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1 **The Influence of 9-marathons completed in 9 days on injury incidence and selected**
2 **musculoskeletal tests**

3

4 **Key Points:**

- 5 • Flexibility, proprioception and balance performance progressively decrease during a
6 multi-day running event.
- 7 • Athletic trainers should design recovery and injury prevention strategies to be used
8 with-in competition based on with-in event data collection.
- 9 • Future studies should adopt this novel with-in competition data collection method to
10 appreciate the dynamic nature of musculoskeletal physiology.

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12 **Key words:** Multi-day running; athletic therapy; musculoskeletal testing.

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21 **Abstract**

22 Multi-day running events are increasingly popular however, research in these events is lacking
23 and fails to consider the dynamic nature of musculoskeletal physiology. Twenty-three athletes
24 completing a ten-day marathon event participated in the study. Proprioception, dynamic
25 balance, knee valgus and flexibility were assessed the day before the event and after one, five
26 and nine consecutive marathons. There were significant reductions in these measurements
27 across the event and reductions were more apparent in the non-dominant side. Each runner
28 suffered on average 4.2 injuries. Runners performed significantly worse in musculoskeletal
29 measurements, particularly on the non-dominant side, as the competition progresses.
30 Therefore, athletic trainers should design appropriate between-day recovery strategies during
31 events based on with-in event data collection.

33 **Introduction**

34 Ultra-distance running events continue to increase in popularity¹. The distance of these events
35 is greater than 26.2 miles with total running times typically over six hours, occurring over
36 multiple days². It is perhaps not surprising that there are higher injury rates in these events
37 relative to shorter running distances³, running of this nature may cause repeated stresses on
38 tissues in a fatigued state⁴. Indeed, injuries occurred in between 60% and 100% of all
39 competitors in previous research on ultra-distance events⁵⁻⁷. Furthermore, in a 7-day running
40 event 84.8% of 396 runners required medical attention, which was equivalent to 3.8 injuries
41 per runner or 7.2 injuries per 1000 hours³. However, there is a lack of research investigating
42 musculoskeletal physiology changes that may inform athletic practice during multi-day
43 running events.

44 It is important for practitioners to know how the musculoskeletal system changes to design
45 effective with-in event treatments⁸. A dynamic approach to injury prevention has been
46 developed in a model of etiology in sport injury⁹. Importantly, this incorporates repeated
47 exposure to events that may lead to musculoskeletal adaptations⁹. This cyclical approach is one
48 that is often missed in literature with clinical measurements being taken only once, before the
49 race occurs; for example, static measures of alignment¹⁰. However, it is important to consider
50 how the body may adapt across a performance taking the dynamic nature of injury occurrence
51 into consideration.

52 There is very little research on the changes in musculoskeletal physiology during a multi-day
53 running event⁵. One important measurement is neuromuscular control which has been linked
54 to efficient running technique¹¹. Poor proprioceptive ability (the ability to perceive position,
55 movement and force of the limbs during running¹²) may be linked to changes in running
56 performance as the central nervous system may not receive effective afferent information
57 (feedback mechanisms) and hence prepare the correct muscle activity for impending
58 perturbations (feed-forward mechanisms)¹². Dynamic balance relies on good neuromuscular
59 control and poor ability is possibly linked to running injuries due to excessive knee valgus
60 positions from poor hip adductor strength during running¹³⁻¹⁵. An increased or decreased range
61 of motion has previously been cited as a potential risk of injury¹⁶⁻¹⁷ due to a potential increase
62 in compressive and tensile stress on lower-limb joints¹⁸. Therefore, it is important these
63 measures are monitored across a multi-day event to identify when musculoskeletal physiology
64 changes and if athletic therapy is required.

65 The lower-extremity is the most common location for running injuries in multi-day events¹⁹.
66 Therefore, the current study considered knee joint position sense (JPS), lower-limb dynamic
67 balance, knee neuromuscular control during single-leg landing and hip and ankle flexibility

68 adaptations during a multi-day event. The aim of this study was to evaluate the effect of running
69 one, five and nine consecutive marathons on musculoskeletal physiology using in-competition
70 data collection methods.

71 **Methods**

72 *Participants*

73 A total of 23 athletes (age 44.7 ± 7.59 years, mass 75.1 ± 12.99 kg, self-reported weekly mileage
74 43.3 ± 12.67 miles) participated in this prospective cohort study. The event involved completing
75 10 marathons in 10 consecutive days on the same course, however data was collected after day
76 zero (D0), marathon one (M1), five (M5) and nine (M9). Table 1 describes participant
77 characteristics. All participants provided voluntary, written informed consent and the rights of
78 the participants were protected. The study was ethically approved by the University Review
79 Board (ref: DC/SB 15/19).

80 *Instrumentation*

81 Knee JPS was collected using a camera (Casio Exilim, EX-FC100, Casio Electronics Co., Ltd.
82 London, UK) on a fixed, level tripod. Dynamic balance was collected using a “Y symbol” taped
83 to the floor (see figure 1) and tape measure. Knee neuromuscular control data was collected
84 using a camera (Casio Exilim, EX-FC100, Casio Electronics Co Ltd, London, UK) mounted
85 on a fixed, level tripod. Flexibility was collected using a 30cm goniometer (Baseline®
86 Evaluation Instruments, White Plains, NY) and tape measure.

87 *Tasks*

88 Reliability statistics for tasks are reported in Table 2.

89 *Knee JPS*

90 Markers were placed on a point on a line following the greater trochanter to the lateral femoral
91 epicondyle, the lateral femoral epicondyle and the lateral malleolus on the dominant leg. The
92 athlete was seated on the end of a treatment table and blindfolded. The leg was passively moved
93 by the experimenter through 30°–60° of extension from a starting knee angle of 90° or 60°–
94 90° of flexion from a starting angle of 0° at an approximate angular velocity of 10°/s (see figure
95 2). The target angle was held by the athlete for 5s before the researcher returned the limb to the
96 starting position. The athlete then replicated the target position. Knee positions were captured
97 using photographs and digitising software (Kinovea, v0.8.15, Joan Chamant & Contrib, 2006-
98 2011). The delta score between target and reposition angles was taken as the absolute error
99 score in degrees and averaged across five trials. The protocol has been validated against an
100 isokinetic dynamometer²⁰.

101 *The Modified Star Excursion Balance Test (SEBT)*

102 Dynamic stability was measured using the modified SEBT. Briefly, this task involves single
103 leg squats, with the non-weight bearing leg reaching maximally towards anterior, posterior-
104 medial and posterior-lateral directions along a designated line and then returning to the start
105 position of single leg stance. Further detail of this protocol can be found in Munro and
106 Herrington²². Each runner completed four trials in each direction on both legs and results were
107 normalised to leg length.

108 *Knee Neuromuscular Control*

109 Knee neuromuscular control was measured using maximum knee valgus angle during single-
110 leg-landing. Markers were placed on the mid-point of the femoral condyles, the mid-point of
111 the ankle malleoli and the anterior superior iliac spine on both legs. The athlete stepped forward

112 from a 30-cm height, dropping as vertically as possible landing in a single-leg stance and
113 holding for 3s, completing three trials on each leg. A trial was void if the non-stepping leg
114 touched either the step or the floor during the task. Knee valgus angles were measured as the
115 greatest angle between the line from the ASIS to the patella and the patella to the ankle marker
116 during the landing performance using digitising software (Kinovea, v0.8.15, Joan Chamant &
117 Contrib, 2006-2011) and the average taken. This task is correlated to forward running
118 technique²⁵.

119 *Lower-Limb Flexibility*

120 Two experienced athletic trainers took flexibility measurements on both legs with consistent
121 roles in each protocol. The pelvis was stabilised to avoid compensatory movements in hip
122 measurements. The flexibility of the iliotibial band was collected using the Ober's protocol²⁶.
123 Hip adductor flexibility measurements were taken in a supine position, the goniometer arms
124 placed in-line with the contralateral anterior-superior iliac spine and the anterior mid-line of
125 the ipsilateral femur. The runner actively performed maximal hip abduction and the value on
126 the goniometer was recorded. Ankle dorsiflexion flexibility was measured using the knee to
127 wall protocol detailed in Powden, Hoch and Hoch²⁸. The runner completed the test in a tandem
128 stance, with the tibia progressing over the talus and the heel remaining fully on the ground until
129 the knee touches the wall. Internal and external rotation of the hip was measured following the
130 Bullock-Saxton and Bullock protocol²⁹. The runner was in prone and the knee passively flexed
131 by the first examiner to 90°. The stationary arm of the goniometer was positioned parallel to
132 the testing surface and the moving arm was placed along the tibia. The additional examiner
133 then palpated the opposite posterior-superior iliac spine and the original examiner passively
134 externally or internally rotated the limb. The measurement was taken at the point before the
135 pelvis began rotating.

136 *Procedures*

137 Data was collected in a sports clinic between May 2015 and June 2016. The number of injuries
138 per athlete was recorded by two athletic trainers three times daily (further details of injury data
139 is reported elsewhere³⁰). An injury was defined as a specific musculoskeletal abnormality that
140 the runner perceived to affect performance⁵.

141 *Statistical Analysis*

142 Normality was checked using the Shapiro-Wilk test, if confirmed, the means and standard
143 deviations of parametric measures were calculated. One-way repeated measures ANOVAs
144 were used to explore the main effect of time and then post-hoc Bonferroni comparisons were
145 utilised when required to complete multiple (six) comparisons. Non-normal data was presented
146 as medians and interquartile ranges and analysed using Friedman's ANOVA and Wilcoxon
147 Signed Rank tests. The significance level was accepted at $p \leq 0.05$.

148 **Results**

149 In total 73%, 50%, 69% and 70% of the sample completed all knee JPS, SEBT, knee valgus
150 and flexibility testing respectively (see Table 3). Post-hoc analysis revealed no significant
151 differences between completers and drop-outs for baseline measures of each tests. Non-
152 parametric data (medians) and parametric data (means) is presented in Table 4.

153 *Knee JPS*

154 There were no effects of time on knee JPS into extension but was into flexion. JPS ability
155 improved from D0 to M1 by 2.4° and reduced from M0 to M5 by 1.3° . On one or more
156 occasions in the event 85% of runners demonstrated JPS difference scores above the SDD into
157 flexion.

158 *Dynamic Balance*

159 Results of the modified SEBT did not alter during the competition on the dominant leg for
160 anterior and posterior-lateral reach directions. However, posterior-medial reach distances
161 reduced from D0 to M5 by 15% of leg length and from D0 to M9 by 19% of leg length (both
162 above the SDD) and 80% of participants produced results above the SDD.

163 Anterior reach distance, posterior-medial reach distance and posterior-lateral reach distance all
164 reduced on the non-dominant side. The anterior reach distances reduced by 9% of leg length
165 from D0 to M9 (above the SDD). The posterior-medial reach distance reduced by 5% of leg
166 length from D0 to M1 (below the SDD) and by 13% of leg length from D0 to M9 (above the
167 SDD). The posterior-lateral reach distances reduced by 12% of leg length from D0 to M9
168 (above the SDD). 70% of runners produced differences greater than the SDD for anterior reach,
169 90% for posterior-medial reach data and 80% for posterior-lateral reach data.

170 *Knee Neuromuscular Control*

171 Knee neuromuscular control did not significantly change during the event for either the
172 dominant or non-dominant side, indeed 77% of runners did not demonstrate difference values
173 over the reported SDD.

174 *Lower-Limb Flexibility*

175 Adductor flexibility and ankle dorsiflexion flexibility on the dominant side of the body
176 reduced. Adductor flexibility reduced from D0 to M5 by 5.6° and M9 by 10.8°. This flexibility
177 also reduced from M1 to M9 by 11°. 91% of runners' data exceeded the reported SDD. Ankle
178 dorsiflexion flexibility was reduced from D0 to M1 (by 1.41cm), M5 (by 2.65cm) and M9 (by
179 3.40cm). There was also a significant reduction in this flexibility between M1 and M9 (by

180 2.00cm). 87% of runners had differences above the SDD during the event. The remaining
181 flexibility measurements on the dominant side did not change.

182 All flexibility measures on the non-dominant side significantly reduced. ITB flexibility reduced
183 from D0 to M9 (by 0.98cm) and from M1 to M9 (by 0.50cm). Flexibility of the adductor
184 muscles again reduced from D0 to M9 (difference 9.1°) and M5 (difference 8.2°). This
185 flexibility also significantly decreased when comparing M1 to M5 (difference 7.4°) and M9
186 (difference 8.3°). 87% of runners' data was above the reported SDD. A similar pattern was
187 evident in ankle dorsiflexion flexibility, there were differences between D0 and M5 (difference
188 2.72cm) and M9 (difference 4.6cm). Ankle dorsiflexion flexibility was also worse after M9
189 compared to M1 (difference 3.6cm) and marathon five (difference 1.8cm). For this
190 measurement 83% of runners displayed differences above the SDD. Internal hip rotation on the
191 non-dominant side significantly increased between D0 and M9 (difference 6.0°). External hip
192 rotation also significantly reduced over time from D0 to M5 by 7.6° and M9 by 10.5°. 78% of
193 runners displayed differences greater than the SDD for hip rotation measures.

194 There were 4.2 injuries per runner; 89% of injuries involved the lower extremity; 24.1% in the
195 foot, 18.5% the hip/buttock, 16.7% the ankle and 16.7% in the lower leg.

196 **Discussion**

197 The aim of this study was to measure the effects of a multi-day running event on knee
198 proprioception, dynamic balance, knee neuromuscular control and flexibility. The results
199 suggest these measures, particularly on the non-dominant side, decrease in performance from
200 D0 to M5 and again to M9 during the event.

201 *Knee Proprioception*

202 There was an initial improvement in knee JPS into flexion from D0 to M1, but this difference
203 was below SDD values²¹. However, knee JPS into flexion reduced from D0 to M5 and this
204 difference was above SDD values²¹. This suggests knee JPS may not reduce after running one
205 marathon but could be impaired after five marathons. To our knowledge this is the first paper
206 to consider JPS ability during a multi-stage running competition. However, previous research
207 has reported a reduction in JPS ability following treadmill running to fatigue³¹⁻³². Three
208 theories have been proposed to explain the mechanisms behind this finding; impaired excitation
209 of motor units³³, increase in knee laxity³⁴ and increase in pain³³. All explanations suggest the
210 afferent signalling used by the CNS to process JPS information is disrupted with fatigue,
211 therefore making this process unstable and increasing errors³⁵. Knee flexion occurs in running
212 from initial touch down to mid-swing phases³⁶. If the runner is unable to correctly perceive the
213 position of their knee this could lead to errors in efferent signalling used for movement
214 preparation. The results of the current study suggest knee JPS ability into flexion reduces after
215 completion of five marathons. Therefore, athletic trainers may incorporate proprioceptive
216 exercises after five days of running.

217 *Dynamic Balance*

218 Dynamic balance significantly reduced in all reach directions on the non-dominant limb and
219 the posterior-lateral direction on the dominant limb from D0 to M9 and all average differences
220 were above SDD values²². Again, to the author's knowledge, this is the first study to measure
221 dynamic balance ability during a multi-day running event. However, the findings from the
222 current study support previous literature that reported a decrease in balance performance
223 following shorter running activities; for example, Steib³⁷ reported a decrease in SEBT
224 performance following treadmill running to exhaustion. Other authors used different methods
225 of balance measurement to present a reduction in ability with fatigue³⁸⁻³⁹. A reduction in

226 dynamic balance has been suggested to potentially increase the risk of running injuries due to
227 a loss in neuromuscular control in lower extremity joints^{31, 40}. The results of dynamic balance
228 in the non-dominant leg got progressively worse across the event with the biggest performance
229 decrease from D0 to M9. This has important implications for the timing of prevention and
230 treatment strategies during an ultra-endurance event, athletic trainers should introduce dynamic
231 balance exercises with-in ultra-running events.

232 *Knee Neuromuscular Control*

233 There were no significant changes to knee neuromuscular control on either leg. This is an
234 unexpected finding however, Munro²⁴ stated the SDD as 7.54°-7.90° for the task and the
235 greatest differences in this study were below the SDD. Therefore, 2D manual digitisation may
236 not be sensitive enough to identify changes in knee valgus angle.

237 *Lower Limb Flexibility*

238 Increased flexibility may be desirable for optimal running performance⁴¹. The flexibility of the
239 adductor muscles and ankle dorsi-flexors significantly reduced on both the dominant and non-
240 dominant sides during the event. All adductor differences were above the reported SDDs apart
241 from dominant leg, D0 to M5. Poor hip adductor flexibility has been linked to reduced stability
242 at the hip and knee joint during gait and increased risk of ITB syndrome⁴². The flexibility of
243 the adductor ankle dorsi-flexors also significantly reduced on both legs and differences were
244 above the SDD except between D0 and M1 on the dominant leg. A reduction in ankle dorsi-
245 flexion may change running mechanics at the ankle, specifically in preparation for foot strike;
246 if the ankle is less flexed, this can modify foot strike patterns and lower-limb absorption
247 mechanics and hence increase ground reaction forces⁴³. Reduced ankle dorsi-flexion has been

248 linked to injuries to the knee⁴⁴ and foot⁴⁵ due to an increase in force transmitted along the
249 kinetic chain.

250 The non-dominant limb also had reduced flexibility in the remaining measurements. Hip
251 internal rotation increased, and external rotation decreased in flexibility across the competition
252 and all differences were above the SDD. A modification in hip internal movement has been
253 associated with modified knee kinematics that may possibly be linked to injury⁴⁶. Poor hip
254 control can lead to reduced neuromuscular control lower in the kinetic chain and potentially an
255 increased risk of injury⁴⁶. Furthermore, a reduction in ITB flexibility may potentially cause
256 patello-femoral pain⁴⁷ and ITB syndrome⁴⁸. These results suggest athletic trainers should
257 consider flexibility recovery strategies after each day of a multi-day running event, particularly
258 on the non-dominant side.

259 *Limitations*

260 Fatigue was not measured objectively, however, previous research has demonstrated fatigue
261 will be present during ultra-marathon events⁴⁹. Reliability estimates were taken from prior
262 studies. However, knee JPS measures were taken by the same assessor from the reliability
263 study. Also, there is over a decade's worth of reliability literature on both flexibility and SEBT
264 measurements. The dropout levels should also be acknowledged; however, appropriate
265 statistical analysis was used based on the assumption of normality.

266

267 *Clinical Implications*

268 The results of this study suggest musculoskeletal physiology performance worsens after five
269 days of marathon running and by nine days this may be significant. Athletic trainers should
270 design individual interventions based on in-event testing that runners can perform both before
271 and during events that target flexibility, knee neuromuscular control and dynamic balance.

272

273 *Future Research*

274 The Meeuwisse model¹¹ of injury prevention states risk of injury is cyclical, hence is event
275 and time dependent, therefore, it is recommended that the in-event data collection design
276 should be utilised in further work with larger sample sizes.

277

278 *Conclusion*

279 Multi-day running events can cause over four injuries per runner and musculoskeletal
280 physiology measures worsen progressively across competitions. Athletes should be aware of
281 the potential changes that will occur and prepare appropriately. Importantly, these
282 modifications became more apparent during the competition; these findings would not have
283 been identified if traditional research designs that do not take measurements within competition
284 had been used. Hence athletic trainers should consider in-event measurement with a view to
285 prescribe recovery strategies that incorporate this knowledge (i.e. balance and flexibility
286 recovery methods) in competition.

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289 participate in this research study and to all the runners themselves for their commitment to the
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291

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For Peer Review

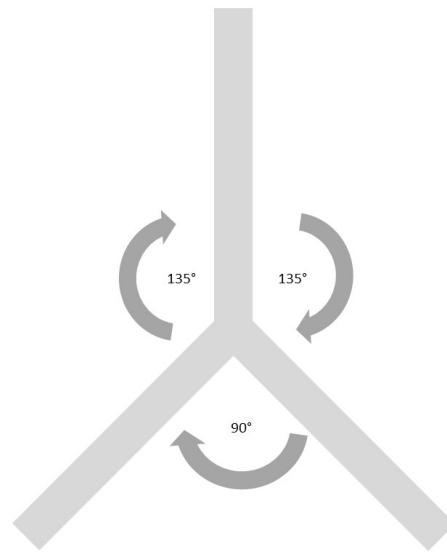


Figure 1. Modified Star Excursion Balance Test (SEBT) set-up
215x279mm (150 x 150 DPI)

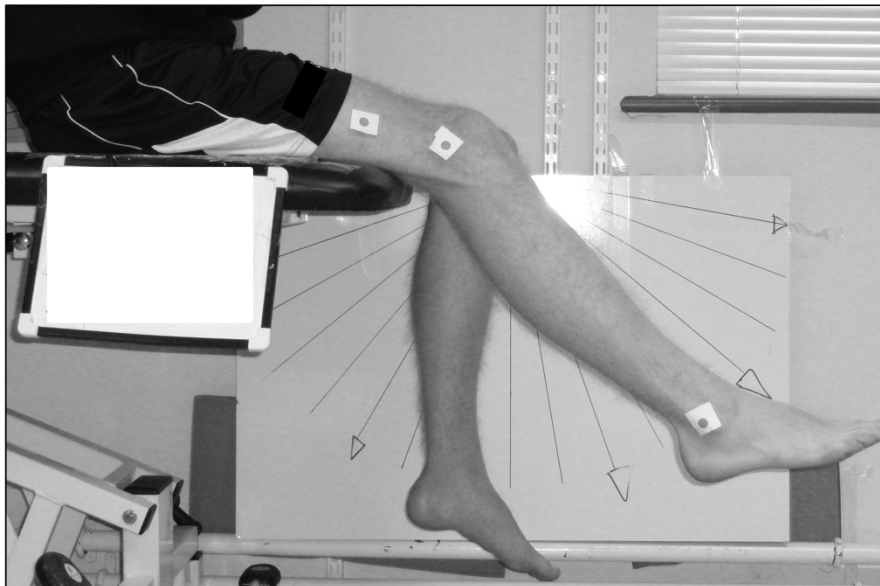


Figure 2. Example of Knee Joint Position Sense (JPS) data collection set-up
665x563mm (144 x 144 DPI)

Table 1. Participant Characteristics (mean±SD unless stated).

| Flexibility Testing (n=23) | |
|---|---------------|
| Age (years) | 44.7±7.59 |
| Mass (kg) | 75.1±12.99 |
| Gender (males/females) | 16/7 (number) |
| Knee JPS and Neuromuscular Control (n=13) | |
| Age (years) | 46.8±5.03 |
| Mass (kg) | 72.3±13.02 |
| Gender (males/females) | 9/4 |
| Dynamic Balance (n=10) | |
| Age (years) | 42.0±9.61 |
| Mass (kg) | 78.8±12.66 |
| Gender (males/females) | 7/3 (number) |

Table 2. Reliability statistics

| Protocol | Test-retest reliability (ICC) | Smallest Detectable Difference (SDD) |
|--|--|--|
| Knee Joint Position Sense ²¹ | Knee Flexion 0.92 Knee Extension 0.86 | Knee Flexion 1.10° Knee Extension 1.67° |
| Star Excursion Balance Test ²²⁻²³ | 0.84-0.92 | Anterior reach 6.87% leg length Posterior-medial reach 8.15% leg length Posterior-lateral reach 7.11% leg length |
| Knee Neuromuscular Control ²⁴ | Men 0.80 Women 0.82 | Men 7.54° Women 7.90° |
| Ober's Protocol ²⁶ | 0.82-0.92 | Not available |
| Hip Adductor Flexibility ²⁷ | 0.92-0.99 | 5.1° - 7.6° |
| Ankle Dorsiflexion Flexibility ²⁸ | 0.99 | 1.57cm |
| Internal Hip Rotation ²⁹ | 0.98 | 4.29° |
| External Hip Rotation ²⁹ | 0.99 | 6.11° |

Table 3. Drop out data (absolute number of runners at each time phase).

| Risk Factor | Day zero | Marathon 1 | Marathon 5 | Marathon 9 | Completion |
|----------------------------|-----------------|-------------------|-------------------|-------------------|-------------------|
| Flexibility | 23 | 23 | 18 | 16 | 70% |
| Knee JPS | 13 | 12 | 11 | 8 | 73% |
| Knee Neuromuscular Control | 13 | 12 | 10 | 9 | 69% |
| SEBT | 10 | 10 | 6 | 5 | 50% |

Table 4. Mean±SD measurements for parametric data and Median [IQR] measurements for nonparametric data at day zero (D0), marathon one (M1), five (M5) and nine (M9) for parametric data. SEBT = Star Excursion Balance Tests. * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

| Variable | D0 | M1 | M5 | M9 | Main Effect p-value | Significant Post-hoc analysis |
|---|------------|-----------|-----------|------------|---------------------|-------------------------------|
| Knee Joint Position Sense Extension (°) | 3.6±1.9 | 3.7±1.8 | 3.3±2.3 | 2.8±1.2 | 0.65 | N/A |
| Knee Joint Position Sense Flexion (°) | 4.7 [3.3] | 2.9 [2.2] | 3.3 [2.9] | 3.3 [3.4] | 0.03 | D0 v M1** M1 v M5* |
| Dominant Leg SEBT Anterior (% of leg length) | 85±8.3 | 85±5.0 | 80±11.5 | 75±6.6 | 0.15 | N/A |
| Dominant Leg SEBT Posterior Medial (% of leg length) | 101 [18.0] | 90 [11.2] | 86 [13.6] | 82 [17.6] | 0.01 | D0 v M5* D0 v M9* |
| Dominant Leg SEBT Posterior Lateral (% of leg length) | 86±10.7 | 84±14.5 | 80±14.2 | 79±11.4 | 0.42 | N/A |
| Non-Dominant Leg SEBT Anterior (% of leg length) | 86 [12.4] | 83 [11.6] | 80 [8.7] | 77 [6.4] | 0.05 | D0 v M9* |
| Non-Dominant Leg SEBT Posterior Medial (% of leg length) | 96±8.6 | 91±10.4 | 84±10.9 | 83±7.4 | 0.004 | D0 v M* D0 v M9* |
| Non-Dominant Leg SEBT Posterior Lateral (% of leg length) | 86 [15.4] | 85 [12.7] | 82 [19.1] | 74 [118.6] | 0.02 | D0 v M9* |
| Dominant Leg Knee Valgus (°) | 5.8±2.0 | 5.5±3.1 | 6.5±5.4 | 6.9±5.1 | 0.57 | N/A |
| Non-Dominant Leg Knee Valgus (°) | 7.6±4.9 | 8.6±3.5 | 5.9±4.7 | 7.8±3.7 | 0.85 | N/A |
| Dominant Leg Iliotibial Band Flexibility (cm) | 14.9±1.7 | 14.8±1.8 | 15.3±1.8 | 15.6±2.0 | 0.21 | N/A |
| Non-Dominant Leg Iliotibial Band Flexibility (cm) | 14.6±1.9 | 15.1±1.7 | 15.6±1.8 | 16.8±2.0 | 0.001 | D0 v M9** M1 v M9* |

| | | | | | | |
|--|-----------|-----------|----------|----------|-------|---|
| Dominant Leg Ankle Dorsiflexion Flexibility (cm) | 11.0±3.1 | 9.6±3.3 | 8.4±3.3 | 7.6±2.9 | 0.001 | D0 v M1** D0 v M5 *** D0 v M9 *** M1 v M9* |
| Non-Dominant Leg Ankle Dorsiflexion Flexibility (cm) | 10.5±3.0 | 9.6±3.7 | 7.8±2.8 | 5.9±2.5 | 0.001 | D0 v M5*** D0 v M9*** M1 v M9** M5 v M9** |
| Dominant Leg Internal Hip Rotation (°) | 31.8±9.5 | 35.3±9.7 | 34.7±9.4 | 34.1±5.4 | 0.32 | N/A |
| Dominant Leg External Hip Rotation (°) | 29.8±11.4 | 30.5±13.5 | 30.4±9.6 | 29.1±8.5 | 0.24 | N/A |
| Non-Dominant Leg Internal Hip Rotation (°) | 31.1±9.9 | 32.9±10.6 | 34.3±7.4 | 37.1±6.5 | 0.01 | D0 v M9** |
| Non-Dominant Leg External Hip Rotation (°) | 34.7±11.6 | 31.8±12.3 | 27.2±8.0 | 24.2±6.9 | 0.001 | D0 v M5* D0 v M9* |