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ORIGINAL RESEARCH ARTICLE

Force and Power Testing During Anterior Cruciate Ligament Reconstruction Rehabilitation: A World-Wide Survey of Current Practices

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Abstract

Background During rehabilitation, the importance of restoring strength and power in a stage-based framework highlights the paramount role of testing and monitoring. Despite theoretical understanding of an optimal recovery pathway, it is unclear and inconsistent as to how practitioners implement force and power assessment following anterior cruciate ligament reconstruction (ACLR).

Objectives We aimed to examine current worldwide practices with evaluating patients post-ACLR, identify the relative utilisation of different devices and methodologies across the rehabilitation process, and to explore the interactions between the implemented devices and respondents' self-perceived testing quality (evaluated by participants via a Likert scale).

Methods Data were collected via an international online survey composed of 100 items, organised across 12 sections, exploring the demographics of respondents and implemented testing devices to assess individuals after ACLR and their perceived testing quality.

Results A total of 1154 practitioners from 78 different countries completed the survey. According to the pre-defined eight categories, 157 different combinations were recorded among practitioners. Respondents tended to use multiple devices (95.8%), with a mean of 3.6 ± 1.4. Patient assessments were most often repeated longitudinally throughout the recovery process post-ACLR (96.4%). Specific devices were used as part of "criteria-based" testing by 46.4% of respondents, "criteria- and time-based" testing by 30.8% and solely "time-based" testing by 21.9%. A significant but weak direct correlation was observed between the number of implemented devices and self-perceived testing quality ($\rho = 0.32$, $p < 0.001$), with force plates, an isokinetic dynamometer, Nordic hamstrings device and a hand-held dynamometer significantly associated with increased self-perceived testing quality ($R^2 = 0.21$, $p < 0.001$).

Conclusions A high degree of variability in test device implementation existed among practitioners. According to the eight pre-defined device categories, over 150 different device combinations were recorded among respondents. Device use was different throughout the stages of rehabilitation and testing was primarily performed as criteria to advance patients throughout the recovery process. While acknowledging that these findings may be influenced by self-serving bias, they suggest that practitioners involved in force and power testing post-ACLR may benefit from implementing a wide range of devices, including more quantitative and objective instruments such as force plates and the isokinetic dynamometer, as these appeared to be related to higher levels of self-perceived testing quality.

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Key Points

A high degree of variability in device implementation has been recorded among practitioners involved in force and power testing in patients after anterior cruciate ligament reconstruction.

Almost half of practitioners structured their testing process using a criteria-based approach, while only one in five relied solely on time.

Both the number and the type of devices implemented during the recovery process of anterior cruciate ligament reconstruction patients are related to practitioners' perceived testing quality. The use of multiple devices, including quantitative and objective instruments such as force plates and an isokinetic dynamometer, tend to lead to higher levels of practitioner satisfaction.

1 Introduction

Anterior cruciate ligament (ACL) ruptures are severe injuries that may lead to devastating consequences in both athletic and general populations [1]. Surgical intervention is typically implemented as a primary treatment, with ACL reconstruction (ACLR) being the preferred treatment option, accounting for roughly one million completed worldwide each year [2]. Recovery outcomes post-ACLR are concerning, with reported reduced quality of life [3–5], including poor knee functioning and a higher incidence of early-onset knee osteoarthritis [6]. Recovery times post-ACLR are long for both recreational (typically $\geq$ 12 months) [7] and professional (usually 6–12 months) athletes [8, 9], often with limited return-to-sport (RTS) rates [1] and a high risk of re-injury [10–12].

Evidence has attempted to provide guidance to improve outcomes post-ACLR, suggesting a staged approach to rehabilitation [13, 14], including pre-operative, early-stage [15], mid-stage [16], and late-stage [17] rehabilitation, followed by an RTS continuum [18, 19] with criteria-based progression. In recent years, the importance of restoring neuromuscular performance (*considered an umbrella term including maximal muscle strength, muscle endurance, power, rate of force development [RFD] and stretch–shortening cycle [SSC] function, as well as kinetic outputs during functional tasks such as landing, jumping and change of directions*) was highligted as an important rehabilitation and RTS theme [17]. Assessment of several of these properties, such as maximal [20], and explosive strength (termed RFD) [21], as well as power [22], have been recommended to support rehabilitation progression and RTS decision making. In particular, maximal strength, especially of the knee extensors and flexors, is one of the most recommended aspects to assess, with multiple studies underlying its relevance to reduce re-injury risk [10, 23], improve functional outcomes [10, 24], support rehabilitation progression [25] and reduce the onset of knee osteoarthritis [26].

Despite the theoretical understanding of an optimal recovery pathway and suggested metrics to assess different socioeconomic and cultural factors [27], such as financial constraints, working sector (private vs public), rehabilitation expectation, geographical access, and clinical expertise, among others, these could pose barriers to test implementation in clinical practice. Furthermore, several assessment methodologies and equipment to assess neuromuscular performance indicies are available (e.g. isokinetic dynamometer [IKD], hand-held dynamometer, isotonic machine, force plate) [28–30], potentially contributing to heterogeneity in testing batteries, outcome measures and analysed metrics. The challenge from a practitioner perspective is to understand what neuromuscular properties should be assessed, and how to accurately assess them within their clinical practice settings. Thus, there is a need to understand practitioners current force and power assessment practices implemented with their recovering patients.

A growing number of published surveys have recently investigated specific aspects of the rehabilitation process, including surgical preferences [31, 32], progression criteria concerning a specific task (e.g. running) [28, 33–37], general practices [28, 33, 34, 36–39] and tests implemented at the RTS stage [28, 33, 34, 36–42]. Yet these studies are often limited by the number of participants, restricted geographic location responses, inclusion of only a single profession (e.g. physiotherapist or surgeon), or by being either too narrow (e.g. RTS focus) or too broad, thereby losing depth when assessing several domains throughout the whole recovery process (e.g. mobility, strength, movement quality). Our study, designed as a survey to be administered to practitioners working with ACLR patients, was aimed to: (1) identify rates of utilisation of different devices and metrics for assessing force and power post-ACLR; (2) report the use of instruments across the rehabilitation process; and (3) investigate potential interactions between the implemented devices and participants' self-perceived force and power testing quality. This information can provide a better understanding of the neuromuscular tests currently implemented by practitioners post-ACLR, highlight the research-practice gap, and set the foundation for future research aimed at enhancing clinical practices and ameliorating patients' outcomes.

2 Methods

2.1 Study Design

Data were collected via an international online survey. Because of the explorative nature of this study, a survey was selected to access a large population, ensure effective data collection and increase rates of truthful shared information owing to the study's anonymous nature [43]. Ethical approval was obtained through the STHS Ethics Committee of St Mary's University, Twickenham, London, UK (SMU_ETHICS_2023-24_366), in December 2023.

2.2 Survey Development

Five individuals highly specialised in managing the testing and recovery process of ACLR patients collaborated to develop the survey: a physiotherapist, a sports scientist, a sports medicine physician and two university sport science academics. The survey was developed through the JISC Online Surveys platform and underwent a series of modifications based on input from collaborators through two rounds of piloting. In the first round, the survey was shared among five additional experienced applied researchers/practitioners involved in ACLR rehabilitation and testing to assess face validity, clarity and usability. Collectively, five professionals with previous experience in designing and conducting survey-based research contributed to the project. The second pilot involved six trusted practitioners of different professions who completed the survey, the results of which were then analysed by the author team to assess and familiarise with the data extraction procedures. When developing the survey, which was to be distributed worldwide across professionals with distinct jobs, educational background and geographical location, the author team thoroughly discussed the importance of terminology to ensure clarity. As the term "neuromuscular assessment" lacks consensus in its definition in the literature, and could be misinterpreted by practitioners, we used the more commonly utilised terms "force and power", which constitute the base of a neuromuscular assessment. As this survey aimed to explore the utilisation of different devices across the population, it was structured around the adopted devices, allowing participants to easily navigate the survey sections and skip those not relevant to their practice. Categories based on device implementation were defined a priori, relying on clinical and research experience of all the authors, and additionally refined in the following survey development steps *(expert opinions and piloting).* Testing categories were organised as follows. (1) Manual muscle testing (MMT), which was conceived as a "non-instrumented" test category, where the practitioner's hands served as an "assessment tool"; (2) IKD, which included the use of the IKD device to assess patients via any contraction mode; (3) hand-held dynamometer (HHD); (4) fixed frame isometric device; (5) Nordic hamstrings device; and (6) isotonic machines, free weights and bodyweight devices, consisting of tests performed using isotonic machines (e.g. leg extension, leg press leg curl), free weights (dumbbells, barbells) and bodyweight exercises (e.g. glutes bridges, heel raises, sit-to-stand; excluding jumping tasks); (7) force plates, including the execution of any tasks, such as isometric testing, sport-specific tasks (e.g. deceleration, change of direction) and jump assessment; (8) jump and hop assessment devices (without a force plate). This last category includes all the devices used to assess jump and hops (displacement-based devices such as use of tape, Vertec and wall reach), excluding the use of a force platform, which constitutes a separate category. The rationale for the creation of this category separated from the force plates lies in the fact that the devices grouped in this category provide derived performance outcomes such as flight time, displacement or estimated jump height, without considering the kinetic component of the task, available through force platform technology, leading the authors to create two separate categories. Furthermore, the inclusion of this category was supported by previous published research, reporting that between one third and almost half of practitioners estimate knee strength from measures such as hop capacity post-ACLR [38, 39]. Finally, as the survey covered the whole rehabilitation continuum, and no consensus has been established on how different phases of the rehabilitation should be defined, we provided a stage-based definition informed by previous published evidence [13, 15–19], as follows: early stage, often referred to as the "acute" or "inflammatory stage", is defined as the immediate post-operative period that usually lasts until the resolution of the acute symptoms (around 4–6 weeks). Mid-stage is defined as the period from the resolution of the acute symptoms to when the patient is engaged in late-stage rehabilitation tasks (e.g. sport-specific rehabilitation, plyometrics, sprinting). Late stage is defined as the period that proceeds the return to training with the team, and in this phase, patients practice in their familiar sport environment (e.g. on-field rehabilitation) but still in a controlled and restricted manner. The RTS process is defined as the continuum of sport-specific rehabilitation (e.g. on-field rehabilitation), followed by a return to training, return to play and ultimately a return to performance. The final version of the survey (Electronic Supplementary Material [ESM]) included a total of 100 items (59% multiple-choice questions, 41% open questions) organised into 12 sections: (1) introduction; (2) demographics; (3–10) nine areas based on the above described implemented testing devices; (11) other tests and devices; and (12) final considerations.

2.3 Survey Distribution

The survey was open to any practitioner aged ≥ 18 years who was involved in rehabilitation of at least one ACLR patient per year. The online survey was anonymous and available for completion in April–July 2024. The estimated duration of the survey was 5–15 min depending on the practitioner's implemented testing process. Participants were recruited using different strategies, including direct contact from the authors' team via e-mail, in-person invitations during scientific conferences and distribution via social media platforms (e.g. LinkedIn, Facebook, Instagram). Social media dissemination was further amplified by the authors and other members of the scientific community by re-sharing the invite to participate within their network, which broadened the survey's reach.

2.4 Data Extraction and Analysis

Raw data were exported into Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) for statistical analysis. Closed questions were assessed using frequency, rate and rank analysis. As the responses for open-ended questions were optional, brief and often disconnected, they did not allow for the development of complex themes and robust thematic analysis. Accordingly, these answers with their relative response rates are presented in the ESM in table format without statistical interrogation. Additionally, answers to the final questions related to the changes that participants would have made in the absence of any constraints were grouped by similarity and divided into descriptive categories (e.g. acquiring new equipment, adding new tests), and reported in the results section to facilitate the accessibility to these findings to the reader. A device implementation trend analysis was conducted across three transition key points specific for criteria-based rehabilitation: (1) early to mid-stage; (2) mid-stage to late stage; and (3) late stage to RTS, according to recommended published stage-based guidelines [13, 15–17, 19]. Linear trend statistical significance was inspected through the Cochran–Armitage test. In the absence of a statistically significant linear trend, the chi-squared test was used to inspect the differences in use frequency between the single key points, and *p*-values were adjusted through Bonferroni correction. A secondary analysis was conducted in SPSS Version 24.0 (IBM Corporation, Armonk, NY, USA) to investigate how the number of devices implemented by practitioners impacted their self-perceived testing quality (scored on a Likert scale: 1 = insufficient, 2 = poor, 3 = reasonable, 4 = good, 5 = excellent). Spearman's rank correlation coefficient ρ was used to assess the relationship between the number of implemented devices and self-perceived testing quality. Correlation was considered weak ($\rho < 0.40$), moderate ($\rho = 0.40$–0.75) or excellent ($\rho > 0.75$) [44]. A multiple regression analysis with a stepwise approach ($p < 0.05$ in, $p > 0.1$ out) was performed to inspect the association between self-perceived testing battery quality (dependent variable) and implemented devices (factors). R2 and standardised coefficients with 95% confidence intervals (CIs) are presented alongside *p*-values.

3 Results

3.1 Respondent Profile

A total of 1154 practitioners from 78 different countries completed the survey. Respondents had a mean experience of 8.7 ± 7.6 years. Demographic and professional characteristics are shown in Table 1, and all collected demographic data are included in the ESM.

3.2 Implemented Devices and Tests

Anatomical areas assessed, symmetry analysis, frequency of testing and reasoning for implementation (time-based vs criteria-based approach) are detailed in Table 2. Figure 1 reports the percentage of implementation percentages of the different pre-defined device categories among respondents. When investigating how respondents integrated utilisation of these different tools, 157 combinations were recorded. Respondents tended to use multiple devices ($n = 1106$, 95.8%), with a mean of 3.6 ± 1.4 instruments. Further information on the adopted metrics for each device is provided in Fig. 2. Additionally, participants' responses to the optional open-ended questions (range: 7–116 responses), related to the implemented devices, are reported in the ESM.

3.2.1 Jumps and Hops Assessment Devices (Without a Force Plate)

This survey indicated that 84.8% of participants ($n = 979/1154$, 95% CI 82.7–86.9) implemented jump and hop assessments using devices other than force plates, which were analysed separately (see Methods for details) [Fig. 1]. Beyond the commonly used tape measure ($n = 478/979$, 48.8%), other relevant implemented technology included camera and app ($n = 434/979$, 44.3%, e.g. My Jump App), two-dimensional/three-dimensional motion capture and analysis system ($n = 166/979$, 17.0%), contact mat ($n = 101/979$, 10.3%), inertial measurement units ($n = 90/979$, 6.7%, e.g. gyroscope, and accelerometer, either alone or integrated within a global positioning system technology), linear position transducers ($n = 24/979$, 2.4%), infrared system ($n = 22/979$, 2.2%) and Vertec ($n = 22/979$, 2.2%). Horizontal hop testing ($n = 907/979$, 92.6%, including anterior–posterior and lateral hops)

Table 1 Summary of the most relevant respondent demographic characteristics

Respondents' demographic characteristics (1154 practitioners)		
	Value (*n*)	%
Geographic location		
Europe	552	47.8
North America	323	28.0
Asia	99	8.6
South America	81	7.0
Africa	50	4.3
Oceania	49	4.2
Antarctica	0	0.0
Years of professional experience		
Mean	8.66	±7.58 (SD)
1–5 years	507	43.9
6–10 years	326	28.2
11–15 years	158	13.7
≥16 years	163	14.1
Range	1–51	–
Main qualifications		
Master's degree	391	33.9
Doctorate or PhD	317	27.5
Bachelor's degree	308	26.7
Main professions (multiple responses allowed)		
Multiple professions	341	29.5
Physiotherapist	954	82.7
S&C coach	148	12.8
Rehabilitation specialist	145	12.6
Sport therapist	134	11.6
Athletic trainer	105	9.1
Area of practice		
Private sector	773	67.0
Public sector	158	13.7
Both sectors	223	19.3
Practice settings (multiple responses allowed)		
Multiple settings	485	42.0
Private practice	758	65.7
Sports teams	431	37.3
Public hospitals	170	14.7
ACLR stage involvement (multiple responses allowed)		
Multiple stages	1072	92.9
Whole process	571	49.5
Pre-operative stage	798	69.2
Early stage	980	84.9
Mid-stage	1023	88.6
Late stage	857	74.3
RTS process	722	62.6
ACLR patients per year		
Low volume (1–5)	312	27.0
Low-to-moderate volume (6–10)	310	26.9
Moderate volume (11–25)	279	24.2
Moderate-to-high volume (26–50)	154	13.3
High volume (≥51)	99	8.6

For questions allowing multiple responses, combined response categories (e.g. multiple professions) were calculated by the authors and were not provided as response options in the survey. Percentages for questions with multiple responses may sum to > 100%

ACLR anterior cruciate ligament reconstruction, *RTS* return to sport, *S&C* strength and conditioning, *SD*

Table 1 (continued) standard deviation

Table 2 Implemented device and test specifics are reported in descending order of implementation (left to right) and expressed as a percentage relative to the entire cohort

Implemented device specifics

Parameter		Jump and Hop assessment devices (no force plate)	Isotonic machines, free weight, and bodyweight	Hand-held dynamometer	Isokinetic dynamometer	Manual muscle testing	Force Plates	Fixed frame isometric device	Nordic Hamstrings device
Device implementation		84.8%	70.9%	48.5%	45.7%	44.7%	35.7%	17.1%	12.6%
Body area	*Knee complex*	-	89.5%	93.4%	99.6%	97.5%	-	69.5%	100.0%
	Hip complex	-	81.4%	66.1%	0.6%	79.8%	-	74.1%	-
	Ankle complex	-	82.3%	20.0%	0.2%	47.5%	-	40.6%	-
	CKC and functional	100.0%	93.8%	-	-	-	100.0%	-	-
Symmetry analysis	*Contralateral limb*	76.0%	87.5%	84.3%	82.9%	-	81.3%	78.7%	78.6%
	Normative values	36.1%	44.6%	46.1%	49.5%	-	51.2%	52.3%	51.0%
	Pre-injury data	41.7%	54.5%	57.7%	60.9%	-	57.3%	62.4%	69.0%
Testing Frequency	*>1*	94.4%	96.0%	98.5%	96.1%	97.2%	96.6%	97.8%	94.4%
	≥3	72.3%	82.0%	91.0%	80.1%	83.6%	81.9%	89.6%	77.5%
	≥5	13.8%	20.7%	30.7%	17.5%	23.4%	31.6%	29.9%	24.1%
	Variable	34.6%	41.7%	28.4%	27.7%	38.4%	27.7%	31.5%	38.6%
Tests and criteria	*Time-based only*	19.4%	17.2%	18.4%	24.7%	30.2%	15.8%	25.9%	23.4%
	Criteria-based only	49.0%	55.0%	42.7%	34.0%	40.3%	49.0%	52.3%	49.0%
	Time and criteria mix	31.4%	25.6%	38.6%	41.2%	27.3%	34.7%	21.8%	26.2%
	Time-based (3 months)	17.1%	30.2%	45.2%	41.9%	47.1%	25.0%	31.5%	13.1%
	Time-based (6 months)	37.7%	27.0%	35.2%	44.6%	28.3%	35.0%	31.0%	29.0%
	Time-based (9 months)	34.6%	21.9%	28.6%	38.1%	17.4%	33.7%	26.4%	22.1%
	Time-based (12 months)	23.4%	13.9%	17.9%	22.2%	11.0%	24.8%	20.3%	18.6%
	Criteria (early–mid)	30.5%	60.9%	70.2%	44.8%	56.4%	43.2%	58.9%	32.4%
	Criteria (mid–late)	64.1%	68.7%	67.5%	58.6%	46.3%	70.1%	65.5%	55.9%
	Criteria (RTS)	72.5%	61.9%	63.0%	67.9%	39.9%	77.4%	64.0%	66.9%

Body areas, symmetry analysis, testing frequency and test implementation criteria details are reported for a comparison between instruments, expressed as a percentage of the respondents. A graded colour scale from red to green, applied via Excel conditioning formatting, indicates the percentage of implementation for each item, with red representing values closer to 0%, and green to 100% (midpoint yellow at 50%). The symmetry section indicates how participants interpreted the metrics, contrasting test results with the contralateral limb, normative values or pre-injury data. Testing frequency indicates how often tests were implemented with each device throughout the recovery process

CKC closed kinetic chain, *RTS* return to sport

was more widely implemented than vertical jump tests ($n = 771/979$, 78.8%) when force plates were not used, with 72.9% of practitioners using a combination of them ($n = 714/979$).

3.2.2 Isotonic Machines, Free Weight and Bodyweight

Assessment via isotonic machines, free weight and bodyweight tests were implemented by 70.9% ($n = 818/1154$, 95% CI 68.3–73.5) of respondents. Bodyweight-based testing was coupled with a mix of isotonic and free weight assessments in most cases ($n = 734/818$, 89.7%). Use of bodyweight tasks ($n = 58/818$, 7.1%) or isotonic machines and free weights ($n = 26/818$, 3.2%) only was more sporadic. Lower limb closed kinetic chain (free weights and machine based) was the most implemented testing approach ($n = 767/818$, 93.8%), followed by knee ($n = 732/818$, 89.5%), ankle ($n = 673/818$, 82.3%), hip ($n = 666/818$, 81.4%) and core musculature assessment ($n = 291/818$, 35.6%).

3.2.3 Handheld Dynamometer

Handheld dynamometer was implemented by 48.5% ($n = 560/1154$, 95% CI 45.6–51.4) of respondents, with 93.4% ($n = 523/560$) assessing the knee (extensor: $n = 506/560$, 90.4%; flexor: $n = 497/560$, 88.8%), 66.1% ($n = 370/560$) assessing the hip (frontal plane, adduction/abduction: $n = 362/560$, 64.6%; sagittal, flexion/extension: $n = 187/560$, 33.4%; transverse, internal/external rotation: $n = 131/560$, 23.4%) and 20.0% ($n = 112/560$) assessing the ankle (plantarflexion, $n = 104/560$, 18.6%; dorsiflexion, $n = 58/560$, 10.4%).

3.2.4 Isokinetic Dynamometer (IKD)

The IKD was implemented by 45.7% of respondents ($n = 527/1154$, 95% CI 42.8–48.6), primarily for a knee assessment (knee: $n = 525/527$, 99.6%; hip: $n = 3/527$, 0.6%; ankle: $n = 1/527$, 0.2%). Three contraction modes were reported: concentric ($n = 443/525$, 84.4%) [*reciprocal knee flexors and extensors, knee extensors and flexors*

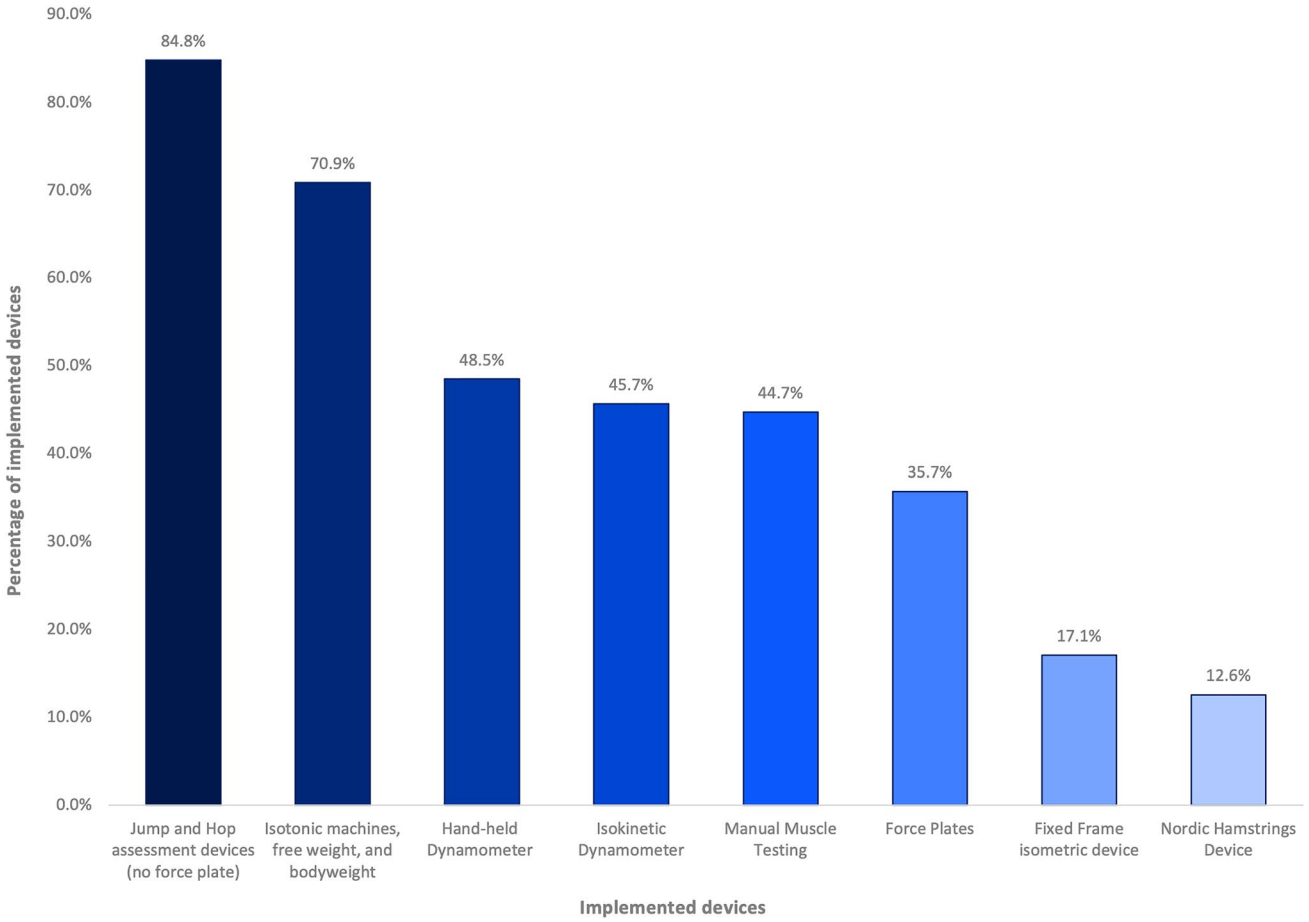

Fig. 1 Devices implemented by respondents throughout the rehabilitation process following anterior cruciate ligament reconstruction, reported in descending order from left to right

alone, or concentric combined with eccentric modality], isometric ($n = 262/525$, 49.9%) [*with a singular contraction, enhanced* via *superimposition or performed in a repetitive explosive manner*] and eccentric ($n = 115/525$, 21.9%) [*flexors and extensors alone, combined with concentric modality or reciprocal flexors and extensors*]. One contraction type (concentric: $n = 217/525$, 41.3%; isometric: $n = 79/525$, 15.0%; eccentric: $n = 0/525$, 0%) was adopted by 56.4% ($n = 296/525$) of respondents. Additional details are reported in the ESM.

3.2.5 Manual Muscle Testing (MMT)

Manual muscle testing use was reported by 44.7% ($n = 516/1154$, 95% CI 41.8–47.6) of respondents. Nearly all ($n = 503/516$, 97.5%) assessed the knee (extensor: $n = 484/516$, 93.8%; flexor: $n = 486/516$, 94.2%), 79.8% ($n = 412/516$) assessed the hip (adduction/abduction: $n = 384/516$, 74.4%; hip flexion/extension: $n = 318/516$, 61.6%; internal/external rotation: $n = 221/516$, 42.8%) and 47.5% ($n = 245/516$) assessed the ankle (plantarflexion: $n = 219/516$, 42.4%; dorsiflexion: $n = 181/516$, 35.1%).

3.2.6 Force Plates

Force plates were used by 35.7% ($n = 412/1154$, 95% CI 32.9–38.5) of respondents. Vertical jump was the most performed test ($n = 397/412$, 96.4%), followed by isometric tests ($n = 220/412$, 53.4%), sport-type movements [e.g. change of direction, deceleration and lateral landing on the force plate] ($n = 140/412$, 34.0%), and horizontal hop from or landing on the platform ($n = 132/412$, 32.0%). Few respondents performed these tests in a fatigued state ($n = 64/412$, 15.5%).

3.2.7 Fixed Frame Isometric Device

The fixed frame isometric device was implemented by 17.1% ($n = 197/1154$, 95% CI 14.9–19.3) of respondents, with 74.1% of them ($n = 146/197$) assessing the hip complex (abduction/adduction: $n = 133/197$, 67.5%; flexion/extension: $n = 81/197$, 41.1%; internal/external rotation:

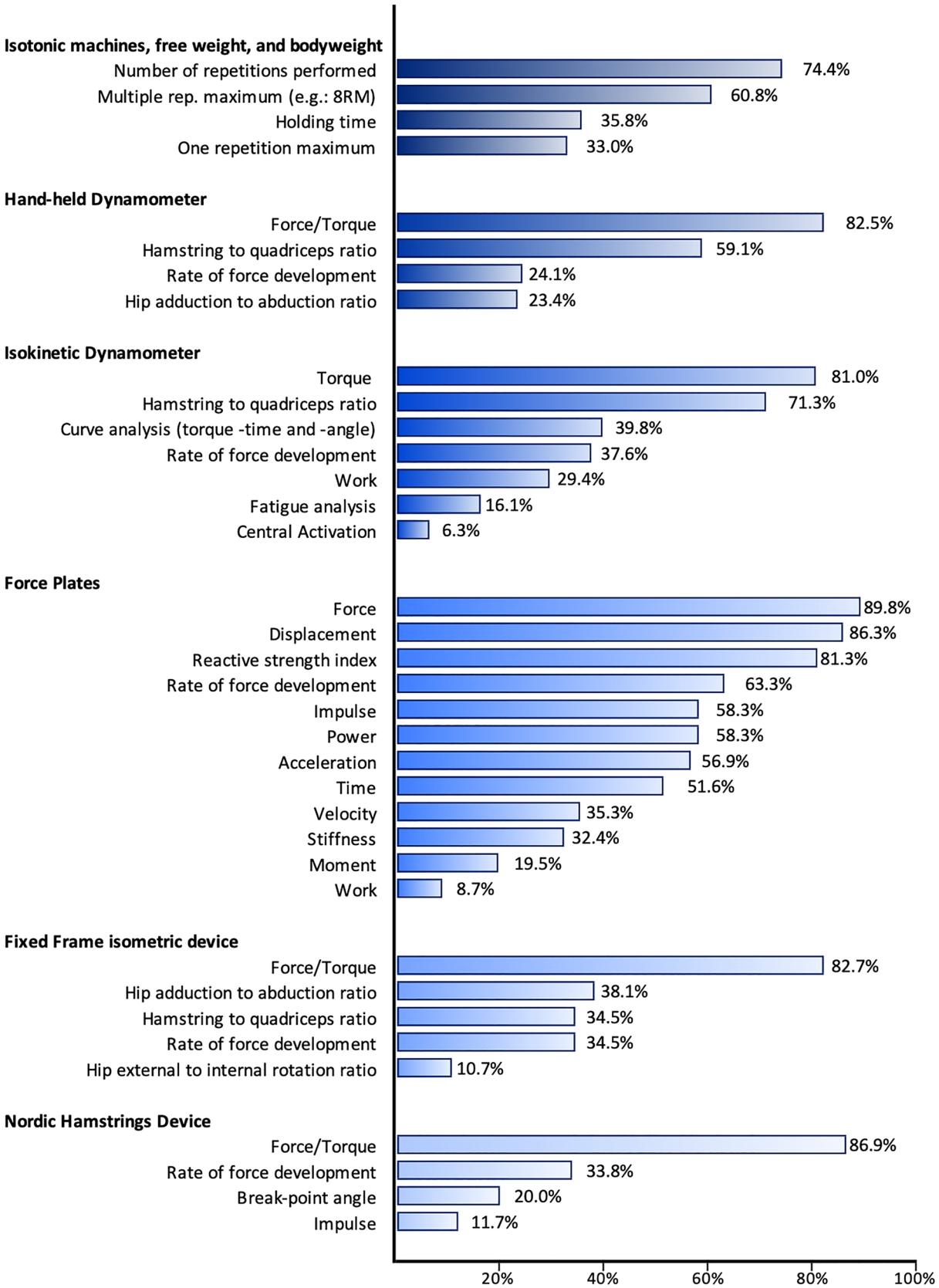

Fig. 2 Analysed metrics based on the implemented assessment device with the relative percentage of usage. *rep* repetition, *RM* repetition maximum

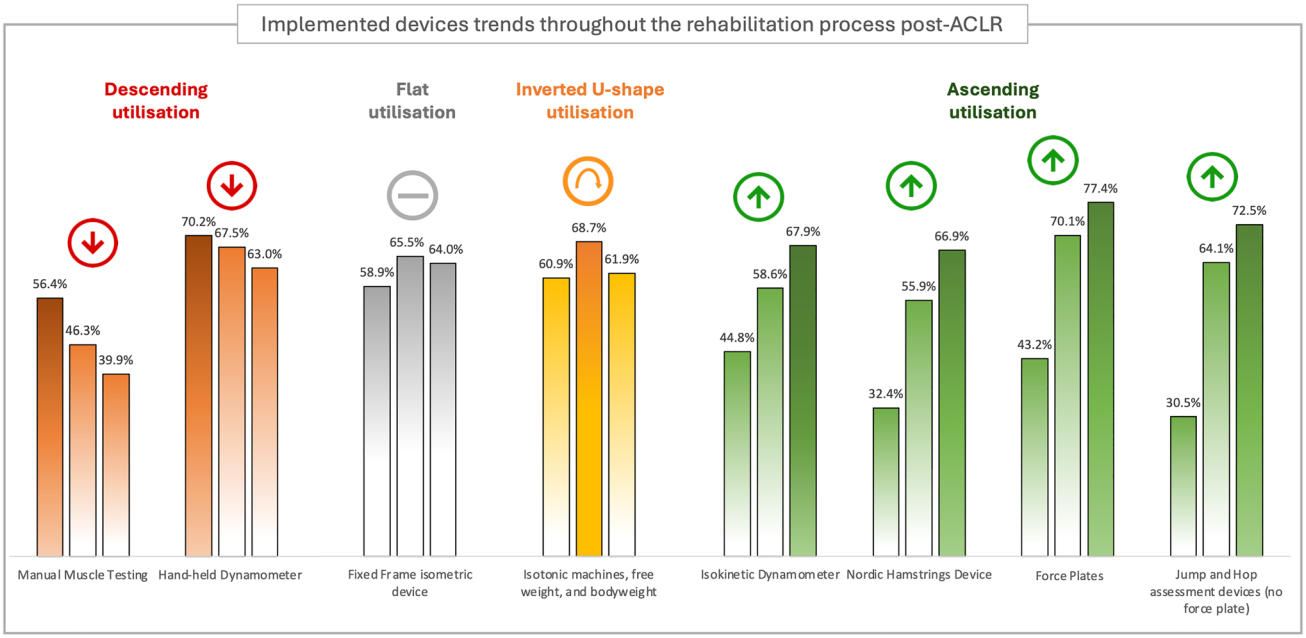

Fig. 3 Device implementation trends throughout the rehabilitation process across stages. *ACLR* anterior cruciate ligament reconstruction

$n = 35/197$, 17.8%), 69.5% ($n = 137/197$) the knee (flexion: $n = 123/197$, 62.4%; extension: $n = 119/197$, 60.4%) and 40.6% ($n = 80/197$) the ankle (plantarflexion: $n = 72/197$, 36.5%; dorsiflexion: $n = 29/197$, 14.7%).

3.2.8 Nordic Hamstrings Device

The Nordic hamstrings device was used by 12.6% ($n = 145/1154$, 95% CI 10.7–14.5) of respondents, with the Nordic hamstrings exercise being the most adopted test ($n = 133/145$, 91.7%), followed by the prone isometric knee flexion ($n = 76/145$, 52.4%), and the razor hamstrings curl test ($n = 17/145$, 11.7%). Collectively, when implementing the Nordic hamstrings device, eccentric hamstrings strength (Nordic hamstrings exercise + razor hamstrings curl) was investigated by 93.1% ($n = 135/145$) of the participants. When both the IKD and the Nordic hamstrings device were adopted ($n = 100$), eccentric strength was assessed in 96% of the cases ($n = 96/100$), primarily with the use of only the Nordic hamstrings device ($n = 59/96$, 61.5%), followed by an evaluation conducted with both the Nordic hamstrings device and the IKD ($n = 36/96$, 37.5%), and finally only with the IKD ($n = 1/96$, 1.0%). The Nordic hamstrings device was mostly implemented in settings of sports teams ($n = 99/145$, 68.3%) and private practices ($n = 65/145$, 44.8%).

3.3 Device Implemented Throughout Rehabilitation

Specific devices were most often used as part of "criteria-based" testing (46.4%), followed by a mix of "criteria- and time-based" testing (30.8%) and solely "time-based" testing (21.9%). Four different trends were identified in the implementation of devices across three key transition points: (a) early to mid-stage; (b) mid- to late stage; and (c) late stage to RTS (Fig. 3). The first trend displayed a descending utilisation, with MMT declining by 16.5% ($Z = -5.3$, $p < 0.001$) and HHD declining by 7.2% ($Z = -2.5$, $p = 0.011$) when considering implementation in the early to mid-stage compared with the late stage to RTS. In contrast, an ascending linear trend was observed for IKD ($Z = 7.6$, $p < 0.001$), Nordic hamstrings device ($Z = 5.9$, $p < 0.001$), force platform ($Z = 10.2$, $p < 0.001$), and jump and hop assessment devices [without a force plate] ($Z = 18.7$, $p < 0.001$). No statistically significant linear trends were recorded for fixed frame isometric devices and isotonic machines, free weights and bodyweight ($p > 0.05$). The chi-squared test showed no difference between the single groups for the fixed frame isometric device (flat trend, $p > 0.05$) and significant differences in early to mid-stage and mid-stage to late stage (U-shape, $p = 0.003$–0.011), suggesting a flat, and an inverted U-shape device utilisation trend for the fixed frame isometric device, and isotonic machines, free weights and bodyweight, respectively (additional statistical information reported in the ESM).

3.4 Self-Perceived Testing Quality

In self-reporting testing quality, 3.4% of respondents reported insufficient quality ($n = 39$), 11.9% reported poor quality ($n = 137$), 41.0% reported reasonable quality ($n = 473$), 36.7% reported good quality ($n = 423$) and 7.1% reported excellent quality ($n = 82$). Of those who did not rate their testing as excellent ($n = 1072/1154$, 92.9%), barriers included: cost of equipment ($n = 828/1072$, 77.2%), lack of space for equipment ($n = 367/1072$, 34.2%), managerial decisions beyond the practitioners' control ($n = 358/1072$, 33.4%), time constraints ($n = 317/1072$, 29.6%), unfamiliarity with testing technology or methodology ($n = 281/1072$, 26.2%) and other (see ESM). Almost 80% of respondents ($n = 836/1072$, 78%) reported that without any constraints, they would modify their testing battery, purchasing new equipment ($n = 487/836$, 58.3%) including force platforms ($n = 258/836$, 30.9%) and an IKD ($n = 180/836$, 21.5%). Additionally, 12.2% ($n = 102/836$) would implement a more thorough biomechanical assessment, 11.1% ($n = 93/836$) would introduce new tests, 6.5% would use more metrics ($n = 54/836$) and 6.0% would like more time for testing ($n = 50/836$). Additional information is presented in the ESM as responses to the final optional open-ended question ($n = 644$ responses).

A weak positive correlation was observed between the number of implemented devices and self-perceived force and power testing quality ($\rho = 0.32$, $p < 0.001$, Table 3). A regression analysis showed that the use of force plates, IKD, Nordic hamstrings device and HHD were significantly associated with greater self-perceived testing quality ($R^2 = 0.21$, $p < 0.001$, Table 4) under the following relation: self-perceived testing quality $= 2.81 + 0.50 \times \text{FP} + 0.44 \times \text{IKD} + 0.29 \times \text{NHD} + 0.21 \times \text{HHD}$.

Table 3 Respondents' self-perceived force and power testing quality stratified based on the number of implemented devices by the respondents

N devices	Participants	Insufficient / Poor	Reasonable	Good / Excellent
0	*6 (0.5%)*	67%	0%	33%
1	*42 (3.6%)*	43%	24%	33%
2	*178 (15.4%)*	27%	43%	30%
3	*366 (31.7%)*	18%	50%	32%
4	*287 (24.9%)*	9%	43%	48%
5	*184 (15.9%)*	6%	35%	59%
6	*55 (4.8%)*	4%	18%	78%
7	*28 (2.4%)*	4%	14%	82%
8	*8 (0.7%)*	0%	25%	75%

The number of devices ranged from 0 to 8 (*first column*), with a different frequency of use by the survey participants (*second column*). The self-perceived quality (*third to fifth columns*) was grouped according to a Likert scale (1–2: "Insufficient/Poor", 3: "Reasonable", 4–5: "Good/Excellent") over the number of participants. *Bars* represent the percentage of respondents in each category. Please note that the results for 0 and 8 devices come with reservation because of the small number of participants in each category

4 Discussion

The primary aim of this survey study was to evaluate how force and power are assessed throughout the recovery process post-ACLR, identifying the rates of utilisation of different devices and metrics. Secondary aims were to explore methods as to when these devices are implemented, what body areas are assessed, which metrics are analysed, and potential interactions between the adopted devices and self-perceived testing quality evaluations. The main findings revealed that there was significant heterogeneity in device implementation among survey respondents. Three device implementation trends were observed, defined as ascending, descending and a shallow inverted U-shape, underlining distinct functions of various instruments throughout the recovery process. The number and type of implemented testing devices affected respondents' self-perceived testing quality. Finally, several barriers were identified in testing utilisation, including the cost of equipment, lack of space and time, and managerial decisions.

Table 4 Multiple regression analysis with self-perceived battery testing quality (Likert scale) as the endpoint

Model		Coeff	SE	t	*p*-value	95% CI
H_0	(Intercept)	3.32	0.03	126.07	< 0.001	3.27–3.37
H_1	(Intercept)	2.81	0.04	68.63	< 0.001	2.73–2.89
	Force plates	0.50	0.05	9.48	< 0.001	0.40–0.60
	Isokinetic dynamometer	0.44	0.05	8.97	< 0.001	0.34–0.53
	Nordic hamstrings device	0.29	0.08	3.88	< 0.001	0.14–0.44
	Hand-held dynamometer	0.21	0.05	4.37	< 0.001	0.12–0.30

Each coefficient describes the strength of the contribution to the improvement of the self-perceived quality. Only statistically significant factors were present in the final model (stepwise approach)

CI confidence interval, *Coeff.* unstandardized coefficient, *SE* standard error

4.1 Implemented Devices and Assessments

Jump and hop assessment devices was the most implemented test category, aligning with the current literature [45], guidelines [2] and practices, especially at RTS clearance [28, 33, 36, 38, 39, 42]. Jump and hop testing is often used as a measure of lower limb performance [46], likely owing to its simplicity and accessibility. Testing requires inexpensive equipment such as tape or phone apps [47], coupled with minimal space demands. Hop testing is a strong predictor of lower limb muscular strength ($R^2 = 0.49–0.57$) [48], while the quadriceps index is positively associated with hop performance ($R^2 = 0.41$, $\beta = 0.45$, $p < 0.005$) [49]. These findings likely encouraged implementation of this test category as a surrogate of force and power metrics, with previous research reporting between one third to almost half of practitioners estimating knee strength from other measures such as hop capacity post-ACLR [38, 39]. However, jump and hop testing provides information on the overall functional status of the patient, reflecting combined demands of strength, power and coordination, rather than isolated strength [46]. Assuming complete restoration of strength on the injured limb when symmetry values are met in comparison with the contralateral side can be misleading, and careful data interpretation is warranted. As reported in Table 2, three quarters of participants (76%) utilised contralateral symmetry values as reference for hop testing, while fewer used pre-injury (41.7%) and normative data (36.1%). While symmetry indices were widely adopted, caution is warranted when using symmetry data alone, as this does not always correlate with equal symmetry in strength outcomes [50], leading to a potential risk to overestimate knee strength symmetry. Further, it is important to note that not all jump and hop tests measure the same neuromuscular construct [51]. Knee, hip and ankle do not contribute equally during horizontal and vertical jumps, with knee propulsion contributing three times more in vertical than horizontal directions [52]. Vertical jumps are more appropriate to assess lower limb functional deficits [53] during propulsive tasks. While previous studies report greater implementation of horizontal (84.3–91.1%) versus vertical hops (1.67–43.5%) [28, 36, 38, 39], our study recorded equal adoption (88.7% horizontal, 88.5% vertical) when considering all implemented assessment devices (e.g., tape, camera and app, force plate), suggesting that our cohort is more aligned with clinical practice recommendations [13, 15–19], and recently published research [52–55].

Previous survey data have reported more than a quarter of practitioners implement repetition maximum (RM) testing via the utilisation of isotonic machines and free weights as a criterion for RTS [28, 39]. We documented a high proportion of respondents (70%) including this type of test throughout the recovery process. This was commonly used to assess knee strength, providing a cheaper and more accessible alternative to IKD. However, careful results interpretation and stricter cut-offs are recommended when implementing isoinertial or a constant load assessment, as it may lack sensitivity in identifying strength asymmetries [56]. Furthermore, using the number of repetitions performed as metrics to assess symmetry may lead to misleading results when testing above 5–8 RM, as different neuromuscular properties such as muscle endurance influence performance. When assessing maximal strength, the further the assessment deviates from the 1 RM, the less accurate the test will be [57], warranting caution when using bodyweight, isotonic machines and free weights to assess strength [56].

Hand-held dynamometer and inline dynamometry (device secured in line with the tested limb) could be considered a cost-effective alternative to the IKD, provided that the devices are correctly positioned to ensure good-to-excellent reliability [56, 58, 59] and moderate-to-excellent validity for both measures of isometric strength and power [60]. Our sample reported higher adoption rates of HHD compared with previous research (49% vs 9–27%) [28, 33, 37, 38]. However, previous studies focused exclusively on knee assessments post-ACL [24, 28, 36, 38, 39, 60], while our study provided novel information on high use at adjacent joints. In clinical practice, when using the HHD without external stabilisation, the test reliability is influenced by the examiner strength, assessed muscle group (large vs small muscles) and the absolute strength of the tested individual [61]. In these cases, caution is warranted, as strength outcomes may be less reliable, and previous studies recommended the use of this device with external stabilisation to enhance reliability [60, 61].

Our sample also reported higher adoption of IKD (46%) versus previous studies (6%–23%) [28, 33, 37–39], which may reflect the characteristics of our recruited cohort. Unlike other devices, the IKD offers a range of assessment modes, velocities and the option to examine torque in different ranges of movement, making it the recommended option for assessing knee extensors and flexors strength post-ACLR according to several authors [16, 17, 62–65]. Currently, despite the inclusion of IKD in multiple RTS guidelines [13, 66], there is no consensus on which test metrics to report [67, 68], potentially explaining the high heterogeneity in implemented protocols. Concentric contraction was the most implemented test modality, similar to previous research [67], followed by isometric and eccentric testing, with many using more than one. Only 20% of those using IKD, and as such 10% of the whole sample assessed eccentric strength. Knee flexor eccentric strength has been widely studied in the literature, likely owing to its implications as a risk factor for hamstring muscle strains in sports [69]. Given ACL injuries are being recognised as largely horizontal deceleration injuries occurring during pressing, tackling and landing injuries

[70–72] and that horizontal deceleration and landing actions impose large eccentric demands on the lower limb, particularly of the knee extensors [73], measurement of this contraction mode likely has important implications for RTS. On-field deceleration workloads and intensities appear to be suppressed at the time of RTS clearance [74], possibly owing to residual deficits in eccentric knee extensor function [75], although data confirming this association remain limited. Despite this being a metric that has not yet received extensive focus in research, in our study, 13.7% ($n = 72/527$) of survey respondents assessed knee extensors in the eccentric contraction mode. When analysing metrics through IKD testing, results from previous surveys on the ACLR population are limited to "strength metrics" and "symmetries" [28, 33, 38, 39, 42] without exploring additional parameters such as the rate of force development and work, which we showed were implemented by around a third of respondents from our study.

Manual muscle testing offers important advantages because of its practicality. The absence of a need for any testing device, coupled with the facility of testing multiple body segments in a time-effective manner, likely explains why this assessment category was adopted by almost half of our survey respondents, a significantly higher value compared with previous reports (11.3–33%) [33, 37, 38].

Although this information was not collected directly through the survey, MMT is commonly quantified through the Medical Research Council 0–5 scale [76] in clinical practice. Despite classifying strength on a scale, the grading system does not provide a quantitative measurement of this metric. Additionally, the reliability of this scale has been questioned, with studies reporting unreliable detection of minor strength deficits (Medical Research Council scale ≥ 3) [77]. Taken together, careful data collection and interpretation are warranted when using MMT as it presents important limitations.

This is the first survey to document utilisation of force plate technology by clinicians in rehabilitation post-ACLR. More than a third of respondents (36%) reported using a force plate. It is likely that advances in technology (quality of portable force plates) and software (automated reporting) have facilitated implementation of what used to be a laboratory-based approach into clinical practice. Respondents almost always reported using force plates for jump–land assessments, but half also performed isometric strength testing. A third of respondents included sport-type movements, and one in six performed tests under fatigue conditions. Recent research shows that jump symmetry can vary between phases of the same movement (e.g. concentric vs eccentric) and that kinetic data are influenced by different movement strategies [46, 55, 78–81]. Therefore, a phase-specific assessment of functional movements that includes both kinetics and kinematics is recommended to contextualise force and power outputs within movement control [82]. Our study showed that almost half of those using force plate technology implemented a two-dimensional and/or three-dimensional analysis in parallel, and nearly one in four performed phase-specific breakdowns (e.g. unweighting, breaking, propulsion) of functional movements, providing additional information on how force and power outcomes are achieved.

The fixed frame isometric device allows measurement of a single joint force production via adjustable sensors. Despite the system being highly adaptable to assess multiple body areas, some concerns have been raised about the test reliability of certain muscle groups. While moderate-to-excellent reliability has been reported for hip adduction and abduction testing performed in different positions [83–85], the reliability of a knee spanning muscle assessment, specifically knee flexors, has been questioned [86]. As nearly two thirds of the respondents utilised this device to assess knee flexors, careful data interpretation is warranted as practitioners may currently be relying on unreliable data in clinical practice [86].

An eccentric hamstrings strength assessment is encouraged post-ACLR [87], as knee flexor strength deficits may be missed with a concentric assessment alone [88]. Interestingly, when both the IKD and Nordic hamstrings device were available, practitioners primarily utilised the latter to assess eccentric hamstrings strength. The choice between these devices may be dictated by contextual factors rather than device and methodological superiority. Although speculative, practitioners may prefer the Nordic hamstrings device because of its quicker administration time, easier set-up and specificity to a hamstring eccentric assessment. Both devices provide valid and reliable measures of eccentric strength; however, they capture different traits of the strength profile and should not be considered interchangeably [89]. This may explain why more than a third of the practitioners reported implementing both devices in parallel to assess eccentric strength. Globally, the Nordic hamstring device was only implemented by one in eight practitioners, likely reflecting its structural limitation and versatility compared with other devices. In the context of clinical practice, space, test administration time, cost, logistics and feasibility often determine the selection of equipment. The Nordic hamstring device is suited for a single muscle group and joint (hamstrings/knee flexion) and thus could be deemed less efficient than other devices. More than two thirds of our survey respondents reporting use of the Nordic hamstring device were practitioners involved in team sports (professional and amateur), environments where hamstring muscle strains contribute substantially to time loss [90, 91]. It is plausible that the Nordic hamstring device is employed for different purposes in these contexts (e.g. rehabilitation and healthy

athlete screening), and used in both isometric and eccentric test modes.

4.2 Time and Criteria of Device Implementation

Current practice suggests implementing tests throughout recovery to inform and guide rehabilitation progression [13, 14, 92], although recent evidence indicates that progression is often based on time [28, 93, 94]. In our study, almost half of respondents implemented force and power tests as progression criteria alone, while only time was used by a fifth of respondents, and nearly a third of respondents adopted a combination of time and objective criteria. The proportion of respondents using criteria-driven progression was greater than in previous studies [28, 93, 94], possibly reflecting the characteristics of the recruited population, which included a highly educated sample (33.9% Master degree and 27.5% Doctorate or PhD), who may be more engaged with testing and up to date with recent evidence. This important finding, even if possibly biased towards this population, represents a positive step forward in aligning practices to current research guidelines, promoting a more criteria-based approach in rehabilitation [95]. Not all devices were implemented with the same frequency in different stages of rehabilitation, with MMT mainly used in early stages, where an approximate assessment is sufficient to detective extreme weakness, but less sensitive to minor strength deficits [77]. Hand-held dynamometer, fixed frame isometric devices, isotonic machines, free weights and bodyweight were utilised throughout the recovery process, likely owing to their versatility. Isokinetic dynamometer [10], force plate [55], hamstrings testing device [96] and jump and hop assessment devices (without a force plate) [23] were primarily utilised in later stages of rehabilitation, aligning with RTS guidelines recommending a combination of analytic (IKD and hamstrings testing device) and functional assessment (force plate, jumps and hops) [13, 14, 92].

4.3 Test Implementation and Self-Perceived Testing Quality

Current evidence suggests the use of comprehensive testing batteries during ACLR rehabilitation [13, 14, 17–19]. However, practitioners face several barriers, such as economic resource constraints, space demands, time burden, lack of confidence and knowledge with technology, other stakeholders' "buy-in" on innovation and resistance to change [97, 98]. Supporting this, our data indicate almost eight out of ten respondents desired to change some aspect of their testing process. Among the most common reported barriers to test implementation, the cost of the equipment was the most mentioned, followed by a lack of space, managerial decisions beyond the practitioners' control, time constraints, and unfamiliarity with testing technology or methodology. These findings highlight that contextual factors beyond practitioner expertise, such as geographic location, sociodemographic characteristics and the healthcare system may influence clinical practices. While contrasting adopted practices based on these contextual factors goes beyond the scope of the survey, some considerations are needed when considering these results. For instance, respondents' geographic location has a profound effect on funding models (e.g. insurance policies), with healthcare structures and cultural background (e.g. national sporting context of interest, rehabilitation believes) and practitioners' education likely playing a role in the adopted practices. The healthcare system structure, private or public, can also influence clinical practices, with two thirds of the participants included in our study being involved in private care, which may facilitate easier access to more advanced and expensive equipment [99]. Future research should aim at investigating these contextual factors in detail, as they may contribute to the recorded heterogeneity in testing utilisation worldwide.

This is the first survey reporting a positive influence of the number of implemented devices on self-perceived testing quality. While this association may be influenced by a self-serving bias, a more extensive and device-enriched neuromuscular assessment can arguably be considered of higher quality and aligned with current evidence [2, 13, 14, 65, 100], likely enhancing respondents' perceptions of a superior testing battery. Caution is warranted when considering only the number of devices, as quantity does not automatically guarantee quality. In fact, not all devices are perceived equally, with high-tech objective assessment instruments often recommended by the evidence [16, 17, 55, 64, 65], such as force platforms, and IKD being reported to have the strongest positive influence on respondents' self-perceived testing quality. However, a combination of all these factors likely allows a technologically advanced, multi-metric, objective rehabilitation and RTS process.

4.4 Strengths and Limitations

This study presents some inherent limitations dictated by the nature of the survey itself and the included participants, which should be careful considered when generalising the findings to the wider practitioner's population. The questions' validity and reliability were not established, and despite efforts to enhance clarity through piloting, there may be variation in question interpretation. While this study is considered a worldwide survey, the survey was administered in English, including participants living in countries where English is not considered the first language. Although English is considered the main language of scientific literature, it is important to underline that this may have influenced the comprehension of some questions leading to response bias. When considering the participants

who took part in the survey, 75% of the respondents were from Europe and North America, thereby limiting the generalisation of the findings to the worldwide rehabilitation community. In addition, most participants reported working in the private sector, which should be considered when applying these results to other contexts. Given the complexity of some questions and the fact that some participants completed the survey in approximately 5 min, the accuracy of their responses may be limited, warranting caution when interpreting the results. Because of the electronic distribution via different communication methods and the anonymous nature of the survey, the response rate could not be determined, introducing the potential for response bias, and favouring the recruitment of practitioners more engaged with online platforms and testing. For instance, the use of IKD in our population is greater than documented in previous research, which may be the result of a biased sample. The heterogeneous sample, which included practitioners working in different practices, cultural background and experience, also introduced variability that may limit generalisability of the findings. However, the authors' team has deliberately decided to include multiple professions as the best current evidence suggests a multidisciplinary approach to ACLR rehabilitation with the goal of capturing the whole testing process across different professions. Nevertheless, we acknowledge that this may result in certain professional groups (e.g. strength and conditioning coached) contributing more to specific rehabilitation stages (e.g. mid-stage, late stage, and RTS stages). Furthermore, only practitioners who were most interested in the survey topic and aims and were willing to take part in the survey were included. Therefore, recorded outcomes may represent an overestimation of the quality of force and power testing implemented in clinical practice. Finally, another potential limitation relates to respondents' interpretation of the device categories. Some overlap may have occurred among categories, with a proportion of participants potentially misclassifying or skipping certain sections based on their available equipment (e.g. differentiating between MMT and HHD, or IKD and other devices such as strain gauge and load cells). This could have slightly influenced the representation of specific testing practices. Cumulatively, while these aspects can limit generalisability, our survey constitutes the largest work to date investigating testing practices post-ACLR. These novel findings provided from worldwide practitioners highlight valuable insights into current assessment practices for assessment methods in ACLR rehabilitation.

5 Conclusions

A high degree of variability in test device implementation post-ACLR exists among practitioners. According to the eight pre-defined device categories, over 150 different device combinations were recorded among respondents. Device use was different throughout the stages of rehabilitation and testing was primarily performed as criterion to advance patients throughout the recovery process, with less than a fifth of respondents relying on time alone for test implementation. Aligned with the current literature and RTS practices, the jump and hop assessment, tested primarily without the use of force plates, was widely implemented by practitioners throughout the recovery process. When force plates were used in the context of jump profiling, vertical jumps were preferred over horizontal jumps, reflecting alignment with the current literature. Isotonic machines, free weights and bodyweight assessment where extensively adopted; however, caution is warranted when utilising these devices to assess maximal strength, especially when considering maximum performed repetitions. The use of HHD was common and supported by the literature, though, external stabilisation is recommended to enhance reliability. When the IKD was implemented, despite the broad range of provided metrics, practitioners primarily focused on peak torque and symmetry, potentially overlooking clinically relevant information. Although suggested in the literature, eccentric strength assessment remains still underutilised, highlighting a gap in current assessment practices. Despite its limitations and questioned validity, MMT appears to be still widely used by respondents, even in the later stages of rehabilitation. Finally, while acknowledging that these findings may be influenced by self-serving bias, as respondents with a stronger interest in the topic may be overrepresented, they suggest that practitioners involved in force and power testing post-ACLR may want to implement a wide range of devices, including more quantitative and objective instruments such as force plates and IKD, as these appeared to be related to higher levels of self-perceived testing quality.

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Declarations

Conflict of Interest Alessandro Compagnin, Francesco Della Villa, Giovanni La Rosa, Stephen Patterson, Paul Read, Lee Herrington, Stefano Di Paolo, Eric Hamrin Senorski, Gregory D. Myer, Mike Davison, Mick Hughes and Matthew Buckthorpe have no conflicts of interest that are directly relevant to the content of this article.

Ethics Approval Ethics approval was obtained from the STHS Ethics Committee of St Mary's University, Twickenham, London, UK (SMU_ETHICS_2023-24_366).

Consent to Participate Participants were informed about the nature of the study, the research team, the data management process and addi-

tional information via the participants information sheet, a downloadable document included in the first page of the survey. Key information was also summarised in the survey's opening page, where participants were encouraged to download and carefully read the information sheet before participating. Collecting a written consent would have required participants to disclose personal identifiers information such as their name, compromising in this way the anonymity of the survey. Therefore, consent was implied through the voluntary completion and submission of the survey rather than being collected in written form.

Consent for Publication Not applicable.

Availability of Data and Material The dataset collected and analysed during the study are not publicly available. However, because of the anonymous nature of the survey, the data are completely anonymised and can be made available by the corresponding author in the case of a reasonable request.

Code Availability Not applicable.

Authors' Contributions AC, SP and MB contributed to the study conception and design. Material preparation was addressed by AC and MB, with a revision by all the other authors. The whole team was involved in the distribution of the survey. AC, MB and SdP supported the analysis and interpretation of results. The first draft of the manuscript was written by AC and MB, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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