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Is it time to develop specific return to running criteria for ACL rehabilitation? An international survey of physiotherapists criteria for return to running following ACL injury

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ABSTRACT

Objective: To determine return to running criteria currently used by physiotherapists following anterior cruciate ligament (ACL) injury.
Design: Self-reported online international survey.
Methods: An online survey of physiotherapists across Australia, the Netherlands and France.
Results: A total of 476 respondants participated in the survey across Australia (n = 153), the Netherlands (n = 162), and France (n = 161). For return to running criteria following a non-operative approach, the majority of respondents chose swelling (40.55%, n = 193/476), pain (38.24%, n = 182/476), knee extensor strength (34.34%, n = 163/476), single leg squat (31.93%, n = 152/476) and knee flexor strength (29.83%, n = 142/476). After ACL reconstruction, the highest responses were also swelling (41.18%, n = 196/476), pain (37.18%, n = 177/476), knee extensor strength (37.18%, n = 177/476) and single leg squat (33.19%, n = 158/476). From the identified themes the most common cutoff variables were pain between 0 and 3/10, swelling < grade 1+ and limb symmetry on strength and hop tests >70 %.
Conclusion: Physiotherapists in Australia, France, and the Netherlands use many different return to running criteria and most of them use more than one criterion. Despite this, there was little consensus on the cut-off physiotherapists use to apply these criteria.

1. Introduction

For many years return to running following anterior cruciate ligament (ACL) injury or ACL reconstruction (ACLR) has been viewed as an early and uncomplicated milestone in ACL rehabilitation. Most of clinical guidelines recommend to return to running 3 months after ACLR (Rambaud et al., 2018), with time since surgery being too often the only criterion. It implies that patients might return to running with persisiting strength, neuromuscular and power deficits in knee extensors and flexors, while it is known these deficits are associated with a deficit in running mechanics (peak knee flexion, peak knee extensor moment and rate of knee extensor moment) (Knurr et al., 2021; Turpeinen et al., 2020). Indeed, altered biomechanics in walking and running are observed in the long term following ACLR (Mikesky et al., 2006; Slemenda et al., 1997). These biomechanical changes can shift the location of load application within the knee joint and have the potential to influence tissue homeostasis in ACL injured and ACLR patients (Andriacchi et al., 2009). Recent studies have shown that lower tibiofemoral joint loads are associated with lower cartilage volume and thickness in patients with ACLR (Saxby et al., 2017; Wang et al., 2020). Hence, the return to running process may be a more important milestone than previously thought, whereby clinicians may need to consider adequate knee function in terms of neuromuscular performance encompassing strength, power and rate of force development in combination with patient self-reported function.

Few studies have addressed return to running criteria following ACL

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injury or ACLR (Rambaud et al., 2018; Van Cant et al., 2022). In their scoping review, Rambaud et al. found that more than 80% of studies included time as the main criterion for return to running. More recently, Van Cant et al. found that there is significant lack of return to running programs for athletes after ACL injury or following ACLR. This is alarming given that it demonstrates a gap in research to inform clinical practice. Physiotherapists often guide patients through the rehabilitation process, and it would be interesting to get an overview of the criteria they use to inform the return to running in absence of research-based recommandations. This can be an indication of whether parameters that may affect future knee health are being well assessed and whether there is heterogeneity between practitioners. For this reason, the purpose of this study was to ascertain what criteria is currently being used by physiotherapists in Australia, the Netherlands and France to determine if their patients are ready to return to running. Additionally, the second purpose was to explore if certain cut off values are being used for specific criteria.

2. Methods

2.1. Study design

We performed a cross sectional international survey exploring physiotherapists' return to running criteria after ACL injury or ACLR was performed. Ethics approval for this project was obtained through ethics committee for use in Australia (#20897), the Máxima Medical Center Eindhoven in the Netherlands (N21.076), and the Centre Hopitalier Universitaire de Saint Etienne ethics committee for use in France (IRBN052022/CHUSTE).

2.2. Survey instrument

The survey was originally designed by TS and revised by co-authors (NvM, AR, JR, AB) and constructed through Qualtrics (Appendix 1). It was pilot tested on a sample of 10 respondants testing clarity and potential issues due to the online dissemination. It was developed with 22 questions divided into two sections. The first section was designed to collect physiotherapists' demographics including level of qualification, years of experience, area of practice and the number of ACL patients seen per month. The role of the second section was to ascertain current clinical practice methods used by physiotherapists in Australia, the Netherlands, and France on return to running in patients following ACL injury or ACLR. This was explored through multiple choice and open answer questions. The survey (Appendix 1) was initially developed for use in Australia by the first author (TS), and subsequently translated to Dutch (NvM) and French (JR and AR). The survey was developed by physiotherapists with clinical and research expertise in managing ACL injuries, with the primary purpose to determine international clinical standards for returning patients to running following ACL injury or ACLR. The survey was available for completion between October 2021 and October 2022. The survey was anonymous, and required physiotherapists to consent before completion.

2.3. Participants

Physiotherapists were recruited by advertising the survey through social media platforms such as LinkedIn and through affiliated physiotherapy organisations in each country. We specifically targeted groups and organisations in sports and musculoskeletal physiotherapy given these physiotherapists are far more likely to see patients following ACL injury and ACLR, and will more likely reflecy current clinical practice in each country.

2.4. Data extraction and analysis

After survey closure, group and individual responses were exported to Microsoft Excel for examination. The prevalence of the different physiotherapists' demographics was reported. The answers to the multiple choice questions were analysed by reporting the prevalence of each of the answers. For the open-ended questions a qualitative analysis was performed using a thematic analysis approach. This approach allows to identify, analyze and report themes within data collected (Castleberry, A. and Nolen, A. 2018). For each open-ended question, data from the three countries were assembled in a Word document (Microsoft Corporation) and imported into the open source software Taguette (Rampin, R. and Rampin, V. 2021). The second phase consisted of two researchers (JR and AJR) manually disassembling the data into smaller pieces and assigning them new labels or "codes". The results of this first coding round were exported into Excel sheets (Microsoft Corp). Codes were then reassembled and combined into themes inspired by the focus of the open questions. In the Excel sheets, a color was assigned to each theme and code cells were colored accordingly. For every question, prevalence of the different themes was noted, and content was interpreted.

3. Results

There were a total of 476 respondents who participated collectively in the survey across Australia (n = 153), the Netherlands (n = 162), and France (n = 161). Table 1 summarises clinical experience, education and practice area of respondents across the three countries. Educational level differed among the three countries with the highest proportion of qualified physiotherapists from Australia (n = 112, 72%), followed by France (n = 89, 55%) and Netherlands (n = 8, 5%). In contrast, the Netherlands had the higher proportion of entry level Bachelor's degree respondants (n = 154, 95%), following by France (n = 72, 44%) and Australia (n = 43, 28%).

3.1. Return to running criteria

For return to running criteria there was a diverse range of answers (Figs. 1 and 2). Across all countries, the highest clinical responses for non-operative maangement as depicted in Fig. 1A was swelling (40.6%,

Table 1
Professional characteristics of physiotherapy respondents across Australia, Netherlands and France. Respondents provided background information on their highest educational qualification, years of clinical practice as a physiotherapist, current area of practice and the number of anterior cruciate ligament (ACL) patients seen per month on average.

	Australia (n = 153) n, (%)	Netherlands (n = 162) n, (%)	France (n = 161) n, (%)
Highest level of qualification			
Bachelor's degree	43 (28)	154 (95)	72 (44)
Post-graduate masters including PhD	112 (72)	8 (5)	89 (55)
Years of experience			
10 +	35 (22)	97 (59)	67 (42)
6–10	30 (19)	36 (23)	48 (30)
<5	90 (59)	29 (18)	46 (28)
Area of practice			
Private practice	127 (83)	145 (90)	144 (89)
Public health	16 (10)	12 (7)	3 (2)
Sports team	10 (7)	3 (3)	9 (5)
Number of ACL patients per month			
10 +	6 (4)	24 (15)	19 (12)
5–10	13 (8)	45 (28)	39 (24)
<5	136 (88)	93 (57)	103 (64)

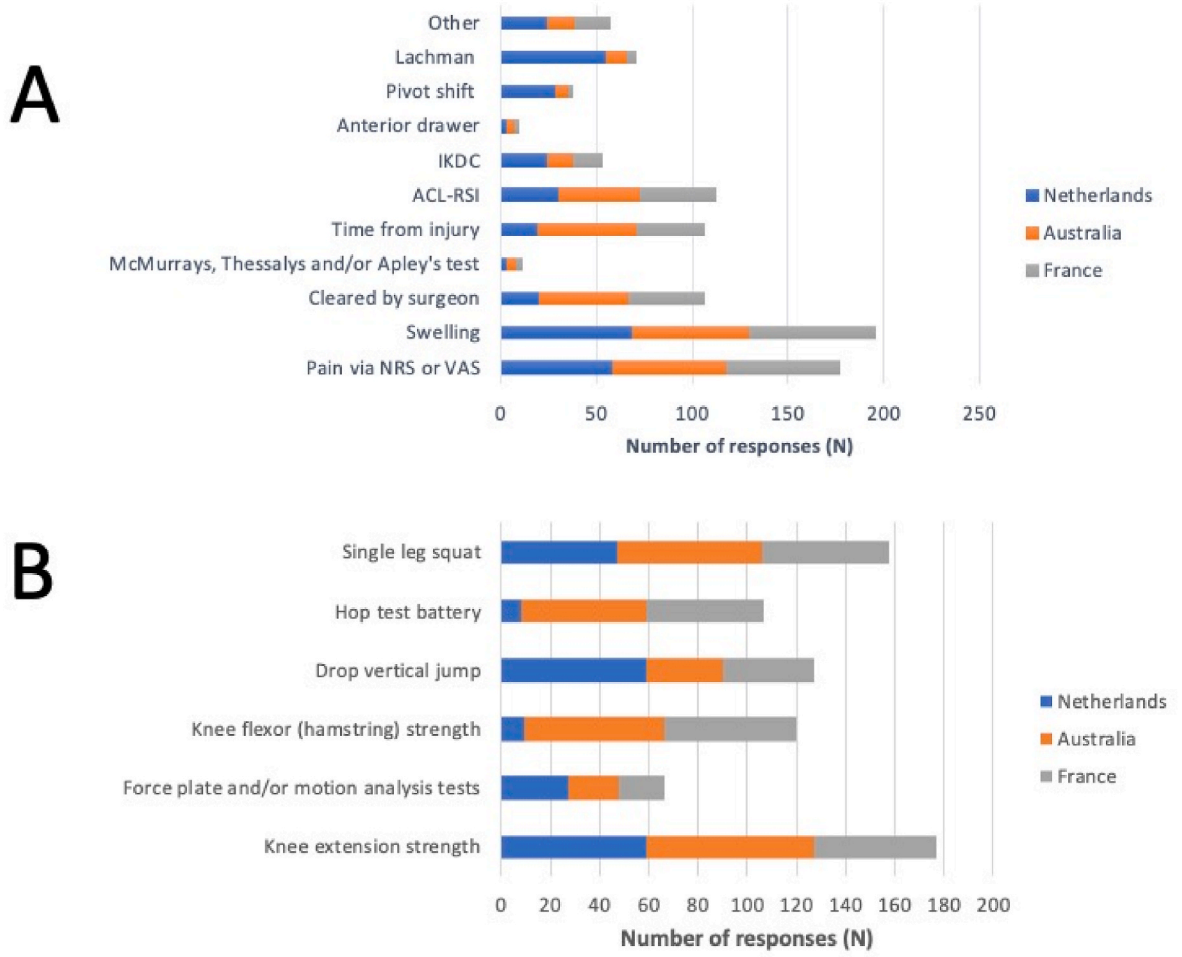

Fig. 1. Criteria for return to running following ACL injury with a non-operative approach. Fig. 1A corresponds to clinical tests summary across the three countries for non-operative management while Fig. 1B depicts the physical/performance based tests for non-operative management. Respondents could provide multiple answers to this section.

n = 193) and pain (38.2%, n = 182) and similarly for operative management the highest responses were pain (37.2%, n = 177) and swelling (41.18%, n = 196, Fig. 2B). For performance/strength criteria in the non-operative group (Fig. 1B) the highest reponses were knee extensor strength (34.3%, n = 163), single leg squat (31.9%, n = 152) and knee flexor strength (29.8%, n = 142). However, after ACL reconstruction (Fig. 2B), the responses were knee extensor strength (37.2%, n = 177), single leg squat (33.2%, n = 158), knee flexor strength (25.2%, n = 120), drop vertical jump (26.7%, n = 127) clearance by surgeon (22.5%, n = 107), time from injury (22.5%, n = 107) and the ACL-RSI questionnaire (23.7%, n = 113).

3.2. Thematic analysis of return to running criteria

The thematic analysis of the return to running criteria in non-operative and postoperative patients revealed eight major areas that physiotherapists targeted in their criteria including specific cut off criteria (Table 2). The key themes were: *clinical examination (irritability, range of motion, strength and pain), biomechanics, functional/performance tests, patient reported outcomes, time from injury, medical clearance, passive stability and other.* For both non-operative and postoperative patients, *functional/performance* theme was the most represented followed by *clinical examination* and *biomechanics*. Key quotes for functional/performance identified 'core control in jumping and landing' 'mobility' and 'vertical hop height' for the functional/performance category. For clinical exmaination 'range of motion', 'isokinetic testing' *'6RM eccentric knee extension strength at 70% BW', 'calf raise endurance > 25 reps bilaterally'* or*'HQ ratio 70%* were common quotes while "gait mechanics' and running analysis'were often cited for biomechanics in both non-operative and postoperative group.

3.3. Cutoff values for return to running criteria

Table 2 summarises the cutoff criteria for return to running in a non-operative patient. 155 responses across all countries (32.6% of all respondents) were recorded regarding the specific cut-off criteria used to decide a patient's readiness to begin running. Within the *clinical examination* theme a pain score using visual analog scale or numerical rating scale of between 0/10 and 3/10 (n = 40, 8.4%), followed by swelling/effusion with the absence of effusion or a swipe test result of <1+ (n = 26, 5.4%) and then full knee range of motion was reported (n = 12, 2.5%). For the *functional/performance tests* theme**,** limb symmetry index in strength and hop tests were cited most, whereby strength symmetry >90% (n = 14, 2.9%) and >70% (n = 11, 2.3%) were the most frequent responses for hop test, symmetry >85% (n = 9, 1.8%), and >70% (n = 9, 1.8%) were the most cited. The remaining themes had very little mention with less than 10 responses and no consensus on cut off values identified.

Concerning management of patients following ACLR, Table 3 summarises the main cutoff criteria recorded from repondents. A total of 150 responses (31.5% of all respondents) were received regarding the specific cut-off criteria. Within the *clinical examination tests* pain the most

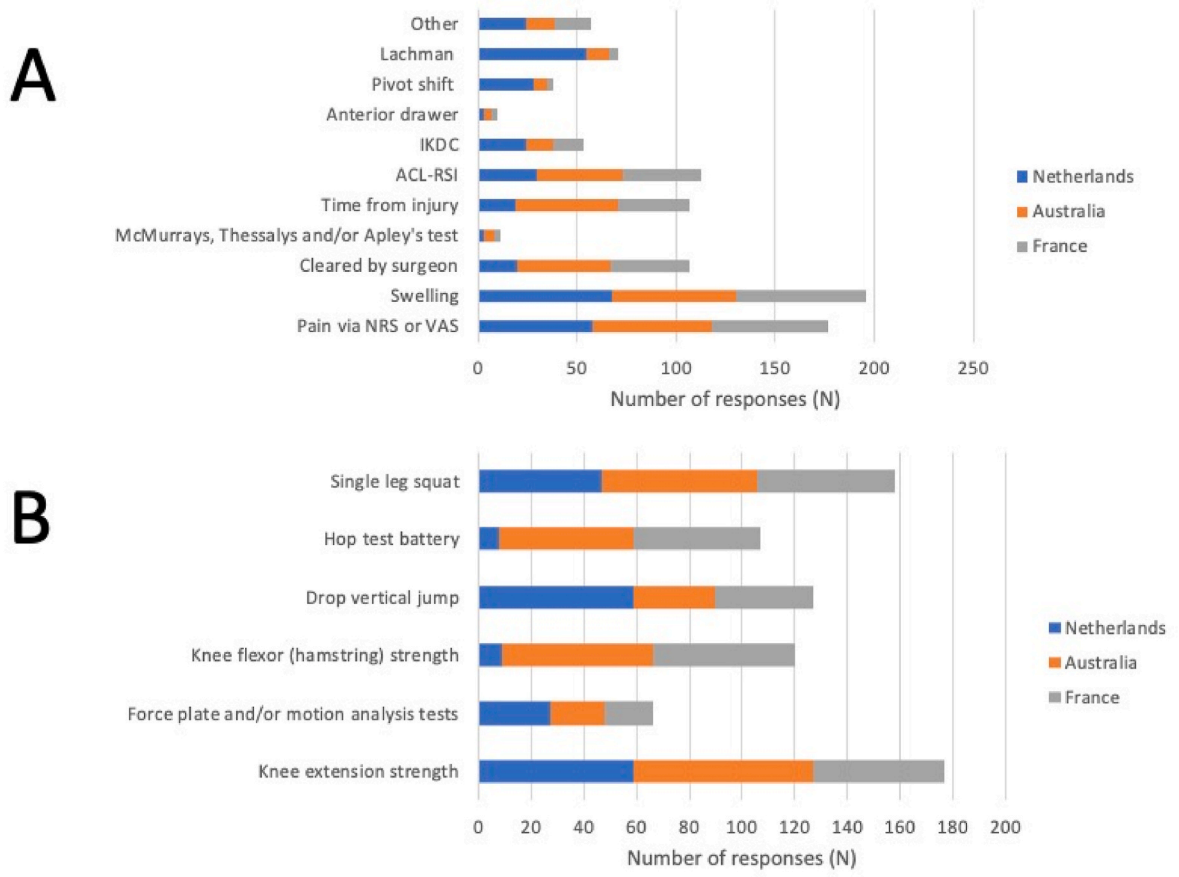

Fig. 2. Criteria for return to running following ACL injury with a operative approach. Fig. 1A corresponds to clinical tests summary across the three countries for operative management while Fig. 1B depicts the physical/performance based tests for operative management. Respondents could provide multiple answers to this section.

Table 2
Summary of cutoff values for return to running with a non-operative approach.

Theme	Outcome	Mentioned by n (%) responders	Cut-off	Mentioned by n (%) responders
Clinical examination	VAS/NRS	40 (8.4)	0-3/10	40 (8.4)
	Swelling/ effusion	26 (5.4)	<1+	26 (5.4)
	ROM	12 (2.5)	Full ROM	12 (2.5)
Functional/ performance	LSI of strength tests	25 (5.2)	LSI >90%	14 (2.9)
			LSI>70%	11 (2.3)
	LSI of hop tests	18 (3.7)	LSI >85%	9 (1.8)
			LSI>70%	9 (1.8)

Table 3
Summary of cutoff values for return to running with an operative approach.

Theme	Outcome	Mentioned by n (%) responders	Cut-off	Mentioned by n (%) responders
Clinical examination	VAS/NRS	21 (4)	0/10	12 (2.5)
			<2/10	9 (1.8)
	Swelling/ effusion	34 (7.1)	No effusion (grade 0)	32 (6.7)
			<1+	2 (0.4)
	ROM	19 (3.9)	Full ROM	19 (3.9)
Functional/ performance	LSI of strength tests	27 (5.6)	LSI >90%	12 (2.5)
			LSI>70%	15 (3.1)
	LSI of hop tests	13 (2.7)	LSI >85%	8 (1.6)
			LSI>70%	5 (1)
Time from surgery	Time from surgery	13 (2.7)	>12 weeks	13 (2.7)

popular answer with 0/10 (n = 12, 2.8%) followed by pain <2/10 pain (n = 9, 1.8%) the most frequent answers. Regarding effusion *'no effusion'* was the most cited cut-off value (32/34), with the remaining 2 responses using swipe test < grade 1+'. Cut-off values related to range of motion came in third with (n = 19, 3.9%) citations and the most frequent quote was *'full knee extension ROM'*. Within the *functional/performance* the most used criterion was strength symmetry with a cut-off value of >70% LSI (n = 15, 2.5%) followed by > 90% LSI (n = 12, 3.1%). Hop tests symmetry came in second with nineteen responses with the cut-off value of 90% LSI (n = 8, 1.6%) followed by 70% LSI (n = 5, 1%) the most frequent. *Time from surgery* was the next most popular cut off criteria mentioned with >12 weeks the most common response (n = 13, 2.7%).

In addition to the specific cut-off values, thematic analysis also revealed considerable barriers to implementation of crtieria for return to running in clinical settings across Australia, the Netherlands and France. Four themes emergered from 173 responses highlighting *working facilities and equipment* (n = 127), *barriers relative to patients* (n = 30), *health system* (n = 24) and *knowledge* (n = 11).

4. Discussion

This study aimed to elucidate how physiotherapists practicing in Australia, Netherlands and France returned patients to running following ACL injury. Given the variation in return to running criteria reported in the literature (Rambaud et al., 2018; Van Cant et al., 2022),

we sought to understand current international clinical practice standards. Although there was variation across countries in the experience level of respondants, we found the majority of respondants worked in private clinics (83–90%), and typically saw between 1 and 10 ACL patients per month. This is similar to previous surveys ascertaining ACL rehabilitation practice of physiotherapists (Fausett et al., 2022), whereby approximately 77% saw their patient 6–24 times between 3 and 6 months (i.e., 2–8 times per month). As such, this provides support that our sample of physiotherapists surveyed manage a similar volume of ACL patients per month and is reflective of current clinical practice in Australia, the Netherlands and France.

The quantative analysis of return to running criteria found that majority of clinicians use pain, swelling, knee extensor strength and single leg squat as key variables for both non-operative and operative approaches. These answers are reflective of current clinical practice guidelines for return to sport and general rehabilitation principles (van Melick et al., 2016). Despite these findings, there was a clear lack of cutoff criteria for these variables, as only 32% of respondents provided cutoff criteria. Within this sample pain <3/10, swelling < grade 1+ and functional hop and strength tests >70% limb symmetry were commonly cited cutoff criteria for both non-operative and operative patients. While this provides some clarity for cutoff criteria in an ACL population, we contest that these variables and cutoff criteria do not represent a thorough benchmark for safe return to running. Indeed, Kotsifaki, Sideris, et al., 2023 recently published clinical guidelines on rehabilitation following ACL injury highlights a lack of return to running criteria. Given that running is a cyclical movement that predominantly occurs in the sagittal plane and is generally divided into braking (eccentric) and propulsive (concentric) forces (Dorn et al., 2012; Pandy and Andriacchi, 2010; Maniar et al., 2022), none of the variables or cutoff criteria in this study have identified biomechanical or specific strength and power based cutoff criteria. It is well known that the proximal hip and distal ankle joint mechanics signiciantly contribute to overall knee loads, such as the soleus attenuating large tibiofemoral contact force and ACL strain rapidly across very short contact times <0.2ms (Dorn et al., 2012; Maniar et al., 2022). Moreover, Kotsifaki et al. found that asymmetries in vertical hop tests, such as peak landing force and eccentric impulse are still evident in ACL patients at return to sport, providing evidence to develop a wider scope of tests for return to sport (Kotsifaki et al., 2023b, Sideris, et al., 2023). As the vertical ground reaction force is the largest contributor to joint load during running-related tasks, we recommend that future studies develop a minimum threshold for physical tests that incorporate vertical single and double leg landing tasks, in combination with clinical symptoms (pain, range of motion and swelling), and strength evaluation to elicit better outcomes for patients that follow a non-operative or operative approach.

Our study also found that working facilities and equipment (n = 127) was a key barrier to implementation of return to running criteria. Indeed, this is something that will likely need to be addressed if we are to improve clinical practice guidelines, particularly with the emergence of new technology to objectively measure patients progress throughout rehabilitation. Specifically, the use of portable force plate technology and handheld dynamometry with appropriate accessories to provide wider lower limb strength and range of motion assessments is likely to be significant in improving return to running in ACL patients. Moreover, we suggest that clinics who are restricted with space and equipment are likely limited in their ability to provide the best return to running environment, simply due to the ability to robustly assess a range of tests related to running, and therefore it may be necessary for some therapists to consider referral of patients to specialist clinics with the capacity to conduct these assessments.

While this study provides insight to return to running criteria used by physioitherapists, there are some limitations to this study, such as the sample size relative to the number of physiotherapists that treat ACL injuries in Australia, the Netherlands and France. For example, in Australia there are over 40,000 registered physiotherapists with approximately 27% (i.e. 10,000 physiotherapists) in private settings where majority of ACL patients are managed for rehabilitation. Given we received 153 responses, the proportion of physiotherapists that responded to our survey may not necessarily reflect the majority of clinical practice standards for over 10,000 physiotherapists in Australia and abroad. Nonetheless, within the sample we have collected, we had a large proportion of physiotherpaists with over 10 years experience and post-graduate eduction, hence we believe that the variability of answers and lack of clear cutoff criteria for return to running would likely be extrapolated to the wider physiotherapy community that treat ACL injuries.

5. Conclusion

Return to running is a signficiant milestone in ACL rehabilitation given the demand imposed on the knee that may increase risk of subsequent injury if not sufficiently prepared. Despite this risk there is limited studies evaluating which criteria physiotherapists currently use in their clinical practice, hence the purpose of this study was to elucidate current clinical practice across the Netherlands, Australia and France. Irrespective of country, we found there is a great amount of variability in return to running criteria, with limited evidence for specific cut-off criteria to progress to running. Hence, this study highights the need for future studies to develop and then evaluate specific return to running criteria to safely return patients to running.

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Ethical approval

Ethics approval for this project was obtained through the University of Melbourne ethics committee for use in Australia (#20897), the Máxima Medical Center Eindhoven in the Netherlands (N21.076), and the Centre Hopitalier Universitaire de Saint Etienne ethics committee for use in France (IRBN052022/CHUSTE).

CRediT authorship contribution statement

Timothy A. Sayer: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Nicky van Melick:** Writing – review & editing, Project administration, Methodology, Data curation, Conceptualization. **Jerome Riera:** Visualization, Validation, Project administration, Methodology, Investigation, Data curation. **Jeremy Jackson:** Visualization, Validation, Data curation. **Adam Bryant:** Writing – review & editing, Writing – original draft, Conceptualization. **Rob Bogie:** Writing – review & editing, Conceptualization. **Nicholas Cross:** Conceptualization, Methodology. **Pascal Edouard:** Writing – review & editing, Writing – original draft, Visualization, Validation. **Alexandre Rambaud:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

There are no declarations of interest for this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2024.02.005.

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