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The effect of physical contact on changes in fatigue markers following rugby union field-based training

1 **Abstract**

2

3 Repeated physical contact in rugby union is thought to contribute to post-match fatigue,

4 however, no evidence exists on the effect of contact activity during field-based training on

5 fatigue responses. Therefore, the purpose of this study was to examine the effect of contact

6 during training on fatigue markers in rugby union players.

7 Twenty academy rugby union players participated in the cross-over study. The magnitude of

8 change in upper- and lower-body neuromuscular function (NMF), whole blood creatine

9 kinase concentration [CK] and perception of wellbeing was assessed pre-training (baseline),

10 immediately and 24 hr post-training following contact and non-contact field-based training.

11 Training load was measured using mean heart rate, session rating of perceived exertion

12 (sRPE) and microtechology (Catapult Optimeye S5).

13 The inclusion of contact during field-based training *almost certainly* increased mean heart

14 rate (9.7; ±3.9%) and sRPE (42; ±29.2%) and resulted in *likely* and *very likely* greater

15 decreases in upper-body NMF (-7.3; ±4.7% versus 2.7; ±5.9%) and perception of wellbeing

16 (-8.0; ±4.8 % versus -3.4; ±2.2 %) 24 hr post-training respectively, and *almost certainly*

17 greater elevations in [CK] (88.2; ±40.7% versus 3.7; ±8%). The exclusion of contact from

18 field-based training *almost certainly* increased running intensity (19.8; ±5 %) and distance

19 (27.5; ±5.3 %), resulting in *possibly* greater decreases in lower-body NMF (-5.6; ±5.2%

20 versus -2.3; ±2.4%).

21 Practitioners should be aware of the different demands and fatigue responses of contact and

22 non-contact field-based training and can use this information to appropriately schedule such

23 training in the weekly microcycle.

24

25 **Key Words:** fatigue**,** recovery, team sport

Introduction

Rugby union match-play involves intermittent high-intensity activities including sprinting, rucking, mauling, scrummaging and tackling (Austin, Gabbett, & Jenkins, 2011; Quarrie, Hopkins, Anthony, & Gill, 2013) that are interspersed with periods of jogging, walking and standing (Cahill, Lamb, Worsfold, Headey, & Murray, 2013). The high intensity activities and collisions sustained during match-play result in acute post-match fatigue that may last for several days following competition. Common manifestations of fatigue include alterations in mood (West et al., 2014), perception of wellbeing (Roe, Till, et al., 2016) and hormone concentrations (Elloumi, Maso, Michaux, Robert, & Lac, 2003; West et al., 2014), reductions in neuromuscular function (NMF) (Roe, Till, et al., 2016; West et al., 2014), and elevations in markers of muscle damage (e.g. increase in creatine kinase concentration [CK]) (Cunniffe et al., 2010; Jones et al., 2014; Roe, Till, et al., 2016).

Understanding the fatigue response to match-play provides paramount information regarding the recovery of players and allows practitioners to appropriately plan the post-match microcycle (Roe, Till, et al., 2016). However, given that players spend a greater amount of time in field-based training than in competition (Bradley et al., 2015; Roe, Darrall-Jones, Till, & Jones, 2016), understanding the fatigue response to field-based training is also needed in order to optimise the training-recovery cycle in preparation for future competition (Fowles, 2006). Currently no study has investigated the fatigue responses of players to field-based training within rugby union players. Additionally, the inclusion or exclusion of collisions during field-based training may alter the demands of such training and influence the fatigue responses of players (Johnston, Gabbett, Seibold, & Jenkins, 2014). Therefore the presence or absence of collisions also needs consideration when assessing fatigue responses of rugby union players to field-based training alongside planning the training microcycle.

Previous research investigating the fatigue response of rugby league players following field-based small-sided games demonstrated *likely* greater decreases in ~~upper-body neuromuscular function (~~NMF~~)~~ at 24 hr post-training when training included collisions (Johnston et al., 2014). This was coupled with a *likely* greater increase in [CK], while changes in perception of wellbeing were *unclear*. In contrast, the exclusion of contact resulted in *likely* greater reductions in lower-body NMF as a result of greater running demands (Johnston et al., 2014). However, the findings from this study might not be applicable to rugby union training as each collision consisted of 5 seconds of shoulder pummels followed by 5 seconds of wrestling, which were unlikely to replicate the magnitude

60   or frequency of collisions sustained during rugby union training (e.g. rucks and tackles).

61   Furthermore, the 'off-side touch' style of small-sided games may have imposed different

62   physical demands on players than experienced in rugby union training.

63   Therefore the aim of the present study was to examine the changes in markers of

64   fatigue in response to contact and non-contact field-based training in rugby union players.

65   This research would provide practitioners with important information regarding the fatigue

66   response to field-based training inclusive or exclusive of contact, and thus allow appropriate

67   scheduling of such training in the weekly microcycle.

68

69   **Methods**

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71

72   *Subjects*

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74   Twenty male players (age 17.6 ± 0.8 years; height 183.5 ± 7.4 cm; body mass $87.1 \pm$

75   11.9 kg) were recruited from a professional rugby union academy. Participants were excluded

76   if they had an injury that prevented them from participating in the testing, or missed any

77   testing session. Ethics approval was granted by the University ethics board and written

78   informed assent was acquired from all subjects along with parental consent.

79

80   *Design*

81

82   A cross-over design was used to assess the magnitude of change in markers of upper-

83   and lower-body NMF, whole-blood [CK] (an indirect measure of muscle damage) and

84   perception of wellbeing following contact (CON) and non-contact (nCON) rugby union field-

85   based training. The study was conducted during the fifth and sixth week of a pre-season

86   period in order to ensure that players were adequately reconditioned following the off-season

87   period to prevent an exaggerated fatigue response to training. Testing was undertaken pre-

88   and immediately post-training, and 24 hr following the pre-training measures (Figure 1).

89   Both training sessions were performed at the same time of day (1pm) under similar weather

90   conditions exactly seven days apart. Participants were advised on nutritional intake but no

91   recovery protocol was undertaken.

92

93   *Training Intervention*

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95　　　　The training sessions were designed to replicate a typical training session undertaken

96　at the club. Each training session began with two 8-minute skill blocks (15 x 20 m pitch)

97　during which players performed tackling (CON training) or passing (nCON training) drills.

98　The players were then divided into teams of 5, with each team containing the same amount of

99　forwards and backs (3 forwards and 2 backs) with the exception of one team, which consisted

100　of 2 forwards and 3 backs. The teams each played three 3-minute small-sided games (5

101　versus 5; 15x20 m pitches) with 90 s of rest in between each game. Following this, players

102　were then divided into 2 teams of 10, one consisting of 5 forwards and 5 forwards and the

103　other of 6 forwards and 4 backs. The teams competed during three 3-minute (10 versus 10;

104　20x30m m pitch) with 90 s of rest between each game. The order of games and members of

105　teams were kept the same for both CON and nCON training sessions.

106　　　　The CON games consisted of full-contact tackles with up to two players from each

107　team, inclusive of the tackler, contesting possession within the ruck area. Each team was

108　allowed unlimited time to attack until one of the following occurred; a try was scored, a turn-

109　over or penalty was conceded in the ruck area, or an error was made (i.e. forward pass or ball

110　knocked forward). The nCON games consisted of non-collision tackles, which, in order to be

111　deemed successful, involved the defending player touching the ball carrier with two hands. If

112　a player was successfully tackled, both the attacking player and defender were required to lie

113　down on the ground to simulate a tackle. Additionally, a secondary attacker and defender

114　were required to position themselves beside the tackle area, simulating a ruck. Again, each

115　team had unlimited possession until a try was scored, a turn-over or penalty was conceded in

116　the ruck area, or an error was made. The games were refereed by experienced coaches in

117　order to ensure that the rules were adhered to. No encouragement was given during the games,

118　but technical coaching was provided during the rest periods.

119

120　　　　　　　　　　　　INSERT FIGURE 1 HERE

121

122　Figure 1: Schematic of study design. Testing was inclusive of lower-body and upper-body

123　neuromuscular function, whole blood creatine kinase concentration and perception of

124　wellbeing.

125

126　*Neuromuscular Function*

127

128   Lower-body NMF was measured using mean power calculated from a

129   countermovement jump (CMJ), while upper-body NMF was measured using flight-time

130   calculated from a plyometric push-up. These measures have previously demonstrated good

131   reliability in this population (typical error = 2.5 to 4.2%) (Roe et al., 2015). It has been

132   recommended that a minimum sampling frequency of 200Hz be used for such measurement

133   (Hori et al., 2009). Therefore the CMJ and plyometric push-up were performed on a portable

134   force plate (400 Series Performance Plate, Fitness Technology, Adelaide, Australia) that was

135   attached to a laptop with software (Ballistic Measurement System, Fitness Technology,

136   Adelaide, Australia) that measured ground reaction forces at 600 Hz. A standardised 2-

137   minute warm-up consisting of dynamic stretching was performed prior to the performance

138   tests (walking lunges, squats, heel flicks, high knees, skipping, legs swings and 3 practice

139   submaximal CMJ and Plyometric-push ups). Following the warm-up, players performed 2

140   maximal CMJ followed by 2 maximal plyomeric push-ups with 1-minute rest between each

141   effort (Roe et al., 2015).

142

143   *Creatine Kinase*

144

145   Whole blood [CK] samples were collected from the non-dominant hand, middle

146   fingertip of each subject. Approximately 30 μl of whole capillary blood was collected using a

147   plastic capillary tube (MICROSAFE®, Safe-tec, Numbrecht, Ivyland, USA) and immediately

148   analysed using reflectance photometry (Refletron® Plus, Boehringer Manheim, Germany).

149   Prior to each session, the machine was calibrated using a standardised CK strip.. The

150   reliability of this method has previously been reported (CV = 26.1%) (Roe et al., 2015).

151

152   *Wellbeing*

153

154   A 6-item questionnaire was adapted from McLean et al (2010) to rate each of sleep,

155   fatigue, muscle soreness (upper- and lower-body), stress and mood on a 5-point Likert scale.

156   Each item was rated from 1 to 5 in 1 score increments and overall wellbeing was assessed by

157   summating all 6 scores. Reliability of this method has previously been reported (CV = 7.1%)

158   (Roe et al., 2015). The questionnaire was administered prior to any other testing being

159   undertaken (McLean et al., 2010). Participants completed the questionnaire on their own in

160   order to prevent any influence from other players (Twist, Waldron, Highton, Burt, & Daniels,

161   2012).

162

163 *Training Load*

164

165   Subjective internal training load was quantified using the session rating of perceived

166 exertion method (sRPE) (Foster et al., 2001) within 15-30 minutes of each session finishing,

167 on a modified Borg scale. This rating was then multiplied by the time spent training to give a

168 training load (sRPE-TL) in arbitrary units (AU) (Foster et al., 2001). Objective internal

169 training load was assessed using mean heart rate. External training loads were assessed using

170 GPS (10 Hz) and accelerometer (100 Hz) technology (Optimeye S5, Catapult Innovations,

171 Melbourne, Australia). Metrics used were total distance and relative total distance (m/min)

172 which have previously been proven valid and reliable (Johnston, Watsford, Kelly, Pine, &

173 Spurrs, 2014), and Player Load^{TM} slow, an accelerometer metric validated for quantifying the

174 collision activity of rugby union players (Roe, Halkier, Beggs, Till, & Jones, 2016).

175

176 **Statistical Analysis**

177

178   All data were log transformed to reduce bias as a result of non-uniformity error. Data

179 were all analysed for practical significance using magnitude-based inferences (Hopkins,

180 Marshall, Batterham, & Hanin, 2009). For variables that were log transformed before

181 modelling, the mean reported is the back-transformed mean of the log transformation, and the

182 dispersion is a factor SD ($\times/\div$) (Hopkins et al., 2009). The thresholds for a change to be

183 considered practically important (the smallest worthwhile change; SWC) was set at 0.2 x

184 between subject standard deviation (SD), based on Cohen's d effect size (ES) principle. The

185 probability that the magnitude of change was greater than the SWC was rated as <0.5%,

186 *almost certainly not*; 0.5-5%, *very unlikely*; 5-25%, *unlikely*; 25-75%, *possibly*; 75-95%,

187 *likely*; 95-99.5%, *very likely*; >99.5%, *almost certainly* (Hopkins et al., 2009). Where the

188 90% Confidence Interval (CI) crossed both the upper and lower boundaries of the SWC

189 (ES±0.2), the magnitude of change was described as *unclear* (Hopkins et al., 2009).

190

191 **3. Results**

192

193   Changes in lower-body NMF are presented in Figure 2. Following CON, CMJ mean

194 power *very likely* decreased from 1215 $\times/\div$ 1.18 W to 1136 $\times/\div$ 1.15 W (-6.5; ±3.1 %)

195 immediately post-training, but demonstrated *likely* trivial changes at 24 hrs (1187 $\times/\div$ 1.17, -

196   2.3; ±2.4%) (A). In response to nCON, CMJ mean power *likely* decreased from 1229 ×/÷

197   1.15 W to 1161 ×/÷ 1.18 W (-5.5; ±3.3%) and 1162.6 ×/÷ 1.17 W (-5.4; ±5.2%) immediately

198   and 24 hr post-training respectively (A)). Decreases in CMJ mean power were *unclear*

199   between CON and nCON immediately post-training, while *possibly* greater in nCON than

200   CON 24 hr post-training. Changes in CMJ mean force (D) were *almost certainly* trivial for

201   both CON and nCON at all time-points.

202

203   INSERT FIGURE 2 HERE

204

205   Changes in upper-body NMF function are presented in figure 3. In response to CON,

206   plyometric push-up flight time *likely* decreased from 0.394 ×/÷ 1.19 to 0.372 ×/÷ 1.18 s (-6.4;

207   ±3.9%) and 0.365 ×/÷ 1.22 s (-7.3; ±4.7%) immediately and 24 hr post-training respectively

208   (A). Following nCON, plyometric push-up demonstrated a *likely* trivial change from 0.399

209   ×/÷ 1.18 s to 0.410 ×/÷ 1.20 s (1.6; ±2.5%) but a *possible* increase at 24 hr post-match (0.412

210   ×/÷ 1.15 s, 2.7; ±5.9%) (A). Decreases in plyomteric push-up flight time (C) were *very likely*

211   greater in CON than nCON immediately post-training, while *likely* greater in CON than

212   nCON 24 hr post-training. Decreases in mean force (D) were *likely* to *almost certainly* trivial

213   for both CON and nCON at all time-points.

214

215   INSERT FIGURE 3 HERE

216

217   Changes in [CK] and perception of wellbeing are presented in Figure 3. Following

218   CON, [CK] *almost certainly* increased from 414 ×/÷ 1.76 IU/L to 691 ×/÷ 1.47 IU/L (66.9;

219   ±22.5%) immediately post training and continued to rise to 779 ×/÷ 1.56 IU/L (88.2; ±40.7%)

220   24 hr post-training (A). Following nCON, [CK] *almost certainly* increased from 395 ×/÷ 1.80

221   IU/L to 543 ×/÷ 1.61 IU/L, but returned to near pre-training concentrationlevels (410 ×/÷

222   1.59 IU/L) at 24 hrs post-training (A). Increases in [CK] were *likely* greater in CON than

223   nCON (immediately post-training, while *almost certainly* greater in CON than nCON 24 hr

224   post-training (A). Perception of well-being was *almost certainly* reduced from 19.8 ×/÷ 1.15

225   to 18.2 ×/÷ 1.15 (-8.0; ±4.8%) 24 hr after CON (D), while *likely* reduced from 21.5 ×/÷ 1.12

226   to 20.8 ×/÷ 1.13 (-3.4; ±2.2%) following nCON (D). Decreases in perception of wellbeing

227   were *likely* greater in CON than nCON at 24 hr post-training. When questionnaire items

228   were analysed individually, there was an *almost certain* and *likely* greater change in

229   perception of upper-body and lower-body soreness following CON, while the differences

230   between changes in other items were *unclear*.

231

232   INSERT FIGURE 4 HERE

233

234   Total distance was *almost certainly* greater (27.5; ±5.3 %) during nCON (2543 ×/÷

235   1.09 m) than CON (1968 ×/÷ 1.14 m). Relative distance was *almost certainly* greater (19.8;

236   ±5.0 %) during nCON (79.4 ×/÷ 1.09 m.mim^{-1}) and CON (65.1 ×/÷ 1.18 m.min^{-1}). Player

237   Load^{TM} slow was *almost certainly* greater (56.5; ±5.7 %) during CON (165 ×/÷ 1.17 AU)

238   than nCON (108 ×/÷ 1.13 AU). Mean heart rate was *almost certainly* greater (9.7; ±3.9 %)

239   during CON (166 ×/÷ 1.07 bpm) than nCON (152 ×/÷ 1.08 bpm) while sRPE was also *almost*

240   *certainly* greater (42; ±29.2%) following CON (417 ×/÷ 1.56) than nCON (294 ×/÷ 1.35).

241

242   **4. Discussion**

243

244   This study examined the fatigue responses to contact and non-contact field-based

245   training in rugby union players. The inclusion of contact during field-based training increased

246   subjective and objective internal training load and resulted in greater upper-body

247   neuromuscular and perceptual fatigue and greater elevations in [CK]. The exclusion of

248   contact from field-based training increased running intensity and distance, resulting in greater

249   lower-body neuromuscular fatigue.

250   Upper-body neuromuscular function demonstrated *likely* greater reductions following

251   CON than nCON at 24 hr post-training, indicating neuromuscular fatigue. This reduction

252   may be attributed to the substantial involvement of the upper-body during rugby union

253   collisions (Hendricks, Matthews, Roode, & Lambert, 2014), and the resultant trauma to local

254   tissues (Johnston, Gabbett, Jenkins, & Hulin, 2015). Similar results were reported by

255   Johnston and colleagues (2014), who observed a *very likely* greater decrease in plyometric

256   push-up peak power 24 hr following contact small-sided games in rugby league players. The

257   greater probability of decrease above the SWC may be due to the particular metric used to

258   measure upper-body NMF. It has been shown that power variables demonstrate larger

259   changes than flight-time in response to training for the CMJ (Roe et al., 2016). Unfortunately,

260   unlike in the study by Johnston and colleagues, in the present study flight-time was used

261   instead of peak power to measure upper-body NMF due to the unacceptable reliability of

262   peak power in this population (Roe et al., 2015). Collectively, however, these findings

263   suggest that upper-body NMF is deceased 24 h following contact training. It may therefore be

264   prudent to plan upper-body resistance training earlier in the weekly microcycle, or allow

265   adequate recovery time following field training inclusive of contact. Furthermore, as

266   plyometric push-up peak power is associated with tackling ability (Speranza, Gabbett,

267   Johnston, & Sheppard, 2015), recovery of upper-body neuromuscular function may be

268   important to prevent reduced tackle performance in subsequent collision training or match-

269   play.

270   This study found *almost certainly* greater increases in [CK] following CON than

271   nCON 24 h post-training. This finding supports previous research in rugby union that

272   demonstrated an almost perfect relationship between collisions and increases in [CK] 24 h

273   post-match (Takarada, 2003), and suggests that collisions are a major contributor to skeletal

274   muscle damage in rugby union players. The rise in [CK] was greater than that observed in the

275   previously mentioned study by Johnston et al (2014). The authors found a *likely* increase in

276   [CK] that rose 54±32% above pre-training measures at 24 hr post-training, which is lower

277   than in the present study (88.2; ±40.7%). The difference is possibly due to the nature of

278   contact. The collisions in Johnston and colleagues' study consisted of 5 seconds of shoulders

279   pummels followed by 5 seconds of wrestling, which were likely to be of lesser magnitude

280   than the tackles and rucks contested in the present study. Indeed, the accumulation of Player

281   Load slow, an accelerometer metric that has shown strong relationships with collisions in

282   rugby union players (Roe, Halkier, et al., 2016) was nearly as high during CON in the present

283   study as during a competitive rugby union match (167±28 versus 197±47 AU) (Roe, Till, et

284   al., 2016). These results suggest that as the intensity and volume of contact in training

285   increases, so too do markers of muscle damage.

286   It must be pointed out that the pre-training concentrationslevels of [CK] (414 ×/÷ 1.74

287   IU/L) in the present study were high relative to in-season concentrationlevel s (212 ×/÷ 1.96

288   IU/L) formerly reported in this cohort (Roe, Till, et al., 2016). It has previously been

289   demonstrated that [CK] concentrationlevels increases during times of high training stress, but

290   may return to baseline concentrationlevels as individuals adapt to the training stimulus

291   (Alaphilippe et al., 2012; Hoffman, Kang, Ratamess, & Faigenbaum, 2005) via the "repeated

292   bout effect" (Koch, Pereira, & Machado, 2014). It is therefore possible that although the

293   present study was undertaken during the middle of pre-season, the four weeks of training

294   preceding data collection were not long enough for such adaptation to occur, resulting in the

295   high pre-training concentration levels observed. To this end, the magnitude of increase in

296   [CK] reported may be understated. Therefore future research is required in a more controlled

297   setting in order to determine the [CK] response of rugby union players to field-based training.

298   Although post-training elevations in [CK] may be primarily attributed to tissue

299   damage as a result of blunt trauma during collisions in rugby union, other non-contact

300   mechanisms may have also played a part. From Figure 2 it can be seen that there was an

301   *almost certain* acute elevation in [CK] immediately post-training following nCON. This

302   acute increase in [CK] may be attributed to eccentric muscle damage as a result of high-speed

303   locomotion (Jones et al., 2014; Wiewelhove et al., 2015). Nevertheless, this increase was

304   *likely* trivial at 24 h post-training, suggesting full recovery.

305   There was a *likely* greater decrease in perception of wellbeing following CON than

306   nCON. In addition, sRPE was *almost certainly* greater following CON than nCON . This is in

307   contrast to findings from the aforementioned study by Johnston et al (2014), where

308   differences between CON and nCON were *unclear* for both measures. As previously

309   discussed, the frequency and magnitude of contact in the present study was likely to be

310   greater during CON, as demonstrated by the large accumulation of Player Load^{TM} slow, thus

311   resulting in a larger perception of effort during, and the greater reductions in wellbeing 24 hr

312   following CON. Indeed, the accumulation of accelerometer load during training has been

313   shown to have large to very large relationships with sRPE in rugby league players (Lovell,

314   Sirotic, Impellizzeri, & Coutts, 2013). Furthermore, perception of upper- and lower-body

315   muscle soreness were *almost certain* and *likely* greater following CON than nCON

316   respectively, which would have contributed to the greater reduction in perception of

317   wellbeing.

318   In addition to sRPE, CON also resulted in *almost certainly* greater heart rate than

319   during nCON. Similarly, previous research by Johnston and colleagues (2011) demonstrated

320   greater mean heart rate and sRPE when tackles were added to a repeated sprint training

321   session. These finings demonstrate the greater physiological and subjective load of collision-

322   based training, which is reflected in the negative changes in the majority of post-training

323   measures of fatigue in the present study.

324   In contrast to upper-body NMF, a *possibly* greater reduction in lower-body NMF was

325   observed following nCON than CON 24 hr post-training. This may be the result of the *almost*

326   *certainly* greater locomotive demands of nCON, and the eccentric damage associated with

327   high-speed running (Jones et al., 2014; Wiewelhove et al., 2015). In comparison, Johnston et

328   al (2014) reported *likely* greater reductions in lower-body NMF following non-contact versus

329   contact small-sided games in rugby league players. The greater probability of reduction

330 above the SWC may be explained by the difference in demands of the particular games

331 played. Johnston et al. (Johnston et al., 2014) implemented 'off-side touch' which resulted in

332 a very high running intensity (140 m/min), which are not representative of a match

333 (95.8±18.6 m/min (Twist et al., 2014)). In contrast, the games in the present study resulted in

334 a greater distance covered (2552m versus 2240m), but at a much lower running intensity

335 (79.9 m/min), although this is more representative of match-play (74±6 m/min (Roe, Till, et

336 al., 2016)). Collectively however, these findings demonstrate that the exclusion of contact

337 from field-based training increases the locomotive demands of field-based training and

338 results in greater decreases in lower-body NMF 24 hr post-training. Such information can be

339 used by practitioners when scheduling activities that require high levels of lower-body power

340 (e.g. power or sprint training) during the weekly microcycle.

341   The results of the present study also demonstrate the individual nature of fatigue

342 response to field-based training in rugby union players, similar to those found following

343 match-play (Roe, Till, et al., 2016) From Figures 1 to 3 (B, C, E and F) it can be seen that

344 players often differed from the group mean response, some presenting with greater changes

345 in fatigue markers, while others not experiencing any fatigue at all. These findings emphasise

346 that although understanding a group response provides valuable information on fatigue

347 induced by field-based training inclusive or exclusive of contact, it is important for

348 practitioners to monitor fatigue response of each individual player following training.

349 Furthermore, future research is needed to understand the mechanisms that contribute to such

350 individual responses.

351   A limitation of the present study is the lack of follow up past 24 hr. However, data

352 collection at 48 hr post-training was not possible due to the players' training schedule. In

353 addition, although players were instructed not to engage in any contact during nCON,

354 accidental collisions with other players did occur. A further limitation of the present study is

355 that participants were not randomised, and a control group was not included. However, due to

356 this research being conducted in an applied setting where players were required to adhere to a

357 strict training schedule, such methods could not be employed. Finally, although the training

358 sessions were designed to replicate a typical field-based training session at the rugby club,

359 these sessions may not be representative of training at other clubs. Therefore caution should

360 be advised when applying the findings from this study to different training situations.

361

362 **Conclusions**

363

364   The inclusion of contact during field-based training increases subjective and objective

365   measures of internal training load and results in greater upper-body neuromuscular and

366   perceptual fatigue, and greater elevations in [CK]. The exclusion of contact from field-based

367   training increases running intensity and distance, resulting in greater lower-body

368   neuromuscular fatigue. Practitioners should be aware of the different fatigue responses of

369   contact and noncontact field-based training and can use this information to appropriately

370   schedule such training in the weekly microcycle. Furthermore, the results demonstrate the

371   individual responses of players to contact and non-contact field-based training, highlighting

372   the need for the individual monitoring of players.

373

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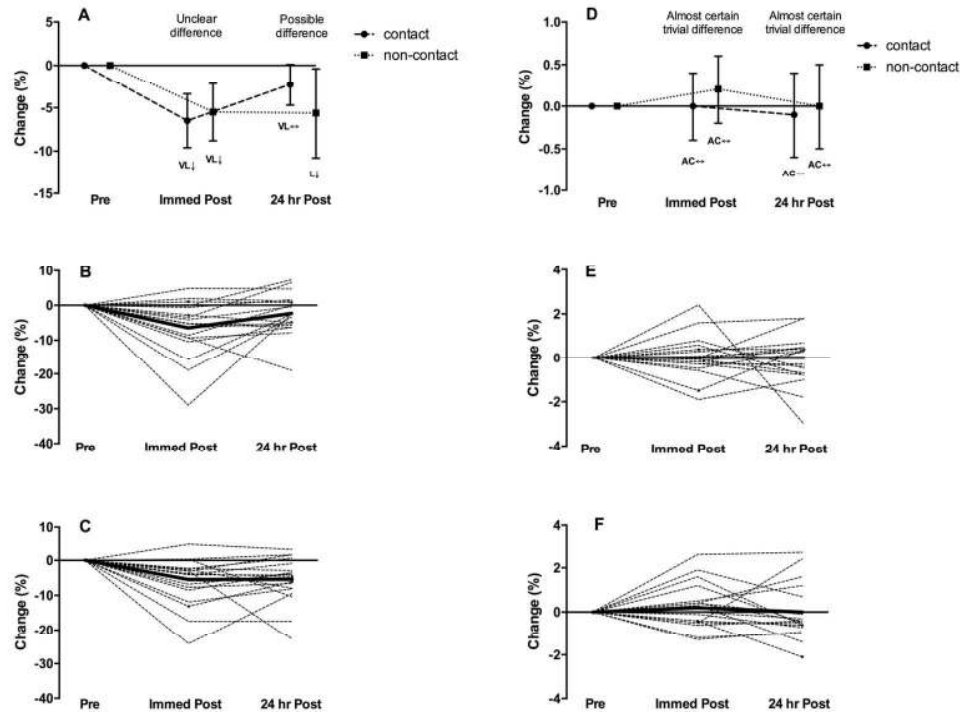402   *Exerc, 37*(7), 1237-1241.

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467

Non-Contact Training

Academy Rugby Union Player (n=20)

PRE-TESTING

Skill Block
- 8 minutes x 2
- 15m x 20m pitch

5 vs 5 SSG's
- 3 minutes x 3
- 15m x 20m pitch

10 vs 10 SSG's
- 3 minutes x 3
- 20m x 30m pitch

POST-TESTING

TESTING 24 h Post

1 WEEK

Contact Training

Academy Rugby Union Player (n=20)

PRE-TESTING

Skill Block
- 8 minutes x 2
- 15m x 20m pitch

5 vs 5 SSG's
- 3 minutes x 3
- 15m x 20m pitch

10 vs 10 SSG's
- 3 minutes x 3
- 20m x 30m pitch

POST-TESTING

TESTING 24 h Post

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Graphs are mean changes in CMJ mean power (A) and mean force (D). Change data are percentage change with 90% confidence interval bars. Above graph ratings of probability refer to between-group comparisons. Below graph ratings of probability refer to within-group changes; P = possibly, L = likely, VL = very likely, A = almost certainly, ↑ = increase, ↓ = decrease, ↔ = trivial. Individual changes are shown for CMJ mean power following contact (B) and non-contact (C) training, and mean force following contact (E) and non-contact training (F).

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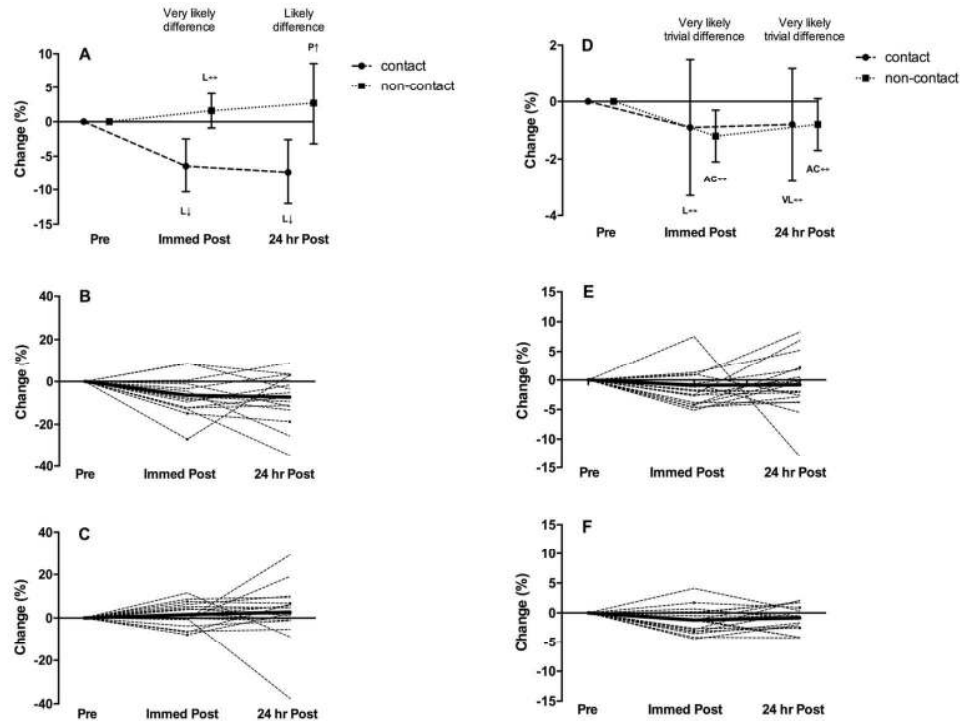
Graphs are mean changes in plyometric push-up flight time (A) and mean force (D). Change data are percentage change with 90% confidence interval bars. Above graph ratings of probability refer to between-group comparisons. Below graph ratings of probability refer to within-group changes; P = possibly, L = likely, VL = very likely, A = almost certainly, ↑ = increase, ↓ = decrease, ↔ = trivial. Individual changes are shown for plyometric push-up flight time following contact (B) and non-contact (C) training, and mean force following contact (E) and non-contact training (F).
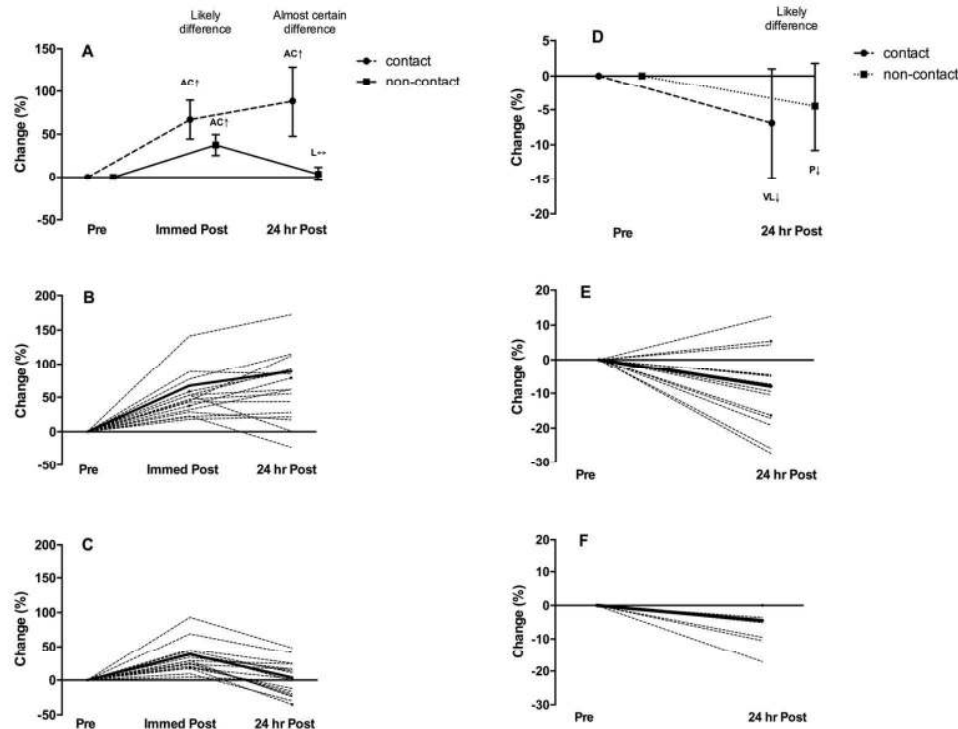
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Figure 4: Graphs are mean changes in creatine kinase (A) and wellbeing (D). Change data are percentage change with 90% confidence interval bars. Above graph ratings of probability refer to between-group comparisons. Below graph ratings of probability refer to within-group changes; P = possibly, L = likely, VL = very likely, A = almost certainly, ↑ = increase, ↓ = decrease, ↔ = trivial. Individual changes are shown for creatine kinase following contact (B) and non-contact (C) training, and wellbeing following contact (E) and non-contact training (F).

130x100mm (300 x 300 DPI)