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Effects of inertial flywheel training on risk factors for tendinopathy: systematic review

Efectos del entrenamiento con volante de inercia en los factores de riesgo de la tendinopatía: revisión sistemática

Authors

Rosalía Soler-Lomba [1]
Ana González-Castro [2]
Pablo Hernandez-Lucas [1]
Iris Machado de Oliveira [1]

[1]Universidade de Vigo (España)
[2]Universidad de León (España)

Autor de correspondencia:
Pablo Hernandez-Lucas
Phernandez@uvigo.es

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Abstract

Introduction: Tendinopathies are highly prevalent, particularly among athletes. This study analyses scientific evidence on the effects of flywheel training on risk factors for tendinopathy.
Methods: A systematic review was conducted following PRISMA guidelines, searching CINAHL, Medline, PubMed, Scopus, and Web of Science. Randomised controlled trials and clinical trials evaluating inertial flywheel resistance exercises for tendinopathy were included. Studies that did not assess functional, morphological, or physiological changes in the tendon were excluded. Three reviewers independently extracted and assessed data quality.
Results: Five studies met the inclusion criteria, involving athletic adults at risk of or diagnosed with patellar tendinopathy, as well as healthy athletes. Training protocols lasted between six and 24 weeks. Most studies reported significant improvements in strength and power, alongside structural changes such as increased tendon cross-sectional area and reduced tendon temperature.
Conclusions: Inertial flywheel resistance training enhances strength, power, and tendon adaptations in active individuals. However, further large-scale, long-term studies are needed to confirm its effectiveness across broader populations and for tendinopathy prevention.

Keywords

Exercise therapy; physical therapy modalities; sports medicine; tendinopathy.

Resumen

Introducción: Las tendinopatías son altamente prevalentes, especialmente entre los atletas. Este estudio analiza la evidencia científica sobre los efectos del entrenamiento con volante de inercia en los factores de riesgo de la tendinopatía.
Métodos: Se realizó una revisión sistemática siguiendo las directrices PRISMA, con búsquedas en CINAHL, Medline, PubMed, Scopus y Web of Science. Se incluyeron ensayos clínicos aleatorizados y estudios clínicos que evaluaban ejercicios de resistencia con volante de inercia para la tendinopatía. Se excluyeron estudios que no valorasen cambios funcionales, morfológicos o fisiológicos en el tendón. Tres revisores extrajeron y evaluaron la calidad de los datos de manera independiente.
Resultados: Cinco estudios cumplieron los criterios de inclusión, con adultos deportistas en riesgo o diagnosticados con tendinopatía rotuliana, así como atletas sanos. Los protocolos de entrenamiento duraron entre seis y 24 semanas. La mayoría de los estudios reportaron mejoras significativas en fuerza y potencia, además de cambios estructurales como aumento del área transversal del tendón y reducción de su temperatura.
Conclusiones: El entrenamiento con volante de inercia mejora la fuerza, la potencia y la adaptación del tendón en individuos físicamente activos. No obstante, se requieren estudios a gran escala y con mayor seguimiento para confirmar su efectividad en poblaciones más amplias y en la prevención de tendinopatías.

Palabras clave

Ejercicio terapéutico; medicina deportiva; modalidades de terapia física; tendinopatía;

Introduction

Tendinopathies have a high global incidence, particularly in the lower limbs. Among athletes, specifically those involving lower-limb activities, the prevalence is approximately 16.6 per 1000 individuals (Bittencourt et al., 2024; Riel et al., 2019). This condition is also observed in the general population, where it can severely impact quality of life (de Jonge et al., 2011).
Tendinopathy represents a spectrum of tendon pathologies involving changes in the structural collagen matrix, the presence of various inflammatory cells, and clinical symptoms such as pain and reduced performance, with the potential to progress to a chronic degenerative condition (Khan et al., 2005; Sharma & Maffulli, 2005).

Tendinopathies are multifactorial conditions in which various risk factors contribute to their development (Peters et al., 2016). Therefore, it is essential to outline the risk factors associated with the injury mechanism of tendinopathy, as well as the morphological and physiological changes linked to this condition (Khan et al., 2005; Sharma & Maffulli, 2005).

Tendinopathy is associated with repetitive mechanical loading of the muscle-tendon unit, particularly in plyometric activities such as running and jumping, where stretch-shortening cycles generate high tensile forces within the tendon tissue (Brar et al., 2021; Ramírez-delaCruz et al., 2022). The tendon's limited adaptive capacity to these demands can lead to structural microdamage, promoting the progressive degeneration of the extracellular matrix. Thus, the relationship between muscle strength and power and the incidence of tendinopathy is critical, as muscular deficits impair the tendon's ability to withstand mechanical loads, making it a predisposing factor for its development (McAuliffe et al., 2019; Nawoczenski et al., 2015). Additionally, tendinopathy-related pain disrupts neuromuscular activation patterns, triggering compensatory responses that increase mechanical stress on the tendon structure, perpetuating the pathological cycle and negatively impacting tissue functionality (Rio et al., 2014).

Tendinopathy is characterised by a series of structural and functional alterations in the affected tendon. Among the key morphological changes are collagen fibre disorganisation, increased extracellular matrix deposition, and neovascularization (Khan et al., 2005; Sharma & Maffulli, 2005). These modifications can be assessed using various imaging techniques. Thermography, for instance, enables the detection of variations in skin surface temperature, which may reflect underlying inflammatory processes within the tendon (de Lacerda et al., 2022). An increase in temperature in the affected area can indicate an active inflammatory response. Additionally, the pennation angle, which refers to the angle formed between muscle fibres and the tendon, may be altered in the presence of tendinopathy (Padhiar et al., 2008; Pearson & Onambele, 2005). Changes in this angle can reflect structural adaptations of the muscle and tendon in response to injury, ultimately affecting the functional capacity and mechanical efficiency of the muscle-tendon unit (Manal et al., 2006; Rekabizaheh et al., 2016).

The most frequently used treatments for tendinopathy are conservative approaches, including cryotherapy (Rees et al., 2009), anti-inflammatory medications (Rees et al., 2009), and even corticosteroid injections (Coombes et al., 2010; Kongsgaard et al., 2009; Speed, 2001), although the latter can cause significant adverse effects and have, in some instances, been discouraged. In contrast, eccentric exercise (EE) has become widely recognised as the gold-standard, first-line management strategy for tendinopathies (Challoumas et al., 2021; Habets & Van Cingel, 2015; Murtaugh & M. Ihm, 2013; Woodley et al., 2007), with robust scientific evidence demonstrating its effectiveness in reducing pain (Kingma et al., 2007) and improving functional capacity (Murtaugh & M. Ihm, 2013).

Regarding eccentric exercise (EE), an innovative method known as inertial flywheel training (IFR) has emerged. This method was developed by Berg and Tesch with the aim of mitigating the adverse effects of weightlessness on astronauts' skeletal muscles (Berg & Tesch, 1994). In IFR, the load spins without changing direction, requiring the user to actively stop it to transition from the concentric to the eccentric phase of the exercise (Berg & Tesch, 1994). IFR can be categorised into two main types based on the design of its axis: machines with a fixed axis (cylindrical), where speed variation directly depends on the user's applied force, and those with a variable axis (cone-shaped), which allow for higher speeds since the larger diameter at the beginning of the concentric phase facilitates a faster and more efficient start (Núñez et al., 2020). These features enable progressive exercise dosing, reducing the risk of injuries associated with the overuse of eccentric loads (Fulford et al., 2015).

This justifies the interest in using EE for the treatment and prevention of tendinopathies. However, due to its relative novelty, no reviews have yet specifically analysed its effects on this condition. Therefore, the aim of this review is to examine the available scientific evidence on the effects of IFR on risk factors associated with the injury mechanism of tendinopathy, including strength, power, and pain, as well as its impact on morphological and physiological changes in the tendon. It is hypothesised that EE performed with IFR could be an effective strategy to mitigate risk factors and accelerate structural and functional adaptations in tendon tissue, due to the inherent benefits of eccentric overload.

Method

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) and the PERSiST recommendations for exercise, rehabilitation, and sport sciences (Ardern et al., 2022). The systematic review protocol was previously registered on the OSF (doi: 10.17605/OSF.IO/PS67T). The systematic search was conducted from 15 December 2024 to 15 February 2025 across five databases: CINAHL, Medline, PubMed, Scopus, and Web of Science. The search strategy employed a combination of the descriptors "tendinopathy" and "tendons" alongside keywords such as "eccentric-overload", "flywheel training", "inertial training", and "inertial flywheel", using Boolean operators AND and OR (see Supplementary Material, Table 1). The strategy was structured according to the PICOS framework: P (Population): Healthy participants or those diagnosed with tendinopathy; I (Intervention): Inertial exercise; C (Control/Comparison): Other interventions, placebo, or no intervention; O (Outcomes): Strength, power, pain characteristics, and tendon functionality; S (Study Designs): Randomised controlled trials or clinical trials. This approach ensured a comprehensive and systematic identification of relevant studies addressing the research question.

Table 1. Databases, terms, and search equation.

Databases	Terms	Search equation
Cinahl	"Tendinopathy", "tendons", "eccentric-overload", "flywheel training", "inertial training", "inertial flywheel"	((MH "Tendinopathy") OR (MH "Tendons")) AND (("eccentric-overload" OR "flywheel training" OR "inertial training" OR "inertial flywheel"))
Medline	"Tendinopathy", "tendons", "eccentric-overload", "flywheel training", "inertial training", "inertial flywheel"	((MH "Tendinopathy") OR (MH "Tendons")) AND (("eccentric-overload" OR "flywheel training" OR "inertial training" OR "inertial flywheel"))
PubMed	"Tendinopathy", "tendons", "eccentric-overload", "flywheel training", "inertial training", "inertial flywheel"	(("Tendinopathy" [MeSH Terms] OR "tendons" [MeSH Terms])) AND (("eccentric-overload" OR "flywheel training" OR "inertial training" OR "inertial flywheel"))
Scopus	"Tendinopathy", "tendons", "eccentric-overload", "flywheel training", "inertial training", "inertial flywheel"	(TITLE-ABS-KEY (tendinoplasty) OR TITLE-ABS-KEY (tendons)) AND (TITLE-ABS-KEY (eccentric-overload) OR TITLE-ABS-KEY ("flywheel training") OR TITLE-ABS-KEY ("inertial training") OR TITLE-ABS-KEY ("inertial flywheel"))
Web of Science	"Tendinopathy", "tendons", "eccentric-overload", "flywheel training", "inertial training", "inertial flywheel"	((TS=("Tendinopathy")) OR TS=(Tendons)) AND (ALL=(eccentric-overload) OR ((TS=("Tendinopathy")) OR TS=(Tendons)) AND ALL= ("flywheel training") OR ((TS=("Tendinopathy")) OR TS=(Tendons)) AND ALL= ("inertial training") OR ((TS=("Tendinopathy")) OR TS=(Tendons)) AND ALL= ("inertial flywheel"))

Study Selection

After removing duplicates, three reviewers independently assessed the eligibility of the articles. In case of disagreement, the reviewers debated until a consensus was reached. The following inclusion criteria were applied for study selection: (i) the full-text article had to be published in a peer-reviewed journal; (ii) inertial exercise had to be administered to the study sample; (iii) the studies had to be randomised controlled trials or clinical trials. Studies that did not align with the aim of the investigation were excluded.

After screening, extracting data, and evaluating titles and abstracts against the inclusion criteria, the full texts of selected articles were obtained. Additionally, articles whose titles and abstracts lacked sufficient information regarding the inclusion criteria were also retrieved in full text. Full-text articles were included only if they met the inclusion criteria, as verified by the three reviewers using a data extraction form.

Data extraction and Quality assessment

The three reviewers independently extracted data from the included studies using a customised data extraction table developed in Microsoft Excel. In case of disagreement, the reviewers debated until a consensus was reached. The following data were extracted from the included articles for further analysis: demographic information (title, authors, journal, and year), sample characteristics (age, gender, inclusion and exclusion criteria, and number of participants), study-specific parameters (intervention duration, adverse events, and intervention methods), and results obtained (analysed variables, instruments used, and follow-up time). The characteristics of the studies and the extracted data were summarised using tables.

The methodological quality assessment was conducted using the Critical Review Form for Quantitative Studies and was independently performed by the three reviewers (Letts et al., 2007).

Results

The systematic search identified a total of 68 articles in electronic databases, of which 51 were excluded during the initial screening due to duplication or irrelevance, leaving 17 articles for further review. Of these 17 articles, 10 were excluded because they did not involve inertial flywheel training (IFR). The remaining 7 articles were assessed for eligibility, and 2 (Grävare Silbernagel et al., 2001; Walker et al., 2020) were ultimately excluded as they did not align with the objectives of this review. Therefore, a total of 5 articles (Gual et al., 2016; Ruffino et al., 2021; Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016) were selected for inclusion in this review. The selection process and its various stages are detailed in Figure 1, presented as a PRISMA flow diagram.

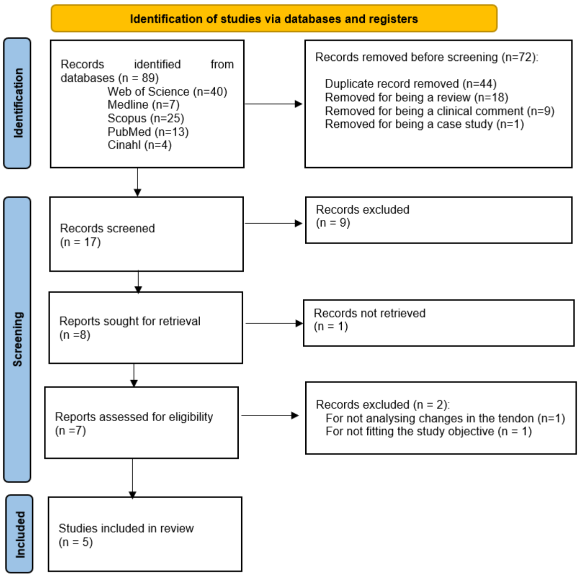
Methodological Quality in the Included Studies

The methodological quality of this study was evaluated following the Critical Review Form for Quantitative Studies (Law et al., 1998), with the results summarised in Table 2. Every article (Gual et al., 2016; Ruffino et al., 2021; Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016) shows a high methodological quality: 13 points out of 14 possible points. The weak points of the revision are that 3 of the studies (Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016) didn't justify the size of the sample and 2 of them (Gual et al., 2016; Ruffino et al., 2021) didn't avoid the intervention risks.

Sample characteristics

The selected studies included a total of 53 participants in Gual et al. (Gual et al., 2016), 42 participants in Ruffino et al. (Ruffino et al., 2021), and 20 participants across the three studies by Sanz-López et al. (Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016). Regarding gender distribution, the proportion of female participants ranged from 49% in Gual et al. (Gual et al., 2016) to 2.3% in Ruffino et al. (Ruffino et al., 2021), while no women were included in the Sanz-López et al. (Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016) studies. The mean age of all participants was 25.1 years, and all samples consisted of athletic adults (Gual et al., 2016; Ruffino et al., 2021; Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016). Gual et al. (Gual et al., 2016) studied a population of volleyball and basketball players at high risk of patellar tendinopathy. In the study by Ruffino et al. (Ruffino et al., 2021), the participants were athletes diagnosed with patellar tendinopathy, whereas Sanz-López et al. (Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016) included healthy athletes as participants.

Figure 1. PRISMA flow diagram.



Intervention characteristics

The interventions varied in duration, type of exercise, and number of sessions, as shown in Table 3. Gual et al. (Gual et al., 2016) implemented a 24-week program focusing on lower-limb power development. Ruffino et al. (Ruffino et al., 2021) employed a 12-week strength training protocol on conventional machines (leg squat, leg press, hack squat), progressively increasing loads from 15 RM to 6 RM. In contrast, Sanz-López et al. (Sanz-López et al., 2017) applied a 6-week program of squats performed with a YoYo-Squat inertial device, whereas in Sanz-López et al. (Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López, Martínez-Amat, et al., 2016), participants underwent similar clinical trials of approximately six weeks' duration emphasizing eccentric training and using ultrasound measurements to assess tendon adaptations. Control groups generally followed traditional exercise routines, such as running three days per week at around 80% of maximum heart rate or using standard weight machines, whereas intervention groups utilized flywheel devices (YoYo-Squat, custom inertial machines) targeting squats or knee extensions with incremental inertial moments ranging from 0.05 kg/m^2 to 0.11 kg/m^2. More detailed information can be found in Table 3.

Table 2. Review Form for Quantitative Studies.

Critical Review Form for Quantitative Studies	Gual et al. (2016)	Ruffino et al. (2021)	Sanz-López et al. (2016a)	Sanz-López et al. (2017)	Sanz-López et al. (2016b)
Was the purpose stated clearly?	1	1	1	1	1
Was relevant background literature reviewed?	1	1	1	1	1
Study design	RCT	RCT	CT	CT	CT
Was the sample described in detail?	1	1	1	1	1
Was sample size justified?	1	1	0	0	0
Were the outcome measures reliable?	1	1	1	1	1
Were the outcome measures valid?	1	1	1	1	1
Intervention was described in detail?	1	1	1	1	1
Contamination was avoided?	1	1	1	1	1
Cointervention was avoided?	0	0	1	1	1
Results were reported in terms of statistical significance?	1	1	1	1	1
Were the analysis method(s) appropriate?	1	1	1	1	1
Clinical importance was reported?	1	1	1	1	1
Drop-outs were reported?	1	1	1	1	1
Conclusions were appropriate given study methods and results?	1	1	1	1	1
TOTAL	13/14	13/14	13/14	13/14	13/14

CT: clinical trial, RCT: randomized control trial, 0: no, 1: yes.

Results on strength, power and pain

Regarding muscle strength and power, Gual et al. (Gual et al., 2016) reported significant improvements in lower-limb power in the intervention group, without additional tendon discomfort and with a clear increase in countermovement jump (CMJ) performance. Ruffino et al. (Ruffino et al., 2021) found that both groups experienced pain reduction and improved function, but no statistically significant differences were observed between the intervention and control groups.

Results on tendon morphological-physiological changes

With respect to the three studies by Sanz-López (Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016), their primary focus was to assess structural changes in the tendon and muscle, as well as thermographic responses. Sanz-López et al. (Sanz-López et al., 2017) found smaller temperature increases on the first day of running in the intervention group compared to the control group, suggesting potential protective effects on tendon tissue. Sanz-López et al. (Sanz-López, Martínez-Amat, et al., 2016) observed a statistically significant increase in the cross-sectional area (CSA) of the tendon after eccentric training, whereas Sanz-López et al. (Sanz-López, Berzosa Sánchez, et al., 2016) reported both an increased CSA and a higher pennation angle, in addition to a greater percentage of neovessels on the third day of running in the IG. Although these studies do not specifically address pain outcomes or vertical jump performance, their findings indicate structural and physiological adaptations that could contribute to improved tendon health. More detailed information can be found in Table 3.

Table 3. Characteristics of studies.

	Gual et al. (2016)	Ruffino et al. (2021)	Sanz-López et al. (2016a)	Sanz-López et al. (2017)	Sanz-López et al. (2016b)
Area	PT	PT	PT, AT	PT, VL	AT, GMM
Study	RCT	RCT	CT	CT	CT
Sample (female)	53 (49%)	42 (2,3%)	20 (0%)		
Control group	Their usual training	LSq, LP, HSq 4x each exercise: 4x15 RM (week 1); 4x12 RM (week 2,3); 4x10 RM (week 4,5); 4x8 RM (week 6-8); 4x6 RM (week 9-12)	Running 1h 3 days/week 80% maximus heart rate		
Intervention group	4x8 RM LSq with YoYo-Squat *IM: 0,11kg/m²*	LSq, LP, KE in custom IFR machines: 4x10 each exercise. *IM week 1-6: 0,05kg/m²* *IM week 6-12: 0,10kg/m²*	4x7 80% RM LSq with YoYo-Squat *IM: 0,07kg/m²*		
Duration	24 weeks	12 weeks	6 weeks		
Variables	Pain and function, lower limb muscle power, CMJ	Pain and function	Temperature	CSA, AP thickness, pennation angle, neovessel	CSA, AP thickness, pennation angle, neovessels
Measuring instruments	VISA-P; Jumping platform	VISA-P	IRT	US and Doppler	US and Doppler
Results	Improvement in lower limb power, functional adaptations without tendon complaints and improved CMJ in IG	No statistical differences between IG and CG in reducing pain and improving function	Smaller temperature increases on 1st day of running in IG	Significant statistical increase in CSA after the eccentric training	Increased CSA and pennation angle, significantly greater percentage of neovessels after the 3rd day of running in IG

AP: anterior-posterior thickness, AT: Achilles tendon, CG: control group, CMJ: vertical countermovement jump, CSA: cross sectional area, CT: clinical trial, EE: eccentric exercise, GMM: gastrocnemius medialis muscle, HSq: hack squat, IFR: inertial flywheel resistance, IG: intervention group, IM: inertial moment, IRT: infrared thermography, LP: leg press, LSq: leg squat, N: number of participants, PT: patellar tendon, RCT: randomized control trial, RM: repetition maximum, VL: vastus lateralis.

Discussion

The aim of this review is to examine the available scientific evidence on the effects of IFR on risk factors associated with the injury mechanism of tendinopathy, including strength, power, and pain, as well as its impact on morphological and physiological changes in the tendon. The articles analysed (Gual et al., 2016; Ruffino et al., 2021; Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016) suggest that IFR can enhance physical qualities such as strength and power

(Gual et al., 2016; Ruffino et al., 2021), in addition to inducing structural changes in the tendon (Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016).

Although evidence in healthy participants suggests benefits of inertial eccentric exercise on tendon structure (Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016), one study (Ruffino et al., 2021) examined individuals with patellar tendinopathy, and another (Gual et al., 2016) involved athletes at risk of developing this condition, also reporting encouraging results. These findings are supported by growing evidence on the effectiveness of eccentric overload exercise in other groups, such as older adults (Kowalchuk & Butcher, 2019), individuals undergoing rehabilitation following trauma or muscle mass loss (Belavý et al., 2017), and patients with conditions including stroke (Fernandez-Gonzalo et al., 2014), multiple sclerosis (de Oliveira et al., 2018), or Alzheimer's disease (Sarmiento et al., 2014).

A common feature across the reviewed studies was the use of squats as the main exercise, supporting the notion that this is one of the most comprehensive exercises for the lower limb in both performance and rehabilitation contexts (Neitzel & Davies, 2000). In all interventions, participants rested for at least 24 hours between sessions (Gual et al., 2016; Ruffino et al., 2021; Sanz-López, Berzosa Sánchez, et al., 2016; Sanz-López et al., 2017; Sanz-López, Martínez-Amat, et al., 2016), which may be explained by the fact that eccentric actions generate approximately 20% more tension than concentric contractions, stimulating collagen production with a peak at around 24 hours. The synthesis of this protein then decreases 24–36 hours after exercise, and too short intervals between sessions may hinder adequate tissue adaptation, thereby increasing the risk of tendinopathies (Heinemeier et al., 2007).

Moreover, most studies included athletic populations, mainly volleyball, basketball, and football players (Gual et al., 2016; Ruffino et al., 2021), and runners (Ruffino et al., 2021), aligning with the fact that sports activity is one of the most common causes of tendinopathy due to abrupt changes in speed and repetitive loading (Ackermann & Renström, 2012). In addition, the synergy between concentric and eccentric contractions is highly important for sports performance and injury prevention. Given that IFR has predominantly been applied in performance enhancement (Petré et al., 2018; Raya-González, Castillo, et al., 2021; Raya-González, Prat-Luri, et al., 2021), it is unsurprising that the studies focused on this particular population profile.

The improvements observed in strength and power in the reviewed studies (Gual et al., 2016; Ruffino et al., 2021) align with the findings of Maroto-Izquierdo et al. (Maroto-Izquierdo et al., 2017), who conducted the first review on the effectiveness of IFR resistance training in enhancing strength, hypertrophy, and muscle mass. This could be explained by the ability of IFR training to promote muscle hypertrophy and increase neural activity (Petré et al., 2018). More specifically, Fernández-Gonzalo et al. (Fernandez-Gonzalo et al., 2014) evaluated adaptations resulting from IFR under different loads and reported greater increases in power among men compared to women, which highlights a lack of data on the female population. In this regard, Moldini-Trissino da Lodi et al. (Mondini Trissino da Lodi et al., 2022) published a review on gender bias, emphasising the information gap in sports medicine due to the scarcity of studies on patellar tendinopathy in women (Mondini Trissino da Lodi et al., 2022). In addition to strength, other relevant variables such as pain and functionality were assessed using the VISA-P questionnaire (Gual et al., 2016; Ruffino et al., 2021). Ruffino et al. (Ruffino et al., 2021) observed significant improvements following the IFR intervention, in line with clinical guidelines that highlight the utility of this form of exercise in the management of tendinopathies (Chimenti et al., 2024; Morrissey, 2015). However, Gual et al. (Gual et al., 2016) did not observe statistically significant changes, possibly due to high baseline VISA-P scores. Pain associated with tendinopathy alters neuromuscular activation patterns, leading to compensatory mechanisms that heighten mechanical load on the tendon, thereby sustaining the pathological process and impairing tissue function (Rio et al., 2014).

Tendon temperature during exercise also appears to be a key factor influencing tendinopathy development (Mangine et al., 1987). Sanz-López et al. (Sanz-López, Martínez-Amat, et al., 2016) identified lower temperature increases in participants performing eccentric exercise compared to those who did not, corroborated by Heildebrandt et al. (Hildebrandt et al., 2012). Likewise, infrared thermography can be considered a promising, non-invasive technique for monitoring changes related to tendon loading (Selfe et al., 2006). Additionally, histological alterations constitute another hallmark of tendinopathy. Sanz-López et al. (Sanz-López, Berzosa Sánchez, et al., 2016) observed an increase in tendon cross-sectional area after a six-week IFR programme, a change comparable to that observed in longer interventions without IFR . (Kongsgaard et al., 2006). In contrast, the variation in anteroposterior thickness differed between groups, with only the control group experiencing an increase in the proximal portion of the patellar tendon, a finding considered a predictor of degeneration in some studies (Helland et al., 2013). These results further highlight the potential usefulness of inertial eccentric training in promoting beneficial adaptations in tendon tissue.

Overall, the reviewed evidence suggests that eccentric exercise with IFR enhances strength, power, and functional adaptations. These findings are consistent with previous studies suggesting that the development of these parameters may be accompanied by beneficial modifications in tendon structure and physiology (McAuliffe et al., 2019; Nawoczenski et al., 2015). Nonetheless, the novelty of this device in clinical and preventive settings calls for further randomised controlled trials with larger sample sizes and extended follow-up, in order to confirm these findings and establish clear recommendations regarding its use in tendinopathy prevention and treatment. It is important to highlight that, to date, this is the only review conducted that analyses the effects of IFR training on risk factors associated with the injury mechanism of tendinopathy, including strength, power, and pain, as well as its impact on morphological and physiological changes in the tendon.

This review has several limitations that should be considered when interpreting its findings. Firstly, the small number of studies and the predominant focus on the sporting domain limit the generalisability of the conclusions to other populations. Secondly, the heterogeneity in the frequency, duration, and variables studied complicates the comparison of results. Furthermore, assessments rely heavily on participants' motivation and maximal voluntary effort, introducing a subjective element. Lastly, it was not possible to stratify data by age or gender due to limited sample sizes, highlighting the need for further research in these subgroups.

Conclusions

Based on the existing evidence, it can be stated that IFR training reduces the threshold value of the main risk factors related to the injury mechanism, as well as tendon morphology and physiology. Current findings indicate that IFR can enhance lower-limb strength and power, while also promoting structural changes in tendon tissues that may contribute to improved tendon health. These benefits appear particularly relevant in athletic populations where intense, repetitive activities increase the risk of tendinopathy. Nonetheless, the limited number of studies and heterogeneity in protocols underscore the need for further high-quality randomised controlled trials that include larger sample sizes, extended follow-up periods, and a greater focus on underrepresented groups especially women. Such research would help consolidate the role of IFR in clinical and preventive settings, clarify the mechanisms underlying its effects on tendon structure and function, and determine its true efficacy in managing tendinopathies.

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Authors' and translators' details:

Rosalía Soler-Lomba	solerlomba@gmail.com	Author
Ana González-Castro	agonzc28@estudiantes.unileon.es	Author
Pablo Hernandez-Lucas	phernandez@uvigo.es	Author/ Translator
Iris Machado de Oliveira	irismacoli@uvigo.gal	Author