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1 **Do Australian Football players have sensitive groins? Players with current**
2 **groin pain exhibit mechanical hyperalgesia of the adductor tendon.**

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11
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40 **ABSTRACT**

41 **Objectives** This is the first study to evaluate the mechanical sensitivity, clinical classifications and
42 prevalence of groin pain in Australian football players.

43

44 **Design** Case-control

45

46 **Method** Professional (n=66) and semi-professional (n=9) Australian football players with and without
47 current or previous groin injuries were recruited. Diagnoses were mapped to the Doha Agreement
48 taxonomy. Point and career prevalence of groin pain was calculated. Pressure pain thresholds (PPTs)
49 were assessed at regional and distant sites using handheld pressure algometry across four sites
50 bilaterally (adductor longus tendon, pubic bone, rectus femoris, tibialis anterior muscle). To assess the
51 relationship between current groin pain and fixed effects of hyperalgesia of each site and a history of
52 groin pain, a mixed-effect logistic regression model was utilised. Receiver Operator Characteristic
53 (ROC) curve were determined for the model.

54

55 **Results** Point prevalence of groin pain in the preseason was 21.9% with a career prevalence of 44.8%.
56 Adductor-related groin pain was the most prevalent classification in the pre-season period.
57 Hyperalgesia was observed in the adductor longus tendon site in athletes with current groin pain
58 (OR=16.27, 95%CI 1.86 to 142.02). The ROC area under the curve of the regression model was fair
59 (AUC=0.76, 95%CI 0.54 to 0.83).

60

61 **Conclusions** Prevalence data indicates that groin pain is a larger issue than published incidence rates
62 imply. Adductor-related groin pain is the most common diagnosis in pre-season in this population.
63 This study has shown that hyperalgesia exists in Australian football players experiencing groin pain
64 indicating the value of assessing mechanical pain sensitivity as a component of the clinical
65 assessment.

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68 **Key Words:** groin, athlete, pressure pain threshold, mechanical sensitivity, hyperalgesia, Australian
69 football

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75 **Introduction**

76 The incidence of groin injuries in athletes has been reported between 2.6-3.6 new injuries per
77 club per season in elite (AFL) Australian football players with recurrence rates ranging between 6%
78 and 43%.¹ However, the pre-season point prevalence and career prevalence of groin pain in these
79 players has not been published nor has the described clinical classifications of groin pain aligned to
80 the Doha Agreement Classifications² of defined clinical entities: adductor-related, iliopsoas-related,
81 inguinal-related and pubic-related groin pain; hip-related groin pain; and other causes.

82 Early identification of players at risk of injury would be valuable but it is currently unclear
83 which objective parameters should be used for screening for susceptibility to groin injury. One factor
84 could be an assessment of tissue sensitivity as this is both non-invasive and provides an objective
85 estimate of the sensitivity of the pain system. Addressing alterations in sensory processing rather than
86 the specific patho-anatomical hypotheses may be justified given the high prevalence rates of imaging
87 findings in asymptomatic athletes^{3,4} and the frequent reporting of multiple diagnoses or entities.⁵

88 In musculoskeletal pain of non-athletic populations, sensory processing changes have been
89 observed leading to central nervous system sensitisation.⁶ The sensation of pain may be triggered by a
90 noxious stimulus (such as an injury or overuse of the structures in the region) with either inhibitory or
91 facilitatory effects observed through the modulation within the peripheral nerves, spinal cord, brain
92 stem and cerebral cortex.⁷ Sensory hypersensitivity is capable of predicting future pain⁸ yet it is
93 currently unknown whether sensory deficits exist in athletes experiencing groin pain. Palpatory
94 tenderness of structures is commonly reported^{5,9} and precedes training capacity restrictions.¹⁰

95 Widespread increase in pain sensitivity has been demonstrated in patients suffering from chronic pain
96 affecting the upper and lower limbs which has been associated with decreased function and extended
97 periods of symptoms.¹¹⁻¹³ Currently, pain sensitivity has not been reported in populations of patients
98 suffering from groin pain which should be considered relevant as palpation is a commonly used and
99 recommended clinical test² which may be influenced via regional or widespread pain mechanisms.

100 Longstanding groin pain has been associated with an enlarged pain area, affecting both the adductor

101 area and the lower abdominal wall.¹⁴ This may potentially be related multiple pathologies or due to
102 the large overlap of anatomical structures in the area¹⁵ but it may also be caused by an activation of
103 central pain mechanisms which has been shown to occur soon after the initial nociceptive stimulus¹⁶.
104 It is plausible that sensitivity of pain mechanisms is an important factor in groin pain and that
105 widespread sensory changes may be predictive of treatment response which is worthy of further
106 investigation.

107 Mechanical sensitivity assessed by manual palpation is a common^{5, 9} [ENREF 5](#) [ENREF 2](#) and
108 reliable¹⁷ diagnostic tool to detect the affected structures in clinical groin pain and there is evidence
109 suggesting that tenderness to manual palpation of groin structures precedes training capacity
110 reductions in AFL players.¹⁰ [ENREF 9](#) However, there are currently no reports of a standardized
111 assessment of mechanical sensitivity of the groin region in athletic populations. It is currently
112 unknown whether a previous injury in the musculoskeletal system leads to persistent sensory changes
113 in the affected area but such a relationship might potentially explain the high recurrence rate of
114 injuries observed particularly in the Australian football population.¹⁸ Emerging evidence highlights
115 that mechanical sensitivity improves with self-reported recovery over a three month period in other
116 musculoskeletal conditions such as patellofemoral pain syndrome.¹⁹ If this is the case, then the use of
117 standardized screening tools in athletic populations might be warranted for early identification of
118 players at risk and to track progression of the condition.

119 The aims of this study were to report the point prevalence and career prevalence as well as the
120 clinical classifications of groin pain aligned to the Doha Agreement taxonomy.² Further aims of this
121 study were to examine two hypotheses concerning the pain sensory profile of an athletic population.
122 These were: (1) mechanical hyperalgesia exists in Australian Rules football players experiencing
123 groin pain (2) mechanical hyperalgesia of the adductor tendon or enthesis persists following
124 resolution of symptoms in Australian Rules football players experiencing groin pain.

125

126 **Methods**

127 This study conforms to the minimum reporting standards for clinical research on groin pain in
128 athletes.²⁰ Professional (n=66) and semi-professional (n=9) male Australian football players (age,
129 23.1±3.1years; height, 187.9±7.3cm; weight, 85.2±7.9kg) with and without current or previous groin
130 injuries were recruited during the pre-season (2015) through two professional clubs in the Australian
131 Football League (AFL). All players (n=90) were offered to participate with recruitment ceasing once
132 the required sample size were reached. Exclusion criteria consisted of analgesic medication use either
133 on enrolment or on a regular basis, current lower limb (other than groin pain), pelvic or lumbar injury
134 that required medical treatment (medical attention injury) or resulted in time loss (competition loss
135 injury) and surgery to these regions in the last 12 months. That is, any injury or medication which
136 would alter the results of the sensory testing. Subjects were given a detailed written and verbal
137 explanation of the experimental procedure prior to giving their written informed consent. The study
138 was conducted in accordance with the Helsinki Declaration and was approved by the University of
139 Newcastle Human Research Ethics Committee (H-2013-0052).

140

141 This study used a case-control design. A case was defined as the participant currently experiencing
142 groin pain at the time of testing as reported by the participant, confirmed where appropriate with the
143 medical staff of the club. Current groin pain was defined by self-reports of groin pain at the time of
144 data collection, confirmed where appropriate with the medical staff of the club, and defined as
145 currently seeking medical attention or a physical complaint resulting in restricted training or
146 competition capacity due to pain experienced in the groin region. For the purposes of secondary
147 analysis, participants who have a history of groin pain, as reported by the participant, confirmed
148 where appropriate with the medical staff of the club, and defined as seeking medical attention or a
149 physical complaint resulting in restricted training or competition capacity due to pain experienced in
150 the groin region in their career were categorised. Control participants were defined as having an
151 absence of “current groin pain” or a “history of groin pain”. All diagnoses were mapped to the Doha
152 agreement² classifications of groin pain; Clinical entities: adductor-, iliopsoas-, inguinal-, pubic-

153 related groin pain; Hip-related groin pain; and other causes of groin pain. A further category of
154 “unknown” is reported where insufficient clinical information was available to accurately classify the
155 pain. The Hip and Groin Outcome Score (HAGOS) was applied and is reported separately²¹.
156
157 Pressure pain thresholds (PPTs) were assessed at regional and distant sites using a handheld pressure
158 algometer (Somedic, Sweden) with a 1cm² probe using a 30 kPa/s ramp. The algometer was applied
159 perpendicularly to the measurement site with the participant asked to press a button when the
160 sensation turned from pressure to pain. This threshold is recorded in kilopascals (kPa). Pressure
161 algometry has demonstrated good inter-rater and intra-rater reliability^{22, 23} (ICC_{2,1} 0.91, 95% CI 0.82-
162 0.97)²², low standard error of measure²² (6.27N/cm², 95% CI 5.35-7.59) and correlation with other
163 measures of pain across all age groups.²⁴ The algometer was calibrated prior to each testing period
164 using the manufacturer’s instructions and equipment. Pressure pain thresholds were assessed across
165 four sites bilaterally and based on an experimental pain model;²⁵ the adductor longus tendon site (AL)
166 defined as 5cm distal from the crease where the leg joins the pelvis, the rectus femoris site (RF),
167 defined as the portion of the muscle that bisects the distance between the superior pole of the patella
168 and the anterior superior iliac spine (ASIS), the anterior surface of the superior pubic body lateral to
169 the pubic symphysis joint line where the adductor longus tendon coalesces with the pubic bone (PB)
170 and the tibialis anterior (TA), the probe was placed in the mid-belly at the point measured as the
171 proximal site 1/3 the distance from the lateral joint line of the knee to the inferior aspect of the lateral
172 malleolus. Each measurement was recorded twice with the average of the measurements used for
173 statistical analysis. The AL and PB sites were chosen given its relevance to clinical diagnostic tests of
174 palpation. The RF site was chosen as it represents a body region close to the adductor site which is
175 functionally and neuro-anatomically distinct from the adductors and the TA site was chosen as it is a
176 common site for similar studies and represents a remote, unrelated site to the pelvic region with
177 respects to function, anatomy and neural systems. These sites have also been utilised in experimental

178 pain studies of the groin region allowing future comparisons between clinical and experimental
179 pain.^{25, 26}

180

181 Point prevalence was defined as currently having groin pain in the late preseason period (2015).
182 Career prevalence was defined as ever having groin pain which has affected training or competition
183 throughout their professional career including adolescence. Each prevalence type was calculated as
184 the proportion of participants reporting groin pain during the pre-season period or throughout their
185 entire senior career (Prevalence=number athletes reporting groin pain/total number of participants).

186 All data was assessed for normality. All statistical analyses were undertaken in Stata 13 (Stata
187 13 IC, StataCorp, USA). Significance was set at $p < 0.05$ for all statistical tests. A priori power
188 calculations utilising pilot data indicated that a minimum of 14 cases and 56 controls were required²⁷
189 ($\alpha=0.05$, $\beta=0.20$; PS Power and Sample Size Calculations, Version 3.0, 2009). To compare the PPTs
190 between sites and sides, a single multivariate analysis of variance (MANOVA) with fixed factors of
191 site and side was utilised. Odds ratios with associated attributable fractions in the exposed (AFE) and
192 attributable fractions in the population (AFP) with 95% confidence intervals (using Fisher's exact) of
193 current groin pain and a history of groin pain were calculated using separate two-by-two tables to
194 highlight the percentage of disease in the exposed group that can be attributed to mechanical
195 hyperalgesia. The exposure variables pertained to hyperalgesia (increased pain from a stimulus that
196 normally provokes pain).²⁸ Hyperalgesia was defined as an asymmetry in PPT values between sides of
197 greater than 10% for each site. This was confirmed post-hoc as the best cut-off using Receiver
198 Operating Characteristic (ROC) curves which indicated a significant difference between asymmetry
199 of 5% with 10% or greater (data not presented). ROC curves allow selection of the optimal diagnostic
200 conditions through evaluation of the performance of a diagnostic test.²⁹ A stepwise, backward, mixed-
201 effect logistic regression model removing the least significant fixed effect was utilised to assess the
202 relationship between current groin pain and fixed effects of hyperalgesia of each site (AL, PB, RF and
203 TA) and a history of groin pain with random effects of the participant to account for within subject

204 correlation. Additionally, a ROC curve was used to run a sensitivity analysis on the significant model
205 to assess the ability of the predictive model to discriminate between athletes experiencing groin pain
206 and asymptomatic athletes at the time of testing. A non-parametric bootstrapped ROC curve was
207 produced for the model, and the area under the curve (AUC) was calculated, with an AUC of 1
208 representing perfect discriminative power.

209

210 **Results**

211 Seventy-five professional and semi-professional Australian football players volunteered for this study
212 with 16 cases (with current pain at the time of testing) and 57 without current pain. Seven of the
213 current pain cases (43.75%) had a previous history of groin pain. Two subjects were excluded due to
214 one sustaining a concussion the previous day and one having a car accident on the day of testing.

215 The point prevalence of groin pain in the preseason phase was 21.9% with career prevalence 44.8%.

216 Participants reporting current pain were mapped to the classifications of adductor-related (n=8,
217 50.0%) and psoas and adductor-related (n=1, 6.3%), hip-related (n=2, 12.6%) and undiagnosed (n=1,
218 6.3%) and unknown (n=2, 12.6%). Participants reporting a history of groin pain were mapped to the
219 classifications hip-related (n=8, 24.4%; femoroacetabular surgery, n=6), adductor-related (n=7,
220 21.2%), pubic-related (n=3, 9.0%), inguinal-related (n=2, 6.1%; surgery, n=1), multiple classifications
221 (n=2, 6.1%) and unknown (n=11, 33.3%).

222 The distributions (median, interquartile range) of the PPT values in the history free controls were: AL
223 (755.0, 455.5-964.8), PB (732.3, 454.0-1005.8), RF (701.3, 310.8-1066) and TA (672.5, 325.5-
224 1084.5). The random effect of participant was not significant ($p>0.05$) and therefore removed from all
225 models. There was no significant difference between PPT values on each site ($df=3$, $F=2.15$, $p=0.14$)
226 or side ($df=1$, $F=1.03$, $p=0.38$). A significant model of current groin pain was observed ($p=0.03$) with
227 a significant fixed effect of hyperalgesia of the AL (OR=16.27, 95% CI 1.86 to 142.02) and non-
228 significant fixed effects of hyperalgesia of the RF (OR=0.36, 0.09 to 1.48) and the TA (OR=3.89,

229 95% CI 0.97 to 15.50). The area under the ROC curve for this model (Figure 1) was fair (AUC=0.76,
230 95% CI 0.54 to 0.83).

231

232 The results of the two-by-two tables are presented in Table 1 for participants reporting current pain in
233 the groin and indicate adductor longus tendon hyperalgesia is significantly related to current groin
234 pain (OR=12.58, 95%CI 1.66 to 549.48). Participants who reported a history of groin pain but no
235 current symptoms did not have increased odds of having hyperalgesia of the adductor tendon
236 (OR=2.73, 95%CI 0.81 to 9.49, p=0.07). Post-hoc power calculations indicate that this study was not
237 adequately powered (β =0.33) to detect a true odds ratio of 2.73 due to the sample size recruited for the
238 analysis of the historical groin pain calculations. To test this hypothesis using the data presented, 75
239 cases and 75 controls would be required.

240 [Insert Table 1 approximately here]

241

242

243 [Insert Figure 1 approximately here]

244

245

246 **Discussion**

247 This study is the first study to demonstrate that primary mechanical hyperalgesia of the proximal
248 adductor longus tendon exists in Australian Football players currently experiencing groin pain.
249 Furthermore, the attributable fraction in the participants with current groin pain was 92% indicating
250 that mechanical hyperalgesia is a significant component of their presentation. This is novel as this is
251 the first report of mechanical hypersensitivity in this population and differs from clinical diagnostic
252 tests with respect to discrete sensory changes that occur in the presence of a noxious stimulus. This is
253 the also first study to describe the clinical entities of groin pain in Australian football using the Doha
254 Agreement taxonomy.² It indicates that during pre-season adductor-related groin pain represents the
255 largest classifications (50%) with hip-related pathologies the highest reported classification in the
256 historical pain group.

257

258 The point prevalence of groin pain (21.2%) in Australian football players during the preseason of
259 which, 50% are classified as adductor-related, has not previously been reported. Career prevalence
260 was 45% indicating that almost half of professional and semi-professional players report seeking
261 treatment or reduce their capacity to train and compete due to groin pain throughout their career. This
262 indicates that the burden of groin pain in Australian football may be underestimated by reports of
263 incidence rates. Hip-related groin pain was the most prevalent cause of pain in the historical groin
264 pain group. This may reflect the recent popularity of femoroacetabular impingement as a diagnosis in
265 this population over the last decade.

266

267 Surprisingly, a history of groin pain was not a significant factor involved in players currently
268 experiencing groin pain in any of the statistical models although seven players (44%) with current
269 groin pain had historical groin pain. It is well established that previous groin injury is a predictor of
270 future injury.³⁰ The results of this study suggest that a history of injury may not be a variable
271 associated with current pain if mechanical sensitivity is accounted for, instead suggesting that
272 mechanical sensitivity after injury exhibits a stronger association than the occurrence of injury alone.
273 Evidence from other bodily areas supports this claim^{31, 32} although future research is warranted to
274 investigate these hypotheses.

275

276 Investigations of the pathoanatomical explanations of groin pain in athletes have increased in the last
277 decade. This study indicates the presence of altered sensation to mechanical stimuli on the adductor
278 longus tendon which is similar to previous findings in athletes with patella tendinopathy³³ and
279 patellofemoral pain.^{19, 34} In our study, we found that pressure pain thresholds at the adductor tendon
280 were significantly affected by the presence of pain in the region. This is novel as we defined
281 hyperalgesia as a deficit of 10% or greater compared with the non-affected side; a precision which is
282 unable to be measured in manual palpation. The attributable fractions of AL hyperalgesia (92%) were
283 surprising given that 50% of the diagnoses were mapped to the adductor-related classification. This

284 disproportionate result indicates that hyperalgesia of the AL contributes to the presentation across the
285 cases independent of clinical entity. No hyperalgesia was observed of the PB site. This is simply
286 hypothesised to be explained by the lack of cases mapped to pubic-related groin pain classification
287 and might also indicate differences in sensory processing between tendons and entheses. A further
288 hypothesis is that the discrimination between the sides is reduced due to the confluence of structures¹⁵
289 and possible common somatosensory distribution.

290

291 The intent of this study was to investigate mechanical hyperalgesia as a defined sensory test rather
292 than clinical palpatory tenderness. The PPT data was modelled to determine whether hyperalgesia
293 could dichotomise Australian football players with and without groin pain. A significant model for the
294 identification of groin pain patients was observed with fair discriminatory power. This model has
295 approximately 75% discriminatory power interpretable as identifying three out of four players with
296 pain. Therefore assessment of mechanical pain sensitivity can be used to identify Australian football
297 players with groin pain or to identify those who share a profile similar to those in pain. The ability of
298 this model to predict players who are likely to develop groin pain was not examined in this study and
299 is an area of future research as tenderness on manual palpation has been shown to be predictive in this
300 population.¹⁰ It opens possibilities for trialling alternative therapeutic options more closely aligned to
301 non-sporting pain patients such as pain education, psychological therapy, desensitisation modalities,
302 and analgesic medications to alter the sensation.

303

304 Assessment of mechanical hyperalgesia of the adductor tendons should be integral to a comprehensive
305 clinical assessment along with distal anatomical sites; regional as well as a non-regional control site
306 such as tibialis anterior. Asymmetry of AL pressure pain thresholds greater than 10% should be
307 considered relevant to the patient and represents primary hyperalgesia of the structure. The results of
308 this study indicate no increased benefit from assessing the pubic bone (adductor enthesis) however,
309 this should be interpreted with caution as the majority of participants did not report enthesal/pubic-

310 related diagnoses. Interestingly, participants who reported a history of pain but did not have
311 symptoms during testing did not display a statistically significant hyperalgesia of their adductor
312 longus tendon ($p=0.07$) however, this could potentially represent Type II error (underpowered to
313 detect small changes) and caution is recommended when interpreting this result.

314

315 Given pain is the major complaint of this population we defined [ENREF 7](#) current groin pain by the
316 presence of pain in the region where the thigh joins the abdomen rather than on pathoanatomical
317 grounds. Due to limitations in sample size subgrouping was not achievable without increasing the
318 Type II error. Future studies should evaluate the effect of subgrouping into the Doha Agreement
319 taxonomy² has on mechanical sensitivity of the region and furthermore whether these subgroups
320 affect pain modulation. Further diagnostic studies are required to accurately be able to define the
321 anatomical source of nociception given the high rate of 'positive' imaging findings in asymptomatic
322 populations.⁴ A reduced sample size in the analysis of hyperalgesia with respect to historical pain was
323 utilised as we excluded participants with current pain in the groin as this alters the results of PPT
324 measurement. This reduced the power of the study. Examining hyperalgesia in those with a history of
325 groin pain but currently asymptomatic was the secondary aim of the study with sample size calculated
326 for the primary aim of examining those with current pain. Future research should examine
327 hyperalgesia and/or other deficits within the somatosensory system in asymptomatic athletes with a
328 history of groin pain in a larger cohort (with 75 cases and 75 controls) as it could potentially be a
329 component of pain recurrence.

330

331 **Conclusion**

332 The point prevalence and career prevalence of groin pain were 21.9% and 44.8% respectively. The
333 most prevalent clinical classification of groin pain aligned to the Doha Agreement taxonomy was
334 adductor-related groin pain. This study has shown that Australian Football players currently

335 experiencing groin pain have primary hyperalgesia of the adductor tendon. A significant model
336 utilising pressure pain thresholds was observed to have fair discriminatory power. Future studies
337 should examine other quantitative sensory testing parameters in this population as well as the value of
338 such measurements in terms of predicting the likelihood of injury and clinical progression toward
339 recovery.

340

341 **Perspectives**

- 342 • Adductor-related groin pain is the most prevalent diagnosis classification in pre-season
- 343 • Primary mechanical hyperalgesia exists in Australian Rules football players with current
344 groin pain
- 345 • Assessment of pressure pain thresholds has fair discriminatory power between Australian
346 Rules football players with and without current groin pain

347

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439 **Tables**

440

441 Table 1 – Odds ratios, attributable fraction in the exposed and population for hyperalgesia at each
 442 muscle site and history of groin pain

443

Explanatory Variable	Point Estimate	95%CI
Adductor longus tendon hyperalgesia		
Odds Ratio	12.58	1.66 to 549.48 ^a
Attributable Fraction in the Exposed	0.92	0.40 to 1.00 [†]
Attributable Fraction in the Population	0.86	-
Pubic bone hyperalgesia		
Odds Ratio	1.19	0.32 to 4.99
Attributable Fraction in the Exposed	0.16	-2.11 to 0.80
Attributable Fraction in the Population	0.11	-
Rectus femoris hyperalgesia		
Odds Ratio	0.95	0.24 to 3.41
Attributable Fraction in the Exposed	0.05	-2.41 to 0.75
Attributable Fraction in the Population	0.02	-
Tibialis Anterior hyperalgesia		
Odds Ratio	2.8	0.75 to 10.21
Attributable Fraction in the Exposed	0.64	-0.32 to 0.90
Attributable Fraction in the Population	0.32	-
History of groin pain		
Odds Ratio	1.00	0.27 to 3.49
Attributable Fraction in the Exposed	<0.00	-0.49 to 0.73
Attributable Fraction in the Population	<0.00	-

444

445 95%CI, 95% confidence interval; ^aStatistically significant at the level of 0.05

446

447

448 **Figure 1**

449 **Figure Title**

450 Receiver Operator Characteristic Curve for the significant model of current groin pain including fixed
451 effects of hyperalgesia of the AL, RF and TA and random effects for participant.

452 **Figure Legend**

453 SD(area)=standard deviation of the area under the curve