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Review

Predictive Factors of Inpatient Rehabilitation Stay After Elective Hip and Knee Replacement: A Scoping Review

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Abstract

Patient stratification strategies based on digital databases and advanced information technology can predict inpatient rehabilitation outcomes and support safe hospital discharge for patients who underwent joint replacement for hip and knee osteoarthritis. The degree of continuity between surgery and rehabilitation, the perioperative process integration, and the setting where rehabilitation is provided are crucial factors to improve care effectiveness, access, minimize readmissions, and cost increase. The primary aim of this scoping review of the literature is to identify perioperative variables that are predictive of inpatient rehabilitation stay after hip and knee arthroplasty for osteoarthritis. These factors are divided by time of assessment through the perioperative pathway and surgical procedure site. The secondary aim is to explore how different data sources and facilities are linked into a patient-centered perioperative pathway. An electronic search of the literature was performed on PubMed, Embase, and Scopus. No time restrictions were applied. All primary research studies investigating predictive factors of inpatient rehabilitation stay after hip and knee osteoarthritis were included. In total, 25 studies were included in the review. Age, caregiver presence, presence of comorbidities, sex, Body Mass Index, Risk Assessment and Prediction Tool composite score, pre-operative Clinician-Reported Outcome Measures, pre-operative Patient-Reported Outcome Measures, and post-operative Barthel Index of autonomy in the Activities of Daily Living were predictive of some degree of inpatient rehabilitation stay in more than one study. The studies were fairly distributed between retrospective and prospective, with multicentric databases more spread among the latter. Data collection occurred in acute hospitals more than in specialized rehabilitation facilities. Using comprehensive models supported by electronic health records and powerful information technologies, analyzing specific inpatient rehabilitation LOS as distinguished from surgical ward rehabilitation, using institutional registries, and including specific rehabilitation factors in these registries, and promoting vocabulary and federated data sharing can strongly enhance the predictivity of models investigating rehabilitation outcomes and support appropriate discharge from inpatient rehabilitation units.

Keywords: hip arthroplasty; data management; electronic health records; inpatient rehabilitation; knee arthroplasty; osteoarthritis; perioperative care; prediction models

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1. Introduction

Patient stratification strategies to optimize inpatient length of stay (LOS) after hip and knee replacement have long been advocated for clinical, organizational, and allocative purposes, pushed by the growing burden of hip and knee osteoarthritis in aging societies [1–7].

The elective nature of the procedure enables planning hospital admission, intraoperative arrangements, postoperative rehabilitation, and possibly also prehabilitation programs, promoting multidisciplinary, perioperative research to identify any possible measures to accelerate patient recovery and reduce waiting lists.

Medical progress, population aging, cost containment and sustainability issues have made the reduction in hospital LOS increasingly possible and necessary, resulting in different accelerated protocols like fast-track [8], enhanced recovery after surgery [9], short stay programs [10], and same-day discharge protocols [11], maintaining high standards of care, comparable safety [12], and non-inferior to better outcomes [13–16]. At the same time, older patients being clinically fit for discharge may prolong inpatient stay because of disadvantaged living conditions and postoperative fragmentation of care, further delaying hospital admissions to the detriment of acute patients [17,18].

After the pandemic, promising information technologies are becoming more common in joint arthroplasty, not only supporting the *reduction* in hospital LOS, but making the *prediction* of hospital LOS easier, through the analysis of large, heterogeneous datasets collected from multiple units, facilities, and professionals [19–21]. Clinicians, researchers, and administrators can track socio-behavioral data, patient visits, clinical observations, and procedures across the pathway, potentially distinguish rehabilitation-specific LOS from total hospital LOS, and link these data through the use of electronic patient identifiers. In this way, predictive factors can be more easily identified at different stages, supporting patient-centered, clinical, and organizational arrangements accordingly. Preoperative, intraoperative, and postoperative information on patient's health, function, and social resources can support an optimal rehabilitation process in advance by making clinicians and administrators able to estimate the time of recovery, the potential complications, design patient-centered pathways (e.g., prehabilitation, nutrition, anesthesia, pain medications, iron diet, physical therapy intensity, Activities of Daily Living recovery), and organize facility shifts efficiently (e.g., from surgical ward to inpatient rehabilitation, and from inpatient rehabilitation to home or primary care facilities). Moreover, medical technology suppliers can identify, develop, and market useful devices to accurately measure clinically relevant, predictive conditions (e.g., wireless wearable accelerometers to measure physical activity levels before surgery) [22,23].

After the COVID-19 pandemic, substantial financial investments are being addressed to the digitalization of healthcare and the integration of acute and post-acute, intermediate and primary care, ideally merging data into patient-centered information systems able to track the patient's pathway across different facilities and professionals [24,25]. Therefore, digital health records, artificial intelligence, and machine learning can improve the perioperative streamlining even further, provided adequate validation measures [26,27]. The goal is to preserve the healthcare system effectiveness, responsiveness, and sustainability building on proactive population health management across healthcare and community settings, both entering and leaving the hospital (e.g., allowing access to the patient's history based on integrated medical records, activating post-acute care on time, facilitating safe home discharge, reducing complications and hospital readmissions due to care fragmentation, monitoring parameters from remote areas, preventing the exacerbation of chronic conditions outside hospitals).

In this context, the degree of continuity between surgery and rehabilitation, the perioperative process integration, and the setting where rehabilitation is provided are crucial factors to improve care effectiveness and access and avoid readmissions and financial losses, both in hip and knee arthroplasty [28–30]. The more predictive variables are known to clinicians, researchers, and policy makers, the more room for patient-centered arrangements to improve postoperative outcomes and care continuity. In turn, sharing experiences about data collection and linking across different providers is key to a) efficiently map, integrate, and plan retrospective and prospective studies, and b) provide good quality digital sets to train and run artificial intelligence, machine learning, and statistical analyses on big data.

The primary aim of this scoping review of the literature is to identify perioperative variables that are predictive of inpatient rehabilitation stay after elective hip and knee arthroplasty. Then, among the studies identified by the review, we aim to describe how different databases (monocentric and multicentric) or registries (institutional, scientific societies) are linked among different professionals, units, and facilities, considering the importance of data integration across different levels.

2. Materials and Methods

The extended version of the Arksey and O'Malley framework for scoping reviews [31] was adopted as a protocol for this research (Table 1). The protocol is also compliant with Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist (Supplementary Material S1).

Table 1. Scoping review protocol.

Identifying research question	– Primary question: what variables are predictive of inpatient rehabilitation stay after elective hip and knee arthroplasty? – Secondary question: among the resulting studies in which there is a linkage between different settings, how are data collected and linked?
Identifying relevant studies	– The PICOS framework [32] was used to define inclusion/exclusion criteria. – Population: patients undergoing joint replacement for hip and knee osteoarthritis (non-elective procedures excluded, e.g., hip replacement for femoral neck fracture). – Intervention: use of any predictive variable of inpatient rehabilitation LOS, regardless of model and method (e.g., linear regression, logistic regression, machine learning techniques). – Control/Comparison: not necessary. – Outcome: inpatient rehabilitation LOS; – Study design: primary research, either observational or interventional, prospective or retrospective, completed or protocol. No literature reviews.
Study selection	– An electronic review of the literature was performed on PubMed, Embase, and Scopus. No time restrictions were applied. No language restrictions were applied, provided that at least an English abstract with all the relevant information was clearly reported. – The following keywords were combined on each platform to find the most possible results: "hip", "knee", "joint replacement", "osteoarthritis", "predictive", "prediction", rehabilitation", "length of stay", "length of rehabilitation". – The research was performed between 5 and 7 August 2025.
Charting the data	– The variables to extract in order to answer the question(s) were identified by the researcher who conducted the review (FP). A person with experience in clinic and research administration evaluated and confirmed the variables and the research results (GB). Although not directly relevant to answer the primary and secondary questions, the study country was reported in order to help potential readers from the same origin retrieve information from similar contexts to those in which they work (e.g., for policy, healthcare organization, mandatory outcomes or reimbursement reasons); the study population size was reported for similar reasons and to give an idea of the study significance. – A pilot review on ten studies was initially performed for iterative purpose; these studies confirmed that the approach was consistent with the research question and purpose. – Qualitative information was standardized and reported by using categories of interest (e.g., data management, data source, hospital vs. inpatient rehabilitation unit stay).
Collating, summarizing, reporting	– The results are reported in Table 2 (See results). – Numerical summary analyses and qualitative thematic results (e.g., data management, data source, hospital vs. inpatient rehabilitation unit stay) are reported narratively in the results; – The variables that were predictive in more than one study (≥2) were discussed in the dedicated section, along with findings related to study purpose and implications for future research, practice, and policy.

The Population, Intervention, Control/Comparison, Outcome, and Study (PICOS) framework was adopted to define the research question, inclusion, and exclusion criteria [32] (Table 1). Put in the terms of the Population, Concept and Context (PCC) framework, the population is made up of patients undergoing joint replacement for hip and knee osteoarthritis, the concept is the investigation of potentially predictive factors of inpatient rehabilitation stay, and the context is all healthcare facilities providing inpatient rehabilitation stay (both as a part of general hospital LOS, as a part of postoperative surgical ward LOS, as a part of postoperative specialized unit LOS in the same facility where surgery was performed, and as a separated facility from the hospital where surgery was performed). Of the studies included in the research, the data collection methodology (prospective or retrospective) and links (professional/scientific registry, institutional registry, monocentric database, multicentric database) through any different sources and providers (general hospital, surgical ward, inpatient rehabilitation unit) were also considered.

A PRISMA flowchart was developed to describe study selection (Results, Figure 1). Two reviewers selected the studies. It was planned to use a third reviewer to resolve any discrepancies. However, no discrepancies needed to be handled, as population, intervention, outcome, and study design (or concept and context) were clear, and no intervention control or comparison was relevant to our scope. The protocol was not registered before initiating, as permitted by the Arksey and O'Malley extended framework for scoping reviews [31]. However, the full electronic research, along with data and results, is available in Supplementary Material S1 in order to ensure reproducibility and transparency.

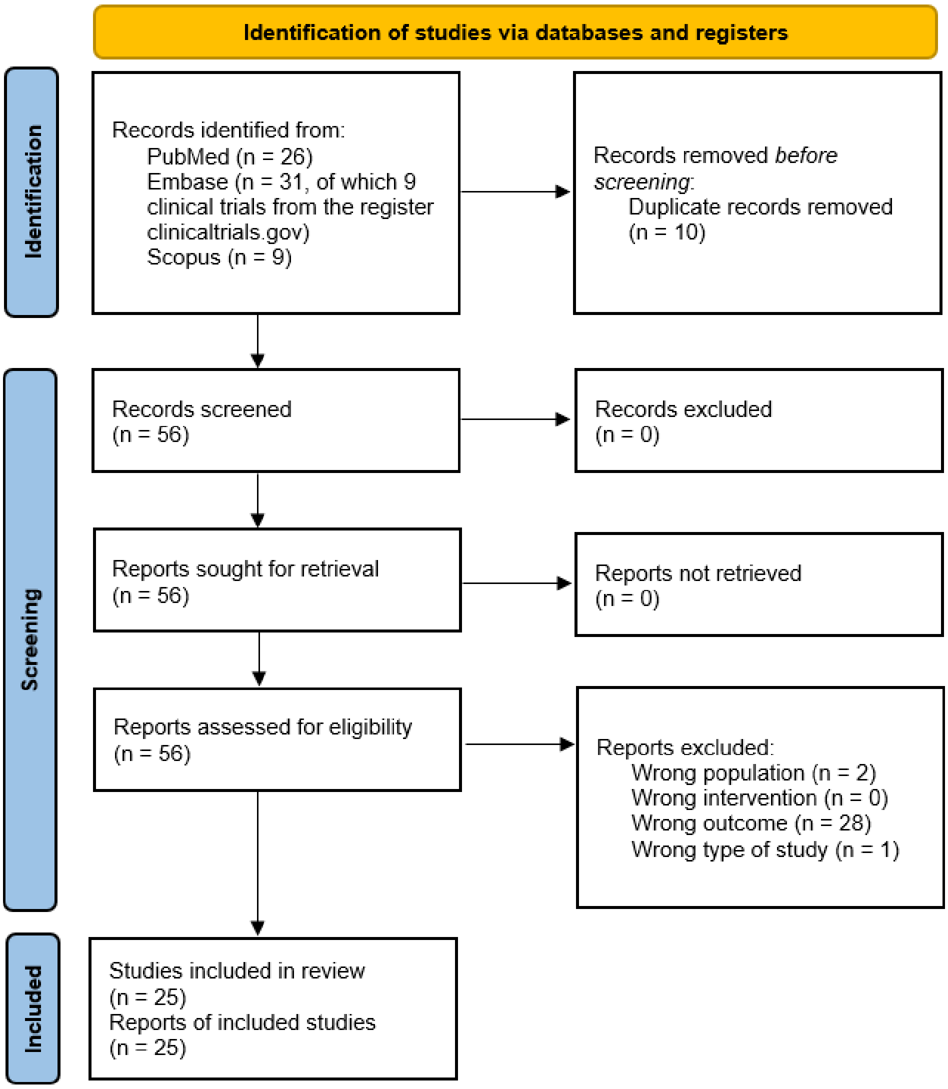

Figure 1. PRISMA 2020 flow diagram (https://www.prisma-statement.org/prisma-2020-flow-diagram accessed on 2 November 2025) for database and register search.

When considering data collection and linking results, data management categories were grouped into professional/scientific society registry, institutional registry, multicentric database, and monocentric database. By data management, we mean the source of data repository and integration. The difference between an institutional registry and a database is the difference between institutional ongoing systems of surveillance and monitoring—see, for instance, European Reference Networks [33], the Swedish Knee Arthroplasty Register [34], or the Italian Registro Nazionale Artroprotesi [35]—and local, spontaneous initiatives from one or more hospitals and healthcare providers, no matter how extended in patient population and time, generally requiring approval from local ethical committees. The professional/scientific society registry category was also added to include data-driven, monitoring registries from the clinical records available to healthcare professionals (e.g., The American College of Surgeons National Surgical Quality Improvement Program) [36].

Data sources were grouped into hospital (if data were collected from a hospital, either including surgical and/or subsequent inpatient rehabilitation stay) and inpatient rehabilitation facility (if data were collected from an external inpatient rehabilitation facility, like a physical medicine and rehabilitation center). For example, if a study is performed in a hospital providing both surgery and subsequent inpatient rehabilitation in the same facility, it is categorized as a hospital study. Otherwise, if a study is performed into a physical medicine and rehabilitation center that also retrieves a patient's history from the previous surgical hospitalization, it is categorized as an inpatient rehabilitation facility study.

3. Results

In total, 66 studies were initially identified from 3 databases; 56 studies resulted after removing duplications, and 25 final studies resulted after applying PICOS criteria from abstract screening to full text reading (Figure 1). The results of the review are represented in Table 2.

Table 2. Final results.

Publication Identifier *	Year	Setting	Arthroplasty Procedure	Population	Intervention.		Outcome	Type of Study	Data Linkage
					Potential LOS Predictors	Actual LOS Predictors			
https://doi.org/10.1186/s12891-024-07878-0. (DOI)	2024.	Denmark, two centers.	Knee replacement.	200 (expected).	Pre-operative physical activity levels (as measured with a wireless medical accelerometer).	Not Applicable (N/A) (protocol).	Length of hospital stay.	Protocol for a Randomized Controlled Trial (RCT).	Multicentric database.
https://doi.org/10.3390/app142411993. (DOI)	2024.	Italy, single-center.	Total hip and knee replacement.	1678	Age, sex, American Society of Anesthesiologists score (ASA), Body Mass Index (BMI), transfusion occurred, blood-borne infection, type of anesthesia, day of surgery, post-operative pain, post-operative cognitive function, living alone/presence of a caregiver/caregiver conditions, occupation, post-operative Barthel Index (BI) of autonomy in the Activities of Daily Living (ADL) at rehabilitation admission, duration of surgery, surgical ward LOS, hemoglobin at rehabilitation admission, post-operative verticalization day, anatomical region (hip or knee), post-operative autonomy in ADL, post-operative autonomy in postural transition, post-operative walking autonomy.	Age, living with a family, occupational status, post-operative BI, duration of surgery.	Length of rehabilitation unit stay.	Observational, retrospective.	Monocentric database.

Table 2. *Cont.*

Publication Identifier *	Year	Setting	Arthroplasty Procedure	Population	Intervention. Potential LOS Predictors	Intervention. Actual LOS Predictors	Outcome	Type of Study	Data Linkage
https://doi.org/10.11622/smedj.2021142. (DOI)	2024.	Italy, single-center.	Primary total knee replacement.	1082	Age, sex, comorbidities (number and type), BMI, presence of caregiver at home, BI at rehabilitation admission, Functional Independence Measure (FIM).	Age, sex, number of comorbidities, heart disease, BMI, presence of a caregiver at home.	Length of rehabilitation unit stay.	Observational, retrospective.	Monocentric database.
https://doi.org/10.21653/tjpr.998961. (DOI)	2023.	Turkey, single-center.	Total knee arthroplasty.	41	Preoperative serum cytokine levels.	Preoperative serum cytokine levels were not predictive.	Length of rehabilitation unit stay up to five days or more.	Observational, prospective.	Monocentric database.
https://doi.org/10.1016/j.arth.2023.05.010. (DOI)	2023.	United States, singe-center.	Primary unilateral knee and hip.	17,713	Single variables: anatomical region (hip or knee), age, sex, BMI, smoking status, payer status, ASA, type of anesthesia, operational time, estimated blood loss, preoperative Hip Osteoarthritis Outcome Score–Joint Replacement (HOOS-JR), Knee Osteoarthritis Outcome Score-Joint Replacement (KOOS-JR), Patient-Reported Outcome Measures Information System (PROMIS)–mental and physical health, Veterans Rand-12 Item Score–mental and physical health, Lower Extremity Activity Scale (LEAS), pain. Multivariate analysis: Risk Assessment and Prediction Tool (RAPT) score.	RAPT score, knee, operational time.	Length of hospital stay.	Observational, retrospective.	Monocentric database.

Table 2. *Cont.*

Publication Identifier *	Year	Setting	Arthroplasty Procedure	Population	Intervention.		Outcome	Type of Study	Data Linkage
					Potential LOS Predictors	Actual LOS Predictors			
NCT06005623. (NCT)	2023.	Denmark, two centers.	Total and unicompart-mental knee arthroplasty.	150 (expected).	Pre-operative physical activity levels (as measured with a wireless medical accelerometer).	N/A (protocol).	Length of hospital stay.	Protocol for an RCT.	Multicentric database.
https://doi.org/10.15619/NZJP/50.1.05. (DOI)	2022.	Australia, single-center.	Total hip and knee replacement.	74.	Age, sex, BMI, anatomical region (hip or knee), ASA, type of anesthesia, post-operative physical activity levels (as measured with step count, sit-to-stand transitions, time upright).	Post-operative physical activity measures (all).	Length of hospital stay.	Observational, prospective.	Monocentric database.
NCT03227120. (NCT)	2020.	United States, single-center.	Total knee arthroplasty.	60.	Prehabilitation compared to standard care.	N/A (protocol).	Length of hospital stay.	Protocol for an RCT.	Monocentric database.
https://doi.org/10.1186/s12891-021-04211-x. (DOI)	2021.	Japan, single-center.	Simultaneous bilateral total knee arthroplasty.	191.	Age, sex, BMI, living alone, Knee Society Function Score (KSFS), ASA, pre-operative hemoglobin, albumin level, Range of Motion (ROM), Kellgren-Lawrence scale.	Age, pre-operative hemoglobin.	Length of hospital stay (three weeks or more).	Observational, retrospective.	Monocentric database.
NCT03894514. (NCT)	2021.	Spain, two-centers.	Total knee arthroplasty.	243.	Pre-operative Oxford Knee Score (OKS), International Physical Activity Questionnaire (IPAQ)–short form, Euro Quality of Life 5D (EQ-5D), Geriatric Depression Scale (GSD), pain, expectations on pain and function, strength, ROM, Timed-Up-and-Go-Test (TUG), Five times sit to stand test, One leg balance test.	N/A (protocol).	Length of rehabilitation unit stay.	Protocol for an Observational, prospective.	Multicentric database.

Table 2. *Cont.*

Publication Identifier *	Year	Setting	Arthroplasty Procedure	Population	Intervention.		Outcome	Type of Study	Data Linkage
					Potential LOS Predictors	Actual LOS Predictors			
https://doi.org/10.1503/cjs.003919. (DOI)	2020.	Canada, single-center.	Unilateral primary total hip or knee arthroplasty.	283.	Sat on the bedside on postoperative day 0 (POD0); stood by the bed or walked in place POD0; Walked in the room POD0; Walked in the hall POD0.	Walked in the hall at POD0. In turn, mobilization was predicted by other factors.	Length of hospital stay.	Observational, retrospective.	Multicentric database.
https://doi.org/10.3928/01477447-20190321-01. (DOI)	2019.	United States, registry.	Primary total hip arthroplasty.	43,179.	Age, sex, BMI, comorbidities (including chronic steroid use), preoperative hematocrit, smoking status, National Surgical Quality Improvement Program (NSQIP)-functional status, type of anesthesia, duration of surgery.	NSQIP functional status.	Length of hospital stay.	Observational, retrospective.	Professional/scientific society database.
https://doi.org/10.1097/rnj.0000000000000126. (DOI)	2019.	Portugal, singe-center.	Total hip arthroplasty.	40.	Age, sex, marital status, education level, number of household members, area of residence, comorbidities, pre-operative vital signs (heart rate, respiratory rate, blood pressure, body temperature), pain, clinical chemistry, BMI, body composition analysis, Mini-Mental State Examination (MMSE), GSD, FIM, Morse Fall Scale, Braden scale.	Weight of the lower limb not affected by osteoarthritis, general overweight, pain before surgery.	Length of hospital stay.	Observational, prospective.	Monocentric database.
https://doi.org/10.1007/s00264-018-3833-y. (DOI)	2018.	Canada, single-center.	Hip or knee arthroplasty.	108.	ASA, Charlson Comorbidity Index (CCI), TUG.	ASA, TUG.	Length of hospital stay.	Observational, prospective.	Monocentric database.

Table 2. *Cont.*

Publication Identifier *	Year	Setting	Arthroplasty Procedure	Population	Intervention.		Outcome	Type of Study	Data Linkage
					Potential LOS Predictors	Actual LOS Predictors			
https://doi.org/10.1016/j.knee.2016.09.022. (DOI)	2017.	Italy, single-center.	Unilateral total knee arthroplasty.	353.	Age, BMI, CCI, depression, previous total hip or knee arthroplasty, pre-operative hemoglobin, BI at rehabilitation admission.	Age, BI at rehabilitation admission.	Length of rehabilitation unit stay.	Observational, retrospective.	Monocentric database.
https://doi.org/10.1016/j.arth.2016.02.017. (DOI)	2016.	United States, singe-center.	Primary total hip and knee arthroplasty.	744.	Model set score 1: age, sex, pre-existing medical conditions (quantified with the CCI); Medical set score 2: Activity Measure for Post-Acute Care 6 Clicks score (24 h after surgery), age, sex, CCI.	No-one. Model 2 was more accurate than model 1, but still characterized by poor predictive performance.	Length of hospital stay (3 days or more).	Observational, retrospective.	Monocentric database.
NCT03044028. (NCT)	2016.	United States, single-center.	Unilateral total knee arthroplasty.	66 (expected)	Use of NeuroMuscular Electrical Stimulation (NMES) device before and after surgery, use of NMES device only after surgery, no use of NMES device (traditional rehabilitation protocol).	N/A (protocol).	Length of hospital stay.	Protocol for an RCT.	Monocentric database.
https://doi.org/10.1016/j.rehab.2014.02.002. (DOI)	2014.	France, 12 centers.	Total hip arthroplasty.	134.	RAPT.	RAPT.	Place of discharge after surgical ward stay. (An RAPT score >9, combined with remote patient home, was predictive of external inpatient rehabilitation LOS).	Observational, retrospective.	Multicentric database.

Table 2. *Cont.*

Publication Identifier *	Year	Setting	Arthroplasty Procedure	Population	Intervention.		Outcome	Type of Study	Data Linkage
					Potential LOS Predictors	Actual LOS Predictors			
https://doi.org/10.5301/hipint.5000100. (DOI)	2014.	United Kingdom, single-center.	Unilateral total hip replacement.	100.	ASA, CCI, age.	CCI, age.	Length of hospital stay.	Observational, prospective.	Monocentric database.
https://doi.org/10.1016/j.arth.2013.06.033. (DOI)	2014.	Canada, single-center.	Total knee arthroplasty.	72.	Age, BMI, comorbidity, post-operative pain, Pain Catastrophizing Scale (PCS), non-operative knee extensor isometric strength, TUG, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) -function score.	Age, comorbidity.	Length of hospital stay.	Observational, retrospective.	Monocentric database.
https://doi.org/10.1007/s10195-013-0264-9. (DOI)	2013.	Italy, single-center.	Total knee replacement.	100.	Age, sex, BMI, comorbidities, ASA, blood transfusion, postoperative analgesia protocol, physiotherapy protocol, day of surgery, surgical access.	ASA, BMI, blood transfusion, age.	Length of hospital stay.	Observational, retrospective.	Monocentric database.
28583060. (PMID)	2013.	United States, two centers.	Total hip or knee replacement.	189.	Age, sex, race, PCS, Medical Outcomes Study Social Support Scale (MOSS-SS).	Sex, race, PCS, MOSS-SS.	Length of hospital stay.	Observational, prospective.	Multicentric database.
https://doi.org/10.1007/BF03337745. (DOI)	2011.	Italy, single-center.	Total hip or knee replacement.	214.	BI at rehabilitation admission.	BI at rehabilitation admission was not predictive.	Length of rehabilitation unit stay (30 days or more).	Observational, retrospective.	Monocentric database.

Table 2. *Cont.*

Publication Identifier *	Year	Setting	Arthroplasty Procedure	Population	Intervention.		Outcome	Type of Study	Data Linkage
					Potential LOS Predictors	Actual LOS Predictors			
https://doi.org/10.1016/j.rehab.2009.01.001. (DOI)	2009.	France, single-center (single rehabilitation center, receiving patients coming from five hospitals).	Primary total knee arthroplasty in absence of complications.	244.	Age, sex, living alone, home help, previous leg arthroplasty, comorbidities, walking distance and autonomy before surgery, pain level, surgical ward LOS, IKSS (combining CROMs and PROMs), Lequesne Index.	Sex, living alone, home help, previous leg arthroplasty.	Length of rehabilitation unit stay.	Observational, retrospective.	Monocentric database.
https://doi.org/10.1302/0301-620X.91B4.21505. (DOI)	2009.	Scotland, single-center.	Unilateral primary total hip replacement.	2302.	Age, sex, BMI, operation day of the week, year of admission, knees, back and other musculoskeletal problems, comorbidities, ischemic heart disease, diabetes, pre-operative use of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs), pre-operative use of Aspirin, smoking status, pre-operative hemoglobin level, consultant code, Scottish Index of Multiple Deprivation, Harris Hip Score (HHS)-combining PROMs and CROMS, Short-Form 36 (SF-36).	Age, sex, pre-operative use of NSAIDS, surgeon performing the operation, operation day of the week, year of admission, HHS–function and activity, SF36 -general health perception.	Length of hospital stay.	Observational, retrospective.	Monocentric database.

* The Digital Object Identifier (DOI) is the preferred identifier. Whether a DOI was not available, although the manuscript is accepted and published, a PubMed IDentifier (PMID) is reported. In case of studies registered on ClinicalTrials.gov, the National Clinical Trial (NCT) identifier is reported.

3.1. Predictive Factors of Inpatient Rehabilitation Stay

The results of the literature review are grouped in Table 3, representing the number of factors investigated ("Analyzed") and actually found to be predictive ("Predictive"). These factors are divided per time of assessment through the perioperative pathway ("Pre-existing patient characteristics; Pre-operative factors; Intra-operative factors; Post-operative factors") and surgical procedure site ("Knee procedures; Hip procedures; Both procedures in the same study").

Pain was considered separately from other Patient-Reported Outcome Measures (PROMs), being a core symptom of osteoarthritis. BI was also considered separately from other Clinician-Reported Outcome Measures (CROMs), because of the regulatory importance it may have in allowing or not allowing hospital discharge [37]. The resulting PROMs employed for predictivity analysis were EQ-5D, GDS, HOOS-JR, IPAQ–Short Form, KOOS-JR, LEAS, Lequesne Index, MOSS-SS, OKS, PCS, PROMIS-Mental and Physical Health, SF-36, Veterans RAND-12 Items core–Mental and Physical Health, and WOMAC-function. The resulting CROMS employed for predictivity analysis were the Braden Scale, FIM, HHS, KSFS, NSQIP–Functional Status, MMSE, and Morse Fall Scale. IKSS combines both Patient-Reported and Clinician-Reported Measures; therefore, it was included in both categories.

Among the pre-existing patient characteristics analyzed, age was the most common predictive factor (7 times predictive up to 13 times investigated), followed by caregiver presence (4 up to 6), sex (4 up to 10), occupation, race, previous leg arthroplasty, use of drugs (NSAIDS, Aspirin), heart disease (1 up to 1), CCI (1 up to 2), anatomical region affected in case of same-study hip and knee population (1 up to 3), and general presence of comorbidities (2 up to 9). Area of residence, blood-borne transmissible infections, chronic steroid use, other specific comorbidities, educational level, marital status, payer status, Scottish Index of Multiple Deprivation, and smoking status demonstrated no predictive value in the studies included.

Among the pre-operative factors analyzed, PROMs (pain excluded) were 3 times predictive up to 15 times investigated, followed by composite scores (2 up to 3), CROMs (2 up to 8), BMI (2 up to 11), hospitalization year (1 up to 1), non-operated limb weight (1 up to 1), pain catastrophizing (1 up to 2), pain (1 up to 4), clinical chemistry (1 up to 6) and ASA score (1 up to 8). Expectations on pain and function, performance, physical activity measures, prehabilitation, and vital signs demonstrated no predictive value in the studies included.

Among the intra-operative factors analyzed, the operating surgeon was 1 time predictive up to 1 time investigated, followed by day of surgery in the week, duration of surgery/operational time, and blood loss/transfusion(s) occurred (1 up to 3). Surgical access technique and type of anesthesia demonstrated no predictive value in the studies included.

Among the post-operative factors analyzed, BI was 2 times predictive up to 3 times investigated, followed by physical activity measures (1 up to 1) and verticalization day (1 up to 2). Analgesia protocol, autonomy in ADL (BI excluded), autonomy in postural transitions, clinical chemistry, cognitive function, composite score, pain, performance measures, physiotherapy protocol, PROMs, surgical ward LOS, and walking autonomy and/or distance demonstrated no predictive value in the studies included.

Table 3. Predictive factors of inpatient rehabilitation stay data chart.

Category	Analyzed	Predictive	Analyzed in Knee Procedures	Analyzed in Hip Procedures	Analyzed in Both Procedures in the Same Study
Pre-Existing Patient Characteristics.					
Age.	13	7	5	4	4
Anatomical region affected (hip or knee).	3	1			3
Area of residence.	1			1	
Blood-borne transmissible infection.	1				1
Caregiver presence (not in a composite score). *	5	3	4		1
CCI.	2	1		1	1
Chronic steroid use.	1			1	
Comorbidities (general presence).	9	2	5	4	
Comorbidities (specific: diabetes, heart disease, other musculoskeletal problems).	4	1	1	3	
Educational level.	1			1	
Marital status.	1			1	
Occupation.	1	1			1
Payer status.	1				1
Race.	1	1			1
Previous leg arthroplasty.	1	1	1		
Scottish Index of Multiple Deprivation.	1			1	
Sex.	10	4	4	3	3
Smoking status.	3			2	1
Use of drugs (NSAIDs, Aspirine).	1	1		1	
Category.	**Analyzed.**	**Predictive.**	**Analyzed in knee procedures.**	**Analyzed in hip procedures.**	**Analyzed in both procedures in the same study.**
Pre-operative factors.					

Table 3. *Cont.*

Category	Analyzed	Predictive	Analyzed in Knee Procedures	Analyzed in Hip Procedures	Analyzed in Both Procedures in the Same Study
ASA score.	8	1	2	1	5
BMI.	11	2	5	3	3
Clinical chemistry. **	6	1	3	3	
Composite scores (e.g., RAPT).	3	2		1	2
CROMs. ***	8	2	2	6	
Expectations on pain and function.	1		1		
Hospitalization year.	1	1		1	
Non-operated limb weight.	1	1		1	
Pain.	4	1	2	1	1
Pain catastrophizing.	2	1	1		1
Performance measures. ****	4		4		1
Physical activity measures.	2		2		
Prehabilitation.	2		1		1
PROMs (pain excluded). ***	15	3	7	1	7
Vital signs.	1			1	
Walking autonomy and/or distance (separated from composite scores).	1		1		
Intra-operative factors.					
Blood loss amounts/transfusion(s) performed.	3	1	1		2
Day of surgery in the week.	3	1	1	1	1
Duration of surgery/operational time.	3	1		1	2
Surgeon.	1	1		1	
Surgical access technique.	1		1		
Type of anesthesia.	4			1	3
Category.	**Analyzed.**	**Predictive.**	**Analyzed in knee procedures.**	**Analyzed in hip procedures.**	**Analyzed in both procedures in the same study.**
Post-operative factors.					

Table 3. *Cont.*

Category	Analyzed	Predictive	Analyzed in Knee Procedures	Analyzed in Hip Procedures	Analyzed in Both Procedures in the Same Study
Analgesia protocol.	1		1		
Autonomy in ADL (multiple measures, Barthel excluded).	1				1
Autonomy in postural transitions.	1				1
Barthel Index (original or modified).	3	2	1		2
Clinical chemistry. **	1				1
Cognitive function.	1				1
Composite scores (e.g., RAPT).	1		1		
CROMS. ***	1		1		
Pain.	1				1
Performance measures. ****	2		2		
Physical activity measures.	1	1			1
Physiotherapy protocol.	1		1		
PROMs (pain excluded). ***	2		2		
Surgical ward LOS.	2		1		1
Verticalization day, including moving away from bed.	2	1			2
Walking autonomy and/or distance (separated from composite scores).	2	1			2

* Including living status, alone or not, number of household members, home help. ** Including albumin, haemoglobin, haematocrit, platelets, prothrombin time, fasting glucose, creatinine and urea, serum cytokine. *** The use of CROMs and PROMs in different populations is reported for every single questionnaire administered. For example, if one study on a knee population investigates the predictive factor of three different PROM questionnaires, the table reports the use of PROMs three times in knee procedures, although they are used in the same study. **** Including TUG, strength, Five times sit to stand test, one leg balance test, walking distance, waking autonomy.

In total, 17 studies included surgery and rehabilitation in a single hospital LOS. Eight studies considered inpatient rehabilitation LOS separately, either in the same hospital (e.g., patients moved from the surgical ward to an internal specialized rehabilitation unit) or in a separate facility (e.g., physical medicine and rehabilitation center). Among the latter, two studies considered surgical ward LOS as a potential predictor for inpatient rehabilitation LOS: one in which surgical stay and specialized rehabilitation stay were part of the same inpatient consecutive pathway, in the same orthopedic hospital [38], and another in which a specialized rehabilitation center received patients from five different hospitals [39].

Coudeyre et al. [30] considered the place of discharge after surgical ward stay as a primary study outcome (home vs. physical medicine and rehabilitation center), and a composite RAPT score as a potential predictor. An RAPT score greater than 9 was found to be actually predictive of home discharge. Among the 25 patients with an RAPT score greater than 9, 5 patients were actually discharged to a physical medicine and rehabilitation center, as they lived in rural, remote areas. These patients had a significantly shorter inpatient rehabilitation LOS than other patients in the same cohort. Therefore, an RAPT score greater than 9, combined with living in an isolated location, was predictive of a shorter inpatient LOS compared with other patients who underwent rehabilitation in an external physical medicine and rehabilitation center. Then, the study was eligible for inclusion.

3.2. Data Collection and Linking

In total, 14 studies were conducted retrospectively and 11 studies were conducted prospectively. In total, 20 studies were completed, and 5 were protocols. Skov et al. [22] and Skov [40] are possibly duplicates of the same study protocol, the former in the version of a clinical trial registration and the latter in the version of a peer-reviewed publication, as the only slight difference is the expected population size (150 vs. 200). In total, 21 studies were observational and 4 were interventional (randomized controlled trials, RCT).

In terms of data management and source, prospective data collection was performed seven times through a monocentric database and three times through a multicentric database, in all cases based on a hospital database. Two of these [22,40] are possibly duplicates of the same protocol. No prospective data collection was performed through an inpatient rehabilitation facility. Retrospective data collection was performed nine times through a monocentric database and three times through a multicentric database. Two of the nine retrospective studies based on a monocentric database retrieved data from a specialist inpatient rehabilitation facility [39,41]. No studies retrieved data from institutional registries. One study retrieved data from a scientific society registry [42].

More specifically, regarding the way these data were collected and linked, among the prospective studies, eight involve specific data collection that is not further detailed. One RCT protocol [43] involves electronic data collection with RedCap software. Two observational, completed studies involved multiple sources of collection and dedicated data linking (internal clinical records, administrative database, and further specific data manually collected) [44,45]. Dedicated data linking means that no pre-established platform existed to allow for routine data collection (e.g., an electronic, integrated health record system), but the dataset is created specifically for the single study and progressively populated.

Among the retrospective studies, 12 used internal data; 5 collected data from clinical records, 5 collected data from an administrative database, registry, or both, and 2 used manually linked data. One drew data from the multicenter registry of a professional society[44] and one used a single hospital's internal data without providing further details [46]. Data collection and linking are represented in Table 4.

Table 4. Data collection and linking.

Prospective Data Collection		
Data Management	**Data Source: Hospital**	**Data Source: Inpatient Rehabilitation Facility**
Professional/scientific society registry.		
Institutional registry.		
Monocentric database.	7	
Multicentric database.	4	
Retrospective data collection.		
Data management.	**Data source: hospital.**	**Data source: inpatient rehabilitation facility.**
Professional/scientific society registry.	1	
Institutional registry.		
Monocentric database.	9	2
Multicentric database.	2	

4. Discussion

Inpatient rehabilitation protocols are fairly standardized [47,48] and so can be the criteria for whether or not to authorize discharge depending on local regulation [37,39]. However, no literature reviews specifically investigate the predictive factors of inpatient rehabilitation LOS to our knowledge, despite the promising advancements of information technology. Moreover, the majority of studies resulting from this research did not distinguish between inpatient rehabilitation stay and acute or surgical stay, despite the necessity of developing specific model predictions of inpatient rehabilitation LOS [5,39].

Older age was the most frequent predictor of post-operative inpatient rehabilitation, both considered alone and associated with other perioperative factors, including pre-operative function (assessed with Clinician-Reported Outcome Measures) [42,49], performance (walking autonomy, distance, aids) [19,30], comorbidities (either in general or aggregated by CCI index) [10,37,50,51] and presence of a caregiver providing extra-hospital support [37–39]. This is in line with the literature [16,52–57] and supports the recommendation to consider age as part of a more comprehensive, pre-operative assessment, including potentially confounding factors like function and burden of care [58]. Interestingly, all the studies included here that found extra-hospital support as a predictor of postoperative LOS specifically considered inpatient rehabilitation unit LOS [37–39], while the studies that did not find such a factor predictive generally used postoperative hospital LOS [3,59]. This finding suggests increasing awareness towards the key role played by social support in rehabilitation outcomes [60].

The presence of extra-hospital, social, and household support was also recalled to hypothesize why male patients tend to have shorter LOS after hip and knee replacements in comparison to females [61–63], as having someone who cares for them at home more frequently can increase the motivation to leave the hospital [64]. Females having longer postoperative LOS is consistent with the results of this review, according to four multivariate analyses, two focusing specifically on the inpatient rehabilitation unit [37,39] and two using general hospital LOS [50,65]. Regardless of the reasons that may explain this trend, it is prudent to consider the possibility of an extended LOS when patients undergoing rehabilitation are females. If the hypothesis about having a caregiver at home less frequently is true, taking into consideration the need for support as early as possible could improve safety and reduce inpatient stays.

Taking social factors into consideration could also have made the RAPT score more predictive [19,29] than other composite scores, including age, sex, comorbidities, and early post-operative performance [50]. The RAPT score was originally developed to predict the need for extended inpatient rehabilitation stay, combining age, sex, preoperative functional capacity with or without technical aids, social support at home, living alone, and patient's preference towards discharge destination into a single, numerical output; the higher the score, the higher the possibility of prosecuting a rehabilitation outpatient, stratifying patients into three levels of risk (high, intermediate, and low) [65].

In the two articles of this review where the RAPT score was investigated, however, it also demonstrated predictive value in terms of inpatient rehabilitation LOS. LeBrun et al. [19] found RAPT to be a strong predictor of postoperative inpatient LOS even after controlling for other relevant covariates, testing the score on almost 18,000 patients, of whom 92% were discharged home. Coudeyre et al. [30] found an RAPT score ≥9 to be predictor of home discharge; however, among the patients actually being clinically ready for home discharge, 20% were unable to comply with outpatient rehabilitation because of disadvantaged home arrangements, and were transferred to a physical medicine and rehabilitation unit, where they reported a shorter LOS in comparison to the inpatient rehabilitation LOS of other patients, presumably discharged here primarily because of a clinical need.

Interestingly, the possibility of using the score by modulating thresholds and patient characteristics makes the prediction adaptable to the local healthcare system needs [66,67]. The focus on key functional and social domains made the RAPT practical for routine preoperative assessment, with a good performance on predicting discharge destination in high-risk or low-risk patients; however, the predictive value seems to diminish in the case of intermediate-risk patients, losing granularity between the extremes [68–70]. Taking advantage of big data analysis, machine learning, and electronic health records, possibly combined [71], can provide more accurate predictions for more clusters of patients, intermediate risk included.

No singular PROM or CROM questionnaire resulted in predictive inpatient rehabilitation LOS in more than one study, either pre-operative or post-operative. Considering PROMs and CROMs on an aggregate level, three pre-operative PROMs (PCS; MOS-SS; SF-36-general health perception) demonstrated predictive value in two studies [50,72], and two pre-operative CROMS (HHS–function and activity; NSQIP–Functional Status) demonstrated predictive value in two studies [43,50]. All the results of this review investigated the predictive value of PROMs (either pre-operative and post-operative) along with other objective factors, including inpatient rehabilitation stay as a separate outcome from surgical ward stay [40,73]. Thanks to the possibility of integrating PROMs in routine clinical workflow [74], the use of PROMs as predictors of post-operative LOS reported good-to-fair results in large populations. For instance, pre-operative PROMs (EQ-5D-5L, EQ-Visual Analog Scale, HOOS-PS, KOOS-PS, PROMIS-Fatigue and Depression Short Forms) collected on almost 5,000 hip and knee replacements demonstrated predictive value for post-operative LOS when analyzed with machine learning and regression models, providing cues to clinicians and healthcare administrators for capacity planning, patient expectation management, and patient risk management [75]. Also, the integration of ordinary clinical workflow records and a dedicated PROM database into a patient-centered, perioperative pathway (including post-discharge follow-up at 3 months) could predict the ideal rehabilitation protocol even before the assignment of surgery based on a machine-learning, second opinion [76]. On the contrary, pre-operative PROMs (KOOS-JR, PROMIS-Mental and Physical Health) collected on almost 3,000 knee replacements could predict extended postoperative stay, but not as effectively as the RAPT score did [77]. However, two of these studies [75,77] did not distinguish between surgical ward rehabilitation and specialist inpatient rehabilitation stay (in the same hospital or elsewhere).

In terms of predictive, pre-operative CROMs, both the questionnaires included in this review assessed patient function before surgery (HHS–function and activity; NSQIP–Functional status), both were collected from patients undergoing hip replacement, and both measured inpatient rehabilitation stay without distinguishing between the surgical ward and the specialist unit [43,50]. The introduction of prehabilitation in hip and knee elective arthroplasty is based on the hypothesis that functional improvement before surgery improves recovery outcomes [78], post-operative LOS reduction included [79,80], although the beneficial effect of prehabilitation itself in reducing postoperative LOS remains controversial [81–84]. In order to better understand the extent to which prehabilitation can reduce postoperative LOS while also improving postoperative outcomes (e.g., pain and function) [79,82], it would be important to capture whether postoperative recovery measures are limited to surgical ward rehabilitation or extended rehabilitation units, specifying the facility where inpatient rehabilitation is provided, both in primary studies and in meta analyses or systematic reviews.

Pre-operative BMI also resulted predictive of inpatient rehabilitation stay in this review. The role played by BMI in the spread of osteoarthritis is generally accepted [85] and used for planning operating lists, in combination with other factors [86]. Both the studies in which BMI demonstrated predictive value were conducted on knee arthroplasty, one considering general hospital stay [46], and one distinguishing between surgical ward and specialist rehabilitation unit 38]. The former study found that BMI $\geq$ 25 predicted 2.3 more hospitalization days, while the latter study found that BMI $\geq$ 30 predicted one fewer rehabilitation unit and overall hospitalization day (surgical ward followed by specialist unit). The other nine studies that investigated BMI in this review did not find such a variable to be predictive. These findings not only confirm the controversial relation between overweight and postoperative LOS [87–89], but possibly make it even more controversial, as being overweight had a protective value in terms of inpatient rehabilitation stay, not explainable by a concurrent extension of surgical ward stay, as this latter factor did not vary in relation to BMI [37].

BI (and subsequent modifications) is a rank-order scale that measures disability impairments to complete ADL, and as such, it is used to measure rehabilitation improvements after surgical interventions [90]. The higher the score, the more independent the patient is in completing ADL, and in turn, the more likely the patient is to return home after a hospital stay. A total score $\geq$ 75 is commonly considered enough to discharge a patient at home, and along with a 30% improvement from inpatient rehabilitation to discharge, it is used as a threshold to authorize patient discharge in orthopedic hospitals of Italy. This is a reasonable explanation of why all the studies that adopted postoperative BI as a potential predictor of inpatient rehabilitation stay are all based in the same region, and all these studies (one concerning hip and knee procedures, two concerning knee procedures only) specifically measured inpatient rehabilitation unit stay [37,38,48]. Two of them adopted inpatient rehabilitation stay in a specialist unit as a primary outcome, and found such a factor to be predictive (the higher the score, the shorter the LOS) [38,48].

Multicentric databases were more often employed in prospective studies (4 times up to 11) than in retrospective studies (2 times up to 14). *Planning* data collection from more than one facility is actually more common and easier than *retrieving* data from multiple facilities, which needs post hoc standardization procedures. Institutional registries sharing data from more facilities should facilitate data standardization and retrieval. However, no studies resulting from this review employed such registries, including prospective studies. Only Raad et al. [42] retrieved data from the Registry of a Scientific Society, adding useful clinical information for research and quality improvement than insurance-based administrative databases [36]. Monocentric databases were fairly distributed between prospective studies (7 times up to 11) and retrospective studies (9 times up to 14). Monocentric databases should be easier to employ as long as data collection does not need the same standardization efforts that are needed among different facilities.

Only two studies, both retrospective, retrieved data from monocentric rehabilitation facilities. This may suggest an underdeveloped data infrastructure in specialist rehabilitation centers compared to acute hospitals. Shedding more light on these facilities could improve patient's health monitoring after hospital discharge, possibly using integrated (and therefore multicentric) datasets accessible by different healthcare providers (e.g., hospital surgeon, inpatient rehabilitation specialist, outpatient rehabilitation specialist, and general practitioner), researchers, healthcare administrators, and policy makers (e.g., to capture gaps in care continuity and find locally fit solutions). The role of digitalization in promoting user-friendly, integrated health records here is clear, along with the role of AI and machine learning analyses in support of patient stratification, outcome prediction, and continuity of care planning and strengthening [24], provided adequate protection measures.

This review has a number of limitations. First, the results of predictive analyses depend on the model. Second, multiple factors represented in Table 3 were predictive in only one study or a few more. Third, none of the studies included completed an external validation process, confirming the model's predictivity in another population [25]. However, we recall that the goal of this scoping review was not to provide evidence-based guidelines for developing ready-to-use prediction models in any context, nor to assess study quality and bias in support of clinical interventions. Rather, the goal was to review the existing practices in order to help healthcare professionals, researchers, and policy makers develop (or improve) specific prediction models in specific situations, having access to similar real-world studies (musculoskeletal population, facility setting, rehabilitation pathway, data management, local regulation, factors most relevant, and factors available). Any time a certain predictor in a certain context seems relevant to the needs of the reader, it is possible to read the methodological details of each study and take them into careful consideration before replying.

5. Conclusions

The idea behind real-world patient stratification for outcome prediction is that we should not seek the optimal outcome (in this case, inpatient rehabilitation LOS) for any patient, in any situation, but the realistic rehabilitation outcome for a certain type of patient, in a certain clinical, social, and organizational context, driving the most appropriate clinical and policy arrangements.

Age, caregiver presence, presence of comorbidities, sex, BMI, RAPT composite score, pre-operative CROMS, pre-operative PROMs, and post-operative Barthel Index were predictive to some degree of inpatient rehabilitation LOS in more than one study. The studies were fairly distributed between retrospective and prospective, with multicentric databases more spread among the latter. Data collection occurred in acute hospitals more than in specialized rehabilitation facilities.

- Using comprehensive models supported by electronic health records and powerful information technologies;
- Analyzing specific inpatient rehabilitation LOS as distinguished from surgical ward rehabilitation;
- Using institutional registries, and including specific rehabilitation factors in these registries;

- Promoting vocabulary standardization (including inpatient rehabilitation LOS across different countries) and federated data sharing;
  The above can strongly enhance the predictivity of models investigating rehabilitation outcomes and support earlier discharge from acute wards when appropriate.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app152211957/s1, File S1: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist.

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Abbreviations

The following abbreviations are used in this manuscript:

ADL	Activities of Daily Living
ASA	American Society of Anesthesiologists
BI	Barthel Index
BMI	Body Mass Index
CCI	Charlson Comorbidity Index
CROMs	Clinician-Reported Outcome Measures
EQ-5D	EuroQol-5 Dimensions
FIM	Functional Independence Measure
GDS	Geriatric Depression Scale
HHS	Harris Hip Score
HOOS-JR	Hip dysfunction and Osteoarthritis Outcome Score–Joint Replacement
IKSS	International Knee Society Score
IPAQ	International Physical Activity Questionnaire
KOOS-JR	Knee dysfunction and Osteoarthritis Outcome Score–Joint Replacement
KSS	Knee Society Score
LEAS	Lower Extremity Activity Scale
LOS	Length Of Stay
MMSE	Mini-Mental State Examination
MOSS-SS	Medical Outcomes Study Social Support Scale
NICE	National Institute for health and Care Excellence

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