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*A randomized crossover trial*

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Isometric exercise and pain in patellar tendinopathy: A randomized crossover trial.

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## **ABSTRACT**

**Objectives:** The aim of this study was to compare the acute effects of isometric versus dynamic resistance exercise on pain during a pain-provoking activity, and exercise-induced hypoalgesia in participants with patellar tendinopathy.

**Design:** This study was a pre-registered randomised crossover study. Participants were blinded to the study hypothesis.

**Methods:** Participants (N=21) performed a single session of high load isometric resistance exercise or dynamic resistance exercise, in a randomised order separated by a 7-day washout period. Outcomes were assessed before, immediately after, and 45 min post-exercise. The primary outcome was pain intensity scored on a numeric pain rating scale (NRS; 0-10) during a pain-provoking single leg decline squat (SLDS). Secondary outcomes were pressure pain thresholds (PPTs) locally, distally and remotely, as well as tendon thickness.

**Results:** There was a significant decrease in pain NRS scores (mean reduction 0.9, NRS 95%CI 0.1 to 1.7;  $p=0.028$ ), and increase in PPTs at the tibialis anterior muscle (mean increase 34 kPa 95%CI 9.5 to 58.5;  $p=0.009$ ) immediately post-exercise. These were not sustained 45 min post-exercise for pain (NRS) or PPTs ( $p>0.05$ ). There were no differences between exercise on any outcome.

**Conclusions:** While patients with patellar tendinopathy decreased pain during SLDS in response to resistance training, but the magnitude was small. Contraction mode may not be the most important factor in determining the magnitude of pain relieving effects. Similarly, there were only small increases in PPTs at the tibialis anterior which were not superior for isometric exercise.

**Keywords:** pain measurement, pain threshold, psychophysiology, exercise induced hypoalgesia, resistance exercise, pain relief, tendon, athletes

*Practical implications*

- Isometric exercises for patellar tendinopathy were advised to be implemented for acute pain relief despite lack of evidence supporting their efficacy
- In the current study, small and varying decreases in pain were observed following isometric and dynamic exercises, which was not sustained for 45 minutes
- When discussing acute pain management options, patients should not be told to expect complete pain reduction from resistance exercises
- Due to the lack of superiority of the acute effect of either isometric or dynamic exercise, patient preferences can be used to guide exercise selection for acute pain management.

## 1 INTRODUCTION

2 Patellar tendinopathy is one of the most common musculoskeletal pain problems associated with sport,  
3 particularly those that includes jumping activities <sup>1</sup>. One of the most commonly used strategies for  
4 managing patellar tendinopathy are loading programs i.e. resistance training. Resistance training (i.e. a  
5 training programme) is effective in reducing pain for a range of musculoskeletal pain conditions,  
6 including tendon pain (tendinopathies) <sup>2,3</sup>. For long-term rehabilitation of tendinopathies, high load  
7 resistance training is frequently used from several weeks to months <sup>2</sup>, with level one evidence supporting  
8 its effect compared to other treatments such as stretching for long-term management <sup>3</sup>. Eccentric and high  
9 load dynamic exercises are often used during rehabilitation, although the choice of optimal modality for  
10 improving patient outcomes is heavily debated <sup>4,5</sup>. There are multiple proposed mechanisms behind the  
11 positive effects exercise rehabilitation including local effects on the tendon structure<sup>4</sup>, the muscle<sup>6</sup> and  
12 central effects<sup>7</sup>.

13 In addition to resistance training, an acute bout of exercise can also acutely reduce pain sensitivity  
14 (hypoalgesia) and pain intensity to normally painful stimuli (analgesia). This is also termed exercise-  
15 induced hypoalgesia (EIH) in healthy individuals and is a short time-limited effect as a result of  
16 neurophysiological mechanisms involved in processing noxious stimuli <sup>8</sup>. This acute effect is likely  
17 independent of structural adaptations, and depend on neurophysiological modulation, such as opioid  
18 analgesic systems <sup>9-11</sup>, or potentially due to the observed decreases in tendon thickness following exercise  
19 <sup>12</sup>.

20 It therefore cannot be assumed that the exercise paradigms which work cumulatively over time are  
21 the best for acute pain reduction. The effect of exercise on pain and hypoalgesia has typically been  
22 evaluated using short-term aerobic exercise, or isometric resistance exercise, and investigated as the  
23 effects on pain sensitivity, measured by changes in pain thresholds <sup>8, 13, 14</sup>. However, the optimal mode  
24 and dosages for reducing pain is unknown.

25 Rio and colleagues <sup>15</sup> found that a single bout of isometric exercise induced greater immediate  
26 subjective pain relief during the single leg decline squat, an aggravating task for patellar tendinopathy  
27 (with an effect size of 1.1 compared to dynamic exercise), indicating the potential for isometric exercise  
as an acute pain management tool. However, contradictory results have been found, with another study

28 finding a much lower pain relieving effect of isometric contractions <sup>16</sup>, and attempts to replicate the  
29 analgesic effect in other tendinopathies have been unsuccessful <sup>17</sup>. Despite this, isometric exercise is  
30 advocated as providing a greater pain inhibition compared to dynamic exercises for tendinopathies, and  
31 specifically patellar tendinopathy <sup>18</sup>. Consequently, there is currently conflicting evidence for the  
32 acute effect of isometric exercises in patients with patellar tendinopathy. A larger and  
33 adequately designed study is needed to improve knowledge within this field.

34 As most research to date has focused on the long-term effects of maintained resistance training in  
35 this population (and associated structural adaptations), there is a lack of research on the short-term effects  
36 including exercise induced hypoalgesia which can be quantified using quantitative sensory testing (QST),  
37 and on the change in hypoalgesia response over time.

38 The primary aim of this study was to compare the acute effects of isometric versus dynamic  
39 exercise during a pain-provoking activity, in participants with patellar tendinopathy. The primary  
40 hypothesis is that isometric exercise will induce greater pain reduction during a pain aggravating activity  
41 in comparison to dynamic exercises. The secondary objective was to compare the effect of isometric and  
42 dynamic exercise on pressure pain sensitivity locally at the patellar tendon, as well as distally and on a  
43 remote site. A tertiary aim was to evaluate changes of patellar tendon thickness following the exercises.

44

## 45 **METHODS**

46 This study was designed as a randomised crossover superiority trial, where participants were blinded to  
47 the study hypothesis. The protocol was approved by the local ethics committee (N-20160084), and all  
48 participants provided written informed consent prior to participation. The trial was pre-registered on  
49 clinicaltrials.gov before inclusion of the first participant (NCT03528746). The reporting of this study  
50 follows the CONSORT guidelines, the Pain-specific CONSORT supplement checklist and TIDieR  
51 guidelines for intervention reporting. All procedures were pilot tested in participants who were healthy  
52 (N=8) and with patellar tendinopathy (N=2) prior to inclusion of the first participant.

53 Based on the pilot study, it was decided not to include pain during exercise due to the cognitive process of  
54 evaluating pain which may influence subsequent pain recording and impede replication of the previous

55 trial. As a result, pain during exercise was not collected as a secondary outcome, which was a protocol  
56 deviation.

57

58 Participants with patellar tendinopathy were recruited through Aalborg University and University College  
59 of Northern Denmark, local sports clubs, local clinics and social media. Interested participants who had  
60 patellar tendon related pain were invited for a clinical examination to establish the diagnosis, rule out  
61 other common causes of anterior knee pain (e.g. Patellofemoral Pain) and assess eligibility for inclusion  
62 into the study. The inclusion and exclusion criteria were as follows: (1) Participants were required to have  
63 patellar tendinopathy and be aged 18-40 years. (2) Diagnosis of patellar tendinopathy was made by a  
64 physiotherapist supervised by an experienced rheumatologist (JLO), which was based on the criteria in  
65 Rio et al.<sup>15</sup> as follows; pain localised to the inferior pole of the patella at palpation and during jumping  
66 and landing activities, and pain during testing on the single-leg decline squat (SLDS). The patellar  
67 tendinopathy diagnosis was confirmed by the presence of characteristic features on ultrasound imaging  
68 (i.e., hypoechoic area, Doppler and focal enlarged tendon were considered characteristic features, but not  
69 all had to present in each patient). Ultrasound (BK Flex Focus 500, BK Medical, Denmark) was done  
70 with the knee flexed to approximately 60 degrees with a transducer head of 48X13mm (High Frequency  
71 Linear 18L5, BK Medical, Denmark). Finally, participants were required to have a minimum pain (worst  
72 pain in the last week) of 3 / 10 on an 11-point numeric rating scale (NRS). Participants were excluded if  
73 they had any concurrent knee pathologies (e.g. the presence of a diffuse knee pain presentation indicative  
74 of PFP with or without tendinopathy), or previous knee surgery or had received a corticosteroid injection  
75 within the previous six months.

76

77 Participants attended two sessions, one week apart, at approximately the same time of day. On the first  
78 day, the diagnosis and eligibility was determined, in line with criteria outlined above. If participants were  
79 eligible, demographic data, including sex, age, height, weight, and sports participation (type and hours per  
80 week) were recorded, whether participants had unilateral or bilateral pain, and if bilateral, which was the  
81 most painful limb. In addition, participants completed the Victorian Institute of Sport Assessment-Patella

82 (VISA-P questionnaire) , duration of pain condition, as well as average and worst pain intensity in the  
83 past week (measured on an 11-point NRS, ranging from 0 to 10 from no pain to worst possible pain).

84 After the baseline assessment, participants performed either isometric or dynamic exercise,  
85 according to the randomisation sequence (see below). The second exercise of the allocation sequence was  
86 completed one week later, at the same time of day (within two hours of the initial assessment).

87 The sequence exercise type was randomised by an independent researcher (not involved in any  
88 other aspects of the study) using a computer generated allocation sequence on random.org. The generated  
89 sequences were then sealed in opaque envelopes. The researcher instructing and supervising the exercise  
90 protocols was blinded to sequence allocation, until after subjects were enrolled and completed baseline  
91 testing, at which point the participant randomly selected an envelope which determined their allocation.  
92 Outcome parameters were recorded immediately pre-exercise, immediately post exercise and 45 min post  
93 exercise.

94  
95 Both the isometric and dynamic exercise protocols were based off previously published protocol by Rio  
96 and colleagues <sup>15</sup>.

97 The isometric exercise session was conducted at 70% maximal voluntary isometric contraction (MVIC).  
98 Prior to completing the isometric exercise, the MVIC was assessed using isokinetic dynamometry  
99 (Biodex System 4 Pro) <sup>15</sup>. Participants were seated in a stable position in the dynamometer, fixated with  
100 trunk and lower limb straps with the knee at 60° of knee flexion. Participants were familiarised with the  
101 procedure and issued standardised instructions to perform a maximal effort knee extension against the  
102 dynamometer for 30 seconds. After a short break, the test was repeated three times. The peak torque  
103 recorded during these three efforts was the MVIC.

104 For the isometric exercise session, participants completed static isometric quadriceps contractions in  
105 the Biodex. Participants were required to isometrically exert a force equivalent to 70% of the MVIC, and  
106 to sustain this for 45s while seated with their knee in 60° flexion. The torque was verified by the Biodex  
107 system. One 45s repetition constituted a set, and this was repeated five times with two minutes break in-

108 between. Participants received standardised and neutral vocal encouragement and feedback. “Push more,  
109 Push less, Great, Come-on”.

110  
111 The dynamic exercise was leg extension, completed in a leg extension machine (Body Solid Inc,  
112 GLCE365). First, the maximum load that can be lifted for eight repetitions (8RM) at 6 sec per repetition  
113 through 90 degrees range of motion (ROM) was determined. This was assessed according to the National  
114 Strength and Conditioning Association (NSCA) guidelines for RM testing. The 8RM load was used for  
115 the dynamic leg extension exercise with a pace (guided by a metronome) of three seconds per concentric  
116 contraction, 0s isometric and three seconds eccentric contraction through 90 degrees ROM. This was  
117 repeated for three sets of eight repetitions, with two minutes break between each set. Similar to the  
118 isometric exercise, participants received standardised neutral vocal encouragement.

119  
120 The primary outcome was pain intensity assessed during a single leg decline squat (SLDS), a reliable test  
121 for provoking pain in patients with patellar tendinopathy <sup>15, 19</sup>. Participants were asked to stand on one  
122 limb, on a decline board, so they were in approximately 25 degrees of plantar flexion of the ankle joint.  
123 They were then asked to perform a squat, to 60 degrees of knee flexion. This was repeated three times.  
124 Participants provided a NRS score, anchored at left with ‘0, no pain’ and at right with ‘10, worst possible  
125 pain’. If participants had bilateral patellar tendinopathy, data from the ‘most painful’ limb (indicated by  
126 participants) was used. The average NRS score across the three SLDS was used for further analysis.

127  
128 The pressure pain thresholds (PPTs) were recorded using a hand-held algometer (Somedic, Hörby,  
129 Sweden) with a 1-cm<sup>2</sup> probe (covered by a disposable latex sheath). The tester placed the probe  
130 perpendicular to the skin at the test site, and increased the pressure 30 kPa/s. Participants were equipped  
131 with a hand-held button, which they were instructed to press at the first instance the sensation changed  
132 from pressure, to pain. The pressure at this point defined the PPT. PPTs were assessed locally at the most  
133 painful site point on the tendon, with the knee flexed to 90° as per previous methods in patellar  
134 tendinopathy, which have demonstrated excellent reliability <sup>20</sup>. PPTs were further assessed bilaterally at

135 the patellar tendon. For participants with unilateral pain, the PPT on the contralateral limb was taken  
136 directly distal of the patellar apex, as previously used in asymptomatic individuals<sup>20</sup>. In addition to this,  
137 PPTs were assessed at the tibialis anterior muscle at the muscle belly on the test leg and on the  
138 contralateral extensor carpi radialis brevis muscle belly. PPTs were recorded in triplicates and the average  
139 value were used for further analysis. At each session, the location of PPTs was marked on the participant  
140 during the baseline assessment to ensure reproducibility in the post-exercise assessments.

141  
142 Ultrasound (BK Flex Focus 500, BK Medical, Denmark), was used to quantify patellar tendon thickness.  
143 The ultrasound measurements were carried out with the participants in a supine position with the knee  
144 flexed to approximately 60 degrees with a transducer head of 48X13mm (High Frequency Linear 18L5,  
145 BK Medical, Denmark). To determine thickness, a transversal scan taken 1cm from the apex of the patella  
146 (marked by marker to ensure it was repeated at the same point post-exercise). The thickest portion of the  
147 tendon was used for measurement by manually selecting two points and measuring the vertical distance  
148 directly in the ultrasound software. The average of three measurements was used for analysis.

149  
150 The sample size was based on the results from Rio et al. where they found a mean reduction of 6 NRS  
151 points in response to isometric exercise<sup>15</sup> in volleyball players. We aimed to account for a potentially  
152 smaller effect size due to a more heterogeneous group (wider sports participation and including females).  
153 Therefore, our samples size was based on detecting a 2±3 point difference between exercises ( $p < 0.05$ ) in  
154 NRS with a within groups design and a power of 0.9 which would require 21 participants.

### 156 *Statistical analysis*

157 Statistics were undertaken according to a pre-established statistical analysis plan (protocol). All outcomes  
158 were approximately normally distributed, determined by visual inspection of Q-Q plots. Data are reported  
159 as mean and 95% confidence interval unless otherwise stated. Significance was accepted at  $P < 0.05$ .

160 To determine if there was an effect of exercise order on the primary outcome, an independent  
161 samples t-test was run (independent grouping variable of allocation sequence; isometric *versus* dynamic)

162 was used to examine the within subject mean differences for each assessment of the primary outcome  
163 (pain during the single leg squat) <sup>21</sup>. Similarly, to check the assumption of negligible carryover effects, an  
164 independent t test was calculated on the within subjects sum of effects for the primary outcomes (pain  
165 during SLDS) from both periods<sup>21</sup>.

166 Separate two-way repeated measures (two within subject factors) analysis of variations (ANOVAs)  
167 were undertaken for the dependent variables of interest (primary and secondary outcomes). The within  
168 subject's factors were exercise type (isometric *versus* dynamic), and time (pre- *versus* post exercise  
169 *versus* 45 min post- exercise). In addition to this, for both isometric and dynamic interventions, effect  
170 sizes was be calculated and plotted for the change in NRS scores of the SLDS evoked pain. In cases  
171 where the assumption of sphericity was violated according to the results of Mauchly's sphericity test,  
172 Greenhouse-Geisser adjustment was used.

173 The primary outcome was also analysed as a categorical variable, defined as the number of  
174 responders to each intervention, quantified by the number of participants with a change equal to, or above  
175 the minimally clinically important difference (MCID) in NRS i.e. 2 points change <sup>22</sup>. McNemars test was  
176 used to test for differences in the proportion of participants categorised as responders to each of the  
177 interventions.

## 180 **RESULTS**

181 Participants were recruited and assessed for eligibility between July 2018 and September 2018 (Figure 1).  
182 Recruitment was ceased when 21 eligible participants were enrolled as per the a priori protocol and  
183 sample size calculation. Of these 21, one participant loss to follow-up (due to family reasons), and did not  
184 complete the dynamic exercise intervention (Figure 1). Therefore, twenty participants were included in  
185 the analysis (Figure 1). The severity of the participant's tendon pain was expressed with the VISA-P score  
186 (mean score: 47.8/100, Table 1) and the majority had contacted at least one health care practitioner (12  
187 contacts to general practitioner, 12 to physiotherapist, one to and orthopaedic surgeon and one to a  
188 rheumatologist). All participants were actively engaged in at least one sport/activity (Table 1), with a

189 large proportion conducting strength training (including Cross-Fit) (n=12 other sports), and other sports  
190 included handball (n=3), gymnastics (n=3) volleyball (n=1), athletics (n=1), triathlon (n=1) and running  
191 (n=1).

192 There were no significant differences on the primary outcome between the two sequence groups  
193 (isometric-dynamic and dynamic-isometric) for the mean differences, or the sum of effects, indicating no  
194 influence of exercise order and negligible carryover effects respectively.

195  
196 In the ANOVA there was no significant interaction between mode of exercise and time on NRS scores of  
197 pain during SLDS ( $F(2,38)=0.6$ ,  $p=0.561$ , partial  $\eta^2 = 0.03$ ; Figure 2; Table 2). There was a main effect of  
198 time ( $F(1.4,38)= 4.7$ ,  $p=0.028$ ), partial  $\eta^2 = 0.19$ ). The pain NRS score was lower immediately post  
199 exercise (mean difference 0.9 NRS points 95%CI 0.1 to 1.7; Post-hoc:  $p=0.028$ ) compared to baseline.

200 There were no significant differences in NRS scores of pain during SLDS between 45 min post exercise  
201 and baseline (mean difference 0.4 NRS points 95%CI -0.1 to 0.8; Post-hoc:  $p= 0.089$ ). The proportion of  
202 responders (NRS scores during SLDS reduced by 2 points compared with baseline) were not significantly  
203 different between isometric and dynamic exercise interventions immediately after the exercise (4 versus 6  
204 respectively;  $p = 0.73$ ) or 45 min after the exercise (0 versus 4 respectively;  $p=0.16$ ).

205  
206 For PPTs at the patellar tendon of the painful knee, there was no significant interaction between mode of  
207 exercise and time ( $F(1.6,38)=0.0$ ,  $p=0.196$ , partial  $\eta^2 = 0.08$ ) or main effect of time ( $F(2,38)=1.5$ ,  
208  $p=0.239$ , partial  $\eta^2 = 0.07$ ) (Table 3).

209 There was no significant interaction effect between mode of exercise and time for PPTs at the  
210 tibialis anterior muscle ( $F(2,38) =0.5$ ,  $p=0.62$ , partial  $\eta^2 = 0.03$ ) (Table 3) but there was a main effect of  
211 time ( $F(2,38)=4.0$ , $p=0.027$ , partial  $\eta^2 = 0.17$ ). Pairwise comparisons revealed increased PPTs at the  
212 tibialis anterior muscle post exercise compared to baseline (mean difference 34 kPa 95%CI 9.5 to 58.5,  
213  $p=0.009$ ), with no differences 45 min post exercise compared with baseline (mean difference 17.2 kPa  
214 95%CI -12.3 to 46.7,  $p=0.238$ ) (Figure 3).

215 There was no significant interaction between mode of exercise and time ( $F(2,38)=0.7, p=0.519$ ,  
216 partial  $\eta^2 = 0.03$ ) (Table 3) or main effect for time ( $F(2,38)=1.1, p=0.340$ , partial  $\eta^2 = 0.06$ ) for PPT at the  
217 contralateral extensor carpi radialis brevis muscle.

218 For PPTs at the contralateral patellar tendon, there was no significant interaction between mode of  
219 exercise and time ( $F(1.5,28.8)=0.04, p=0.603$ , partial  $\eta^2 = 0.02$ ) (Table 3) or main effect for time  
220 ( $F(1.4,26.8)=0.9, p=0.383$ , partial  $\eta^2 = 0.05$ ).

221  
222 There was no significant change in patellar tendon thickness from pre to post exercises ( $F(2,38)=0.5$ ,  
223  $p=0.593$ , partial  $\eta^2=0.03$ ) (Table 3) or interaction between mode of exercise and time  
224 ( $F(2,38)=0.2, p=0.821$ , partial  $\eta^2=0.01$ ).

## 226 **DISCUSSION**

227 The current study aimed to test previous findings on the short-term analgesic effect of isometric resistance  
228 exercise for patients with patellar tendinopathy. Contrary to our pre-defined hypothesis, no significant  
229 difference was found between isometric and dynamic resistance exercise on acute pain during a pain-  
230 provoking activity, or pain sensitivity. There was an effect of time, i.e. a small decrease in self-reported  
231 pain during movement evoked pain immediately following exercises, with no differences between  
232 isometric or dynamic exercises. This finding was supported by the increased PPTs at the tibialis anterior  
233 muscle immediately post exercise, indicating EIH, but not at the patellar tendon or in other locations  
234 indicating a lack of a systemic effect. However, no significant difference was observed between the two  
235 exercises for either outcome. Changes were not sustained 45 minutes post-exercise, despite a tendency for  
236 pain to be lower than at baseline ( $p=0.089$ ), indicating pain ratings were returning to baseline at the  
237 45min follow-up. Only a small number of participants reported a clinically relevant decrease in pain,  
238 which was not different between the exercise conditions.

239  
240 Overall, the magnitude of the exercise-induced changes in pain intensity found in the current study were  
241 discouraging, based on the previous data indicating a substantial effect of isometric exercise (over 6

242 points on the NRS) <sup>15</sup>. The current study contradicts the magnitude of these effects and challenges the  
243 generalisability of previous findings. Despite replicating the exercise protocol, the magnitude of pain  
244 reduction to dynamic exercise reported by Rio and colleagues <sup>15</sup> was also much larger and clinically  
245 relevant, compared to the present results where only a small proportion of participants had a clinically  
246 relevant change in pain after exercise. The populations are similar in terms of severity (VISA-P score of  
247 47.9 in the current study compared to 52.8 <sup>15</sup>, although the relatively long symptom duration and high  
248 proportion of bilateral cases in the current study could indicate a high severity. However, these data were  
249 not provided by Rio and colleagues which hampers a direct comparison in populations. Furthermore, the  
250 study by Rio and colleagues included only n=6 adult male volleyball players, which would make the  
251 generalisability to wider populations of patellar tendinopathy limited. We included all types/sports and  
252 both males and females, and sex may be important due to established sex differences in pain perception,  
253 although women have been demonstrated to be more responsive to EIH <sup>23</sup>. On the other hand Pearson et  
254 al. <sup>16</sup> recently compared short versus longer contraction times in patients with patellar tendinopathy and  
255 found they were equally effective on acute pain relief with pain during a SLDS reduced by 1.7 cm on a  
256 VAS scale. The magnitude of change in pain is much more similar to our results compared to the study by  
257 Rio and colleagues, which may indicate the large decrease in pain following contractions in these 6  
258 individuals may not be generalizable. Several papers which have investigated the acute pain-relieving  
259 effects of isometric exercises on common lower limb tendinopathies. In Achilles tendinopathy, <sup>17</sup> some  
260 patients reported an improvement, while others had a pain flare-up after the heavy isometric loading  
261 while Riel et al. <sup>24</sup> did not find a difference in the acute effects on pain between the two exercise types, in  
262 patients with plantar fasciopathy.

263 In our study, EIH was detected distally at the tibialis anterior by increases in PPTs immediately post  
264 exercise. The observed magnitude of the EIH response detected by PPTs distally after exercise is similar  
265 to that which has previously been detected after isometric or aerobic exercise <sup>23,25</sup>. Despite this, a positive  
266 EIH response was not found locally at the patellar tendon or remotely at the extensor carpi radialis brevis  
267 muscle. This is surprising, as EIH is considered a systemic/centrally mediated pain modulation <sup>11,26</sup>. This  
268 could be due to dysfunctional endogenous pain inhibition, as has been demonstrated in patients with other

269 musculoskeletal pain conditions such as shoulder myalgia<sup>27</sup>. It cannot be ruled out that such  
270 manifestations are present in painful- persistent tendinopathies, considering the mean pain duration of the  
271 current sample is 24 months, and patients with patellar tendinopathy have previously been demonstrated  
272 increased pain sensitivity<sup>28</sup>. However, this is speculative as we did not include a control group without  
273 tendon pain for comparison.

274  
275 While the mechanisms of exercise on pain and EIH are not yet fully understood, there appear to be  
276 multiple analgesic systems which play a role<sup>9,10</sup>. Some characteristics, such as exercise stress/severity  
277 (e.g. exercise duration and temperature) appear to influence the relative contribution of opioid versus non-  
278 opioid mechanisms in animals<sup>29</sup>. Further research is needed to investigate which other parameters  
279 contribute to this, and whether results are similar between patient populations and healthy controls. For  
280 example, data in healthy subjects show that both short and long duration contractions, and low and high  
281 load isometric exercise affect pain perception with hypoalgesia occurring after only one minute of low  
282 load (25%MVIC) contractions<sup>8,13,14</sup>. Whether or not these parameters have similar responses on tendon  
283 pain has yet to be determined. One possibility, was that changes in patellar thickness may explain the  
284 potential effect of one exercise over another. However, in the current study we found no changes in  
285 tendon thickness following resistance training exercises, which is in contrast to previous research  
286 showing that acute tendon overload via cross-fit training resulted in an increased tendon thickness in  
287 healthy individuals<sup>12</sup> which could indicate that the volume or intensity play a role. However, further  
288 research in patients with patellar tendinopathy is needed to determine if such an acute change in thickness  
289 is indeed associated with changes in symptoms.

290 In healthy individuals meta-analysis indicated that both isometric and dynamic exercise are  
291 effective in influencing pain perception<sup>8</sup>. Isometric exercise has commonly been used, many studies have  
292 also evaluated aerobic exercise<sup>8</sup>, and there are data available regarding dynamic or concentric resistance  
293 exercise. These have found dynamic exercise effective<sup>8,30</sup>, and data from first investigations over 20  
294 years ago, show large effect sizes of around 0.99-1.08<sup>31</sup>.

296 Isometric exercises for immediate pain relief was quickly highlighted as a strong tool for managing pain  
297 in patients with lower limb tendinopathies <sup>7, 18</sup>. Based on the current study there was no statistically  
298 significant superior effect of isometric exercise compared to dynamic exercises. It should be noted that  
299 this study included adult participants with chronic tendinopathy of a relatively long symptom duration. It  
300 is unclear if participants' with acute tendinopathy or adolescents with other patellar tendon related pain  
301 conditions (e.g. Osgood Schlatter) may produce different results. Further research is needed to further  
302 elucidate the mechanisms underpinning acute and cumulative exercise induced analgesia in order to  
303 inform how to modulate exercise intensity and dosages to optimise outcomes for patients with  
304 tendinopathy in both the short and long term.

305 One of the strengths of the current study is the study design, which was pre-registered with the statistical  
306 analysis plan specified a priori in the protocol. Additionally, we based our diagnosis of patellar  
307 tendinopathy on objective characteristic features examined by ultrasound, in addition to the clinical  
308 assessment. One of the limitations of the current design is the lack of a 'no-exercise' control condition, so  
309 it cannot be ruled out the SLDS NRS declines over time. However, this limitation doesn't affect the  
310 overall conclusion regarding the superiority of the contraction modes. Another limitation is that the  
311 assessor was not blinded to the different exercise conditions. Further, isometric and dynamic strength was  
312 measured on the same day as testing. However, as the EIH effect is relatively short-lived and participants  
313 were given a break prior to baseline pre-exercise assessment, and as this was the same under both  
314 conditions, we do not believe this affects the conclusion of results. The effect of the different exercises on  
315 the affective dimension of pain (i.e. pain unpleasantness) was not documented, which is also a limitation.  
316 Finally, we did not detect a functional EIH response at all sites, but without a control group cannot  
317 determine if these patients with patellar tendinopathy have a decreased response to exercise induced  
318 analgesia compare to healthy individuals without musculoskeletal pain. Further research could investigate  
319 this, as well as whether or not it has implications for treatment outcomes. Similarly, due to the large  
320 heterogeneity in the acute effects to acute pain relief, whether or not this is associated with sustained pain  
321 relief following a resistance training intervention is warranted.

322

323 The current study demonstrates that there is no statistically superior immediate effect of isometric  
324 exercise compared to dynamic exercise on pain, or on pain perception (hypoalgesia). The optimal mode  
325 and dosage for inhibiting pain in patients with patellar tendinopathy has been controversial, but this study  
326 indicates that the contraction mode may not be the most important factor.

327

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403 **Figure Legends**

404 **Figure 1.** Flowchart of included participants.

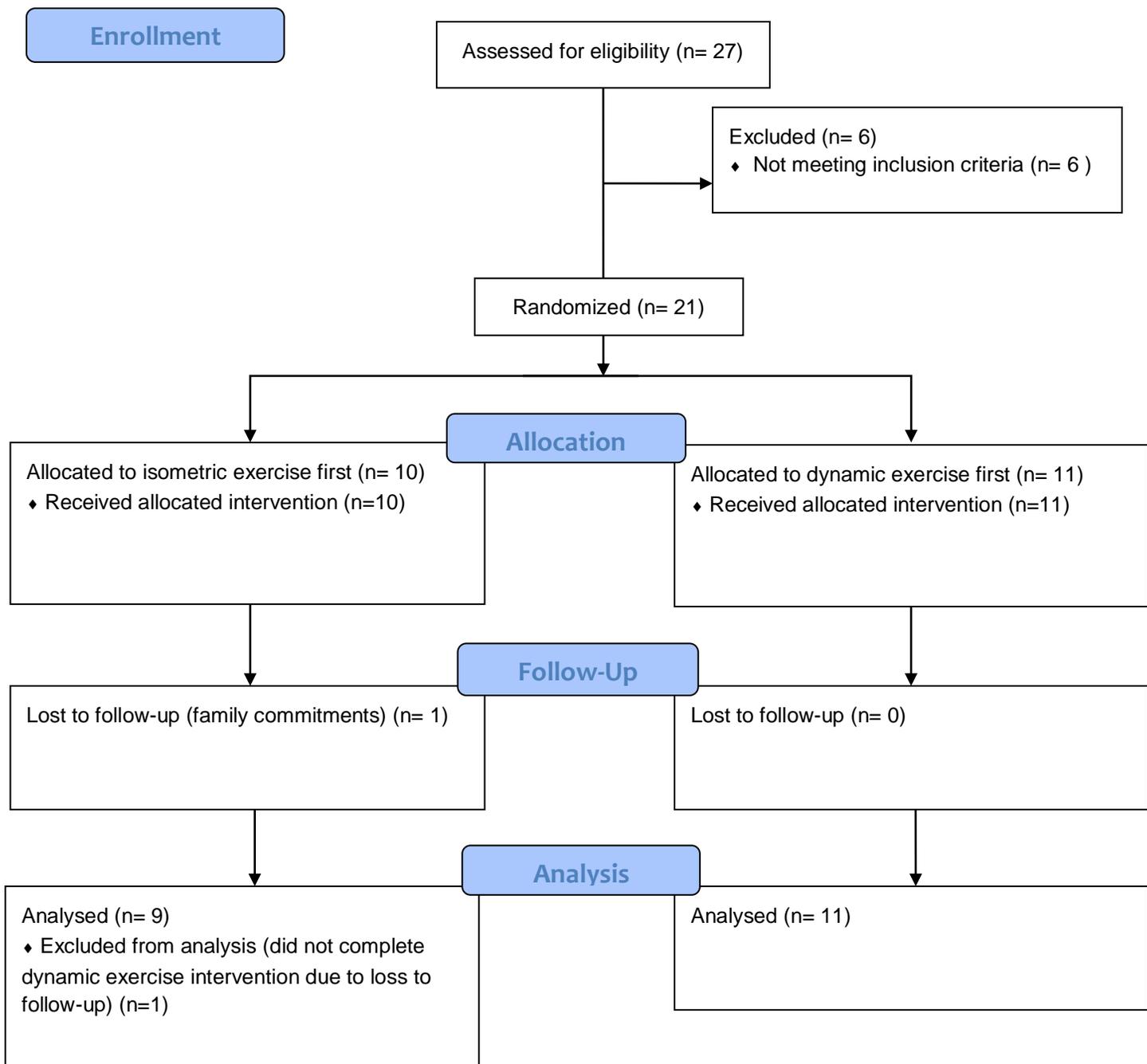
405 **Figure 2.** Individual participant data plot of pain during SLDS on the test limb before, immediately after  
406 and 45 min after isometric exercise (top) and dynamic exercise (bottom).

407 **Figure 3.** Mean change (95% CI) in pressure pain thresholds from baseline. (\*indicated significant  
408 difference from baseline; test indicates test limb; contra indicates contra-lateral limb).

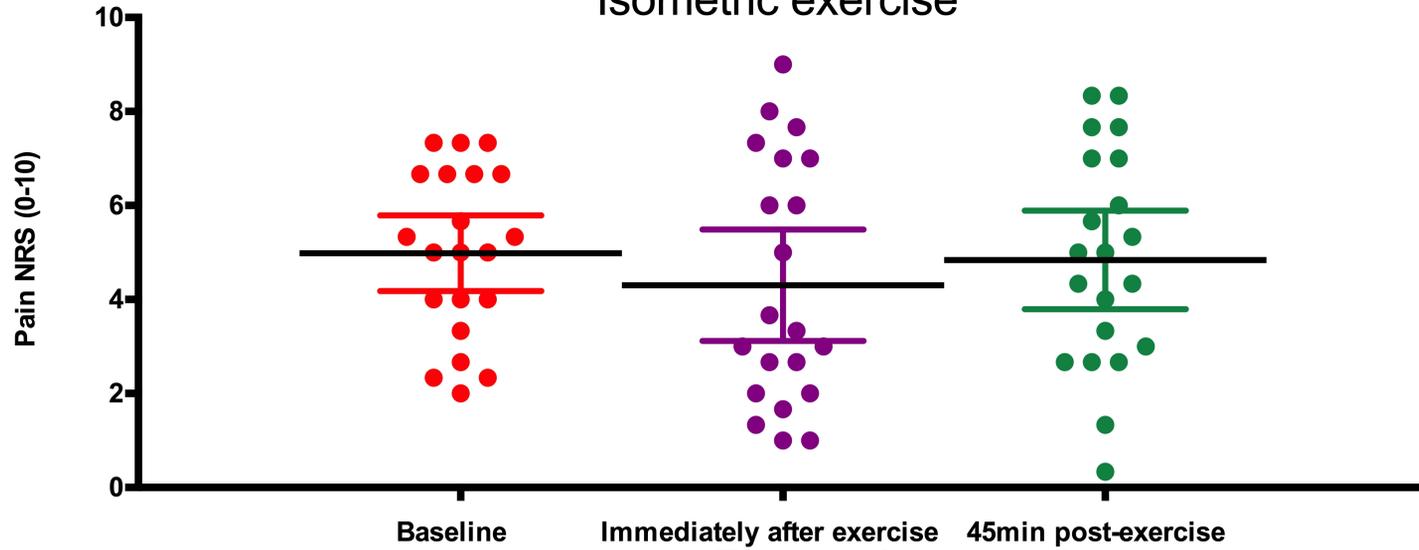
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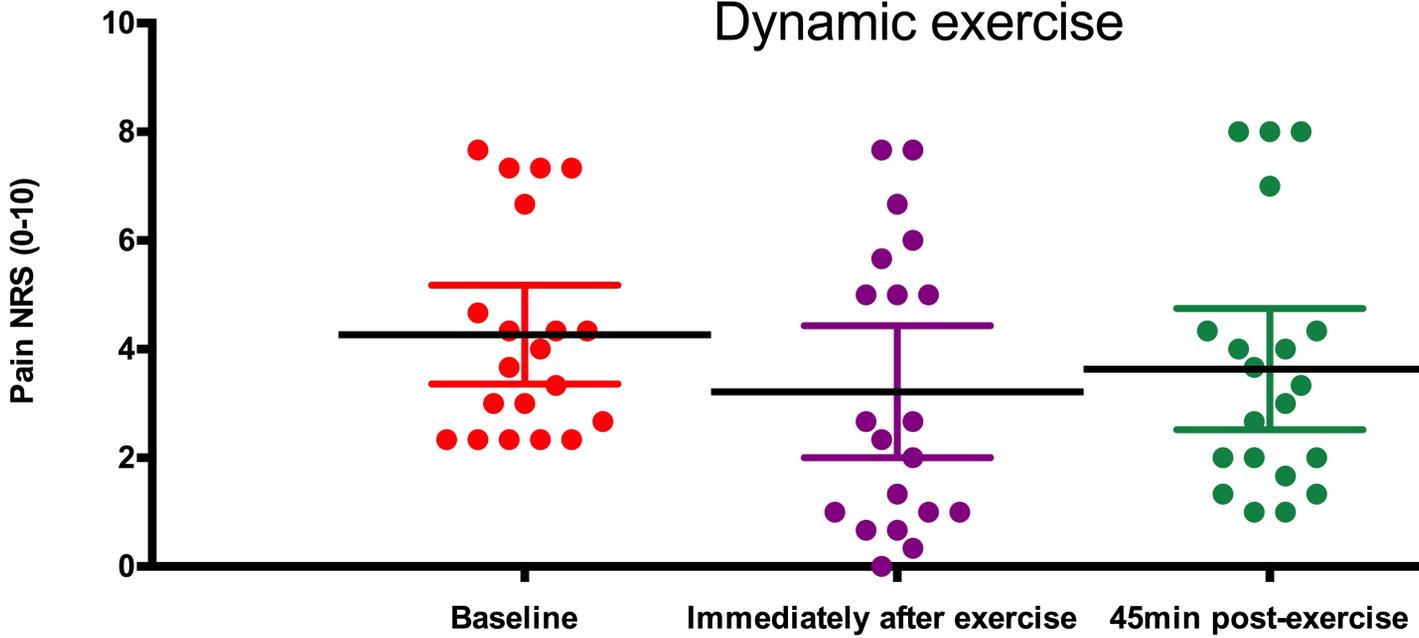
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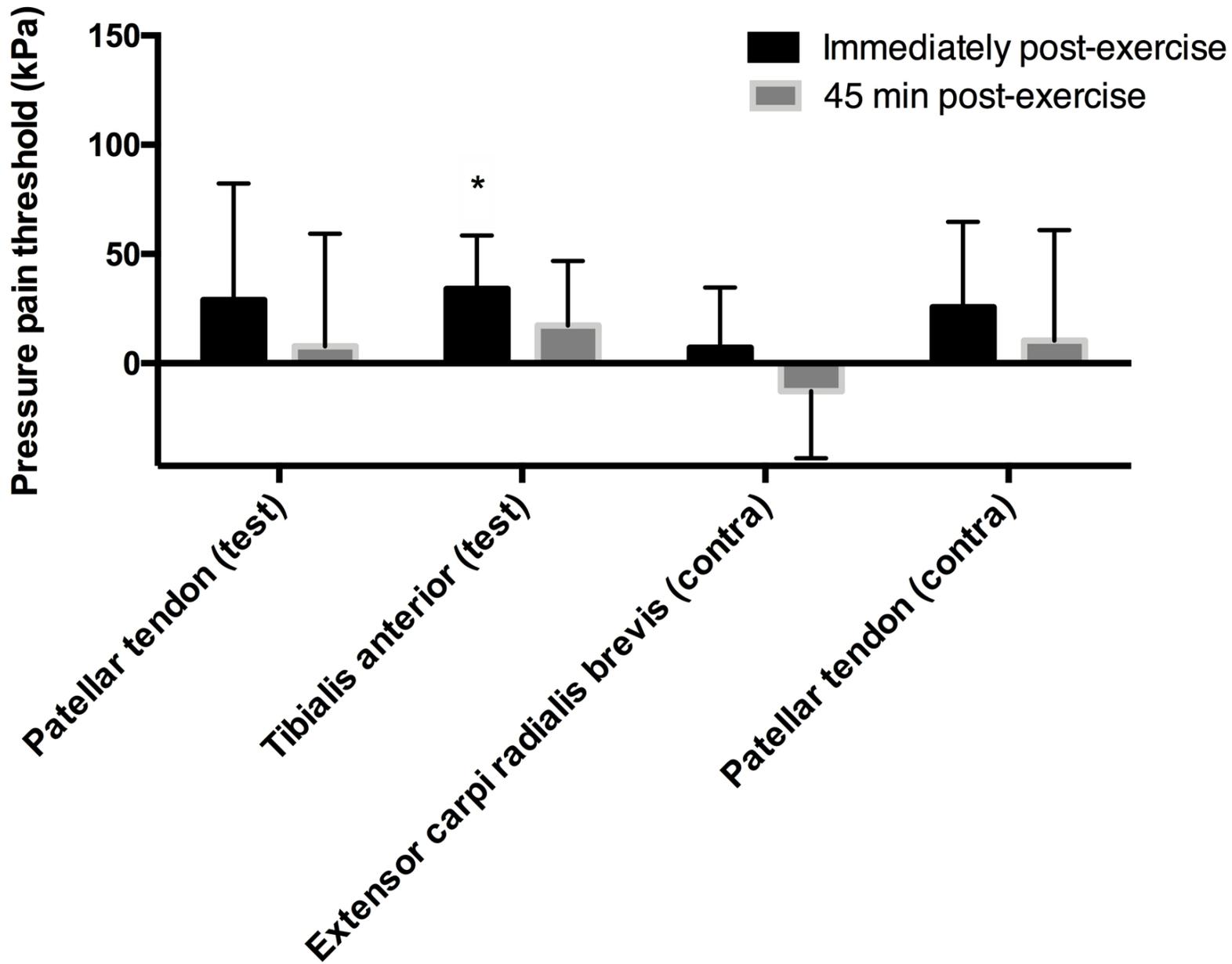


### Isometric exercise



### Dynamic exercise





Age (years)	26.5 (6.4)
Sex (% female)	41
BMI* (kg/m <sup>2</sup> )	25.6 (23.2 – 29.1)
VISA-P Score (0-100, 100 being best)	47.9 (11.6)
Symptom duration* (months)	24 (10 -84)
Bilateral pain (%)	52
Contact with health care practitioner due to knee pain (%Yes)	82
Worst pain past week (NRS points)	7.9 (1.6)
Mean pain past week (NRS points)	4.3 (1.6)
Weekly sports participation (h)	8.8 (4.2)

**Table 1.** Participant demographics and characteristics at baseline reported as mean (standard deviation) unless otherwise indicated (\*: indicates median and inter-quartile range). VISA-P: Victorian Institute of Sport Assessment-Patella.

<b>Time</b>	<b>Mean</b>	<b>95% CI</b>
	<b>Isometric</b>	
<i>Baseline</i>	5	4.1 to 5.8
<i>Immediately post- exercise</i>	4.2	3.0 to 5.5
<i>45 min post-exercise</i>	4.8	3.7 to 5.9
	<b>Isotonic</b>	
<i>Baseline</i>	4.3	3.4 to 5.2
<i>Immediately post- exercise</i>	3.2	2.0 to 4.4
<i>45 min post-exercise</i>	3.6	2.5 to 4.7
	<b>Difference (isometric - isotonic)</b>	
<i>Change from baseline to immediately post- exercise</i>	-0.3	-1.3 to 0.7

Time		Isometric		Dynamic		Mean difference Isometric vs Dynamic	
		Mean	95% CI	Mean	95% CI	Change from baseline to post- exercise	95% CI
PPT Patellar tendon (kPa)	<i>Baseline</i>	489	399 to 579	454	348 to 560		
	<i>post- exercise</i>	492	371 to 613	509	383 to 634	-53	-128 to 23
	<i>45 min post- exercise</i>	458	363 to 552	470	356 to 583		
PPT Tibialis Anterior (kPa)	<i>Baseline</i>	442	349 to 536	407	321 to 493		
	<i>post- exercise</i>	485	377 to 593	432	343 to 522	18	-38 to 73
	<i>45 min post- exercise</i>	456	349 to 546	427	337 to 518		
PPT contra- lateral extensor carpi radialis brevis (kPa)	<i>Baseline</i>	271	225 to 318	287	225 to 350		
	<i>post- exercise</i>	293	225 to 361	280	210 to 350	29	-14 to 72
	<i>45 min post- exercise</i>	263	15 to 332	270	214 to 326		
PPT contralate ral patellar tendon (kPa)	<i>Baseline</i>	553	435 to 670	526	413 to 640		
	<i>post- exercise</i>	590	465 to 715	540	421 to 660	23	-63 to 110
	<i>45 min post- exercise</i>	559	432 to 687	541	417 to 664		
Patellar tendon	<i>Baseline</i>	0.5	0.45 to 0.55	0.51	0.47 to 0.55		

<b>thickness (cm)</b>	<b>post- exercise</b>	0.49	0.44 to 0.53	0.5	0.46 to 0.55	0.01	-0.04 to 0.03
	<b>45 min post- exercise</b>	0.5	0.45 to 0.55	0.51	0.46 to 0.55		

**Table 2.** Mean (95% CI) pressure pain threshold (PPT) and patellar tendon thickness at baseline, immediately post-exercise and 45min post-exercise.