Exercise parameters to consider for Achilles tendinopathy: a modified Delphi study with international experts

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ABSTRACT

To assess the level of agreement among experts on the heel raise exercise parameters that influence midportion and insertional Achilles tendinopathy (AT) rehabilitation outcomes.

An international expert panel in AT rehabilitation was invited to complete a three-round Delphi survey. In the first two rounds, experts were asked to review a pregenerated list of exercise parameters (based on the heel raise exercise) and rate their perceived influence on rehabilitation outcome, using a 5-point Likert scale. For each parameter, consensus criteria for major influence on rehabilitation were (a) median≥4, (b) ≥75% of scoring 4 or 5 and (c) IQR≤1. The third round aimed to rank the exercise parameters according to importance (from most to least important) during rehabilitation.

17 experts participated in the entire Delphi process. A total of 16 exercise parameters were assessed, of which 4 (intensity of contraction, total time under tension, number of repetitions and sets, type of contraction) reached consensus as having a major influence on rehabilitation for midportion AT and 3 reached consensus for insertional AT (range of ankle dorsiflexion during the exercise, intensity of contraction, number of repetitions and sets). The rankings of parameters that reached consensus showed that contraction intensity was perceived as the most important variable for midportion AT rehabilitation, while range of ankle dorsiflexion was deemed the most important variable for insertional AT rehabilitation.

This study identified key exercise parameters for midportion and insertional AT rehabilitation based on expert opinion. This information should assist practitioners in optimising their approach to deliver more effective, patient-specific exercises for AT rehabilitation.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Exercise-based rehabilitation is the most effective treatment strategy for Achilles tendinopathy (AT).
⇒ Exercise instructions vary widely within protocols, leading to confusion about the optimal exercise parameters for rehabilitation success.

WHAT THIS STUDY ADDS

⇒ Based on expert consensus, clinicians should prioritise contraction intensity across all cases, but for insertional AT, avoiding dorsiflexion in early rehabilitation phases may optimise outcomes.
⇒ Other parameters such as total time under tension, number of repetitions and sets, and type of contraction are also perceived to have a major influence on AT rehabilitation outcome, depending on the subtype of tendinopathy involved.
⇒ These findings emphasise the need for individualised exercise prescription based on AT location.

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INTRODUCTION

Achilles tendinopathy (AT), defined as a 'persistent Achilles tendon pain and loss of function related to mechanical loading',[1] is a relatively common pathology among athletes,[2] but can also occur in a more sedentary population.[3–5] About 6% of the general population will experience AT at least once in their lifetime, while the incidence rate rises to 24% among elite athletes and to 52% among middle- and long-distance runners.[6] Despite the evolution of treatments, AT remains difficult to manage, with recurrence rates of 23%–43% following rehabilitation[7 8] and persistent symptoms in up to 60% of patients after 5 years.[9] The natural history of AT is still not fully understood, its pathophysiology is complex and the risk factors are numerous,[10 11] which makes it difficult to implement a one-size-fits-all strategy. Primary AT management typically involves education, advice and exercises that gradually increase tendon load.[2 9 12–15] These exercises are the cornerstone of rehabilitation[2 9 12–14 16] and aim to stimulate tendon remodelling, to reduce pain and to improve calf muscle endurance and strength, as well as lower leg function.[16] Thereby, several progressive loading protocols focusing mainly on exercises involving heel raises have been developed, evolving from Stanish and Curwin programme[17 18] to Alfredson's eccentric exercises,[19] Silbernagel's combined approach[16 20] and Heavy-Slow Resistance protocol.[21] Although most of these exercise-based programmes have shown efficacy in improving patients' symptoms,[21–23] a recent systematic review failed to show clear improvement in muscle structure or function after completing exercise rehabilitation.[24] Even though the impact of exercises is not limited to the modification of muscular properties, this highlights the necessity to refine tendon loading protocols to optimise their effectiveness.

Experts usually describe their tendon loading protocol by defining several variables: (a) the type of exercise performed; (b) exercise parameters (eg, positioning, intensity, etc) and (c) session frequency and programme duration. However, although exercise-based protocols consistently use the heel raise exercise, instructions for other variables are not always specified, and if they are, they often differ depending on the programme chosen.[16 19 21 25] These variations produce uncertainty regarding how rehabilitation exercises should be performed for rehabilitation success. To date, there is no clear indication on which specific exercise parameters have the greatest influence on clinical outcomes in AT rehabilitation, limiting the ability to optimise and personalise loading protocols. Consensus on this topic would provide valuable insight into how exercises should be performed and which are the key exercise parameters. A Delphi study, which seeks expert consensus through iterative feedback while ensuring anonymity and minimising social pressure,[26–28] is a suitable method for this purpose. The consensus reached, based on both scientific evidence and expert experience, will offer clinicians clear guidelines for exercise implementation.[26 28] Since the heel raise exercise is consistently proposed in AT loading protocols, it appears appropriate to use this exercise as a model for this investigation.

The objective of this study was therefore to assess the level of agreement among experts on the heel raise exercise parameters that influence midportion and insertional AT rehabilitation outcomes. The information gathered will help enhance the efficiency of practitioners' daily practice and contribute to improving the standards used for AT exercise protocols in future research. This consensus might notably be used together with the Consensus on Exercise Reporting Template—which has standardised the information to be reported when conducting exercise interventions in clinical trials[29]—to help determine which exercise variables to focus on.

METHODS

Study design

A modified Delphi study was conducted with a panel of international experts in Achilles tendon rehabilitation. The methodology used was based on the guidelines provided by Jünger *et al*[30] and Boulkedid *et al*,[31] and the whole process was reported according to the CREDES and CHERRIES guidelines (online supplemental files 1 and 2).

Steering committee

A steering committee was established to assist with the Delphi process, the development of the questionnaires and the analysis of the results. It comprised the researchers responsible for the day-to-day management of the Delphi process (YD, SO'N, RT) and an advisory committee (VG, FD, FCB, AR). The steering committee included one woman and six men and was composed of junior (n=1) and senior (n=6) researchers from different disciplines: physiotherapy (n=2), biomechanics (n=1), medicine (n=3) and sport science (n=1). Three of the members had participated in and/or published a Delphi study (VG, SO'N, RT), and one was an AT expert (SO'N). None of the steering committee members participated in the Delphi process as experts.

Participants

Potential panellists

Only experts who had conducted and published research in the field of exercise-based rehabilitation for AT were included in the list of potential participants. An initial list of experts was established from two sources: (a) the top 66 Achilles tendon specialists referenced on the Expertscape website (https://expertscape.com/ex/achilles+tendon), and (b) the authors of the 'ICON 2019/2020—International Scientific Tendinopathy Symposium Consensus' publications.[1 32–35] To refine the selection, a PubMed search was conducted for each expert, using the query: ((Name[Author - First]) OR (Name[Author - Last])) AND (Achilles tend*). The criteria for inclusion as a potential participant were: experts who had published at least two articles as first or last author on exercise-based rehabilitation or the effects of exercise in AT. Case reports, editorials, commentaries, symposium abstracts and infographics were excluded.

A second PubMed search was then conducted to identify experts not listed in Expertscape or ICON publications and who had published at least two articles as first or last author on exercise-based rehabilitation or the effects of exercise in AT. The search used the following query: ((((calcaneal) OR (Achill*)) AND (tend*)) NOT (Achilles tendon rupture[Title/Abstract])) AND (((((exercise[MeSH Terms]) OR (exercise therapy[MeSH Terms])) OR (rehabilitation[MeSH Terms])) OR (resistance training[MeSH Terms])) OR (physical therapy)). Only studies published in the last 10 years and involving human participants were considered. Case reports, editorials, commentaries, symposium abstracts and infographics were excluded. All experts identified through this second search were added to the list of potential participants.

Size of the panel

The ideal sample size for a Delphi study mainly depends on its objectives, complexity and the available resources.[36] While de Villiers *et al* suggest that a range of 15–30 participants is appropriate,[36] other studies consider a minimum of 12 participants sufficient for achieving consensus.[37 38] As our study focuses specifically on experts in AT exercise-based rehabilitation, a panel of 15 participants was deemed sufficient to represent experts' opinion.

Initial invitation

The email addresses of all potential participants were collected by the principal investigator (YD) from their recently published studies. An email invitation, including an information letter and a consent form (online supplemental files 3 and 4), was sent by another investigator (SO'N) to each of the identified experts.

Preparatory phase

The first stage of this modified Delphi study involved designing a survey to address the research question. A literature review was conducted to identify the loading parameters used for the heel raise exercise during AT rehabilitation, as this exercise is common to all protocols. This review focused on a detailed analysis of the four exercise-based protocols[16 18 19 21 25] cited in two recent systematic reviews.[2 39] Through this process, 12 exercise

Table 1 List of the parameters included in the Delphi questionnaires

Quantitative parameters	Qualitative parameters
Parameters from exercise-based programmes	
Number of repetitions and sets	Type of contraction
Intensity of the contraction	Range of ankle dorsiflexion during the exercise
Duration of the contraction	Degree of knee flexion
Total time under tension	
Tempo	
Loading rate	
Rest time between each set	
Pain caused by the exercise	
Frequency of sessions	
Parameters added by the steering committee	
	Position of the foot
	Rotation of the ankle/leg
Parameters added in round 2 questionnaire	
	Exercise performed with or without shoes
	Range of ankle plantar flexion during the exercise

parameters were identified, with 2 additional parameters added following discussions with the steering committee (table 1).

Based on this information, a questionnaire was developed using the Limesurvey software (V.3.17.16; LimeSurvey GmbH, n.d.). A 5-point Likert scale (from 1 'has no influence at all' to 5 'has a very high influence') was used to assess the influence of each parameter on the outcome of rehabilitation for both midportion and insertional AT. Participants were provided with optional free-text fields to justify their responses and could suggest additional parameters for inclusion in subsequent rounds at the end of the survey, ensuring a comprehensive exploration of the study topic.[11 40]

To refine the questionnaire and address potential issues related to content, format and technical functionality,[40–42] a pilot test was conducted with seven healthcare professionals (three sports physicians, three sports physiotherapists and one sports scientist). The participants were comfortable with AT, and three of them had already participated in one or more Delphi studies. They completed the questionnaire and provided feedback on usability and any encountered difficulties. Identified issues were addressed where possible to improve the final version.

Rounds

For each of the three Delphi rounds, the participants received an email with a direct link for unique access to the online questionnaire. Each round lasted between 9 and 11 weeks, consisting of an initial period for survey completion, followed by a second period for data analysis, questionnaire modifications and feedback preparation. Two reminder emails were sent to participants who had not completed their survey (one after 2 weeks and another 1 week later).

In the first round, all the experts were asked to complete the initial questionnaire (online supplemental file 5), which also included a section for collecting personal information.

The second-round questionnaire was updated through a multi-step process. First, all exercise parameters were retained for the second round, regardless of the results from the first round. This allowed participants to revise their assessments while being aware of the opinions expressed during the first round. Second, questions that appeared to be misunderstood or misinterpreted following the experts' comments were modified to improve clarity, after careful analysis and discussion by the steering committee. Third, the additional parameters suggested by the participants were considered by the steering committee and either added to the list of exercise parameters in the second-round questionnaire or excluded if they were judged to be out of context or overlapping with existing parameters. This updated questionnaire was sent to all participants, who were asked to reassess the influence of each exercise parameter (online supplemental file 6).

In the third round, experts were asked to rank in order of importance: (a) the parameters that had reached a consensus as having a major influence after round 2 and (b) all the exercise parameters. The benefit of this ranking was twofold. First, it highlighted the key exercise parameters, particularly when multiple parameters met the consensus threshold as having a significant influence on rehabilitation. This information is useful for daily practice and for determining potential directions to prioritise in future research on exercise parameters. In addition, the ranking of all exercise parameters helped to identify whether parameters close to the consensus threshold were ranked among the most important by experts and should still be considered relevant. This enabled us to refine the results obtained in the first two rounds.

Data analysis

All answers were extracted into an Excel spreadsheet, and data were stored on the Secure Storage of Scientific Data server of the University of Reims Champagne Ardenne. For rounds 1 and 2, quantitative data were analysed using descriptive statistics, including measures of central tendency (median), frequency distributions (percentage obtained for each 5-point Likert scale rating value) and dispersion (interquartile range (IQR)).[42–44] Given its robustness as a statistical measure, the IQR is often used to assess the stability of responses in Delphi studies.[45] The qualitative analysis focused on the comments provided by the experts in the free text fields and used a thematic analysis. These comments were summarised and classified according to their content in five categories[46]: justification, clarification, recommendation, scientific link and misunderstanding. Experts' justifications and clarifications were then critically examined to (a) understand the reasons why certain parameters reached a consensus of major influence on AT rehabilitation outcomes and (b) establish whether this rationale was based on scientific evidence.

Feedback

After each round, a feedback report was provided to each participant via email and within the questionnaire used in the subsequent round. This feedback included, for each item: (a) the quantitative results of the group, (b) a summary of all the experts' comments and (c) the participant's personal rating and comments. This information allowed participants to reconsider their responses, with awareness of the group's overall position, and without any external pressure.[11 31 43]

Consensus

Consensus is defined as 'a general agreement; the judgment arrived at by most of those concerned'.[43] However, the criteria to determine consensus are not clearly established.[31 43 44 47] Based on scientific recommendations,[30 44 47] the predetermined thresholds used to achieve consensus of major influence on rehabilitation outcomes (subsequently described as consensus of major influence) were: (a) a median≥4 on the 5-point Likert scale, (b) ≥75% of scoring 4 or 5, and (c) an IQR≤1. Conversely, consensus indicating a minor influence on rehabilitation outcomes (subsequently described as consensus of minor influence) was reached when the median score was ≤2, ≥ 75% of participants scored 1 or 2, and the IQR was ≤1. Any other scenario resulted in an absence of consensus.

Equity, diversity and inclusion statement

Although there were no gender or residency restrictions, the specificity of the studied topic did not allow for a balanced number of men and women from different geographical regions to be included in the expert panel. Women were less represented (n=4), as were some geographical locations (Africa, Asia).

RESULTS

The Delphi process is presented in figure 1, and an overview of round 1 and round 2 results is available in online supplemental files 7 and 8, respectively.

Panel of experts

The two-step process used to identify experts resulted in a group of 26 potential participants (19 from ICON publications and the list of Achilles tendon specialists referenced by Expertscape, and 7 from the complementary PubMed search). Of these 26 experts, 21 responded to the initial invitation (80.8%). Two declined to participate, and one was excluded because he did not consider himself an expert in the field covered by this study. A total of 18 experts was therefore included in the final list of participants. One expert did not answer the questionnaire distributed in round 1, reducing the number of participants to 17 (94.4%) for the following rounds. As no response was received after the two reminder emails, the reasons for this dropout could not be explained. Participants were mainly clinician-researchers living in Australia, Europe or North America. Most of them were men (n=13), PhD holders (n=11) and were physiotherapists (n=9) and/or university/academic professors (n=9). Table 2 details the characteristics of all participants.

Round 1 outcomes

Of the 14 exercise parameters proposed, only one (intensity of contraction) reached a consensus of major influence for midportion AT, while two met the same consensus for insertional AT (intensity of contraction, range of ankle dorsiflexion during the exercise) (table 3, figure 2).

An additional 22 exercise parameters were suggested by the participants. After review by the steering committee, two were added to the round 2 survey (range of plantar flexion during the exercise, and performing the exercise with or without shoes). The others were rejected because (a) they did not directly relate to how the exercise should be performed (n=15) or (b) they overlapped with parameters already proposed (n=5).

A total of 160 comments were collected, including 107 justifications, 19 clarifications, 24 recommendations, 9 scientific links and 1 misunderstanding. All the Delphi comments are available in online supplemental file 9.

Round 2 outcomes

The round 2 questionnaire included 16 exercise parameters and resulted in 32.1% of the ratings being different from those assigned in round 1 (table 3). Two exercise parameters (intensity of contraction, number of repetitions and sets) reached a consensus of major influence for both midportion and insertional AT. The type of contraction and the total time under tension (total TUT) reached a consensus of major influence only for midportion AT, and the range of ankle dorsiflexion during exercise only for insertional AT. All other exercise parameters failed to meet both consensus thresholds defined a priori (table 3, figure 2).

The qualitative analysis revealed 41 new comments for the items already proposed in round 1, including 31 justifications, 7 clarifications and 2 misunderstandings (online supplemental file 9). In addition, 15 comments were provided for the item 'Range of ankle plantar flexion during exercise' (5 justifications, 6 clarifications and 4 recommendations), while the item 'Exercise performed with or without shoes' received 13 comments (9 justifications and 4 recommendations).

Round 3 outcomes

Several experts (n=5) stated that it was difficult to propose a ranking of the exercise parameters, and one of them was unable to rank the proposed items. The reasons given were mainly related to the fact that many exercise parameters are interrelated or depend on other factors not specific to the tendon.

The rankings of exercise parameters for midportion AT show that the intensity of contraction is considered the most important variable, ahead of the parameters related to loading volume (total TUT and number of repetitions and sets, respectively) and the type of contraction (figure 3). The ranking of the three parameters that reached consensus of major influence for insertional AT shows that the range of ankle dorsiflexion is considered the most important variable, followed by the intensity of contraction and the number of repetitions and sets. However, when the experts ranked all the exercise parameters, contraction intensity was identified as more important than the range of dorsiflexion. Finally, the overall classification of exercise parameters shows that the parameters that achieved consensus of major influence in round 2 (intensity of contraction, total TUT, number of repetitions and sets, and type of contraction for a midportion AT; range of ankle dorsiflexion during the exercise, intensity of contraction, and number of repetitions and sets for an insertional AT) are also considered the most important exercise parameters for AT management.

DISCUSSION

This study aimed to assess the level of agreement among experts on the heel raise exercise parameters that influence midportion and insertional AT rehabilitation outcomes. Of the 16 parameters proposed during the Delphi process, four reached a consensus of major influence for midportion AT (type of contraction, number of repetitions and sets, intensity of contraction, total TUT) and three for insertional AT (number of repetitions and sets, intensity of contraction, range of ankle dorsiflexion during the exercise). All other parameters did not reach either a consensus of major influence or a consensus of minor influence. The rankings reveal that contraction intensity (for midportion and insertional AT) and range of ankle dorsiflexion (for insertional AT) are considered the most important variables in AT rehabilitation.

Contraction intensity

Contraction intensity is widely considered by experts to be a key parameter—and often the most important—regardless of the type of pathology (figure 3).

Experts' comments suggest that this variable is fundamental primarily because contraction intensity is thought to drive tendon adaptation. Mechanical loading induces tendon strain,

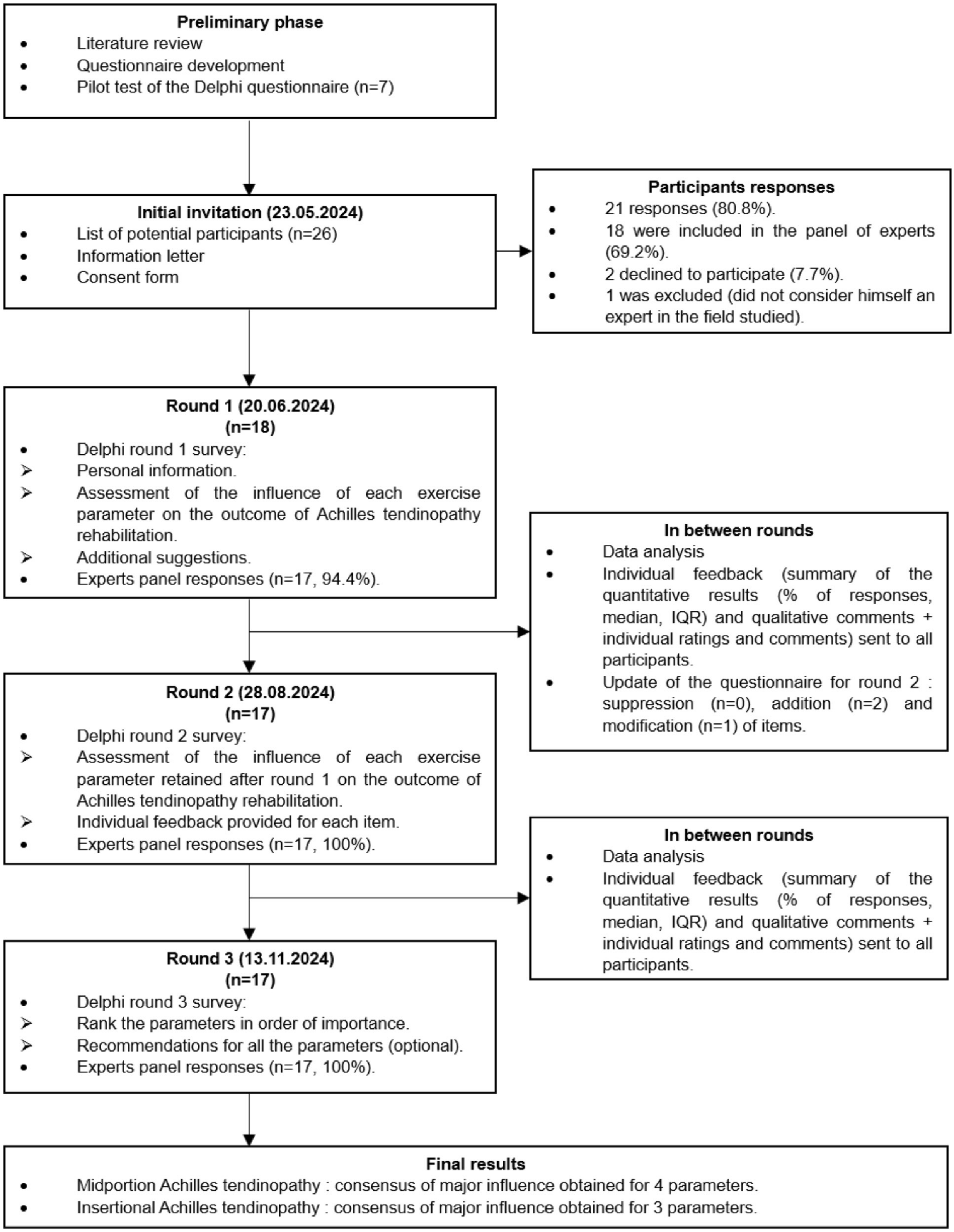

Figure 1 Flowchart of the Delphi process.

which initiates a tendon deformation-adaptation cycle. This cycle includes a series of events leading to changes in tendon mechanical (stiffness), material (Young's modulus) and morphological (cross-sectional area) properties.[48] The optimal level of strain to induce tendon adaptations is thought to be between 4.5% and 6.5%,[49 50] and Arampatzis *et al* showed that a high intensity of contraction (90% maximal voluntary isometric contraction (MVIC)) is required to reach that level of strain.[51 52] Similarly, a systematic review by Bohm *et al* explains that exercise performed at intensities above 70% repetition maximum (RM)/maximal voluntary contraction (MVC) induces greater gains in stiffness than exercise performed at intensities below 70% RM/

Table 2 Characteristics of the experts participating in the entire Delphi process

	Experts n=17
Sex	
Women	4 (23.5)
Men	13 (76.5)
Age	
Median (IQR; min–max) years	49 (17; 29–70)
Country of residence	
Australia	4 (23.5)
Sweden	3 (17.7)
UK	3 (17.7)
Netherlands	2 (11.8)
Spain	2 (11.8)
USA	2 (11.8)
Canada	1 (5.9)
Highest academic degree	
No university qualification	0 (0)
Bachelor	0 (0)
Master	1 (5.9)
PhD	11 (64.7)
Other	5 (29.4)
Role	
Researcher only	5 (29.4)
Clinician and researcher	12 (70.6)
Professional situation	
Sport medicine physician	2 (11.8)
Orthopaedic surgery	2 (11.8)
Physiotherapy	9 (52.9)
Rheumatology	2 (11.8)
Podiatry	0 (0)
Sport scientist	0 (0)
University/academic professor	9 (52.9)
Other	2 (11.8)

Unless otherwise stated, all the data are presented as n (%).
IQR, interquartile range.

MVC.[53] These data are consistent with the results of a recent meta-analysis showing that bodyweight exercises produce less improvement in clinical outcomes than if additional loads are used,[54] and support the concept that achieving high contraction intensities during rehabilitation is necessary to obtain optimal results. However, the results of two other systematic reviews are inconsistent with those of Bohm *et al* and do not show a clear relationship between tendon adaptations and the intensity of contraction.[55 56] One possible explanation for these discrepancies is the large inter-individual variability observed between the intensity of the contraction and the amount of Achilles tendon strain induced,[49 57] making the association between intensity and tendon adaptations difficult to establish. In fact, it appears that tendon strain levels of 4.5%–6.5% can be produced by contractions ranging from 30% to 90% MVC.[49] This would suggest that lower contraction intensities may also have the potential to induce sufficient tendon strain. This inter-individual variation may be significant, as several experts suggest that excessive loads could also have harmful effects because of excessive tendon strain, although this hypothesis has yet to be investigated. The challenge would therefore be to find the appropriate contraction intensity which places sufficient strain on the tendon without overloading it and thereby becoming detrimental. Patient's level of physical activity and familiarity with exercise may, for example, play an important role here.

Beyond its influence on tendon adaptations, contraction intensity may also affect tendon function and performance. Functional activities required for return to sport—such as high-speed running and jumping—place substantial loads on the Achilles tendon, with forces reaching up to 7.71 bodyweight (BW) for running and 7.3 BW for one-legged lateral and forward hopping.[58] Achieving high-intensity contractions is therefore essential to ensure that the tendon can withstand these functional demands. Furthermore, contraction intensity also influences the function and performance of the muscles contributing to the Achilles tendon. The development of specific physical qualities such as muscle strength, endurance, hypertrophy and power is highly dependent on the intensity of contraction, as well as the number of sets and repetitions. For example, developing muscular strength requires high contraction intensities with a limited number of repetitions, while developing muscular endurance involves a larger number of repetitions at lower intensities.[59] Thus, especially in the later stages of rehabilitation, these parameters could be tailored to the patient's specific needs and weaknesses.

Finally, from a psychosocial perspective, the ability to perform exercises with heavy loads without exacerbating the condition may play an important role in boosting patients' self-efficacy and confidence in movements.

Loading volume

The results obtained for the three parameters associated with loading volume (number of sets and repetitions, duration of contraction, total TUT) were inconsistent (table 3). Consensus of major influence was met for the number of sets and repetitions in both midportion and insertional AT. In contrast, contraction duration did not reach consensus for either form of AT. The total TUT met consensus of major influence only for midportion AT, although the results obtained for insertional AT were close to the consensus thresholds (a single additional rating of 4 or 5 would have been sufficient to reach the consensus cut-off). Given the small number of experts (n=17), the absence of feedback supporting a possible difference between midportion and insertional AT, and the overall ranking for insertional AT which places total TUT closely behind exercise parameters with a consensus of major influence, it can be hypothesised that the rationale for this parameter is relevant for both subtypes of AT.

It is noteworthy that a similar rationale is consistently found for these three parameters. This justification is based on the fact that the tendon requires a sufficient stimulus (in terms of loading duration) to induce physiological adaptations, with insufficient or excessive stimulation becoming ineffective or harmful, respectively. In fact, due to the viscoelastic nature of the tendon's extracellular matrix, the transmission of the external tendon strain to the cellular level is considered to be time-dependent.[48 60] This biomechanical property suggests that prolonged contraction durations may enhance tendon adaptation. Several studies have shown that short contraction times (eg, during jump exercises) are less favourable for tendon adaptations than longer sustained contractions.[48 55 61] Additionally, during dynamic exercise, contraction duration is closely associated with contraction velocity, and a recent study showed that slow-speed contractions are more likely to modify tendon thickness and stiffness than fast-speed contractions.[62] These findings are consistent with experts' comments and with the instructions generally provided within loading protocols, which mainly recommend slow/long

Table 3 Summary of the quantitative data from round 1 and round 2

Parameter	Round 1 Median	Round 1 IQR	Round 1 % 1+2	Round 1 % 3	Round 1 % 4+5	Round 2 Median	Round 2 IQR	Round 2 % 1+2	Round 2 % 3	Round 2 % 4+5	Different rating from round 1 (%)
Midportion Achilles tendinopathy											
Type of contraction	4.0	2.00	11.76	35.29	52.94	4.0	0.00	5.88	17.65	76.47	41.2
Number of repetitions and sets	4.0	2.00	5.88	35.29	58.82	4.0	1.00	0.00	17.65	82.35	41.2
Intensity of contraction	5.0	1.00	0.00	17.65	82.35	5.0	1.00	0.00	17.65	82.35	17.6
Duration of the contraction	4.0	1.00	11.76	35.29	52.94	4.0	1.00	5.88	29.41	64.71	35.3
Total time under tension	4.0	1.00	5.88	35.29	58.82	4.0	0.00	5.88	17.65	76.47	29.4
Tempo	3.0	2.00	29.41	35.29	35.29	3.0	1.00	11.76	52.94	35.29	35.3
Loading rate	4.0	2.00	17.65	23.53	58.82	5.0	2.00	11.76	17.65	70.59	29.4
Rest time between each set	3.0	1.00	41.18	35.29	23.53	3.0	1.00	47.06	29.41	23.53	11.8
Presence/absence/severity of pain during the exercise	4.0	2.00	18.75	12.50	68.75	4.0	3.00	29.41	11.76	58.82	50.0
Range of ankle dorsiflexion during the exercise	3.0	1.00	11.76	47.06	41.18	3.0	2.00	11.76	47.06	41.18	52.9
Position of the foot during the exercise	3.0	2.00	29.41	35.29	35.29	3.0	2.00	29.41	35.29	35.29	23.5
Rotation of the ankle/leg during the exercise	3.0	1.00	41.18	41.18	17.65	2.0	1.00	52.94	35.29	11.76	35.3
Degree of knee flexion during the exercise	4.0	1.00	5.88	35.29	58.82	4.0	1.00	11.76	17.65	70.59	17.6
Frequency of sessions	4.0	2.00	11.76	29.41	58.82	4.0	1.00	5.88	23.53	70.59	35.3
Range of ankle plantar flexion during the exercise	Not included					3.0	2.00	47.06	17.65	35.29	
Performing the exercise with or without shoes	Not included					2.0	1.00	52.94	29.41	17.65	
Insertional Achilles tendinopathy											
Type of contraction	3.0	1.00	11.76	41.18	47.06	4.0	1.00	5.88	23.53	70.59	41.2
Number of repetitions and sets	4.0	2.00	11.76	35.29	52.94	4.0	0.00	0.00	23.53	76.47	41.2
Intensity of contraction	5.0	1.00	0.00	17.65	82.35	4.0	1.00	0.00	17.65	82.35	11.8
Duration of the contraction	4.0	1.00	11.76	35.29	52.94	4.0	1.00	5.88	29.41	64.71	35.3
Total time under tension	4.0	1.00	5.88	35.29	58.82	4.0	1.00	5.88	23.53	70.59	35.3
Tempo	3.0	2.00	29.41	35.29	35.29	3.0	1.00	17.65	47.06	35.29	29.4
Loading rate	4.0	2.00	17.65	29.41	52.94	4.0	2.00	5.88	35.29	58.82	41.2
Rest time between each set	3.0	1.00	41.18	35.29	23.53	3.0	1.00	47.06	29.41	23.53	11.8
Presence/absence/severity of pain during the exercise	4.0	1.25	12.50	12.50	75.00	4.0	2.00	23.53	11.76	64.71	50.0
Range of ankle dorsiflexion during the exercise	5.0	1.00	0.00	17.65	82.35	5.0	0.00	0.00	0.00	100.00	35.3
Position of the foot during the exercise	3.0	2.00	35.29	29.41	35.29	3.0	2.00	29.41	35.29	35.29	29.4
Rotation of the ankle/leg during the exercise	3.0	1.00	41.18	41.18	17.65	2.0	1.00	52.94	35.29	11.76	35.3
Degree of knee flexion during the exercise	4.0	1.00	11.76	29.41	58.82	4.0	1.00	17.65	17.65	64.71	11.8
Frequency of sessions	4.0	2.00	11.76	29.41	58.82	4.0	1.00	5.88	23.53	70.59	35.3
Range of ankle plantar flexion during the exercise	Not included					4.0	3.00	35.29	11.76	52.94	
Performing the exercise with or without shoes	Not included					3.0	2.00	35.29	23.53	41.18	

Green = consensus of major influence on rehabilitation outcomes; Yellow = no consensus reached.
IQR, interquartile range.

strengthening exercises,[16 19 21] with integration of faster/shorter contractions during the second stage of rehabilitation.[16] In this context, the absence of consensus of major influence for contraction duration is somewhat surprising.

With regard to the total TUT and the number of sets and repetitions, the available literature failed to identify a relationship between tendon adaptations and either training volume (sets×repetitions×intensity)[56] or weekly loading volume (expressed in seconds per week).[63] In addition, conflicting results were reported when assessing the effect of total TUT on pain and disability,[64–66] and varying the number of repetitions within the same exercise protocol resulted in comparable improvements in VISA-A and visual analogue scale scores.[67] Hence, there is currently a lack of scientific evidence to explain the importance of the total TUT and the number of sets and repetitions on tendon adaptations, pain and disability.

The discrepancy between the results obtained for the parameters relating to loading volume and the available scientific evidence highlights the necessity for further research in this area to better understand their respective impact. Additionally, given the conceptual similarity between total TUT and contraction duration, along with overlapping expert commentary across both variables, a potential confusion or conflation between these constructs cannot be excluded.

Nevertheless, the consensus obtained for the number of sets and repetitions was also justified by the effect this parameter can have on muscle performance and psychological aspects. Similar to contraction intensity, these two variables can be tailored to align with the desired physical and neuromuscular adaptations during rehabilitation. From a psychological perspective, prescribing a high number of repetitions and sets may also support inhibitory learning by reinforcing the

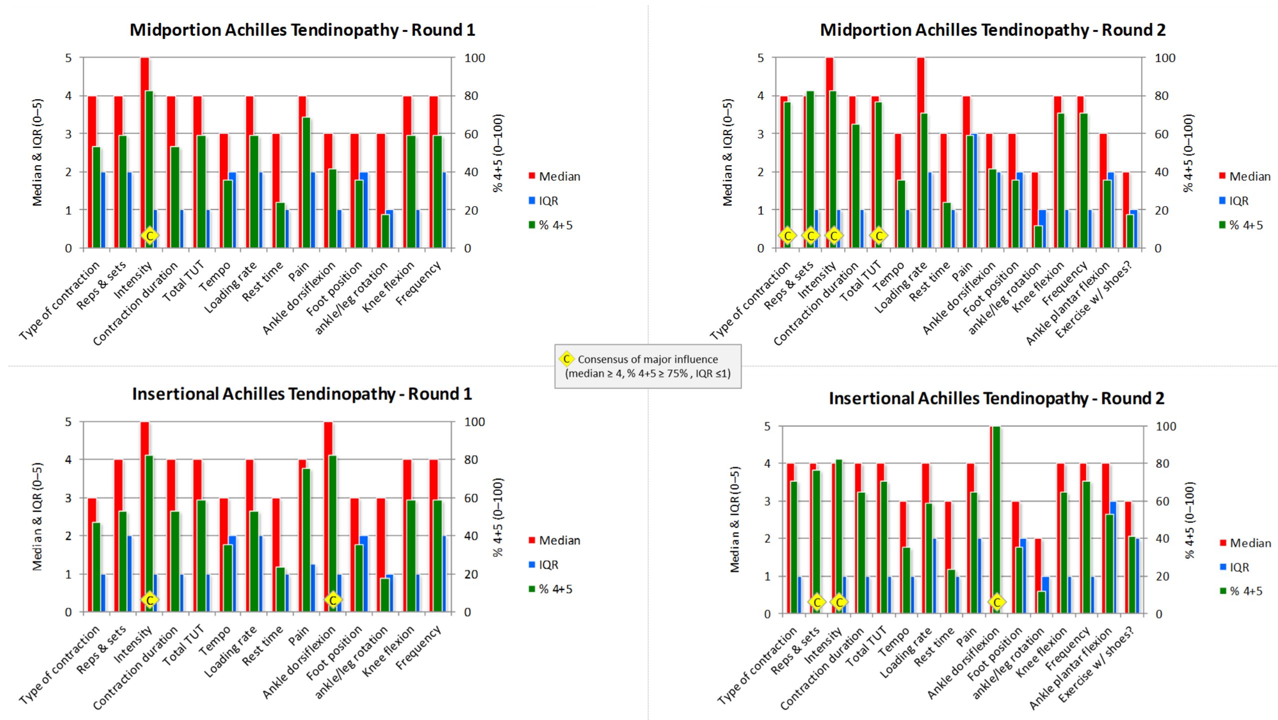

Figure 2 Overview of the median, IQR and % of 4+5 ratings achieved for each exercise parameter in cases of midportion and insertional Achilles tendinopathy. IQR, interquartile range; TUT, time under tension.

safety of tendon loading, thereby reducing fear and promoting adherence.[68]

Type of contraction

The type of contraction met consensus of major influence only for midportion AT, but the values obtained for insertional AT were very close to this consensus. Following a justification similar to that applied to total TUT, it is reasonable to hypothesise that the underlying rationale for this parameter may be applicable to both midportion and insertional AT.

Experts' comments suggest that the impact of the type of contraction is not attributable to distinctions between isometric, concentric or eccentric modalities, but rather to the specificity and functional relevance of plyometric training in AT rehabilitation. Historically, eccentric loading has formed the cornerstone of exercise-based interventions for AT[18 19 69]; however, current evidence does not strongly support the preferential use of any single type of contraction. Studies have demonstrated comparable levels of Achilles tendon loading during both eccentric and concentric phases of dynamic tasks, such as heel raises,[70 71] and similar effects of isometric, concentric or eccentric contractions have been reported, both in terms of clinical outcomes[72 73] and tendon adaptations.[53 55 56] Nevertheless, other mechanisms such as tendon force fluctuations[72 74 75] or shear forces between the paratenon-fascial-tendon layers,[74] as well as the relative ease with which eccentric movements can generate high loads,[55 72] may support the inclusion of eccentric contractions.

From a functional standpoint, deficits in concentric, eccentric-concentric and plyometric muscle performance have been reported on the symptomatic limb of individuals with AT, compared with their asymptomatic side.[76] These findings underscore the importance of including a variety of contraction types in rehabilitation programmes to restore the full functional capacity of the muscle-tendon unit. The selection of the contraction type to be favoured may also be individualised based on the weaknesses identified during the initial assessment[72] to best respond to the patient's specific deficiencies.

Unlike other contraction modalities, plyometric exercises appear to have a distinct role in AT rehabilitation. In addition to being characterised by short contraction durations, which may limit their efficacy in promoting tendon adaptation,[48 53 55] plyometrics are associated with high tendon loading[58] and frequently induce pain during the earlier rehabilitation phases. For these reasons, they are generally introduced in the later stages of rehabilitation where their high-load and functionally dynamic nature serve to prepare the tendon for the stress of daily and athletic activities.[77 78]

Range of dorsiflexion during the exercise

The range of ankle dorsiflexion during exercise is the only parameter whose influence appears to be predominantly relevant to insertional AT. For midportion AT, full-amplitude exercises are recommended as soon as possible, because (a) they reproduce the amplitudes required during functional activities and (b) a greater range of ankle dorsiflexion increases the force produced by the Achilles tendon during the exercise,[70] thereby promoting adaptations within the tendon tissue. However, it has been suggested that ankle dorsiflexion may play an important role in the case of plantaris involvement. In fact, loading into ankle dorsiflexion is thought to increase the compression between Achilles and plantaris tendons, and is generally not recommended when the plantaris is involved.[79] However, a cadaveric study showed that the compression was greater in plantarflexion than in dorsiflexion, challenging this theory.[80] As the lowest compression was observed in the mid-range position, the latter is likely to be favoured in the case of a midportion AT with plantaris involvement.[79]

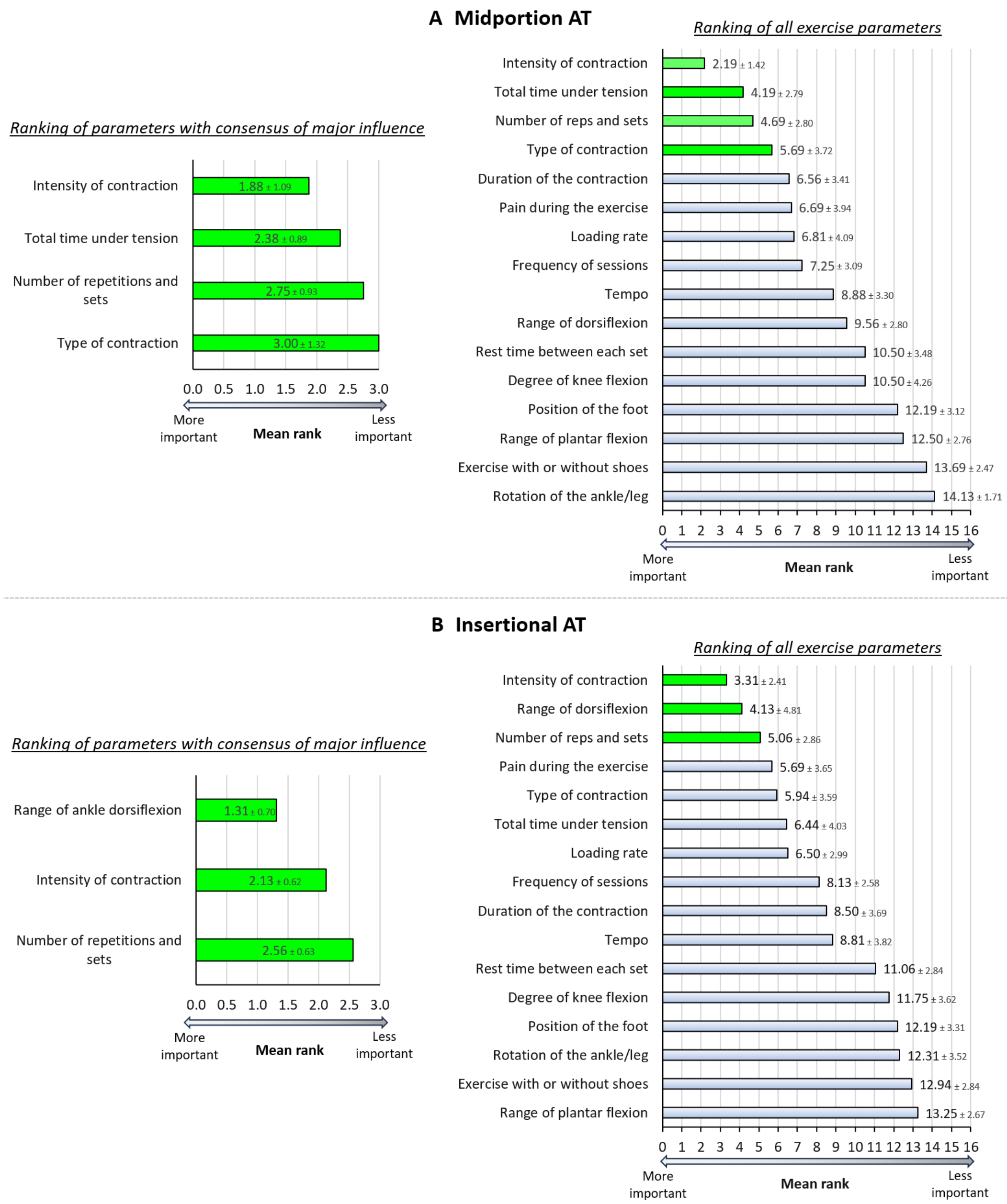

Figure 3 Ranking, in order of importance, of the parameters that met consensus as having a major influence on rehabilitation (left panel) and of all exercise parameters (right panel) for (A) a midportion AT and (B) an insertional AT. The values reported in the graphs represent the mean rank±SD obtained for each item. The lowest mean ranks correspond to the variables considered the most important. Conversely, the highest mean ranks correspond to the variables considered the least important. AT, Achilles tendinopathy.

In contrast, for insertional AT, ankle dorsiflexion is associated with increased compressive forces exerted on the deep fibres of the Achilles tendon against the superior facet of the calcaneus,[81] and this compressive load is considered a key component in the onset and persistence of the pathology.[82] Thus, it is usually recommended to minimise or avoid ankle dorsiflexion during rehabilitation.[16] Supporting this approach, several studies have demonstrated improved clinical outcomes when exercises for insertional AT are performed within a limited range, avoiding dorsiflexion over the neutral position.[83–85] Nonetheless, restoration of the full functional range of motion should not be avoided, but rather implemented gradually during the latter stages of rehabilitation, ensuring a gradual and controlled adaptation of the tendon to compressive and tensile loads.

What about pain?

Pain is considered an essential parameter in the diagnosis of AT,[86] and exercise rehabilitation protocols rely mainly on the pain experienced during exercise to guide progression.[16 18 19 21 25] However, although this variable ranks highly in the overall classification of exercise parameters (figure 3), it did not reach the predefined thresholds for consensus of major influence (table 3). One possible explanation is that pain is generally used as a regulatory tool to guide the prescription of other exercise parameters—such as load, volume or intensity—rather than being viewed as a direct modulator of tendon properties or function.[16 19 21 25] Furthermore, effective pain monitoring in rehabilitation likely requires a broader temporal perspective. According to the commonly applied pain monitoring model,[16 20] pain should be assessed not only during the exercise session itself, but also in the immediate post-exercise period and on the following day. This approach allows clinicians to adjust exercise dosage more accurately. Finally, patients' interpretation of pain could be more important than the pain intensity per se, particularly for patients with high levels of kinesiophobia. In such situations, education about acceptable pain levels and adaptive pain behaviours can help reduce fear-avoidance beliefs, promote adherence to loading protocols and support favourable clinical outcomes by reinforcing the idea that tendon loading within a tolerable pain range is both safe and beneficial.[2] Thus, and as highlighted by some experts, a moderate level of pain is tolerated during the exercise and can be useful for the patient to reconceptualise this concept. However, if the pain is too intense, patients will not adhere to the exercise, their confidence in loading the tendon will not increase and the rehabilitation outcomes will be sub-optimal.

Strengths, limitations and perspectives

This study has several strengths: it was conducted according to specific Delphi process guidelines, there was a clear use of quantitative and qualitative feedback between Delphi rounds, and a strong rationale was provided to link clinical relevance and biomechanical reasoning. Some limitations should also be mentioned. First, the expert panel was composed exclusively of researchers (n=5) and clinician-researchers (n=12), thereby excluding non-researcher healthcare professionals. This decision was intentional, as the primary aim of the study was to elucidate the rationale behind exercise prescription as understood and communicated by expert researchers. Including a broader range of non-research clinicians may have increased panel size, but would have altered the focus of the investigation. For similar considerations, patients were not involved in the design or execution of this Delphi study. Incorporating patient output into future studies aiming to develop comprehensive rehabilitation protocols could, however, provide valuable information on the feasibility, acceptability and perceived burden of treatment. The research was not limited to a specific geographic region but resulted in the inclusion of participants from only seven different countries, with some continents, such as Asia and Africa, not represented. This could limit the extent to which the proposed practical applications can be generalised. Furthermore, to minimise participant attrition, the number of rounds was limited to three. This decision reduced dropout risk, but may have limited the opportunity to reach consensus on parameters with values close to the predefined threshold. Nevertheless, even in the absence of universal consensus, the process succeeded in identifying key trends and areas of convergence among experts.[87] Supporting this, 22 of the 32 parameters evaluated in round 2 yielded IQRs ≤1, suggesting a generally low degree of response variability. The survey did not attempt to differentiate between different categories of patients (eg, active vs inactive individuals). Several subgroups of patients with AT have been identified, each exhibiting differential responses to rehabilitation protocols.[88 89] The goals of rehabilitation, and therefore the exercise parameters to focus on, could then differ according to the characteristics of the patient. However, including different categories of patients would have made the questionnaires more cumbersome and taken the study away from its original objective. Future research incorporating these subgroups will help refine and tailor exercise recommendations to the different clinical presentations of AT.

To establish a clear framework to implement the questionnaires, the heel raise exercise was chosen, given its frequent use in AT rehabilitation. While the results can be extrapolated to most Achilles tendon strengthening exercises, other factors may need to be considered for more specific exercises, such as plyometrics. From a clinical perspective, it is noteworthy that factors other than those specific to exercise execution can influence the outcomes of AT rehabilitation, such as session frequency and loading programme duration. For instance, AT rehabilitation programmes lasting at least 12 weeks seem necessary to promote improvements in physiological and clinical parameters.[53 90] Psychosocial factors may also influence the effectiveness of rehabilitation programmes and should therefore be considered in the management of AT.[89]

Finally, the absence of consensus of major influence for some parameters does not mean that they should be disregarded, but rather that current scientific knowledge does not permit a clear opinion to be formed. This highlights the need for further research in these areas to better understand their effects and unify general opinion about their impact on AT rehabilitation.

CONCLUSION

This international modified Delphi study identified the most important exercise parameters to consider during rehabilitation for AT. For midportion AT, contraction intensity emerged as the most important parameter, followed by total TUT, number of sets and repetitions, and the type of contraction. For insertional AT, the range of ankle dorsiflexion and the intensity of contraction appear to be essential, followed by the number of sets and repetitions. The experts' rationale primarily emphasised the influence of these variables on tendon adaptation and functional recovery, with additional consideration given to their psychosocial impact. This study provides clinicians with valuable guidance on important exercise parameters (as identified by experts) to consider in clinical interventions, will help shape future research projects and improve the quality of exercise prescriptions in rehabilitation protocols.

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