

European Journal of Sport Science

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

Journal:	<i>European Journal of Sports Science</i>
Manuscript ID	TEJS-2016-0556.R3
Manuscript Type:	Original Paper
Keywords:	Fatigue, Recovery, Team Sport

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2
3 1 **Abstract**
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6 3 Repeated physical contact in rugby union is thought to contribute to post-match fatigue,
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8 4 however, no evidence exists on the effect of contact activity during field-based training on
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10 5 fatigue responses. Therefore, the purpose of this study was to examine the effect of contact
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12 6 during training on fatigue markers in rugby union players.

13 7 Twenty academy rugby union players participated in the cross-over study. The magnitude of
14
15 8 change in upper- and lower-body neuromuscular function (NMF), whole blood creatine
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17 9 kinase concentration [CK] and perception of wellbeing was assessed pre-training (baseline),
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19 10 immediately and 24 hr post-training following contact and non-contact field-based training.
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21 11 Training load was measured using mean heart rate, session rating of perceived exertion
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23 12 (sRPE) and microtechnology (Catapult Optimeye S5).

24 13 The inclusion of contact during field-based training *almost certainly* increased mean heart
25
26 14 rate ($9.7_{\pm} \pm 3.9\%$) and sRPE ($42_{\pm} \pm 29.2\%$) and resulted in *likely* and *very likely* greater
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28 15 decreases in upper-body NMF ($-7.3_{\pm} \pm 4.7\%$ versus $2.7_{\pm} \pm 5.9\%$) and perception of wellbeing
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30 16 ($-8.0_{\pm} \pm 4.8\%$ versus $-3.4_{\pm} \pm 2.2\%$) 24 hr post-training respectively, and *almost certainly*
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32 17 greater elevations in [CK] ($88.2_{\pm} \pm 40.7\%$ versus $3.7_{\pm} \pm 8\%$). The exclusion of contact from
33
34 18 field-based training *almost certainly* increased running intensity ($19.8_{\pm} \pm 5\%$) and distance
35
36 19 ($27.5_{\pm} \pm 5.3\%$), resulting in *possibly* greater decreases in lower-body NMF ($-5.6_{\pm} \pm 5.2\%$
37
38 20 versus $-2.3_{\pm} \pm 2.4\%$).

39 21 Practitioners should be aware of the different demands and fatigue responses of contact and
40
41 22 non-contact field-based training and can use this information to appropriately schedule such
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43 23 training in the weekly microcycle.

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45 25 **Key Words:** fatigue, recovery, team sport
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26 Introduction

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

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

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

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3 60 or frequency of collisions sustained during rugby union training (e.g. rucks and tackles).
4 61 Furthermore, the 'off-side touch' style of small-sided games may have imposed different
5 62 physical demands on players than experienced in rugby union training.
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8 63 Therefore the aim of the present study was to examine the changes in markers of
9 64 fatigue in response to contact and non-contact field-based training in rugby union players.
10 65 This research would provide practitioners with important information regarding the fatigue
11 66 response to field-based training inclusive or exclusive of contact, and thus allow appropriate
12 67 scheduling of such training in the weekly microcycle.
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18 69 **Methods**

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23 72 *Subjects*

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27 74 Twenty male players (age 17.6 ± 0.8 years; height 183.5 ± 7.4 cm; body mass $87.1 \pm$
28 75 11.9 kg) were recruited from a professional rugby union academy. Participants were excluded
29 76 if they had an injury that prevented them from participating in the testing, or missed any
30 77 testing session. Ethics approval was granted by the University ethics board and written
31 78 informed assent was acquired from all subjects along with parental consent.
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36 80 *Design*

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40 82 A cross-over design was used to assess the magnitude of change in markers of upper-
41 83 and lower-body NMF, whole-blood [CK] (an indirect measure of muscle damage) and
42 84 perception of wellbeing following contact (CON) and non-contact (nCON) rugby union field-
43 85 based training. The study was conducted during the fifth and sixth week of a pre-season
44 86 period in order to ensure that players were adequately reconditioned following the off-season
45 87 period to prevent an exaggerated fatigue response to training. Testing was undertaken pre-
46 88 and immediately post-training, and 24 hr following the pre-training measures (Figure 1).
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58 93 *Training Intervention*

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The training sessions were designed to replicate a typical training session undertaken at the club. Each training session began with two 8-minute skill blocks (15 x 20 m pitch) during which players performed tackling (CON training) or passing (nCON training) drills.

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The players were then divided into teams of 5, with each team containing the same amount of forwards and backs (3 forwards and 2 backs) with the exception of one team, which consisted of 2 forwards and 3 backs. The teams each played three 3-minute small-sided games (5 versus 5; 15x20 m pitches) with 90 s of rest in between each game. Following this, players were then divided into 2 teams of 10, one consisting of 5 forwards and 5 forwards and the other of 6 forwards and 4 backs. The teams competed during three 3-minute (10 versus 10; 20x30m m pitch) with 90 s of rest between each game. The order of games and members of teams were kept the same for both CON and nCON training sessions.

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The CON games consisted of full-contact tackles with up to two players from each team, inclusive of the tackler, contesting possession within the ruck area. Each team was allowed unlimited time to attack until one of the following occurred; a try was scored, a turn-over or penalty was conceded in the ruck area, or an error was made (i.e. forward pass or ball knocked forward). The nCON games consisted of non-collision tackles, which, in order to be deemed successful, involved the defending player touching the ball carrier with two hands. If a player was successfully tackled, both the attacking player and defender were required to lie down on the ground to simulate a tackle. Additionally, a secondary attacker and defender were required to position themselves beside the tackle area, simulating a ruck. Again, each team had unlimited possession until a try was scored, a turn-over or penalty was conceded in the ruck area, or an error was made. The games were refereed by experienced coaches in order to ensure that the rules were adhered to. No encouragement was given during the games, but technical coaching was provided during the rest periods.

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INSERT FIGURE 1 HERE

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Figure 1: Schematic of study design. Testing was inclusive of lower-body and upper-body neuromuscular function, whole blood creatine kinase concentration and perception of wellbeing.

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Neuromuscular Function

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3 128 Lower-body NMF was measured using mean power calculated from a
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5 129 countermovement jump (CMJ), while upper-body NMF was measured using flight-time
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7 130 calculated from a plyometric push-up. These measures have previously demonstrated good
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9 131 reliability in this population (typical error = 2.5 to 4.2%) (Roe et al., 2015). It has been
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11 132 recommended that a minimum sampling frequency of 200Hz be used for such measurement
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13 133 (Hori et al., 2009). Therefore the CMJ and plyometric push-up were performed on a portable
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15 134 force plate (400 Series Performance Plate, Fitness Technology, Adelaide, Australia) that was
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17 135 attached to a laptop with software (Ballistic Measurement System, Fitness Technology,
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19 136 Adelaide, Australia) that measured ground reaction forces at 600 Hz. A standardised 2-
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21 137 minute warm-up consisting of dynamic stretching was performed prior to the performance
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23 138 tests (walking lunges, squats, heel flicks, high knees, skipping, legs swings and 3 practice
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25 139 submaximal CMJ and Plyometric-push ups). Following the warm-up, players performed 2
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27 140 maximal CMJ followed by 2 maximal plyometric push-ups with 1-minute rest between each
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29 141 effort (Roe et al., 2015).
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32 143 *Creatine Kinase*

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34 145 Whole blood [CK] samples were collected from the non-dominant hand, middle
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36 146 fingertip of each subject. Approximately 30 µl of whole capillary blood was collected using a
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38 147 plastic capillary tube (MICROSAFE®, Safe-tec, Numbrecht, Ivyland, USA) and immediately
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40 148 analysed using reflectance photometry (Refletron® Plus, Boehringer Mannheim, Germany).
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42 149 Prior to each session, the machine was calibrated using a standardised CK strip.. The
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44 150 reliability of this method has previously been reported (CV = 26.1%) (Roe et al., 2015).
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47 152 *Wellbeing*

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49 154 A 6-item questionnaire was adapted from McLean et al (2010) to rate each of sleep,
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51 155 fatigue, muscle soreness (upper- and lower-body), stress and mood on a 5-point Likert scale.
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53 156 Each item was rated from 1 to 5 in 1 score increments and overall wellbeing was assessed by
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55 157 summing all 6 scores. Reliability of this method has previously been reported (CV = 7.1%)
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57 158 (Roe et al., 2015). The questionnaire was administered prior to any other testing being
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59 159 undertaken (McLean et al., 2010). Participants completed the questionnaire on their own in
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61 160 order to prevent any influence from other players (Twist, Waldron, Highton, Burt, & Daniels,
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63 161 2012).

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163 *Training Load*

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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™ slow, an accelerometer metric validated for quantifying the
174 collision activity of rugby union players (Roe, Halkier, Beggs, Till, & Jones, 2016).

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176 *Statistical Analysis*

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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 ($ES \pm 0.2$), the magnitude of change was described as *unclear* (Hopkins et al., 2009).

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191 **3. Results**

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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 ($-6.5 \pm 3.1\%$)
195 immediately post-training, but demonstrated *likely* trivial changes at 24 hrs ($1187 \times/\div 1.17$, -

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3 196 2.3_±2.4%) (A). In response to nCON, CMJ mean power *likely* decreased from 1229_{×/±}
4 197 1.15 W to 1161_{×/±}1.18 W (-5.5_±3.3%) and 1162.6_{×/±}1.17 W (-5.4_±5.2%) immediately
5
6 198 and 24 hr post-training respectively (A)). Decreases in CMJ mean power were *unclear*
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8 199 between CON and nCON immediately post-training, while *possibly* greater in nCON than
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10 200 CON 24 hr post-training. Changes in CMJ mean force (D) were *almost certainly* trivial for
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12 201 both CON and nCON at all time-points.
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15 203 INSERT FIGURE 2 HERE
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18 205 Changes in upper-body NMF function are presented in figure 3. In response to CON,
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20 206 plyometric push-up flight time *likely* decreased from 0.394_{×/±}1.19 to 0.372_{×/±}1.18 s (-6.4_±
21 207 ±3.9%) and 0.365_{×/±}1.22 s (-7.3_±4.7%) immediately and 24 hr post-training respectively
22
23 208 (A). Following nCON, plyometric push-up demonstrated a *likely* trivial change from 0.399
24
25 209 _{×/±}1.18 s to 0.410_{×/±}1.20 s (1.6_±2.5%) but a *possible* increase at 24 hr post-match (0.412
26
27 210 _{×/±}1.15 s, 2.7_±5.9%) (A). Decreases in plyometric push-up flight time (C) were *very likely*
28
29 211 greater in CON than nCON immediately post-training, while *likely* greater in CON than
30
31 212 nCON 24 hr post-training. Decreases in mean force (D) were *likely* to *almost certainly* trivial
32
33 213 for both CON and nCON at all time-points.
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35 215 INSERT FIGURE 3 HERE
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38 217 Changes in [CK] and perception of wellbeing are presented in Figure 3. Following
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40 218 CON, [CK] *almost certainly* increased from 414_{×/±}1.76 IU/L to 691_{×/±}1.47 IU/L (66.9_±
41 219 ±22.5%) immediately post training and continued to rise to 779_{×/±}1.56 IU/L (88.2_±40.7%)
42
43 220 24 hr post-training (A). Following nCON, [CK] *almost certainly* increased from 395_{×/±}1.80
44
45 221 IU/L to 543_{×/±}1.61 IU/L, but returned to near pre-training concentration levels (410_{×/±}
46
47 222 1.59 IU/L) at 24 hrs post-training (A). Increases in [CK] were *likely* greater in CON than
48
49 223 nCON (immediately post-training, while *almost certainly* greater in CON than nCON -24 hr
50
51 224 post-training (A). Perception of well-being was *almost certainly* reduced from 19.8_{×/±}1.15
52
53 225 to 18.2_{×/±}1.15 (-8.0_±4.8%) 24 hr after CON (D), while *likely* reduced from 21.5_{×/±}1.12
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55 226 to 20.8_{×/±}1.13 (-3.4_±2.2%) following nCON (D). Decreases in perception of wellbeing
56
57 227 were *likely* greater in CON than nCON at 24 hr post-training. When questionnaire items
58
59 228 were analysed individually, there was an *almost certain* and *likely* greater change in
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229 perception of upper-body and lower-body soreness following CON, while the differences
230 between changes in other items were *unclear*.

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232

INSERT FIGURE 4 HERE

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234 Total distance was *almost certainly* greater (27.5 ± 5.3 %) during nCON ($2543 \times / \div$
235 1.09 m) than CON ($1968 \times / \div 1.14$ m). Relative distance was *almost certainly* greater ($19.8 \pm$
236 5.0 -%) during nCON ($79.4 \times / \div 1.09$ m.min⁻¹) and CON ($65.1 \times / \div 1.18$ m.min⁻¹). Player
237 LoadTM slow was *almost certainly* greater (56.5 ± 5.7 %) during CON ($165 \times / \div 1.17$ AU)
238 than nCON ($108 \times / \div 1.13$ AU). Mean heart rate was *almost certainly* greater (9.7 ± 3.9 -%)
239 during CON ($166 \times / \div 1.07$ bpm) than nCON ($152 \times / \div 1.08$ bpm) while sRPE was also *almost*
240 *certainly* greater (42 ± 29.2 %) following CON ($417 \times / \div 1.56$) than nCON ($294 \times / \div 1.35$).

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 decreased 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 $54 \pm 32\%$ above pre-training measures at 24 hr post-training, which is lower
277 than in the present study ($88.2 \pm 40.7\%$). 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 concentrations levels of [CK] ($414 \times / \div 1.74$
287 IU/L) in the present study were high relative to in-season concentration level s ($212 \times / \div 1.96$
288 IU/L) formerly reported in this cohort (Roe, Till, et al., 2016). It has previously been
289 demonstrated that [CK] concentration levels increases during times of high training stress, but
290 may return to baseline concentration levels 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

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3 296 [CK] reported may be understated. Therefore future research is required in a more controlled
4 297 setting in order to determine the [CK] response of rugby union players to field-based training.

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6 298 Although post-training elevations in [CK] may be primarily attributed to tissue
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8 299 damage as a result of blunt trauma during collisions in rugby union, other non-contact
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10 300 mechanisms may have also played a part. From Figure 2 it can be seen that there was an
11 301 *almost certain* acute elevation in [CK] immediately post-training following nCON. This
12 302 acute increase in [CK] may be attributed to eccentric muscle damage as a result of high-speed
13 303 locomotion (Jones et al., 2014; Wiewelhove et al., 2015). Nevertheless, this increase was
14 304 *likely* trivial at 24 h post-training, suggesting full recovery.

15
16 305 There was a *likely* greater decrease in perception of wellbeing following CON than
17 306 nCON. In addition, sRPE was *almost certainly* greater following CON than nCON. This is in
18 307 contrast to findings from the aforementioned study by Johnston et al (2014), where
19 308 differences between CON and nCON were *unclear* for both measures. As previously
20 309 discussed, the frequency and magnitude of contact in the present study was likely to be
21 310 greater during CON, as demonstrated by the large accumulation of Player LoadTM slow, thus
22 311 resulting in a larger perception of effort during, and the greater reductions in wellbeing 24 hr
23 312 following CON. Indeed, the accumulation of accelerometer load during training has been
24 313 shown to have large to very large relationships with sRPE in rugby league players (Lovell,
25 314 Sirotic, Impellizzeri, & Coutts, 2013). Furthermore, perception of upper- and lower-body
26 315 muscle soreness were *almost certain* and *likely* greater following CON than nCON
27 316 respectively, which would have contributed to the greater reduction in perception of
28 317 wellbeing.

29 318 In addition to sRPE, CON also resulted in *almost certainly* greater heart rate than
30 319 during nCON. Similarly, previous research by Johnston and colleagues (2011) demonstrated
31 320 greater mean heart rate and sRPE when tackles were added to a repeated sprint training
32 321 session. These findings demonstrate the greater physiological and subjective load of collision-
33 322 based training, which is reflected in the negative changes in the majority of post-training
34 323 measures of fatigue in the present study.

35 324 In contrast to upper-body NMF, a *possibly* greater reduction in lower-body NMF was
36 325 observed following nCON than CON 24 hr post-training. This may be the result of the *almost*
37 326 *certainly* greater locomotive demands of nCON, and the eccentric damage associated with
38 327 high-speed running (Jones et al., 2014; Wiewelhove et al., 2015). In comparison, Johnston et
39 328 al (2014) reported *likely* greater reductions in lower-body NMF following non-contact versus
40 329 contact small-sided games in rugby league players. The greater probability of reduction

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3 330 above the SWC may be explained by the difference in demands of the particular games
4 331 played. Johnston et al. (Johnston et al., 2014) implemented 'off-side touch' which resulted in
5 332 a very high running intensity (140 m/min), which are not representative of a match
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7 333 (95.8±18.6 m/min (Twist et al., 2014)). In contrast, the games in the present study resulted in
8 334 a greater distance covered (2552m versus 2240m), but at a much lower running intensity
9 335 (79.9 m/min), although this is more representative of match-play (74±6 m/min (Roe, Till, et
10 336 al., 2016)). Collectively however, these findings demonstrate that the exclusion of contact
11 337 from field-based training increases the locomotive demands of field-based training and
12 338 results in greater decreases in lower-body NMF 24 hr post-training. Such information can be
13 339 used by practitioners when scheduling activities that require high levels of lower-body power
14 340 (e.g. power or sprint training) during the weekly microcycle.

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16 341 The results of the present study also demonstrate the individual nature of fatigue
17 342 response to field-based training in rugby union players, similar to those found following
18 343 match-play (Roe, Till, et al., 2016) From Figures 1 to 3 (B, C, E and F) it can be seen that
19 344 players often differed from the group mean response, some presenting with greater changes
20 345 in fatigue markers, while others not experiencing any fatigue at all. These findings emphasise
21 346 that although understanding a group response provides valuable information on fatigue
22 347 induced by field-based training inclusive or exclusive of contact, it is important for
23 348 practitioners to monitor fatigue response of each individual player following training.
24 349 Furthermore, future research is needed to understand the mechanisms that contribute to such
25 350 individual responses.

26
27 351 A limitation of the present study is the lack of follow up past 24 hr. However, data
28 352 collection at 48 hr post-training was not possible due to the players' training schedule. In
29 353 addition, although players were instructed not to engage in any contact during nCON,
30 354 accidental collisions with other players did occur. A further limitation of the present study is
31 355 that participants were not randomised, and a control group was not included. However, due to
32 356 this research being conducted in an applied setting where players were required to adhere to a
33 357 strict training schedule, such methods could not be employed. Finally, although the training
34 358 sessions were designed to replicate a typical field-based training session at the rugby club,
35 359 these sessions may not be representative of training at other clubs. Therefore caution should
36 360 be advised when applying the findings from this study to different training situations.

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362 **Conclusions**

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3 364 The inclusion of contact during field-based training increases subjective and objective
4 365 measures of internal training load and results in greater upper-body neuromuscular and
5 366 perceptual fatigue, and greater elevations in [CK]. The exclusion of contact from field-based
6 367 training increases running intensity and distance, resulting in greater lower-body
7 368 neuromuscular fatigue. Practitioners should be aware of the different fatigue responses of
8 369 contact and noncontact field-based training and can use this information to appropriately
9 370 schedule such training in the weekly microcycle. Furthermore, the results demonstrate the
10 371 individual responses of players to contact and non-contact field-based training, highlighting
11 372 the need for the individual monitoring of players.
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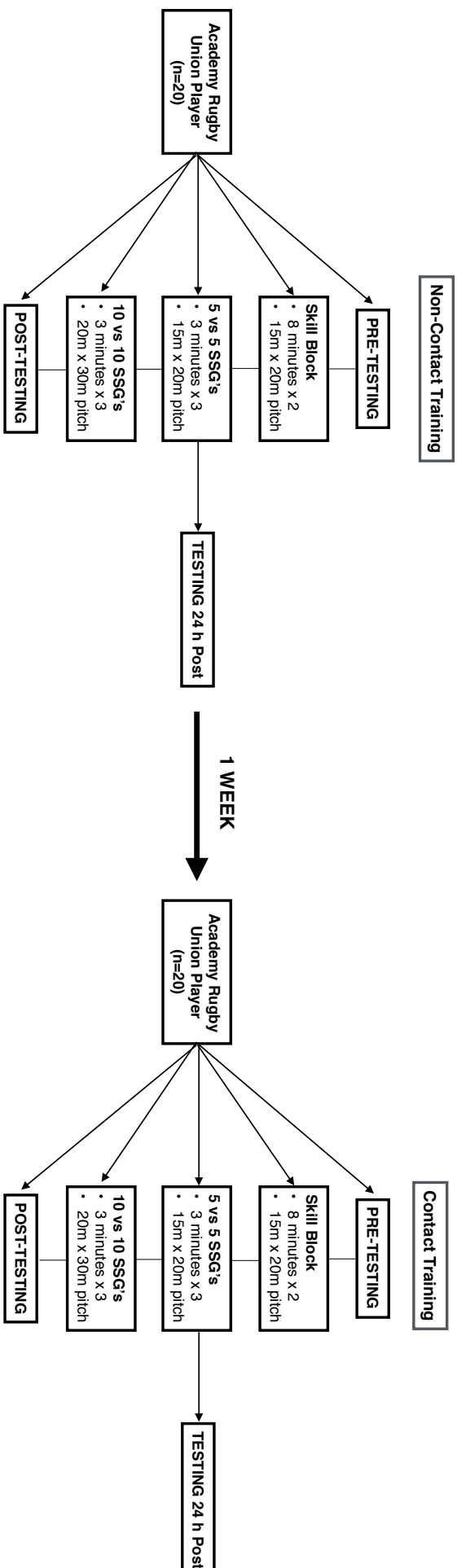
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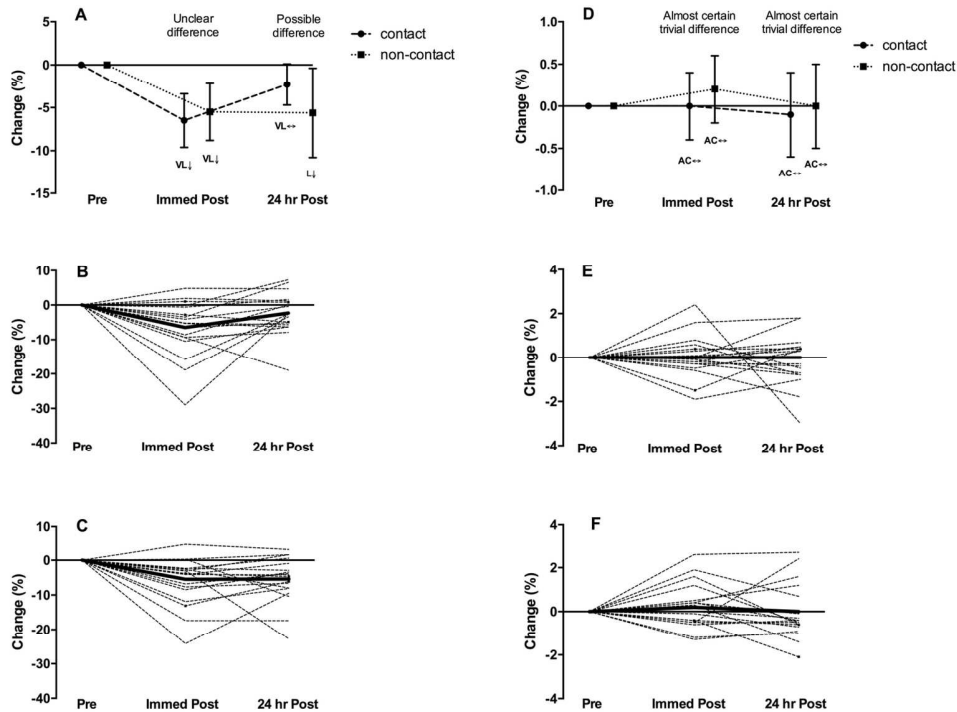
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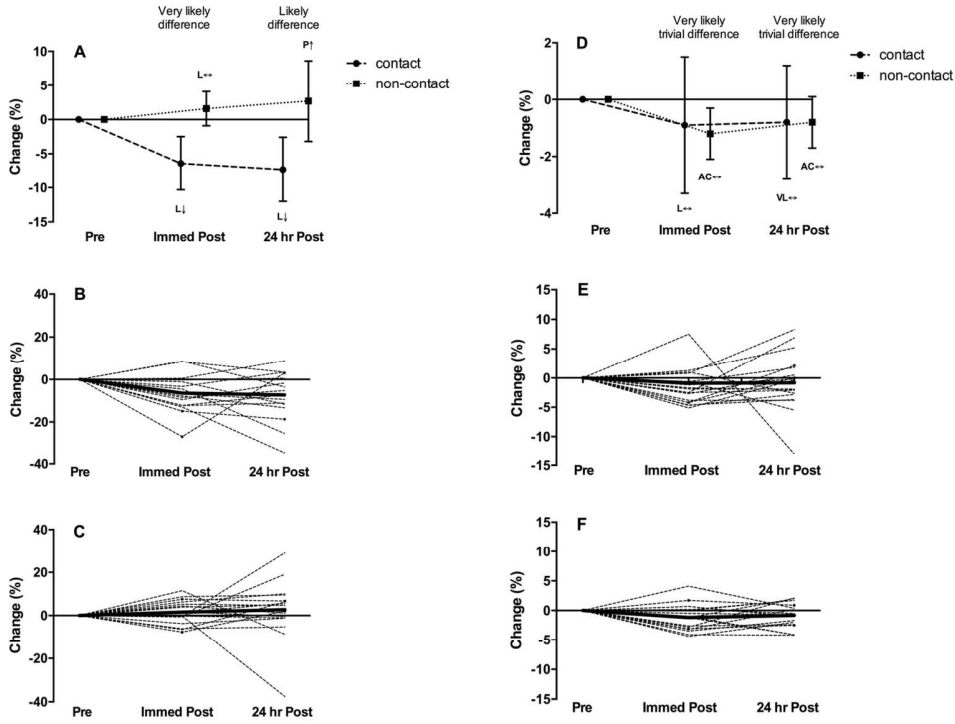




Graphs are mean changes in CMJ mean power (A) and mean force (D). Change data are percentage change with 90% confidence interval bars. Above graph ratings of probability refer to between-group comparisons. Below graph ratings of probability refer to within-group changes; P = possibly, L = likely, VL = 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).

133x100mm (300 x 300 DPI)

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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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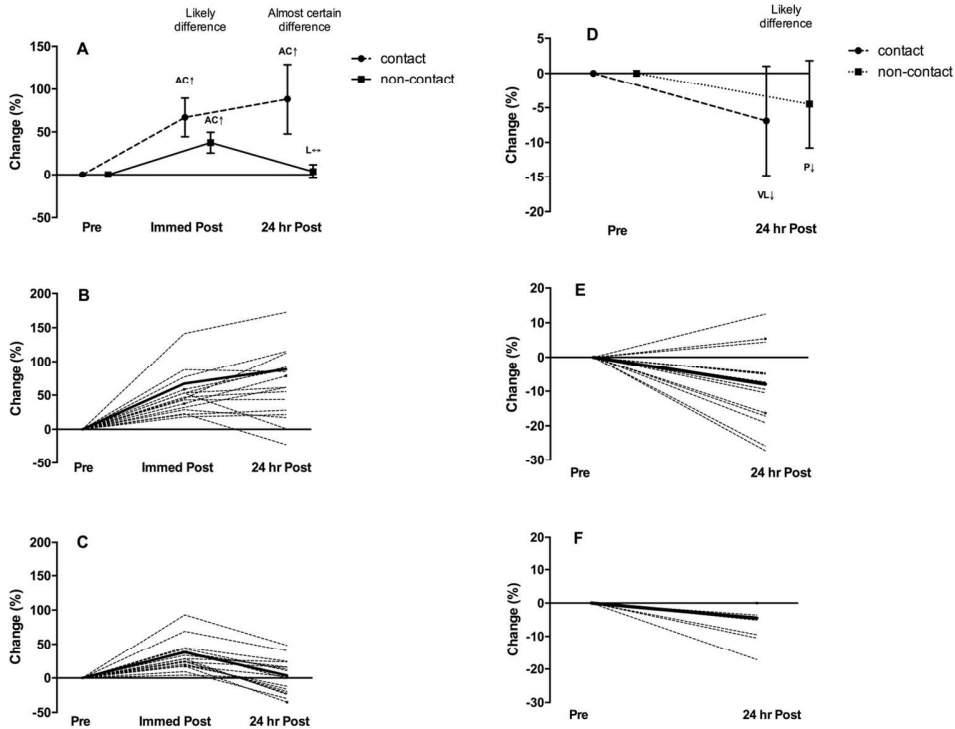


Figure 4: Graphs are mean changes in creatine kinase (A) and wellbeing (D). Change data are percentage change with 90% confidence interval bars. Above graph ratings of probability refer to between-group comparisons. Below graph ratings of probability refer to within-group changes; P = possibly, L = likely, 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)

Only