Correlation between general patient-related factors and the subscales barriers and facilitators – non-parametric test.

Patient-related factors	Subscale barriers	Subscale facilitators
Age	$rs = -0.024, p = 0.807$	$rs = -0.053, p = 0.587$
Gender	$rs = -0.116, p = 0.236$	$rs = -0.052, p = 0.593$
BMI ($n = 105$)	$rs = -0.011, p = 0.908$	$rs = -0.098, p = 0.322$
LOS	$rs = -0.077, p = 0.434$	$rs = 0.012, p = 0.901$
ES	$rs = -0.283, p = 0.003*$	$rs = 0.584, p < 0.001*$

Notes: Data are presented based on $n = 106$, unless stated otherwise. Cronbach's alpha for the 8-item PB-subscale $\alpha = 0.696$, for the 14-item PF-subscale $\alpha = 0.869$, for the 20-item PSD-subscale $\alpha = 0.825$. Since different patients were connected to different medical devices, a mean of items comprising medical devices in the room and ward was calculated to replace the individual items for medical devices. ES experienced support from healthcare professionals (mean of agreement on experienced support from nurses, physiotherapists and physicians together). *Indicates that the correlation is significant.

2021; Koenders et al. 2019; Koenders, Potkamp-Kloppers, et al. 2021; van Delft et al. 2020).

However, designing an enabling environment also requires understanding of patient perceptions of barriers and facilitator (Hesselink et al. 2020; Meagher 2020). To this end, patients must feel welcome to use PA-supporting facilities and understand how to optimize these opportunities provided by their environment (Gibson 2015, 131, 132, 246; Heft 2001, 289, 290; Meagher 2020).

In our study, medical devices were identified as the main barriers to PA, a restriction consistent with Geelen et al.'s findings (2021). Also, our results showed that moving around safely was supported by furniture, handrails, walking aids and well-lit, spacious layouts, aligning with healthcare providers' perspectives (Geelen et al. 2022).

Many supportive features identified in our study overlapped with findings from other research – e.g. comfortable chair, attractive and inviting design, training space for exercise bikes or equipment, communal room (Geelen et al. 2021; Koenders et al. 2019; Koenders, Potkamp-Kloppers, et al. 2021; van Delft et al. 2020).

Interestingly, some features recommended in other studies scored low in our research, including walking zones, PA-supporting technology, joint lunches (Geelen et al. 2021; Koenders, Potkamp-Kloppers, et al. 2021; van Delft et al. 2020). This discrepancy may be explained by patient unfamiliarity with these features, as familiarity promotes comprehensive use of the physical environment (Heft 2001, 290; Meagher 2020) and helps navigate across an entire setting.

Our findings support specific design concepts across different scales (room, ward, hospital) (Meagher 2020). Literature suggests distinguishing between rooms for rest and outside spaces for activity (Koenders, Marcellis, et al. 2021). However, our results indicate this needs nuance, as in-room furniture and eating out of bed were found to be highly supportive for PA, consistent with other studies (Geelen et al. 2021; van Delft et al. 2020). Using the room as a starting point for PA may increase the continuity of a PA-friendly environment beyond the room, extending towards the rest of the building.

Table 7. Result content-analysis: key findings and the role of the physical hospital environment in physical activity.

Summary of experiences per category (⊜)	Subcategories (n participants)
Accessibility: Facilities and interesting places were generally considered sufficient, though some found it not diverse, interesting or challenging. Sufficiency of verbal and written information on PA varied widely: from well-informed to receiving no information or too much at once.	- Presence of facilities/interesting places $n = 19$ (⊜15, ⊕11) - Verbal information $n = 25$ (⊜15, ⊕10) - Written and illustrated information $n = 8$ (⊜4, ⊕6)
Convenience: The layout was considered sufficiently spacious and well-arranged. Walking aids were generally experienced as adequate for mobilization. Experiences with medical devices varied: from constraining to no major constraint, to only carrying devices for the first few days. Exercise equipment (e.g. bike) was present but not very visible or accessible.	- Layout & aids $n = 41$ (⊜39, ⊕9) - Spaces and exercise equipment exercise $n = 10$: (⊜6, ⊕4) - Conditions $n = 1$ (⊜1) - Medical devices $n = 40$ (⊜40) - Wayfinding $n = 4$ (⊜4) - Not wanting to leave ward $n = 10$ (⊜10)
Safety: Feeling safe to walk around depended on a spacious, well-lit layout and assistive devices and rest facilities. The presence of nurses was mostly mentioned for feeling safe to be active. Personal uncertainty about one's own physical capacity also influenced feeling safe.	- Layout/design $n = 18$ (⊜18) - Support/interaction with others $n = 46$ (⊜46) - Medical devices $n = 6$ (⊜6, ⊕1) - Personal factors $n = 18$ (⊜18)
Desirability: Opinions on aesthetics varied from functional and sober to tasteful. Cleanliness was perceived as an important factor. Some mentioned that greenery, outside the window or as pictures on the wall, was lacking.	- Aesthetics $n = 25$ (⊜20, ⊕8) - Maintenance $n = 19$ (⊜19, ⊕12) - Natural elements $n = 2$ (⊜2, ⊕1)
Room preference: Opinions on room type preference varied: most patients preferred a single room, valuing quietness, privacy and recovery at one's own pace. Shared rooms were valued for social interaction and the positive influence of seeing others recover, though experiences depended on roommates.	- 1-person room $n = 40$* - 2-person room $n = 18$* - 4-person room $n = 16$* - No preference $n = 10$*
Contextual notes: Most participants reported overall satisfaction with care. Recall bias is mainly related to used medical devices. Personal context included current PA levels and expectations regarding follow-up. COVID-19 restrictions constrained mobilization, though reduced ward occupancy positively influenced feeling safe.	- Satisfaction $n = 13$ (⊜13) - Recall bias $n = 8$ (⊜7, ⊕1) - Personal context $n = 18$ (⊜18) - COVID-19 $n = 12$ (⊜12)
Overall concept: role of the physical hospital environment in PA	*Quotes*
Direct influence: The physical environment is important in providing facilities and adequate space to move around. Some thought it wouldn't matter how the physical environment looks, while others think it will motivate unconsciously and natural elements and a quiet environment will enhance recovery. Information (written/illustrated and verbal) is important to learn which activities can be undertaken. *Influenced by/ depending on:*	*(the design) 'Motivates unconsciously.'* *'I could move easily with a walker in the spacious hallway.'* *'I found a bike in the corner and got help to use it.'*
Support (from HCPs): Encouragement from HCPs and guidance in what to do are of great importance in PA-behaviour (to regain trust in one's own capacity and opportunities). A good atmosphere and interactions with others (HCPs, patients and visitors) also contribute to recovery.	*'I experienced that staff has drawn attention to "get out of bed and walk" from day one, and I think that that is the best support together with information (verbal and written) beforehand (as did happen).'*
Length of stay: Length of stay is rather short, and therefore most recovery in PA takes place after discharge, which makes the opportunity the physical environment offers for PA a less prominent factor.	*'For those few days, it was fine. I'm not saying the opportunities were enervating, but they were sufficient for time and goal.'*
Personal factors/motivation: The main focus is on recovery and personal capacity, and that might be the strongest motivator for PA-behaviour regardless of the attractiveness of the physical environment.	*'The ward is not very attractive to stumble around. But my motto is: if you want to move forward you need to get active!'* *'Motivation to get active should come from oneself.'*

4.2. Information

An enabling design requires a solid understanding of how to use the opportunities the environment offers and knowledge of how to navigate. Therefore, written/illustrated and verbal information are valuable resources (Gibson 2015, 246; Meagher 2020). This aligns with the findings of this study and recommended features in previous studies (Koenders, Potkamp-Kloppers, et al. 2021; van Delft et al. 2020; Zisberg et al. 2018). This entails written information about what the ward is offering (e.g. leaflets explaining the importance of PA, possibilities to be physically active, places at the ward to visit). Similar ideas are an important part of multifaceted interventions (Koenders, Potkamp-Kloppers, et al. 2021; van Delft et al. 2020).

4.3. HCPs' support

HCPs play an important role in providing information as part of educating and supporting patients on how to use the opportunities the physical environment offers to be physically active. Although other studies underscore the importance of information and support of HCPs, including education of HCPs to support patients with PA (Koenders et al. 2019; Koenders, Potkamp-Kloppers, et al. 2021; van Delft et al. 2020), the broader scope is rarely described. One study investigating facilitators for PA in retirement communities concluded that older people may need support from staff to become familiar with their surroundings (Bjornsdottir, Arnadottir, and Halldorsdottir 2012). Similarly, patients were found to be unfamiliar with the hospital environment and feel insecure about engaging in PA in their current condition, which is in line with the results of this study (Geelen et al. 2021). Thus, HCPs should be aware of their role in guiding and familiarizing patients with their new environment, as patients learn about affordances through social interaction and instruction (Heft 2001, 290; Meagher 2020). Moreover, as recommended in other studies, stimulating PA, tailored to the patient's characteristics and perspective, should be part of the hospital culture (De Klein, Valkenet, and Veenhof 2021; Geelen et al. 2022; van Delft et al. 2020).

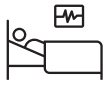
	Barriers	Facilitators	Design recommendations
Room & Ward 	× Medical devices (chest tube, catheter)⊖ # × Exercise equipment not visible or accessible (e.g., exercise bike) ⊖ × Facilities not sufficiently diverse or challenging (e.g., small coffee room) ⊖ × Insufficient or poorly timed PA information⊖ × Hard to personally regulate temperature⊖ × Lacking of greenery, outside the window or as pictures on the wall⊖ × Lack of walkers⊖ × Feeling unsafe due to condition⊖# × Too crowded during visiting hours⊖	Convenient and functional layout#⊖ Accessible furniture to get out of bed# Walking aids & handrails#⊖ Seats on ward⊖ Resting possibilities Written/verbal PA information# Sufficient facilities⊖ Receiving a training schedule⊖ Tidy and well-maintained room and ward#⊖	✎ Comfortable chair near bed# ✎ Interesting to explore and well maintained# ✎ Domestic/cozy ambiance⊕ ✎ PA leaflet/poster with graded exercises#⊕ ✎ Training space and equipment#⊕ ✎ Graduate walking routes with signs⊕ ✎ Recreation room (patient/visitor only, not staff) ⊕ ✎ Greenery⊕ ✎ More colour and decoration (cozy ambiance) ⊕ ✎ Tranquile environment⊕
Hospital & direct surroundings 	× Feeling unsafe walking around hospital#⊖ × Wayfinding difficulties#⊖ × Lack of knowledge about facilities outside ward⊖ × Not wanting to leave ward (no desire, not aware of possibility)⊕	Telemetry gave sense of safety⊖	✎ Roof terrace#⊕ ✎ Natural elements / greenery⊕ ✎ Alarm to monitor heart outside ward⊕ ✎ Training space#⊕
HCP role (cross-level) 	× Insufficient verbal PA guidance from HCPs (specifically physiotherapists)⊖	HCP support (being well informed and guided) ⊖ Presence of nurses for feeling safe to be active⊖	✎ Pre-operative PA information⊕ ✎ Personal guidance by physiotherapists / individual training program⊕ ✎ Joined and/or supported trainings⊕ ✎ Encouragement builds patient confidence⊕ ✎ Good atmosphere⊕

Figure 2. Summary of barriers, facilitators and design recommendations for physical activity in the hospital environment per scale level and HCP support as a cross-level factor.

Note: #Main quantitative results (Tables 4 and 5); ⊖experience and ⊕ideas for improvement from open-ended questions (Appendix D).

4.4. Strengths and limitations

To our knowledge, this is one of the first studies to combine a healthcare and environmental design perspective – specifically applying the ecological model and affordance theory alongside the COM-B model – to examine how the physical hospital environment can support PA in postoperative patients. This addresses a gap identified in the EBD literature, where

theoretical frameworks remain underutilized (Elf et al. 2024). This multidisciplinary approach enriches perspectives on interventions (Elf et al. 2024; Sallis et al. 2006). While barriers and facilitators are context-specific, the identified supportive features offer general insights into patient preferences.

However, this study has some limitations. First, sampling bias might have occurred. Although the response rate was more than 45%, a substantial proportion of eligible patients did not respond. The open answers showed an overall positive experience at the LUMC, which could have led to a higher agreement on facilitators and a positive attitude towards supportive features. Second, the sample was taken during a period in which the COVID-19 pandemic resulted in measures such as distancing, which may have decreased PA-behaviour and the curiosity about exploring the surroundings. Moreover, during this period, healthcare delivery was affected, and elective surgical procedures were postponed at times. This may have influenced the number and characteristics of included patients, for example, with respect to case severity, and may limit the generalizability of the findings to routine clinical practice. Third, the data were collected in 2021–2022. However, no major changes have taken place in open-heart surgery procedures or in the protocols for postoperative care and hospitalization since then. We, therefore, consider the cohort to remain representative of current practice.

Fourth, this study made use of patients who underwent surgery 1–13 months prior to filling out the survey, which could have led to a recall bias. Finally, in the absence of a validated questionnaire, our self-developed survey is not validated. Therefore, the outcomes should be interpreted with care. However, the relation between HCPs' support and experienced barriers and facilitators was substantiated by the content analysis.

4.5. Implications and recommendations for further research

Our findings indicate the need for an integrated approach when designing an intervention for supporting PA during hospitalization, which involves:

(1) creating an enabling design in which the environment offers (or 'affords') the physical 'Opportunities' for PA-behaviour across the level of scales, room and ward, hospital and direct surroundings;
(2) designing these 'affordances' requires an understanding of the patients' perception of barriers and facilitators. Reciprocally, patients need to understand why and how to navigate and utilize the environment ('Capability'). This can be facilitated by using familiar opportunities and providing written and verbal information as patients need to learn about the affordances to become meaningful to them (Heft 2001, 290; Meagher 2020) and
(3) HCPs have an important role in supporting patients (social 'Opportunity'), which can enhance the patients' 'Motivation' for PA-behaviour, as the social environment influences the interaction between a person and the physical environment.

Overall, this integrated approach could enhance the applicability of an enabling design to optimize affordances that guide behaviour, and help to integrate PA-behaviour into hospital culture, thereby creating a 'behaviour setting for PA'. For this integration, the COM-B model for behaviour change (Capability, Opportunity and Motivation influences Behaviour) seems appropriate. The ecological model and environmental psychology, as frequently practised in urban settings, appears to provide additional insight into the interaction between the patient and the hospital environment, as this is where PA-behaviour occurs.

At last, the findings of this current study support the idea that interventions should be ward-specific (van Delft et al. 2020) as only 17.1% of the respondents went outside the ward during hospitalization. It would therefore be sensible to focus mainly on the scale of the room and ward when adjusting the physical hospital environment to enhance PA at cardiothoracic surgery wards.

Further research into physical environmental factors influencing behaviour in a hospital setting seems warranted. In addition, in line with the existing surveys for measuring attributes of the physical neighbourhood environment on PA an equivalent for the hospital setting could be developed (Saelens et al. 2003; Spittaels et al. 2010). Thus, this topic asks for further transdisciplinary research (e.g. built design, health science) and user involvement (patients and staff) to optimize multilevel interventions (Sallis et al. 2006). This aligns with the call in the EBD literature for shared responsibility between healthcare providers, architects, and researchers in creating environments that meet the needs of patients and staff (Elf et al. 2024).

5. Conclusion

To enhance PA during hospitalization for patients after cardiothoracic surgery, the physical hospital environment should offer opportunities for PA, based on the patients' perception of this unfamiliar environment, and focusing on the level of scales, room and ward. Furthermore, HCPs have an important role in educating patients about the meaning and usability of the opportunity to optimize its use. Understanding the role of the physical hospital environment for its users is essential to enhance the recommended multifaceted and multilevel interventions.

6. Ethical considerations

The study did not fall within the scope of the Dutch Medical Research Involving Human Subjects Act according to the Medical Ethics Committee (MEC) of Leiden University Medical Centre (G21.068).

7. Consent to participate

The electronic data capture system, Castor EDC (Castor 2022), was used to send out the invitation letter by email and to obtain informed consent. The invitation letter comprised the study information and the link to the online survey. All data was collected anonymously by using encryption within the electronic data capture system, Castor EDC (Castor 2022).

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Author contributions

CRediT: **Lisenka te Lindert:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing; **Machiel Van Dorst:** Supervision, Validation, Writing – original draft, Writing – review & editing; **Arend De Weger:** Conceptualization, Resources, Writing – review & editing; **Eric Vermeulen:** Conceptualization, Writing – review & editing; **Thea Vliet Vlieland:** Conceptualization, Methodology, Supervision, Writing – review & editing; **Rienk Dekker:** Validation, Writing – original draft, Writing – review & editing; **Åsa Mennema:** Visualization, Writing – review & editing; **Aleid De Rooij:** Validation, Visualization, Writing – original draft, Writing – review & editing; **Jorit Meesters:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing

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No potential conflict of interest was reported by the authors.

Data availability statement

Due to privacy legislation, the study data are not available.

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