

1      **Effects of prophylactic knee bracing on patellar tendon loading parameters during**  
2                      **functional sports tasks in recreational athletes.**

3      **Keywords:** Biomechanics, knee brace, patellar tendon, tendinopathy

4      **Word count:** 3200

5      **Conflict statement:** No conflict of interest to declare.

7      **Abstract**

8      **PURPOSE:** This study investigated the effects of prophylactic knee bracing on patellar  
9      tendon loading parameters.

10      **METHODS:** Twenty recreational athletes (10 male & 10 female), from a different athletic  
11      disciplines performed run, cut and single leg hop movements under two conditions  
12      (prophylactic knee brace/ no-brace). Lower extremity kinetics and kinematics were examined  
13      using a piezoelectric force plate, and three-dimensional motion capture system. Patellar  
14      tendon loading was explored using a mathematical modelling approach, which accounted for  
15      co-contraction of the knee flexors. Tendon loading parameters were examined using 2  
16      (*brace*)\*3 (*movement*)\*2 (*sex*) mixed ANOVA's.

17      **RESULTS:** Tendon instantaneous load rate was significantly reduced in female athletes, in  
18      the run (brace = 289.14BW/s no-brace = 370.06BW/s) and cut (brace = 353.17BW/s/ no-  
19      brace = 422.01BW/s) conditions whilst wearing the brace.

20      **CONCLUSIONS:** Female athletes may be able to attenuate their risk from patellar  
21      tendinopathy during athletic movements, through utilization of knee bracing, although further  
22      prospective research into the prophylactic effects of knee bracing is required before this can  
23      be clinically substantiated.

25      **Introduction**

26 Chronic patellar tendinopathy is an extremely common musculoskeletal condition in both  
27 recreational and elite athletes, and has previously been reported to account for as many as  
28 25% of all soft tissue injuries (1). Patellar tendinopathy is characterized by pain localized at  
29 the lower pole of the patella, and pain symptoms that are augmented by activities which place  
30 high demands on the knee extensors, notably in physical disciplines which repeatedly store  
31 and release elastic energy in the tendon itself (2). Patellar tendinopathy is more common in  
32 skeletally mature individuals, and there remains disagreement as to whether this condition is  
33 most common in male or female athletes (3). Chronic patellar tendinopathy is established  
34 after 1-3 months, as degenerative alterations occur in the tendon itself (4). Degenerative  
35 alterations at the tendon are mediated primarily by the absence of inflammatory cells within  
36 the tendon itself, which reduces healing of the tendon and ultimately leads to decreased  
37 tensile strength and disorganization of the collagen fibers (5). Patellar tendinopathy can be  
38 debilitating; Cook et al., (6) showed that 1/3 of athletes with patellar tendinopathy are unable  
39 to return to physical activity within 6 months, and it has also been evidenced that 53% of  
40 athletes who present with this condition were forced to permanently cease physical activities.

41

42 Knee braces are utilized extensively in both recreationally active and competitive athletes, in  
43 order to attenuate their risk from knee pathology (7). Knee braces are external devices which  
44 are designed to improve the alignment of the knee joint (8). Prophylactic knee braces aim to  
45 protect athletes from sustaining injury, whilst being minimally restrictive, allowing athletes to  
46 utilize full knee range of motion during their physical activities (9). Recently, the effects of  
47 prophylactic knee braces on the biomechanics of the knee joint during dynamic sports tasks  
48 have received significant attention in clinical literature. Sinclair et al., (7), examined the  
49 effects of knee bracing on knee joint kinetics and kinematics in netball specific movements.  
50 They showed that the brace did not alter knee kinetics but did reduce range of motion in the

51 transverse plane. Ewing et al., (10), examined muscle kinetics with and without the presence  
52 of a prophylactic knee brace during double limb drop landings. Hamstring and vasti muscles  
53 produced significantly greater flexion and extension torques, and greater peak muscle forces  
54 in the brace condition. Lee et al., (11), analyzed the effects of a prophylactic bilateral hinge  
55 brace, fitted with torque transducers during four functional sports tasks; drop vertical jump,  
56 pivot, stop vertical jump and cut. Their results showed that the knee brace hinges absorbed up  
57 to 18% of the force and 2.7% of the torque at the knee, during the different athletic motions.  
58 Which they concluded, was minimal evidence that the brace was able to reduce the  
59 mechanical load at the knee. Although knee braces have been studied in terms of both their  
60 therapeutic and prophylactic effects, there is currently no literature which has considered  
61 their role in the prevention of patellar tendinopathy.

62

63 Therefore, the aim of the current investigation was to investigate the effects of a prophylactic  
64 knee brace on patellar tendon loading parameters linked to the aetiology of patellar  
65 tendinopathy, in male and female recreational athletes. Research of this nature may provide  
66 important clinical information, regarding the potential role of prophylactic knee bracing for  
67 the prevention of patellar tendinopathy.

68

## 69 **Methods**

### 70 *Participants*

71 Twenty participants (10 male; age =  $26.70 \pm 4.24$ , mass =  $73.90 \pm 5.3$ , stature =  $176.50 \pm$   
72  $4.25$  & BMI =  $23.73 \pm 1.80$  & and 10 female age =  $27.60 \pm 4.72$ , mass =  $60.40 \pm 7.86$ , stature  
73 =  $166.50 \pm 5.06$  & BMI =  $21.86 \pm 2.21$ ), volunteered to take part in the current investigation.  
74 Participants were all recreational level athletes who came from squash, netball, basketball and  
75 association football athletic backgrounds, with a minimum of 2 years of experience in their

76 chosen discipline. In addition, all were free from lower extremity pathology at the time of  
77 data collection, and had not previously experienced an injury to the patellar tendon. Written  
78 informed consent was provide,d in accordance with the declaration of Helsinki and the rights  
79 of all participants were protected. The procedure was approved by the Universities Science,  
80 Technology, Engineering, Medicine and Health ethics committee, with the reference STEMH  
81 295.

82

### 83 *Knee Brace*

84 A single knee brace was utilized in this investigation, (Trizone, DJO USA), which was worn  
85 on the dominant limb in all participants. The brace examined in the current investigation  
86 represents a compression sleeve reinforced with silicone designed to support the knee joint  
87 and improve proprioception.

88

### 89 *Procedure*

90 Participants were required to complete five repetitions of three sports specific movements';  
91 jog, cut and single leg hop, with and without presence of the brace. The order that  
92 participants performed in the movement/ brace conditions was counterbalanced. To quantify  
93 lower extremity segments, the calibrated anatomical systems technique was utilized (12).  
94 Retroreflective markers (19 mm), were positioned unilaterally allowing the; foot, shank and  
95 thigh to be defined. The foot was defined via the 1st and 5th metatarsal heads, medial and  
96 lateral malleoli and tracked using the calcaneus, 1st metatarsal and 5th metatarsal heads. The  
97 shank was defined via the medial and lateral malleoli and medial and lateral femoral  
98 epicondyles and tracked using a cluster positioned onto the shank. The thigh was defined via  
99 the medial and lateral femoral epicondyles and the hip joint centre and tracked using a cluster  
100 positioned onto the thigh. To define the pelvis additional markers were positioned onto the

101 anterior (ASIS) and posterior (PSIS) superior iliac spines and this segment was tracked using  
102 the same markers. The hip joint centre was determined using a regression equation, which  
103 uses the positions of the ASIS markers (13). The centers of the ankle and knee joints were  
104 delineated as the mid-point between the malleoli and femoral epicondyle markers (14, 15).  
105 Each tracking cluster comprised four retroreflective markers, mounted onto a rigid piece of  
106 lightweight carbon-fibre. Static calibration trials were obtained allowing for the anatomical  
107 markers to be referenced in relation to the tracking markers/ clusters. The Z (transverse) axis  
108 was oriented vertically from the distal segment end to the proximal segment end. The Y  
109 (coronal) axis was oriented in the segment from posterior to anterior. Finally, the X (sagittal)  
110 axis orientation was determined using the right hand rule and was oriented from medial to  
111 lateral.

112

113 Data were collected during run, cut and jump movements using the protocol below:

114

#### 115 *Run*

116 Participants ran at  $4.0 \text{ m}\cdot\text{s}^{-1} \pm 5\%$ , and struck the force platform with their right (dominant)  
117 limb. The average velocity of running was monitored using infra-red timing gates  
118 (SmartSpeed Ltd UK). The stance phase of running, was defined as the duration over  $> 20 \text{ N}$   
119 of vertical force was applied to the force platform (16).

120

#### 121 *Cut*

122 Participants completed  $45^\circ$  sideways cut movements, using an approach velocity of  $4.0 \text{ m}\cdot\text{s}^{-1}$   
123  $\pm 5\%$  striking the force platform with their right (dominant) limb. In accordance with McLean  
124 et al., (17), cut angles were measured from the centre of the force plate and the corresponding  
125 line of movement was delineated using masking tape, so that it was clearly evident to

126 participants. The stance phase of the cut-movement was similarly defined as the duration over  
127 > 20 N of vertical force was applied to the force platform (16).

128

### 129 *Hop*

130 Participants began standing by on their dominant limb; they were then requested to hop  
131 forward maximally, landing on the force platform with same leg without losing balance. The  
132 arms were held across the chest to remove arm-swing contribution. The hop movement was  
133 defined as the duration from foot contact (defined as > 20 N of vertical force applied to the  
134 force platform), to maximum knee flexion. The hop distance was recorded and maintained  
135 throughout data collection.

136

### 137 *Processing*

138 Dynamic trials were processed using Qualisys Track Manager, and then exported as C3D  
139 files. Ground reaction force and marker data were filtered at 50 Hz and 15 Hz respectively  
140 using a low-pass Butterworth 4th order filter, and processed using Visual 3-D (C-Motion,  
141 Germantown, MD, USA). Internal moments were computed using Newton-Euler inverse-  
142 dynamics, allowing net knee joint moments to be calculated. Angular kinematics of the knee  
143 joint were calculated using an XYZ (sagittal, coronal and transverse) sequence of rotations,  
144 allowing sagittal angles at footstrike and peak flexion angles to be extracted.

145

146 A commonly utilized mathematical model for the quantification of patellar tendon loading is  
147 that developed by Janssen et al., (18). Whereby the Patellar tendon load is determined by  
148 dividing the knee extensor moment by the estimated patellar tendon moment arm. This  
149 algorithm has been successfully utilized previously, to resolve differences in patellar tendon

150 kinetics during different movements (18), different footwear conditions (19), and also  
151 between sexes (20).

152

153 However, a limitation of the aforementioned model is that the knee extensor moment does  
154 not account for co-contraction of the knee flexor musculature. In order to account for this, we  
155 also calculated hamstring and gastrocnemius force in accordance with the procedures  
156 described by DeVita and Hortobagyi (21). To summarize, the hamstring force was calculated  
157 using the hip extensor moment, hamstrings and gluteus maximus cross-sectional areas (22),  
158 and by fitting a 2<sup>nd</sup> order polynomial curve to the data of Nemeth & Ohlsen, (23) who  
159 provided muscle moment arms at the hip as a function of hip flexion angle. The  
160 gastrocnemius force, was calculated firstly by quantifying the ankle plantarflexor force,  
161 which was resolved by dividing the plantarflexion moment by the Achilles tendon moment  
162 arm. The Achilles tendon moment arm was calculated by fitting a 2<sup>nd</sup> order polynomial curve  
163 to the ankle plantarflexion angle in accordance with Self and Paine (24). The quantity of  
164 plantarflexion force accredited to the gastrocnemius muscles, was calculated via the cross-  
165 sectional area of this muscle relative to the triceps surae (22).

166

167 The hamstring and gastrocnemius forces were multiplied by their estimated muscle moment  
168 arms to the knee joint in relation to the knee flexion angle (25), and then added together to  
169 estimate the knee flexor moment. The derived knee flexor moment was added to the net knee  
170 extensor moment quantified using inverse dynamics, and then divided by the moment arm of  
171 the patellar tendon, generating the patellar tendon force. The tendon moment arm was  
172 quantified as a function of the sagittal plane knee angle, by fitting a 2<sup>nd</sup> order polynomial  
173 curve to the data provided by Herzog & Read, (26), showing patellar tendon moment arms at  
174 different knee flexion angles.

175

176 All patellar tendon load parameters were normalized by dividing the net values by  
177 bodyweight (BW). Patellar tendon instantaneous load rate (BW/s), was quantified as the peak  
178 increase in patellar tendon force between adjacent data points. In addition, we also calculated  
179 the total patellar tendon force impulse (BW·s) during each movement using a trapezoidal  
180 function.

181

### 182 *Statistical analyses*

183 Descriptive statistics of means, standard deviations and 95% confidence intervals (95% CI)  
184 were obtained for each outcome measure. Shapiro-Wilk tests were used to screen the data for  
185 normality. Differences in patellar tendon loading parameters between conditions, were  
186 examined using 2 (*brace*) \* 3 (*movement*) \* 2 (*sex*) mixed ANOVA's. Statistical significance  
187 was accepted at the P<0.05 level. Effect sizes for all significant findings were calculated  
188 using partial Eta<sup>2</sup> ( $\eta^2$ ). Post-hoc pairwise comparisons were conducted on all significant  
189 main effects. Significant interactions were further evaluated by performing simple main  
190 effect examinations on each level of the interaction, in the event of a significant simple main  
191 effect pairwise comparisons were performed. All statistical actions were conducted using  
192 SPSS v22.0 (SPSS Inc, Chicago, USA).

193

### 194 **Results**

195 Tables 1-4 and figure 1 present patellar tendon loading parameters as a function of *brace*,  
196 *movement* and *sex*.

197

198 @@@ **FIGURE 1 NEAR HERE** @@@

199 @@@ **FIGURE 2 NEAR HERE** @@@



200 @@@ TABLE 1 NEAR HERE @@@

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204

205 *Peak patellar tendon force*

206 A significant main effect ( $P < .05$ ,  $\eta^2 = .20$ ) was found for *movement*. Post-hoc pairwise  
207 comparisons showed that peak patellar tendon force was significantly larger in the cut  
208 movement compared to the hop ( $P = .046$ ) and run ( $P = .008$ ) conditions.

209

210 In addition a significant main effect ( $P < .05$ ,  $\eta^2 = .31$ ) was observed for *brace*. Post-hoc  
211 pairwise comparisons showed that peak patellar tendon force was significantly larger in the  
212 no-brace ( $P = .013$ ) condition compared to wearing the brace.

213

214 *Patellar tendon instantaneous load rate*

215 A significant main effect ( $P < .05$ ,  $\eta^2 = .29$ ) was found for *movement*. Post-hoc pairwise  
216 comparisons showed that patellar tendon instantaneous load rate was significantly larger in  
217 the cut ( $P = .032$ ) and hop ( $P = .003$ ) conditions compared to the run movement. In addition a  
218 significant main effect ( $P < .05$ ,  $\eta^2 = .45$ ) was observed for *brace*, with patellar tendon  
219 instantaneous load rate being significantly in the no-brace condition compared to wearing the  
220 brace.

221

222 Finally a significant ( $P < .05$ ,  $\eta^2 = .19$ ) *brace \* movement \* sex* interaction was shown.  
223 Follow up analyses using simple main effects showed for males that there was a significant  
224 main effect ( $P < .05$ ,  $\eta^2 = .21$ ) for *movement*, with the hop ( $P = .01$ ) and cut ( $P = .04$ )

225 movements being associated with a greater instantaneous load rate than the run movement.  
226 For females there was a significant main effect ( $P < .05$ ,  $\eta^2 = .86$ ) for *movement*, with the hop  
227 ( $P = .00001$ ) and cut ( $P = .002$ ) movements being associated with a greater instantaneous load  
228 rate than the run movement. In addition there was also a main effect ( $P < .05$ ,  $\eta^2 = .57$ ) for  
229 *brace* with instantaneous load rate being significantly ( $P = .018$ ) larger in the no-brace  
230 condition. Finally a significant ( $P < .05$ ,  $\eta^2 = .42$ ) *brace \* movement* interaction was found for  
231 females. Follow up analyses showed that there were main effects for the run ( $P < .05$ ,  $\eta^2 =$   
232  $.89$ ) and cut ( $P < .05$ ,  $\eta^2 = .72$ ) movements, with instantaneous load rate being significantly  
233 greater in the no-brace condition for both movements (cut –  $P = .004$  & run –  $P = .00001$ ). No  
234 differences were shown for the hop condition.

235

#### 236 *Patellar tendon impulse*

237 A significant main effect ( $P < .05$ ,  $\eta^2 = .20$ ) was found for *movement*. Post-hoc pairwise  
238 comparisons showed that peak tendon impulse was significantly larger in the cut ( $P = .0002$ )  
239 and hop ( $P = .048$ ) movements compared to the run condition.

240

241 In addition a significant main effect ( $P < .05$ ,  $\eta^2 = .19$ ) was observed for *brace*, with patellar  
242 tendon impulse was significantly larger in the no-brace ( $P = .042$ ) condition compared to  
243 wearing the brace.

244

245 Finally, a significant ( $P < .05$ ,  $\eta^2 = .19$ ) *brace \* movement \* sex* interaction was shown.  
246 Follow up analyses using simple main effects showed for males that there was a significant  
247 main effect ( $P < .05$ ,  $\eta^2 = .35$ ) for *movement*, with the hop ( $P = .001$ ) and cut ( $P = .023$ )  
248 movements being associated with a greater impulse than the run movement. For females there  
249 was a significant main effect ( $P < .05$ ,  $\eta^2 = .22$ ) for *movement*, with the cut ( $P = .01$ ) being

250 associated with a greater impulse than the run movement. Finally a significant ( $P < .05$ ,  $\eta^2 =$   
251  $.56$ ) *brace \* movement* interaction was found for females. Follow up analyses showed that  
252 there was a main effect for the run ( $P < .05$ ,  $\eta^2 = .89$ ) movement, with impulse being  
253 significantly ( $P = .0004$ ) greater in the no-brace condition.

254

### 255 *Sagittal knee kinematics*

256 For the knee flexion angle at footstrike, a significant main effect ( $P < .05$ ,  $\eta^2 = .36$ ) was  
257 observed for *brace*, with knee flexion being reduced in the brace condition. For the peak  
258 flexion angle, a significant main effect ( $P < .05$ ,  $\eta^2 = .28$ ) was observed for *brace*, with peak  
259 flexion being reduced in the brace condition. In addition, a significant main effect ( $P < .05$ ,  
260  $\eta^2 = .60$ ) was observed for *movement*. Post-hoc pairwise comparisons indicated that peak  
261 flexion was significantly greater in the cut ( $P = .000008$ ) and hop ( $P = .0000009$ ) movement in  
262 comparison to the run and also in the hop compared to the cut ( $P = .02$ ). Finally, a significant  
263 *brace \* sex* ( $P < .05$ ,  $\eta^2 = .22$ ) interaction was found. Follow up analyses showed that in  
264 female athletes only peak knee flexion was significantly reduced in the brace condition for  
265 the run ( $P < .05$ ,  $\eta^2 = .37$ ) and hop ( $P < .05$ ,  $\eta^2 = .66$ ) movements.

266

## 267 **Discussion**

268 The aim of the current investigation was to investigate the effects of a prophylactic knee  
269 brace on patellar tendon loading parameters linked to the aetiology of patellar tendinopathy,  
270 in male and female recreational athletes. To the authors' knowledge, this represents the first  
271 investigation to examine the effects of prophylactic knee bracing in relation to the aetiology  
272 patellar tendinopathy.

273

274 A key finding from the current study is that indices of patellar tendon instantaneous load rate  
275 and impulse were found to be significantly reduced in female athletes during the run and cut  
276 movements when wearing the knee brace. This observation is interesting in that female  
277 athletes exhibited significant reductions in patellar tendon loading parameters as a function of  
278 the prophylactic brace, yet in male athletes there were no statistical alterations. The  
279 mechanisms responsible for this observation are unknown at this stage. However, previous  
280 analyses have shown that female's exhibit diminished knee joint proprioception in relation to  
281 males (27-30). Prophylactic knee sleeves, such as that used in the current investigation are  
282 proposed to promote stimulation of type  $\delta$  sensory fibres within skin mechanoreceptors (31),  
283 and clinical research into their efficacy has shown that they are associated with improvements  
284 in knee joint proprioception (32-34). It can be speculated upon that there may be more scope  
285 for proprioceptive benefits in females, and that the positive effect of the knee brace in female  
286 athletes was mediated by a proprioceptive effect, which may have been responsible for the  
287 alterations in peak knee flexion that were evident only in female participants. Reductions in  
288 knee flexion are associated with lengthening of the moment arm of the patellar tendon itself,  
289 which leads to a reduction in tendon loading. Nonetheless, further mechanistic investigations  
290 into the specific effects of prophylactic knee sleeves on joint position sense at the knee are  
291 required before this notion can be recognized.

292

293 As stated previously, the aetiology of patellar tendinopathy in athletic populations, relates to  
294 the storage and release of energy by the tendon during sports movements (2). Therefore given  
295 the increased rate at which the tendon was loaded in the no-brace condition, this observation  
296 may have clinical significance. It can be conjectured that female athletes may be able to  
297 attenuate their risk from patellar tendinopathy during specific athletic movements through

298 utilization of prophylactic knee bracing. However, further prospective research into the  
299 prophylactic effects of knee bracing is required before this can be clinically substantiated.

300

301 A further important observation from this investigation, is that for both male and female  
302 athletes, patellar tendon loading was significantly greater in the cut and hop movements in  
303 relation to the run condition. It is proposed that this observation relates to the ballistic nature  
304 of cut and single leg hop movements, in relation to the run condition, placing greater  
305 demands on the knee extensors. It has been shown through epidemiological analyses, that the  
306 aetiology of patellar tendinopathy is related to the magnitude of the loads experienced by the  
307 tendon itself (2). Importantly, cutting is one of the key abilities of sports games (35) and  
308 cutting actions are functionally specific to a range of different individual and team events  
309 including but not limited to; association football (36), American football (37), netball (4),  
310 tennis (38), squash (16) and basketball (39). In addition, single leg hop landings are similarly  
311 common in multidirectional sports including but not limited to; association football (40),  
312 American football (41), gymnastics (42), netball (7) and basketball (39). The findings from  
313 the current investigation indicate that cut and hop motions may place athletes at increased  
314 risk from patellar tendon pathology, therefore conservative prophylactic measures such as  
315 knee bracing may be important apparatuses in athletic disciplines and their associated training  
316 regimens whereby these movements are common. Future prospective research is clearly  
317 required to investigate the longitudinal prophylactic effects of different conservative  
318 modalities, in sports which place high mechanical demands on the patellar tendon.

319

320 A potential drawback to the current investigation is that patellar tendon loading parameters  
321 were quantified via a musculoskeletal driven model. Although this approach represents an  
322 advancement in relation to previous mechanisms, further progression is needed to improve

323 the efficacy of musculoskeletal modeling of patellar tendon kinetics. Although muscle driven  
324 simulations of musculoskeletal loading require a range of mechanical assumptions, they have  
325 developed significantly in recent years. Thus, musculoskeletal simulations have the potential  
326 to become useful tools for clinical analyses in the field of biomechanics.

327

328 In conclusion, whilst previous analyses have investigated the therapeutic and prophylactic  
329 effects of knee bracing, the current knowledge with regards to the effects of prophylactic  
330 knee bracing on the patellar tendon in functional athletic movements is limited. The current  
331 investigation therefore addresses this, by examining the effects of wearing a prophylactic  
332 knee brace on patellar tendon loading parameters during run, cut and jump movements in  
333 male and female athletes. The current study showed firstly that patellar tendon loading  
334 parameters were significantly reduced in female athletes in the run and cut conditions whilst  
335 wearing the brace. In addition, for both males and females the cut and hop movements were  
336 associated with significantly greater tendon loading in relation to the run motion. Given the  
337 association between patellar tendon loading and the aetiology of patellar tendinopathy, this  
338 observation may be clinically important. **It can be conjectured that female athletes may be  
339 able to attenuate their risk from tendinopathy during specific athletic movements through  
340 utilization of knee bracing, although further prospective research into the prophylactic effects  
341 of knee bracing is required before this can be clinically substantiated.**

342

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459 Table 1: Patellar tendon load parameters (means, standard deviations and 95% confidence intervals) as a function of *brace* and *movement*  
 460 conditions in male athletes.

	Male																	
	Run						Cut						Hop					
	Brace			No-Brace			Brace			No-Brace			Brace			No-Brace		
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
<b>Peak patellar tendon load (BW)</b>	7.03	1.25	6.24 - 7.83	7.48	1.48	6.54 - 8.42	8.08	2.03	6.80 - 9.37	8.30	1.46	7.37 - 9.22	7.76	1.67	6.69 - 8.82	8.07	1.22	7.30 - 8.85
<b>Patellar tendon instantaneous load rate (BW/s)</b>	335.41	115.57	261.98 - 408.84	358.54	114.05	286.07 - 431.01	445.64	162.25	342.55 - 548.73	457.89	153.72	360.22 - 555.56	442.39	184.86	324.94 - 559.85	518.55	270.58	346.63 - 690.49
<b>Patellar tendon impulse (BW·s)</b>	0.61	0.13	0.52 - 0.69	0.82	0.25	0.66 - 0.97	1.01	0.31	0.81 - 1.21	0.98	0.30	0.79 - 1.17	1.01	0.50	0.69 - 1.32	0.96	0.38	0.72 - 1.20

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474 Table 2: Patellar tendon load parameters (means, standard deviations and 95% confidence intervals) as a function of brace and movement  
 475 conditions in female athletes.

	Female																	
	Run						Cut						Hop					
	Brace			No-Brace			Brace			No-Brace			Brace			No-Brace		
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
<b>Peak patellar tendon load (BW)</b>	7.69	0.76	7.05 - 8.32	9.42	1.03	8.56 - 10.29	8.79	1.14	7.84 - 9.73	9.26	1.93	7.64 - 10.87	7.88	0.76	7.24 - 8.52	8.70	2.38	6.72 - 10.69
<b>Patellar tendon instantaneous load rate (BW/s)</b>	289.14	65.59	234.31 - 343.98	370.06	93.67	291.75 - 488.40	353.17	116.46	255.81 - 450.54	422.01	142.91	302.54 - 541.49	484.43	63.87	431.0 - 537.83	487.58	115.96	390.64 - 584.53
<b>Patellar tendon impulse (BW·s)</b>	0.79	0.10	0.70 - 0.87	1.00	0.07	0.94 - 1.05	0.95	0.12	0.89 - 1.05	1.05	0.19	0.90 - 1.25	0.84	0.09	0.76 - 0.91	0.99	0.42	0.64 - 1.34

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478 Table 3: Knee flexion parameters (means, standard deviations and 95% confidence intervals) as a function of brace and movement conditions in  
 479 male athletes.

	Male																	
	Run						Cut						Hop					
	Brace			No-Brace			Brace			No-Brace			Brace			No-Brace		
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
<b>Angle at footstrike (°)</b>	10.92	4.34	8.16-16.68	13.30	5.98	9.50-17.10	10.26	4.48	7.42-13.11	12.67	5.76	9.01-16.32	12.94	6.29	8.95-16.94	13.70	3.16	11.70-15.71
<b>Peak flexion (°)</b>	36.55	2.64	34.87-38.23	39.05	4.06	36.47-41.63	44.45	4.18	41.79-47.10	43.92	3.82	41.50-46.35	45.26	6.60	41.07-49.46	45.00	5.79	41.32-48.68

480 Table 4: Knee flexion parameters (means, standard deviations and 95% confidence intervals) as a function of brace and movement conditions in  
 481 female athletes.

	Female																	
	Run						Cut						Hop					
	Brace			No-Brace			Brace			No-Brace			Brace			No-Brace		
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
<b>Angle at footstrike (°)</b>	11.46	2.66	9.24-13.69	16.44	4.94	12.31-20.57	13.16	3.98	9.83-16.49	17.87	4.53	14.09-21.65	12.49	3.14	9.86-15.12	17.99	6.27	12.74-23.23
<b>Peak flexion (°)</b>	36.64	1.92	35.04-38.25	41.12	3.84	37.91-44.33	44.35	2.12	42.85-46.12	45.71	3.12	43.10-48.32	49.74	8.48	42.65-56.83	53.39	11.50	43.78-63.00

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485 **List of figures**

486 Figure 1: Patellar tendon forces as a function of brace and movement conditions – black = no-brace & grey = brace (a. = male run, b. = female

487 run, c. = male cut, d. = female cut, e. = male hop and f. = female hop).