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1 **How useful is a single measurement of patellar mobility in the assessment of**  
2 **patients with patellofemoral pain?**

3

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13

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15

16 Keywords:

17 • Patellofemoral Pain

18 • Patellar mobility

19 • Physiotherapy

20 • Subgroups

21 • Stratification

22 Abstract

23 Introduction: Patellar mobility is often routinely assessed in people with  
24 patellofemoral pain (PFP) in clinical practice. This study assessed the stability of the  
25 data when measuring patellar mobility using the total medial-lateral patellar glide test  
26 across multiple repetitions. It also compared patellar mobility of people with healthy  
27 knees to people with PFP and within subgroups of PFP.

28 Methods: Twenty-two people without knee problems underwent five repetitions of  
29 the total medial-lateral patellar glide test. Differences in mean value for each  
30 repetition and the intra-class correlations (ICC) between the first assessment and the  
31 average values of additional repetitions were calculated. Mean patellar mobility was  
32 compared with 127 participants with PFP who took part in a previously published  
33 subgrouping study. Differences between the healthy knee group and PFP subgroups  
34 were also explored using a one-way ANOVA with pairwise comparisons.

35 Results: The mean patellar mobility in healthy individuals was 16.4 mm (SD 5.3),  
36 difference in mean patellar mobility across repetitions was minimal and the ICC  
37 ranged between 0.93 and 0.95. People with PFP had significantly lower patellar  
38 mobility than the healthy knee group. Two of three PFP subgroups had statistically  
39 significantly lower mean patellar mobility (difference in mean -5.6mm and -6.5mm;  
40  $P < 0.001$ ).

41 Discussion: A single medial-lateral patellar glide test appears as informative as  
42 repeated tests in practice. One off measures of patellar mobility using the total  
43 medial-lateral patellar glide test may identify subgroups of PFP to help guide  
44 treatment in clinical practice. Further work is needed to assess other reliability  
45 parameters for this measure.

46 **Contributions of the Paper:**

47 • A one off measure of the total medial-lateral patellar mobility is as accurate as  
48 the average of multiple measures.

49 • There is a difference between healthy participants and people with PFP in  
50 total patellar mobility

51 • There is evidence of lower patella mobility as measured by a one off measure  
52 of the total medial lateral patellar mobility in some subgroups of PFP patients

53

## 54 **Introduction**

55 Patellofemoral pain (PFP) is a common disorder in younger adults. Despite it being  
56 seen by many as a trivial condition [1], over 90% of those presenting with the  
57 condition are still suffering four years after diagnosis [2-4]. There is an indication that  
58 participants could develop osteoarthritis at a later stage [3], however the link  
59 between PFP and osteoarthritis in later life is currently weak due to the limited  
60 evidence base [5].

61 Assessment of patellar mobility is common in clinical practice for patients suspected  
62 of having PFP. This is as one of the dominant theories for the aetiology of PFP has  
63 been malalignment and/or mal-tracking of the patella through the trochlear groove.  
64 This mal-tracking leads to reduced patellofemoral joint contact area which increases  
65 the load on that joint and, hence, may contribute to increased pain [6]. Consequently,  
66 many treatments for patellofemoral pain have focused on improving patellofemoral  
67 control, through, for example, proximal (hip abductors and quadriceps) strengthening  
68 and stretching exercises [7], patella mobilisations [8], patella taping [9]. Both  
69 hypomobility and hypermobility of the patella are considered to be clinically  
70 important. However, there has been increasing recognition that the aetiology of PFP  
71 is more complex and that there may be other mechanisms contributing to reduced  
72 patellofemoral joint contact area and/or elevated patellofemoral joint loading (Powers  
73 et al 2017). This has led to increased interest in identifying subgroups of  
74 patellofemoral pain so that treatment can be targeted more optimally and efficiently  
75 [10].

76 In a recently published subgrouping study (TIPPS), we identified three subgroups  
77 among 127 adults aged 18 to 40 years with PFP using six clinical tests routinely  
78 available in practice [11]. These subgroups included a 'weak and tight' (39%)

79 subgroup, a 'weak and pronated feet' (39%) subgroup and a 'strong' (22%)  
80 subgroup. One of the clinical tests used in TIPPS was the total medial-lateral  
81 patellar glide test. The mean patellar mobility using this test was similar in the 'weak  
82 and tight' subgroup and the 'strong' subgroup but it was significantly higher in the  
83 'weak and pronated' subgroup [11]. One difficulty in interpreting this data clinically  
84 was the limited published data on normative means, standard deviations or ranges.  
85 Studies that had been published had either been in adolescents only [12], had used  
86 different methods to measure patellar mobility [13], or used methods that could not  
87 be repeated in routine practice [14,15].

88 From the literature, it was also unclear how many measurements were needed for an  
89 accurate assessment. In the TIPPS study, only one measurement of patellar mobility  
90 using the lateral-medial patellar glide test was taken; this is in line with routine  
91 clinical practice. This is because the method involves making a mark on the knee  
92 with a pen. However, others have also repeated the patellar mobility measurement  
93 three times [13,14]. This is also usual practice for many of the other clinical tests  
94 used in the TIPPS study and in clinical practice, such as measuring quadriceps  
95 strength, which involves taking the average of three measurements to achieve stable  
96 values [11].

97 Therefore, in this study, we examined the stability of the data from the medial-lateral  
98 patellar glide test across sequential measurements. Additionally, we aimed to  
99 measure patellar mobility in a group of young adults without a recent history of knee  
100 pain, to provide data for comparison with that of patellofemoral pain patients [11].

101

102

103 **Methods**

104 This study was approved by the University of Central Lancashire ethics committee  
105 (Science Technology, Engineering, Medicine and Health (STEMH) project number  
106 355).

107

108 Participants

109 Twenty-three participants were recruited through advertising across the University  
110 and through word of mouth. Participants were aged between 18 and 40 years  
111 without current neurological or musculoskeletal disorders, knee pain or history of  
112 surgery to the lower extremities. Informed written consent was obtained. We were  
113 unable to fully test one participant in this study as they were hyper-sensitive to the  
114 patellae being touched, but a complete dataset was available for the remaining 22  
115 participants.

116 The comparison data consisted of 127 patients with patellofemoral pain who were  
117 included in the TIPPS subgrouping study. These patients were aged between 18 and  
118 40 years and diagnosed with non-specific unilateral or bilateral PFP. Detailed  
119 information about these patients can be found in Selfe et al 2016.

120

121 Procedure

122 All participants were asked to attend one testing session at a University  
123 Physiotherapy clinic, where first the participant's age, gender, height and weight  
124 were recorded. One researcher, a trained physiotherapist, performed the total  
125 medial-lateral patellar glide test. The participant lay in a supine position with the  
126 quadriceps relaxed and knees extended. After a verbal explanation of the test, the

127 researcher applied a medially directed force to the lateral border of the patella with  
128 the thumbs and the maximum displacement of the inferior pole of the patella was  
129 marked on the skin with a piece of tape. This was followed by a laterally directed  
130 force to the medial border of the patella and again the maximum displacement of the  
131 inferior pole of the patella was marked on the skin using tape. The distance between  
132 medial displacement tape and the lateral displacement tape was measured by the  
133 researcher with a tape measure in millimeters and was recorded as the total  
134 displacement of the inferior pole of the patella in the coronal plane (Figure 1). Both  
135 pieces of tape were removed between tests. This was repeated five times, with a  
136 one-minute rest between each test. Then the contralateral leg was measured in the  
137 same manner. Usually in clinical practice, markings are made on the skin with a pen  
138 but tape was used in this study so that researcher had no visual clues from previous  
139 tests.

140 *(Insert Figure 1 here)*

141

## 142 Statistical Analysis

143 Individuals with healthy knees: the mean (and standard deviation) patellar mobility  
144 was calculated for the first assessment of the 44 legs of the 22 participants with  
145 healthy knees. The difference in mean (95% confidence intervals (CI)) between left  
146 and right legs and between dominant and non-dominant legs was calculated. For  
147 each of the other four repetitions, the mean value for that repetition and the average  
148 value of the means of the repetition and each preceding repetition were calculated.  
149 The intra-class correlations (ICC) between the first assessment and the average  
150 values were also calculated using SPSS statistical package version 23 (SPSS Inc,

175 Chicago, IL) using average measures, absolute-agreement, 2-way mixed-effects  
176 model [16]. An ICC over 0.75 was indicative of an excellent correlation [17].

177

#### 178 Comparison with mean patellar mobility in PFP patients:

179 Mean patellar mobility for the first assessment of the 22 participants with healthy  
180 knees were compared with the mean patellar mobility observed in the TIPPS study  
181 population overall and, then, with each of the three PFP subgroups identified in the  
182 TIPPS study [11]. In this latter study the test was only applied on one occasion using  
183 the same technique as described above with the exception that only the leg with PFP  
184 (or if bilateral, worst pain) was measured and skin marks were made with a pen.

185 As both legs on an individual with healthy knees were measured, there was potential  
186 for introducing a clustering effect, which would inflate the standard error of statistical  
187 tests, when comparing the mean values with those of the TIPPS study. Therefore,  
188 the data was explored for potential clustering at participant level (two legs) by  
189 estimating the variance inflation factor. As the variance inflation factor was 1.29,  
190 suggesting clustering between legs, the patellar mobility value from one leg was  
191 randomly selected from each participant, using an online randomization program  
192 (<https://www.randomizer.org>). This leg was used in comparisons between the healthy  
193 knee group and the PFP group, using an unpaired t-test, and the 3 PFP subgroups,  
194 using one way ANOVA and pairwise comparisons with Bonferroni correction in the  
195 presence of a statistically significant difference.

#### 196 Sample size

197 Assuming that the mean patellar mobility in adults without PFP (healthy knees) was  
198 similar to that of adults with PFP, i.e., a mean of 12.2 mm and SD of 4.6 (Selfe et al

2016), we estimated we would need at least 40 knees (20 participants) to estimate to  
+/- 1.5 mm with 95% confidence. A sample of 20 healthy knee participants would  
allow a difference of at least 4.6 mm (the smallest difference between two TIPPS  
subgroups) to be detected between the healthy knee and PFP group taking into  
account the imbalance between the number of observations in the healthy knee and  
the TIPPS subgroups (smallest 1 to 1.45) for a 99% statistical significance (to allow  
for the Bonferroni Correction for 4 groups) and a study power of 80%.

206

## 207 **Results**

208 Of the 22 participants, 13 (60%) were female. The mean age was 26 years (SD 6.7),  
209 the mean weight was 71.2 kg (SD 13.9) and mean height 1.7 m (SD 0.09). This was  
210 similar to the TIPPS subgrouping study in which 66% were female, the mean age  
211 was 26 years (SD 5.6), the mean weight 73.5 kg (SD 18.3) and height 1.7 m (SD  
212 0.11) (Selfe et al 2016).

213

214 Total medial-lateral patellar mobility in 44 healthy knees: The mean patellar mobility  
215 for the 44 healthy knees on first measurement was 15.9 (SD 5.0) mm. There was no  
216 statistically significant difference in mean patellar mobility between the right and left  
217 leg (difference in mean = 0.6 (SD 3.8) mm, 95% CI for difference in mean -1.1 to 2.3  
218 mm; t-test 0.729; df 21 ;P=0.47), and dominant and non-dominant side (difference in  
219 mean = 0.1 (SD 3.8) mm, 95% CI for difference in mean -1.6 to 1.8; t-test 0.166; df  
220 21; P=0.87). The mean patellar mobility and the ICC appeared to be very stable over  
221 the multiple repetitions (Table 1).

222

*Insert Table 1 here*

223

224 A comparison of healthy individuals with people with PFP: Following random  
225 selection of one knee from each participant with healthy knees, 14 right and 8 left  
226 healthy knees were available for comparison with the 127 knees from the PFP  
227 participants in the TIPPS study. The mean patellar mobility in the 22 randomly  
228 selected healthy knees was 16.4 mm (SD 5.3) and in those with PFP was 12.2 mm  
229 (SD 4.6) (table 2). This difference was statistically significant (difference in mean 4.2  
230 (SD 4.9) mm, 95% CI for difference in mean -6.3 to -2.0 mm;  $t = -3.81$ ,  $df = 1$ ,  
231  $P < 0.001$ ). When the data of the healthy knee group was compared to the three PFP  
232 subgroups, a significant difference was observed ( $F = 22.48$ ,  $P < 0.001$ ), but pairwise  
233 comparisons showed that only the 'weak and tighter' ( $P < 0.001$ ) and 'strong'  
234 subgroups ( $P < 0.001$ ) had significantly lower mean patella mobility (Table 2). There  
235 were no significant difference in mean patellar mobility between the 'weak and  
236 pronated feet' PFP subgroup and the healthy knees group ( $P = 1.000$ ) (Table 2).

237

238 *Insert Table 2 and Figure 2 here*

239

## 240 **Discussion**

241 We have, for the first time, provided normative data for the medial-lateral patellar  
242 glide test as measured in adults. Our findings are similar to those reported for  
243 adolescents (mean 16.0 mm) using a similar technique [12]. However, our mean  
244 patellar mobility is considerably lower than what Witvrouw et al reported in a much  
245 larger sample of similar age [13]. In this study, though, medial and lateral mobility  
246 were performed separately and later added to calculate the total patellar mobility.

247 This different execution might explain the difference between the values in the two  
248 studies.

249

250 Like Witvrouw, however, we did find a difference in mean scores between those with  
251 healthy knees and those with PFP overall [13]. When different PFP subgroups were  
252 considered participants allocated to the 'weak and tighter' and 'strong' subgroups  
253 were found to have significantly lower patellar mobility than healthy participants,  
254 which provides some evidence for patellar hypomobility in these subgroups. Those  
255 participants who fell into the 'weak and pronated feet' subgroup had a similar mean  
256 patellar mobility to the healthy knee group. This subgroup made up 39% of the PFP  
257 participants in the TIPPS study, but were this prevalence higher in other PFP  
258 samples, it might explain why some studies have not found a difference between  
259 PFP and healthy knee groups [14]. More research needs to be conducted to  
260 understand patella mobility in the weak and pronated PFP subgroup as a possible  
261 explanation for the lack of difference could be the participants' position during the  
262 test. In standing, pronation of the feet will lead to an internal rotation of the tibia,  
263 which causes the patella to move medially [18]. This in turn can increase the contact  
264 area between the medial patella facet and the femoral condyle [18] and potentially  
265 reduce patellar mobility. However, in this test the participants were in a supine  
266 position and therefore internal rotation of the tibia and with it reduction of patellar  
267 mobility might not have occurred.

268

269 This study also suggests that a single measurement of the medial-lateral glide test  
270 as practiced routinely is sufficient. This has implications for clinical practice, as only

271 one assessment will reduce the time required to be spent on clinical assessment.  
272 The difference in mean patellar mobility across repetitions was minimal and the ICC  
273 remained above 0.9, well into the excellent range [17].

274

275 This study was not designed to measure the standard error of measurement (SEM),  
276 as there was not enough time between recordings on participants to reduce the risk  
277 of recall bias. This limits the interpretation of the differences between the PFP  
278 subgroups and those with healthy knees. However, if we were to assume no recall  
279 bias, then the SEM for healthy knees is 1.24mm (when  $SD \cdot \sqrt{(1-ICC)}$  using the 1<sup>st</sup>  
280 and 2<sup>nd</sup> repetitions: see table 1) [19] and the minimal detectable change ( $MDC_{95}$ )  
281 3.4mm (when  $MDC_{95} = 1.96 \cdot SEM \cdot \sqrt{2}$ ) [20]. As the MDC is less than the difference  
282 between the healthy knees and the weak and tight PFP subgroup and the difference  
283 between the healthy knees and the strong PFP subgroup, it would suggest that  
284 these differences are real. Further research is needed to estimate the SEM under  
285 more optimal conditions in PFP patients to facilitate comparisons between  
286 subgroups, and to estimate other important measurement properties, such as, inter-  
287 rater reliability.

288

289 It might be argued that another important limitation of this study was the non-  
290 randomization of the ordering of the test between left and right leg, but the mean  
291 patellar mobility was similar in the two legs. Data was lost because our approach to  
292 handling clustering was to randomly select one leg per healthy knee participant for  
293 comparison with the PFP group/subgroups. However, this was necessary to ensure

294 consistency across groups as only one leg was measured in the TIPPS study, even  
295 when both knees were affected.

296

## 297 **Conclusion**

298 The total medial-lateral patellar mobility can be measured reliably in a one-off  
299 measurement using the patellar glide test. The mean patellar mobility of healthy  
300 adult participants was significantly different to the mean patellar mobility in  
301 participants with PFP and suggests hypomobility in at least two subgroups of people  
302 with PFP. This could help direct therapeutic intervention in these patients but further  
303 work is needed on the diagnostic properties of this test.

304

## 305 **Acknowledgements**

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307 PFP patients (grant number 19950) ARUK) and the Erasmus Scheme for funding a  
308 European physiotherapist to work with our team on this project.

309

310 Ethical Approval: This study was approved by the University of Central Lancashire  
311 Science, Technology, Engineering, Medicine and Health ethics committee (STEMH  
312 355). The PFP study (TIPPS) was approved by NRES Committee North West—  
313 Greater Manchester North, REC reference: 11/NW/0814 and University of Central  
314 Lancashire (UCLan) Built Sport and Health (BuSH) Ethics Committee Reference  
315 Number: BuSH 025. R&D approval was also obtained from each participating NHS  
316 trust.

317

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320 the normative data.

321

322 The authors declare no conflicts of Interest.

323

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397 changes in health status questionnaires: distinction between minimally detectable  
398 change and minimally important change. *Health Qual Life Outcomes*. 2006 Aug  
399 22;4:54.

400 Table 1: Stability of the data from the total medial-lateral patellar glide test in healthy  
 401 knees (n=44)

	Repetition				
	1	2	3	4	5
Mean in mm	15.9 (SD 5.0)	15.9 (SD 4.4)	15.8 (SD 4.2)	15.8 (SD 4.5)	15.8 (SD 4.4)
Average of mean over repetitions in mm	n/a	15.91 (SD 4.69)	15.89 (SD 4.51)	15.87 (SD 4.50)	15.85 (SD 4.46)
ICC (CI)*	n/a	0.93 (0.86-0.96)	0.95 (0.90-0.97)	0.95 (0.90-0.97)	0.94 (0.88-0.97)

402 Abbreviations: mm= millimeters, SD=standard deviation, ICC= intra-class correlation  
 403 coefficient, CI= 95% confidence interval n/a = not applicable,\* 1<sup>st</sup> compared to  
 404 average of repetitions

Table 2: Comparison of mean patellar mobility between healthy and PFP knees

	Mean (SD) patellar mobility in mm and 95% CI	Difference in mean (mm) between healthy knees group and PFP subgroup (95% CI difference in mean)	Pairwise comparison (p value)
Healthy Knees (N=22) <sup>+</sup>	16.4 (5.3) 14.0 – 18.7		-----
PFP subgroup-weak and tighter (N=49)	9.9 (3.6) 8.9 - 10.9	-6.5* (-9.3 to -3.7)	<0.001
PFP subgroup - weak and pronated (N=49)	15.4 (4.6) 14.1 - 16.7	-1.0 (-3.8 to 1.9)	1.000
PFP subgroup – strong (N=29)	10.8 (3.0) 9.6 - 11.9	-5.6 (-8.7 to -2.5)	<0.001

Abbreviations: N=number of participants in the group, mm= millimeters, SD=standard deviation, + one leg was randomly chosen,

CI= confidence interval.

## Figures

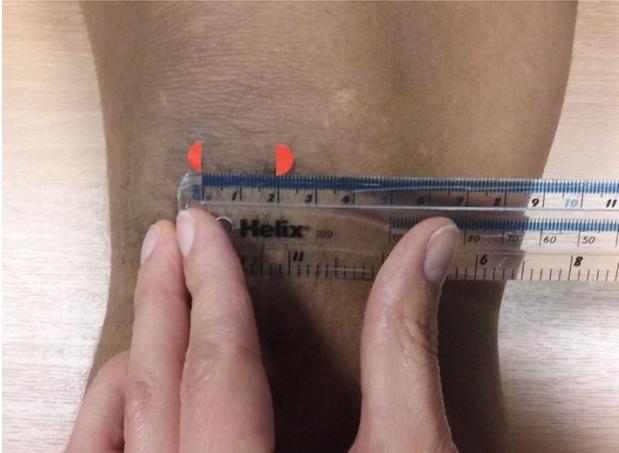


Figure 1: the total medial-lateral patellar glide test with markings on the skin

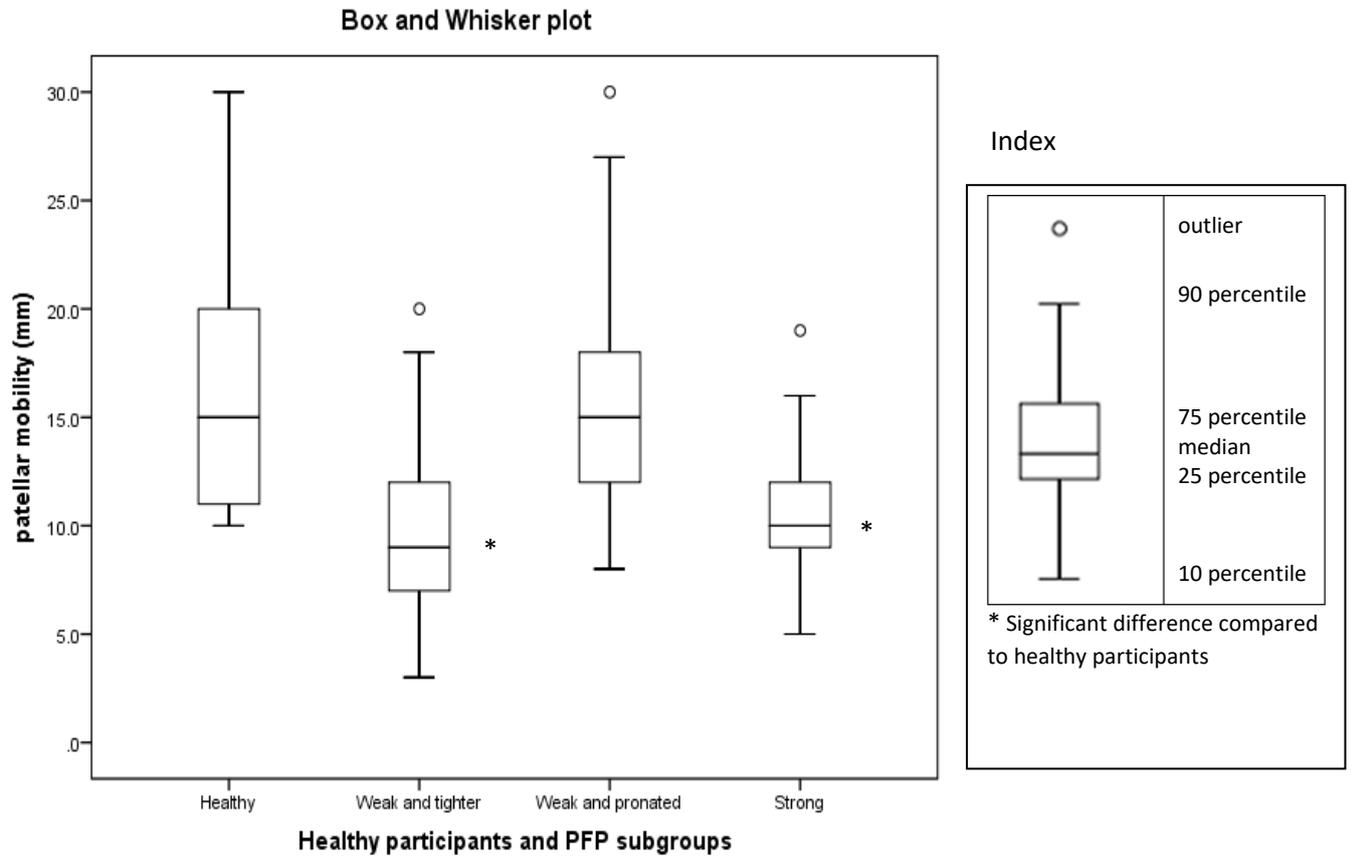


Figure 2: Box and Whisker plot for healthy participants and participants allocated to the three PFP subgroups.