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Intervention Treating Kinetic Chain Factors *versus* Heavy-Slow Resistance Training in Athletes with Patellar Tendinopathy: Protocol for a Randomized Blind Clinical Trial

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SUMMARY

Introduction. Heavy Slow Resistance Training (HSR) is one of the most recommended interventions for the treatment of patellar tendinopathy (PT). However, the HSR protocol does not address known risk factors for PT. Athletes with PT have been shown to have stiff jump-landings, decreased ankle dorsiflexion range of motion and hip extensors strength compared to asymptomatic athletes. This study aims to verify the effects of an intervention addressing kinetic chain factors in comparison to the HSR protocol on pain, symptoms severity and function, strength and flexibility of the lower limb and landing mechanics in athletes with PT.

Methods. Blind randomized, clinical trial consisting of 28 male recreational athletes, divided into two groups: Heavy slow resistance training group (HSG; n = 14) and kinetic chain group (KCG; n = 14). Both interventions will be delivered 3 times per week, for 12 weeks. Pain will be measured with a visual analog scale and disability will be measured with the VISA-P questionnaire, at baseline, after 6 weeks of intervention, immediately after the intervention, as well as at 6 months after the interventions. Lower limb strength and flexibility and landing mechanics will also be assessed before and after the 12-week interventions. The HSG intervention will involve the squat, Leg Press and Hack Squat, with progressive loads. The KCG intervention will involve the squat exercise, hip extensors and ankle plantar flexors strengthening, interventions to improve ankle dorsiflexion and a jump-landing training. General linear models will be used to compare the intervention effects.

Results. The results of this study will expand the evidence base on different exercise programs for patellar tendinopathy, and may aid clinicians in choosing the most appropriate program for the treatment of athletes with this condition.

Conclusions. This randomized controlled trial will compare the effectiveness of an intervention addressing kinetic chain factors to a standard patellar tendon progressive loading program for the rehabilitation of athletes with patellar tendinopathy.

Study registration: EnsaiosClinicos.gov.br (Identifier: RBR-74nhx9).

KEY WORDS

Knee joint; pain; jumper's knee; muscle strength; tendinitis.

INTRODUCTION

Patellar tendinopathy is a condition characterized by focal pain and dysfunction in the patellar tendon (1). It more frequently occurs in sports involving jumps such as basketball and volleyball, affecting 11.8% and 14.4% of recreational athletes of these modalities, respectively (2). Male athletes are at greater risk of developing patellar tendinopathy than female athletes (2). Patellar tendinopathy may be a rather limiting dysfunction for athletes. Often, athletes with patellar tendinopathy need to move away from training and competition for a long time and 53% of athletes terminate their careers because of this condition (3). The high prevalence of patellar tendinopathy in the athlete population and its impact in both sports career and daily life highlights the importance of identifying effective treatment options for this condition.

The progressive exercise program known as heavy slow resistance training (HSR) (4) has been highlighted by recent systematic reviews (5, 6) as one of the most recommended interventions for the rehabilitation of athletes with patellar tendinopathy. This intervention involves a progressive loading protocol for the quadriceps and, consequently, for the patellar tendon, resulting in improvement in the pain and function of athletes with patellar tendinopathy (4). Specifically, the HSR protocol involves three exercises: squat, leg press and hack squat; performed so that each repetition of each exercise involves 3 seconds for the eccentric phase and 3 seconds for the concentric phase. This protocol resulted in greater patellar tendon collagen turnover and greater athlete satisfaction when compared to an intervention composed solely of eccentric exercises (4), which is often considered the gold-standard intervention for patellar tendinopathy (5).

Rehabilitation programs that exclusively involve quadriceps exercises with progressive loads, such as the eccentric protocol or the HSR, may not be the best option for long-term symptoms resolution in athletes with patellar tendinopathy. Since these interventions focus only in providing the patellar tendon with progressive loads to improve its capacity, they do not address important risk factors for patellar tendinopathy (7). Interventions with a restricted look to the knee and the quadriceps muscle overlook variables that may be important to increase the patellar tendon forces in sports activities, potentially favoring recurrences. Kinetic chain factors, including hip and ankle joint strength and flexibility deficits and jump-landing alterations, have already been observed in athletes with patellar tendinopathy (7-9). In a prospective study with basketball athletes, Backman & Danielson (9) observed that restriction of ankle dorsiflexion range of motion is a risk factor for patellar tendinopathy. Restricted dorsiflexion movements may limit the eccentric action of the plantar flexor muscles in deceleration forces, with the ankle potentially becoming less efficient at force dissipation near end of range (7). This may alter the mechanics of the lower limb at landing, which may lead to an increase in the load on the patellar tendon and the risk of injury (7).

Scattone Silva *et al.* (7) observed that athletes with patellar tendinopathy present lower hip extensor torque when compared to asymptomatic athletes. Weakness in the extensor hip muscle probably increases the demand on knee extensors to dissipate ground reaction forces during jump landings, which could contribute to patellar tendinopathy (7). Despite these findings, the most frequently recommended interventions for the treatment of patellar tendinopathy (6) do not take into account deficits in strength and/or range of motion in the ankle and hip joints for rehabilitation of athletes.

Regarding jump landing, a recent systematic review concluded that athletes with patellar tendinopathy have a stiffer jump landing pattern when compared to asymptomatic controls (8). A stiffer landing requires energy to be dissipated more quickly, which leads to increased ground reaction forces and increased loads at the knee joint (10). Stiff landings, with an extended trunk, also decrease the contribution of the hip muscles for dissipation of the landing forces and increase the peak patellar tendon force (10). Thus, an abnormal landing may contribute to the development or perpetuation of patellar tendinopathy.

In this context, kinetic chain biomechanical alterations may contribute to increase patellar tendon stress, potentially contributing to patellar tendon overload in athletes (7). It is possible that a more comprehensive intervention, taking into account kinetic chain factors, may produce superior results than interventions directed at local factors (such as the HSR protocol) to treat athletes with patellar tendinopathy. However, the effect of an intervention directed to kinetic chain factors compared to a progressive loading protocol for the treatment of patellar tendinopathy in athletes has not been verified.

The primary objectives of the present study are to verify the short-term (after 6 weeks of intervention and immediately after 12 weeks of intervention) and long-term (6-month follow-up) effects of an intervention directed to kinetic chain factors in comparison to the HSR protocol in athletes with patellar tendinopathy in terms of knee pain, symptoms severity and function. The secondary objectives are to verify the short-term effects of these interventions in terms of lower limb isometric strength; of ankle dorsiflexion range of motion and jump landing mechanics.

MATERIALS AND METHODS

Design

This is a blind randomized clinical trial protocol, developed and reported in accordance with the Standard Protocol Items Recommendations for Intervention Trials (SPIRIT) (11). Participants will be randomized and allocated to the heavy-slow resistance training group (HSG) or the kinetic chain group (KCG).

The methods of this clinical trial will follow the recommendations and determinations of the Consolidated Standards of Reporting Trials (CONSORT) (12). This trial was registered in the Brazilian Registry of Clinical Trials (REBEC).

Recruitment

Participants will be recruited from the waiting list of patients of the Physiotherapy School Clinics of Federal University of Rio Grande do Norte. Announcements will also be made on local radios and social media and advertisements will be placed at training centers and schools in the cities of João Pessoa, Natal and Santa Cruz (Brazil).

Ethics

The project was approved by the Research Ethics Committee of the Federal University of Rio Grande do Norte (Number 3.577.145) and participants will sign an informed consent form. In the case of underage participants, the legal guardian will also sign a consent form. Results will be disseminated via publications in scientific journals, social media and presentations in scientific events.

Eligibility criteria

The eligibility criteria will be checked by means of a telephone screening by one of the authors. Suitable participants will be asked to attend the research site where they will be assessed for further eligibility screening.

Inclusion criteria

Male athletes with age between 15 and 40 years.

Practice physical activity involving activities with high demand for the knee extensor mechanism (volleyball, basketball, handball, *etc.*) at least 2 times a week.

Present with localized pain in the patellar tendon, confirmed by palpation, during activities that impose load to the patellar tendon (jumping, squatting, *etc.*) with a duration of 3 months or longer (7).

Have patellar tendon pain during the single-leg decline squat test (13, 14).

Present with a positive Royal London Hospital Test (15).

Present with a score lower than 88 points in the Victorian Institute of Sport Assessment-Patella (VISA-P) questionnaire (16).

Exclusion criteria

Use corticosteroid-based medication in the last 6 months.

Symptoms related to trauma or previous knee surgery.

Knee symptoms associated with other dysfunctions, such as intra-articular lesions, patellofemoral pain, patellar instability and Osgood-Schlatter or Sinding-Larsen-Johansson disease (7).

Inability or unwillingness to commit with conducting treatment during the intervention period.

Sample calculation

The sample size was calculated based on the results of a previous study comparing different interventions with exercises for the rehabilitation of athletes with patellar tendinopathy (4). The primary outcome variable used for the calculations was the Victorian Institute of Sport Assessment-Patella (VISA-P) questionnaire score, The sample size calculation considered $\alpha = 0.05$ and a power of 80%, with a difference between groups in the VISA-P of 22 points. This difference in the VISA-P score is greater than the minimal clinically important difference of the questionnaire (17). Based on these calculations, a sample size of 12 individuals per group was obtained. Considering a sample loss of 15%, which is expected in clinical studies of this nature (18), the sample size was determined to be of 28 subjects. The study flow chart is presented in **figure 1**.

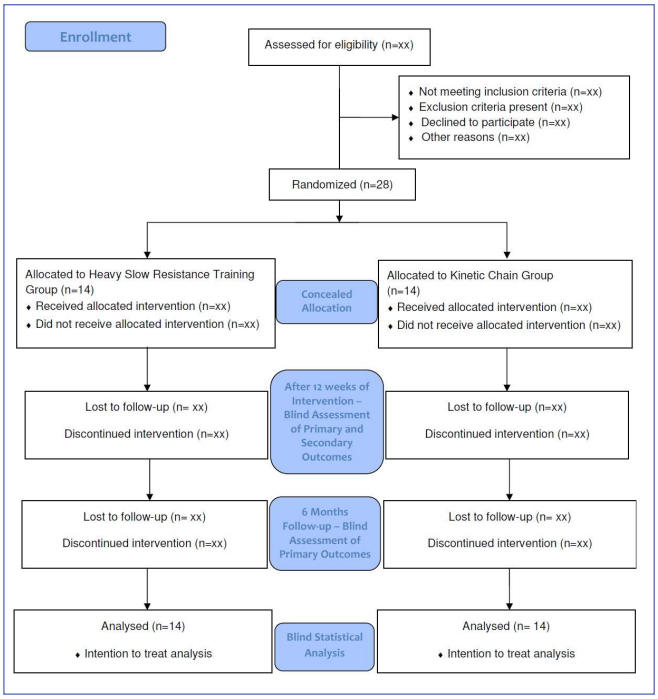


Figure 1. Participants flow chart.

Randomization and strategies for bias minimization

For the participant's randomization, a sample randomization system (blocks of four) will be used by generating a list of random numbers on a computer (http://www.randomization.org). Consecutively numbered opaque envelopes will be filled in and sealed with the numbers generated prior to the start of the study. An individual with no knowledge of the participants will perform this procedure and their allocation in the HSG and KCG groups. Randomization will be performed prior to the initial evaluation and participants will remain blinded to the group to which they were allocated. In order to ensure this, the participants of different groups will perform the treatment sessions separately, not knowing about the exercises performed by the other group (19).

The interventions will be conducted at a training center with fitness gym equipment localized in the cities of Natal, Santa Cruz and João Pessoa (Brazil). Given the nature of the intervention in question, it will not be possible to blind the therapist who will carry out the interventions. All evaluations, before and after the intervention, will be performed by a researcher who will not be involved with the administration of the interventions (blind assessor). In addition, data analysis will be performed by a researcher who will remain blind to the treatment groups.

Evaluations

Initially, participants will complete an identification form, containing personal information, including body mass, height, age and information regarding the sports modality they practiced. The Brazilian Portuguese short version of the International Physical Activity Questionnaire (IPAQ) will be used for the evaluation of the participants' level of habitual physical activity practice (20). The short version of the IPAQ consists of eight open questions and its information allows an estimation of the time spent per week in different dimensions of physical activity and physical inactivity (20).

Primary outcome measures

Pain rating

A 10-cm visual analogue scale (VAS) will be used to evaluate the participants' pain, with 0 indicating no pain and 10 indicating the worst imaginable pain (21). Pain measurement will be performed in two ways: the worst pain in the previous week 18 and pain during the single-leg decline squat test (13). The latter is a validated provocative test, where the participant, on standing on a platform with a 25° inclination and keeping the trunk upright, performs a single-leg squat up to 90° of knee flexion (13). The VAS is a reliable for the evaluation of individuals with knee pain, with a minimal important difference of 2 cm (22).

Function and severity of symptoms

The VISA-P is an 8-item questionnaire for assessing the severity of symptoms and disability of individuals with patellar tendinopathy (23). The total score in VISA-P ranges from 0 to 100 points, with a maximum score indicating absence of symptoms and disability (23). Changes greater than 13 points after interventions in the VISA-P questionnaire are considered clinically relevant (17). The Brazilian Portuguese version of the questionnaire will be used (24).

Global perception of change

A 15-point Likert scale that measures the impression of change in health status after a treatment intervention will be used. The scale ranges from - 7 ("much worse") to + 7 ("much better"), so a score of 0 indicates "no change" (25). Changes equal to or greater than four points on this scale have been considered clinically important in the treatment of patellar tendinopathy (26).

The primary outcomes will be assessed before the intervention, after 6 weeks of intervention, immediately after the end of the interventions (at 12 weeks) and six months after the end of the interventions, by a researcher who will remain blind to group allocation.

Secondary outcome measures

Isometric strength test

A portable handheld dynamometer (Lafayette Instrument Company, Lafayette, IN) will be used to assess lower limb strength. Four repetitions of each strength test will be performed, one to familiarize the participant with the procedure, followed by 3 valid repetitions, which will be used for analysis. At each repetition, the participant will be required to exert maximum force for 5 seconds, with a 15 second interval between repetitions (7). The assessments described below have been shown to be reliable, with intraclass correlation coefficients ($ICC_{3,3}$) ranging from 0.78 to 0.93 (7).

In order to measure hip extensors strength, the participant will be positioned in the prone lying with the knee of the limb to be tested at 90° of flexion and the dynamometer positioned immediately above the popliteal fossa (7). An inelastic belt will be positioned around the participant's hip and the examination table in order to stabilize the trunk, and another belt will be positioned in the distal thigh region to stabilize the dynamometer and resist the movement (7).

To assess the knee extensors strength, the participant will be positioned in supine, with 30° of knee flexion and approximately 20° of hip flexion (7). A foam roll will be placed

in the posterior region of the knee to maintain the desired angle. The dynamometer will be positioned in the midpoint between the malleoli, with an inelastic belt positioned to stabilize the equipment and resist the movement (7).
The strength of the ankle plantar flexors will be measured with the participant in prone lying, with the foot of the evaluated lower limb positioned outside of the examination table (7). The dynamometer will be positioned in the plantar aspect of the metatarsal heads with an inelastic belt stabilizing the equipment and resisting the movement (7).
The peak force results will be converted to torque values [force (N) × action length of the segment (m)]. The torque data will be normalized by the body mass and height of each participant (7).

Dorsiflexion range of motion

The lunge test (7, 9) will be performed using an inclinometer (Baseline Bubble, NY, USA), positioned 15 cm distal to the tibial tuberosity. For this measurement, the participant will be instructed to flex the knee to touch a wall with the patella without removing the heel from the ground. At the maximum distance that the participant can touch the patella on the wall without removing the heel from the ground, the examiner will verify the angle relative to the vertical will be recorded for analysis. Good reliability was observed for this test in a previous study ($ICC_{3,3}$ = 0.90) (7).

Landing mechanics

The Landing Error Scoring System (LESS) is a clinical tool described for evaluation of jump landing biomechanics (27). For this evaluation, two cameras (Panasonic NV-GS180, Matsushita Group, JP) will be positioned 3 m away from a 30 cm box, one in the frontal plane and the other in the sagittal plane. In front of the box, a landing zone will be demarcated, at a distance of 50% of the height of the participant. The test consists of two jumps, one from the box to the landing zone and another, immediately after, upwards with maximum effort. The landing mechanics will be measured through a 17 items tool, which considers the position of the lower limbs and trunk at the time of initial contact with the ground as well as the peak movements during landing, both in the sagittal and frontal planes. Higher values indicate worst landing quality. This evaluation presents good reliability ($ICC_{2,1}$ = 0.91) and high agreement with three-dimensional movement evaluations (27).
The secondary outcomes will be assessed before the intervention and immediately after the end of the interventions (at 12 weeks), by a researcher who will remain blind to group allocation. The symptomatic lower limb will be evaluated and, in cases of bilateral symptoms, the most symptomatic limb will be submitted to the evaluations. The time points of all evaluation of this trial are summarized in **figure 2**.

		STUDY PERIOD					
	Enrolment	Allocation	Post-Allocation				Close-out
TIMEPOINT	$-t_1$	0	t_1	t_2	t_4	t_4	t_5
ENROLMENT:							
Eligibility Screening	X						
Informed Consent	X						
Allocation		X					
INTERVENTIONS:							
Heavy Slow Resistance Training (Squat, Hack Squat, Leg Press)			←	—	→		
Kinetic Chain Group (Hip and knee extensors and ankle plantar flexors strengthening, improving dorsiflexion range of motion and landing training)			←	—	→		
ASSESSMENTS:							
Primary Outcomes (Pain, severity of symptoms and disability, perception of change)		X		X		X	X
Secondary Outcomes (Strength, lower limb flexibility and jump-landing mechanics)		X				X	

$-t_1$=Before allocation; 0=Allocation and baseline evaluations; t_1=1st Month; t_2=2nd Month; t_3=3rd Month; t_4=Evaluations immediately after the interventions; t_5=6 Months after the interventions

Figure 2. Description of the Standard Protocol Items Recommendations for Intervention Trials (SPIRIT).

Interventions

Participants of both the KCG and HSR will be treated during 12 weeks of rehabilitation, with the interventions of both groups lasting approximately 50 minutes in each session. Participants will be encouraged to come to the treatment setting 3 times/week for in-person supervised rehabilitation. If that is not possible for any reason, the treating therapist will be available to supervise the participant's session via telehealth. If that is also not possible, the participant will be instructed to conduct that specific session unsupervised, following the previously provided instructions and filling a training diary which will include information about the number of repetitions, load and pain during each exercise.
During the strengthening exercises in both groups, each participant will be using a headset and will have the auditory stimulus of a metronome adjusted to a rate of 60 beats per minute, to control the concentric and eccentric phases of each exercise. Recently, it has been suggested that auditory stimuli are important in the treatment of tendinopathies to improve motor control, increasing muscle excitability and decreasing muscle inhibition (28, 29). In the sessions when the participant is unavailable for in-person supervised treatment or for telehealth supervised treatment, he

will be instructed to perform the exercises using his phone or computer with the metronome provided by the Google platform (available at https://g.co/kgs/paexw4). In the first supervised session, the participants will be given instructions on how to access this and how to set the frequency to 60 beats/minute.

Heavy Slow Resistance Training Group intervention

The HSG participants will be submitted to the Heavy-Slow Resistance Training (HSR) protocol proposed by Kongsgaard *et al.* (4). The HSR consists of three exercises: squat, hack squat and leg press (**figure 3**). The parameters of each exercise are described in **table I**. This intervention has already been shown to be effective to reduce pain and improve function in athletes with patellar tendinopathy, both in short and in long term (4).

During the HSR protocol, knee pain will be acceptable as long as it is of a maximum intensity of 3/10 in the VAS (4). If pain intensity during the intervention is greater than 3, the exercise will be modified with a reduction in range of motion and/or load.

Table I. Heavy Slow Resistance Training Detailed Protocol.

Exercises
Squat, Leg Press and Hack Squat
Progressive load for strengthening exercises
1st week: 4 × 15 – Load 15 repetition maximum (RM)
2nd / 3rd weeks: 4 × 12 – Load 12RM
4th / 5th week: 4 ×10 – Load 10RM
6th-8th week: 4 × 8 – Load 8RM
9th-12th weeks: 4 × 6 – Load 6RM
Muscle activation time
Concentric phase - 3s
Eccentric phase - 3s
Rest time between sets: 2 minutes
Range of motion: 0º (full extension) to 90º of knee flexion



Figure 3. Heavy Slow Resistance Training Protocol.
Squat **(A)**, Leg Press **(B)** and Hack Squat **(C)**.

Kinetic Chain Group intervention

Participants assigned to the KCG will undergo a protocol involving not only knee extensors strengthening, but also strengthening of the hip extensors and ankle plantar flexors, interventions to improve ankle dorsiflexion range of motion (stretching/mobilization) and a jump-landing training (**figure 4**). The parameters of all the strengthening exercises of the KCG intervention will be identical to the parameters used in the HSG exercises and are described in **table II**.



Figure 4. Kinetic Chain Group Intervention.
Joint mobilization to improve dorsiflexion with an inelastic belt **(A)** and soleus muscle stretching **(B)**. Hip extensor strengthening exercise – Single-limb deadlift initial position **(C)** and final position **(D)**. Ankle plantar flexors strengthening exercise – Seated heel-rise initial position **(E)** and final position **(F)**. Squat exercise initial position **(G)** and final position **(H)**. Jump landing training emphasizing soft landing – Initial position (I) and final position, landing with trunk flexion and backwards hip projection **(J)**.

Table II. Kinetic Chain Group Detailed Protocol.

Joint mobilization for dorsiflexion: 4 ×10 s (20 s rest)
Soleus muscle stretching: 3 × 30 s (10 s rest)
Exercises: Single-Limb Deadlift, Squat and Seated Heel Raise
Progressive load for the strengthening exercises:
1st week: 4 × 15 – Load 15 repetition maximum (RM)
2nd / 3rd weeks: 4 × 12 – Load 12RM
4th / 5th week: 4 ×10 – Load 10RM
6th-8th week: 4 × 8 – Load 8RM
9th-12th weeks: 4 × 6 – Load 6RM
Muscle activation time
Concentric phase - 3s
Eccentric phase - 3s
Rest time between sets: Squat **-** 2 minutes; Remaining exercises **-** 1 minute
Range of motion: Squat - 0º (full extension) to 90º of knee flexion; Seated heel raise - Full range; Single-limb deadlift - 0º (trunk upright) to 90º of hip flexion.
Jumping landing strategy modification training (after the 4th week): 2 × 10

Ankle plantar flexors strengthening
The seated heel raise will be the exercise used to strengthen the ankle plantar flexors of the KCG. For this exercise, the participant will be positioned in sitting with 90° of hip and knee flexion, with the tips of the feet resting on a 15 cm step. The exercise will consist of raising the heel as much as possible, keeping the toes in contact with the step, followed by a slow lowering of the heel to the maximum possible dorsiflexion range of motion (**figure 4**) (30). Additional load for this exercise will be imposed with a bar with weights which will be positioned on the thighs of the participant, the bar surrounded by padding to avoid discomfort.

Hip Extensors strengthening
The single-limb deadlift will be the exercise performed to strengthen the hip extensors of the KCG athletes. For this exercise, the participant will stand only in one leg and performs an anterior lean of the trunk keeping the spine erect until the trunk is parallel to the ground, later returning to the initial position (**figure 4**) (31). Loads will be added with dumbbells in the hands of the participant. This exercise will be carried out bilaterally to avoid asymmetric loads during the landing of a jump (26).

Knee Extensors strengthening
The squat exercise (**figure 4**) will also be performed by the KCG athletes, in order to strengthen the knee extensor muscles, which have been shown to be weak in this population (32), and to provide progressive load to the patellar tendon (4). The exercise will be performed with the exact same parameters used by the HSG (**table I**).

Jump Landing Strategy Modification training
From the fourth week of intervention, in addition to strengthening exercises, participants will perform an exercise to change their landing strategy. The participant will receive verbal instructions to land softly, minimizing the impact of the landing. Landing with a forward trunk lean and greater hip flexion will be encouraged, with the aim of increasing the contribution of the hip muscles to dissipate ground reaction force, in order to decrease the forces in the patellar tendons (26). The instructions given to the participant will be as follows: "Keep your knees slightly bent before landing and try to land as softly as possible. Lean your trunk forward and project your hips back as you bend your knees, in order to minimize the impact of the landing. Pay attention to the sound of your landing and use this information to help you to land more softly". After each jump landing, feedback will be given to the participant if he does not incorporate one or more of these recommendations into his strategy. At each session of the intervention, the participant will perform drop vertical jump landings with a bipodal support of a 30 cm box in 2 sets of 10 repetitions, with 5 seconds rest between landings and 1 minute between sets (**figure 4**) (26).

Interventions to improve dorsiflexion
A cut-off angle of 36° in the lunge test has been previously determined as a risk factor for patellar tendinopathy in athletes (9). For participants of the KCG with dorsiflexion movement restriction (lunge results < 36°), interventions to improve range of motion will be pragmatically implemented. It has been suggested that interventions directed at tissue that is limiting the movement are more effective to improve ankle dorsiflexion range of motion (33). In this sense, both joint mobilizations and muscle stretching would be important to increase the range of motion and, therefore, will be performed in these participants of the KCG.
Joint mobilizations with movement will be performed with an inelastic belt around the tibia of the participant's affected limb and the waist of the therapist. For the mobilization technique, the therapist will apply a sustained posteroanterior glide to the tibia through the belt by leaning backwards, which causes a posterior glide of the talus in the ankle mortise (34). Then, the participant will be instructed to perform a slow dorsiflexion movement until the first onset of pain or end of range (**figure 4**). Once this point is reached, the glide will be maintained for 10 seconds. The participant will then return to the initial standing position and the mobilization force will be released. Each set of mobilization will consist of 4 glides, followed by a

20-second rest period. Four sets of mobilizations with movement will be applied in each treatment session (34).

The soleus muscle stretch will be done with the participant standing with his hands on a wall, the lower limb to be stretched positioned behind, keeping the entire foot in contact with the ground and the toes pointing forward. From this position the participant will flex both knees, until reaching the limit of movement without lifting the heel of the ground (**figure 4**) (35). The stretch position will be held for 30 seconds and will be repeated 3 times, with a period of 10 seconds between the stretches.

Load monitoring during daily activities and adverse effects

Participants will be allowed to continue practicing the sporting modality they usually practice, only being asked to avoid activities that cause pain greater than or equal to 3/10 in the VAS (4, 26). Participants will be instructed not to change their daily routines and to record the number and duration of training sections. Participants will be asked to refrain from seeking other treatments during the study period, but analgesia and anti-inflammatory drugs will be permitted (18). All medication use and co-interventions will be recorded. If any pain medication is used during the intervention period, the participants will be asked to record the amount and dosage of each drug, reporting this information in the post-intervention evaluation (18, 36). If the participants experience any adverse event at any time during the study, they will be asked to report it to the investigators. All adverse events will be included in the final manuscript.

Statistical analysis

Statistical analyses will be performed using SPSS software (version 17.0; SPSS Inc, Chicago, IL). Data normality and homoscedasticity will be verified with the Shapiro-Wilk and Levene tests, respectively. General linear models will be used to compare the results obtained at baseline, after 6 weeks of interventions, immediately after the interventions and six months after the interventions of both groups, with a significance level of 5% in all analyses. An intention-to-treat analysis will be used for the analysis and the statistician will remain blind to groups.

DISCUSSION

Considering that strength and range on motion impairments in different segments of the kinetic chain may increase patellar tendon overload, rehabilitation programs that focus only on progressively loading the patellar tendon with quadriceps-focused exercises may not be ideal, especially for the long-term. To our knowledge, this is the first clinical trial that focuses on verifying the effects of an intervention addressing kinetic chain factors known to be associated with patellar tendinopathy, in comparison to a progressive patellar tendon loading program. A recent study from our research group found that an in-season prevention program addressing kinetic chain factors, such as hip extensors strength and ankle dorsiflexion range of motion, significantly decreased the incidence of patellar tendinopathy in jumping athletes (37). In a previous study we also observed promising long-term results of pain and function improvements in a volleyball athlete with patellar tendinopathy that was treated solely with hip extensors strengthening exercises and a jump-landing strategy modification (26). It is possible that these promising results are occurring due to a better load distribution between the different joints of the lower limb during their sport participation, which potentially decreased the overload in the knee joint. However, randomized controlled trials are necessary to verify the effects of interventions addressing kinetic factors in athletes with patellar tendinopathy.

The main strengths of this study come from the scientific rigor in terms of randomization, concealed allocation, blinding and intention-to-treat analyses. These are important aspects to be considered because if they are not accounted for, they are strong sources of bias in clinical trials (38-40). In addition to performing adequate randomization and allocation procedures, we will blind the participants, the researcher responsible for the evaluation of the outcomes and the researcher responsible for the statistical analyses. An intention-to-treat approach will also be used for data analysis in order to ensure an unbiased estimate of treatment effect (41).

Some limitations are also expected in the study. Blinding of the therapist delivering the interventions will not be possible due to the study design. As a way to minimize this limitation, the therapist will deliver the treatments using standardized procedures. Another limitation is the fact that, although participants will be encouraged to undergo three supervised treatments per week, they will be allowed to take part in only one supervised treatment session per week, with the possibility of telehealth or home unsupervised exercises for the remaining two weekly sessions. This limitation will be minimized by the use of a training diary where the participant will report the details of his unsupervised session (repetitions, load, *etc.*). Although this is a limitation, we believe this approach more closely resembles the reality of treatment of these patients. Finally, we will not control the participants' medication intake throughout the study. However, medication intake will be monitored during the study by means of a diary that will be delivered to participants on their baseline assessment. If significant differences in medication intake are observed during the study, this variable will be accounted for in data analyses.

CONCLUSIONS

In conclusion, this randomized controlled trial will compare the effectiveness of an intervention addressing kinetic chain factors to a standard patellar tendon progressive loading program for the rehabilitation of athletes with patellar tendinopathy. The results of this study will expand the evidence base on different exercise programs for patellar tendinopathy, and may aid clinicians in choosing the most appropriate program for the treatment of athletes with this condition.

FUNDINGS

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

EHDA, NR, RSS: the initial draft manuscript writing. All authors contributed to and revised subsequent drafts and approved the final version.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Rudavsky A, Cook J. Physiotherapy management of patellar tendinopathy (jumper's knee). J Physiother 2014;60(3):122–9.
2. Zwerver J, Bredeweg SW, Van Den Akker-Scheek I. Prevalence of jumper's knee among nonelite athletes from different sports: A cross-sectional survey. Am J Sports Med 2011;39(9):1984–8.
3. Kettunen JA, Kvist M, Alanen E, Kujala UM. Long-term prognosis for jumper's knee in male athletes: A prospective follow-up study. Am J Sports Med 2002;30(5):689–92.
4. Kongsgaard M, Kovanen V, Aagaard P, *et al*. Corticosteroid injections, eccentric decline squat training and heavy slow resistance training in patellar tendinopathy. Scand J Med Sci Sport 2009;19(6):790–802.
5. Malliaras P, Barton CJ, Reeves ND, Langberg H. Achilles and patellar tendinopathy loading programmes: A systematic review comparing clinical outcomes and identifying potential mechanisms for effectiveness. Sport Med 2013;43(4):267–86.
6. Lim HY, Wong SH. Effects of isometric, eccentric, or heavy slow resistance exercises on pain and function in individuals with patellar tendinopathy: A systematic review. Physiother Res Int 2018;23(4):e1721.
7. Scattone Silva R, Nakagawa TH, Ferreira ALG, Garcia LC, Santos JEM, Serrão F V. Lower limb strength and flexibility in athletes with and without patellar tendinopathy. Phys Ther Sport 2016;20:19–25.
8. van der Worp H, Zwerver J, Hamstra M, van den Akker-Scheek I, Diercks RL. No difference in effectiveness between focused and radial shockwave therapy for treating patellar tendinopathy: a randomized controlled trial. Knee Surg Sports Traumatol Arthrosc 2014;22(9):2026–32.
9. Backman LJ, Danielson P. Low range of ankle dorsiflexion predisposes for patellar tendinopathy in junior elite basketball players: A 1-year prospective study. Am J Sports Med 2011;39(12):2626–33.
10. Scattone Silva R, Purdam CR, Fearon AM, *et al*. Effects of Altering Trunk Position during Landings on Patellar Tendon Force and Pain. Med Sci Sports Exerc 2017;49(12):2517–27.
11. Chan AW, Tetzlaff JM, Altman DG, *et al*. SPIRIT 2013 statement: Defining standard protocol items for clinical trials. Ann Intern Med 2013;158(3):200-7.
12. Schulz KF, Altman DG, Moher D, Group C. Special Article CONSORT 2010 statement : Updated guidelines for reporting parallel group randomised trials. BMC Med 2010;8:18.
13. Purdam CR, Cook JL, Hopper DM, Khan KM. Discriminative ability of functional loading tests for adolescent jumper 's knee. Phys Ther Sport 2003;4(1):3–9.
14. de Groot R, Malliaras P, Munteanu S, Payne C, Morrissey D, Maffulli N. Foot Posture and Patellar Tendon Pain Among Adult Volleyball Players. Clin J Sport Med 2012;22(2):157-9.
15. Maffulli N, Oliva F, Loppini M, Spiezia F, King JB. The Royal London Hospital Test for the clinical diagnosis of patellar tendinopathy. Muscles Ligaments Tendons J 2017;7(2):315-22.
16. Mendonça LD, Ocarino JM, Bittencout NF, Macedo LG, Fonseca ST. Association of Hip and Foot Factors With Patellar Tendinopathy (Jumper's Knee) in Athletes. J Orthop Sport Phys Ther 2018;48(9):676–84.
17. Hernandez-Sanchez S, Hidalgo MD, Gomez A. Responsiveness of the VISA-P scale for patellar tendinopathy in athletes. Br J Sports Med 2014;48(6):453–7.
18. Mellor R, Bennell K, Grimaldi A, *et al*. Education plus exercise versus corticosteroid injection use versus a wait and see approach on global outcome and pain from gluteal tendinopathy: Prospective, single blinded, randomised clinical trial. BMJ 2018;361:k1662.
19. Baldon R de M, Serrão FV, Scattone Silva R, Piva SR. Effects of functional stabilization training on pain, function, and lower extremity biomechanics in women with patellofemoral pain: a randomized clinical trial. J Orthop Sport Phys Ther 2014;44(4):240–51.
20. Pinto Guedes D, Correa Lopes C, Pinto Guedes JER. Reproducibility and validity of the International Physical Activity Questionnaire in adolescents. Rev Bras Med do Esporte 2005;11(2):151–8.

21. Price DD, Mcgrath PA, Rafii A, Buckingham B. The Validation of Visual Analogue Scales as Ratio Scale Measures for Chronic and Experimental Pain. Pain 1983;17:45–56.
22. Crossley KM, Bennell KL, Cowan SM, Green S. Analysis of outcome measures for persons with patellofemoral pain: Which are reliable and valid? Arch Phys Med Rehabil 2004;85(5):815–22.
23. Visentini PJ, Khan KM, Cook JL, Kiss ZS, Harcourt PR, Wark JD. The VISA score: An index of severity of symptoms in patients with jumper's knee (patellar tendinosis). J Sci Med Sport 1998;1:22–8.
24. Wageck BB, Noronha MA de, Lopes AD, Cunha R alves da, Takahashi RH, Costa RH. Cross-cultural Adaptation and Measurement Properties of the Brazilian Portuguese Version of the Victorian Institute of Sport Assessment-Achilles (VISA-A) Questionnaire. J Orthop Sport Phys Ther 2013;43(3):163–71.
25. Jaeschke R, Singer J, Guyatt GH. Measurement of Health Status Ascertaining the Minimal Clinically Important Difference. Control Clin Trial 1989;10(4):407–15.
26. Scattone Silva R, Ferreira ALG, Nakagawa TH, Santos JEM, Serrão F V. Rehabilitation of Patellar Tendinopathy Using Hip Extensor Strengthening and Landing-Strategy Modification: Case Report With 6-Month Follow-up. J Orthop Sport Phys Ther 2015;45(11):899–909.
27. Padua DA, Marshall SW, Boling MC, Thigpen CA, Garrett WE Jr, Beutler AI. The Landing Error Scoring System (LESS) Is a valid and reliable clinical assessment tool of jump-landing biomechanics: The JUMP-ACL study. Am J Sports Med 2009;37(10):1996-2002.
28. Leung M, Rantalainen T, Teo W, Kidgell D. Motor cortex excitability is not differentially modulated following skill and strength training. Neuroscience 2015;305:99–108.
29. Rio E, Kidgell D, Moseley GL, *et al*. Tendon neuroplastic training : changing the way we think about tendon rehabilitation : a narrative review. Br J Sports Med 2016;50(4):209-15.
30. Trappe TA, Raue U, Tesch PA. Human soleus muscle protein synthesis following resistance exercise. Acta Physiol Scand 2004;182(2):189–96.
31. Distefano LJ, Blackburn JT, Marshall SW, Padua DA. Gluteal muscle activation during common therapeutic exercises. J Orthop Sports Phys Ther 2009;39(7):532–40.
32. Kaux JF, Croisier JL, Libertiaux V. Isokinetic strength profile of subjects with proximal patellar tendinopathy. Muscles Ligaments Tendons J 2019;9(2):210–6.
33. Terada M, Pietrosimone BG, Gribble PA. Therapeutic interventions for increasing ankle dorsiflexion after ankle sprain: A systematic review. J Athl Train 2013;48(5):696–709.
34. Vicenzino B, Branjerdporn M, Teys P, Jordan K. Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. J Orthop Sports Phys Ther 2006;36(7):464–71.
35. Rosenbaum D, Hennig EM. The influence of stretching and warm-up exercises on achilles tendon reflex activity. J Sports Sci 1995;13(6):481–90.
36. Bisset L, Beller E, Jull G, Brooks P, Darnell R, Vicenzino B. Mobilisation with movement and exercise, corticosteroid injection, or wait and see for tennis elbow: Randomised trial. Br Med J 2006;333(7575):939–41.
37. Bittencourt NFN, de Oliveira RR, Vaz R de PM, Scattone Silva R, Mendonça LDM. Preventive effect of tailored exercises on patellar tendinopathy in elite youth athletes: A cohort study. Phys Ther Sport 2022;53:60–6.
38. Kamper SJ. Blinding: Linking evidence to practice. J Orthop Sports Phys Ther 2018;48(10):825–6.
39. Kamper SJ. Bias: Linking evidence with practice. J Orthop Sports Phys Ther 2018;48(8):667–8.
40. Kamper SJ. Randomization: Linking evidence to practice. J Orthop Sports Phys Ther 2018;48(9):730–1.
41. Kamper SJ. Per-protocol, intention-to-treat, and compliER average causal effects analyses in randomized controlled trials: Linking evidence to practice. J Orthop Sports Phys Ther 2021;51(6):314–5.