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## **Workload and non-contact injury incidence in elite football players competing in European leagues.**

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Gregory Dupont

► **To cite this version:**

Barthelemy Delecroix, Benoit Delaval, Brian Dawson, Serge Berthoin, Gregory Dupont. Workload and non-contact injury incidence in elite football players competing in European leagues.. European Journal of Sport Science, 2018, European journal of sport science, pp.1-8. 10.1080/17461391.2018.1477994 . hal-02378973

**HAL Id: hal-02378973**

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Submitted on 25 Nov 2019

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**Title: Workload and injury incidence in elite football academy players.**

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# 1 **Workload and injury incidence in elite football academy players.**

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3  
4 2 Abstract

5 3  
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7 4 The aim of this study was to prospectively analyse the relationship between  
8 5 workloads and injury in elite football academy players.

10 6  
11 7 Elite football academy players (n = 122) from under-19 (U19) and under-21  
12 8 (U21) of a professional football team competing in UEFA European Cups were  
13 9 followed during 5 seasons. Injuries were collected and absolute workload and  
14 10 workload ratios (4-weeks, 3-weeks, 2-weeks and week-to-week) calculated using  
15 11 a rolling days method with the help of the session Rate of Perceived Exertion.

18 12  
19 13 There was no association between absolute workload or workload ratio with the  
20 14 injury incidence in the U19. In the U21, the level of cumulative absolute  
21 15 workloads during 3-weeks (RR=1.39, p=0.026) and during 4-weeks (RR=1.40,  
22 16 p=0.019) were associated with an increase in injury. There was no association  
23 17 between workload ratio and injury in U21.

24 18  
25 19 The significant link between high cumulated 3-weeks and 4 weeks workloads and  
26 20 injury in U21 confirmed the requirement to monitor the internal subjective  
27 21 workload in U21 in order to prevent injury. Further studies exploring the  
28 22 relationships between workload and injury are required in football academy.

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## 25 Introduction

26 Mean injury incidence (match and training) across seven UEFA clubs during seven  
27 seasons was reported as eight injuries per 1,000 hours of exposure, which corresponds  
28 to 50 injuries per season in a team of 25 players, or two injuries per player per season  
29 (Ekstrand, Hagglund, & Walden, 2011). This injury incidence is 1,000 times higher than  
30 in typical industrial occupations considered as highly risked (Drawer and Fuller, 2002).  
31 During the 2012 Olympics, the football competition represented the highest level of  
32 injury, with 35.2% of total number of injuries during the Olympics (Engebretsen et al.,  
33 2013). This high injury incidence highlights the importance of injury prevention in elite  
34 football.

36 According to the model of van Mechelen (1992) about the prevention of sports  
37 injuries, once the injury incidence and severity have been evaluated through  
38 epidemiological studies, the second step to prevent injury risk is to identify the risk  
39 factors and injury mechanisms. The third step is to introduce measures that are likely to  
40 reduce the future risk and/or severity of injuries. The last step is characterised by  
41 assessing the effect of the measures by repeating the first step (Van Mechelen, Hlobil,  
42 & Kemper, 1992). According to this model, several injury risk factors have been  
43 identified. In a survey, McCall et al. (2014a) reported that elite football  
44 medicine/science practitioners considered previous injury as the most important injury  
45 risk factor (121 points of importance on a score of 132). In their systematic review,  
46 McCall et al. (2014b) confirmed the practitioners' perceptions: previous injury was the  
47 injury risk factor with the highest level of scientific evidence (level 2++ according to  
48 the system for graded recommendations guidelines published in British Medical  
49 Journal) (Harbour and Miller, 2001). A previous hamstring, calf, groin or knee injury

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increases two to three times the risk to sustain a new injury in the same body part during the following season (Hagglund et al., 2013). A previous injury also increases the overall injury risk, and not only in the previously injured body part (hazard ratio = 2.7, CI95% 1.7 to 4.3) (Hagglund et al., 2006). As a previous injury is a non-modifiable internal injury risk factor, it is important to prevent initial injuries which occur during the youth academy period. The fact to have already been injured during this period would become a non-modifiable risk factor in their future professional career. Moreover, during an injury period, youth players do not have the same training protocol, it could represent an additional gap to bridge in their improvements. Several studies examined the injury incidence in elite youth football academy. In a systematic review of literature, Pfirrmann et al. (2016) reported, in youth academies, an overall injury incidence from 2.0 to 19.4 injuries per 1,000h of exposition and a training injury incidence in youth academies from 3.7 to 11.4 injuries per 1,000h of training. For the last year spent in the academy, the overall injury incidence of U18 and U19 (between 6.8 and 10 per 1,000h of exposition) (Nilsson et al., 2016 ; Renshaw & Goodwin, 2016) is comparable to the one reported in elite professional football players (7.6 injuries per 1,000h of exposition) (Ekstrand, Hagglund, Kristenson, Magnusson & Walden, 2013). These results concerning the high injury incidence in youth football academy highlights the needs to identify injury risk factors with this population in order to implement injury prevention strategies, especially to reduce the risk to sustain a first injury. Although a few studies have already dealt on the identification of the risk factors and injury prevention in youth academy (Bowen et al., 2017), most of the studies dealt on high-level professional players (Ekstrand, Hagglund, & Walden, 2011; Hagglund, Walden, & Ekstrand, 2013).

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74 In their survey, McCall et al. (2014a) reported that the practitioners considered  
75 the fatigue (105 points of importance on a maximal score of 132) as the second most  
76 important injury risk with professional football players. Fatigue could come from the  
77 repetition of training and matches. Several studies found a significant association  
78 between workload and injury incidence among professional football players (Malone et  
79 al., 2017; Lu et al., 2017 ; Jaspers et al., 2017). Two reviews of literature concluded that  
80 internal/subjective tools were more sensitive and related to injury incidence than  
81 external and/or objective tools (Saw, Main, & Gustin, 2016; Jones, Griffiths, &  
82 Mellalieu, 2017). Jones, Griffiths, & Mellalieu (2017) included 21 studies evaluating  
83 the association between internal workload and injury incidence in sports in a systematic  
84 review of literature. The majority (90%) of these studies concerned team sports. The  
85 authors concluded that there was a moderate evidence that the internal workload was  
86 associated with injury incidence. In professional football, Malone et al. (2017)  
87 identified that an absolute workload calculated with sRPE higher than 1,500 arbitrary  
88 units (A.U.) was associated with an elevated injury risk, and that an acute:chronic  
89 workload ratio calculated with the sRPE between 1.00 and 1.25 was associated with a  
90 lower injury incidence in elite football players. In youth elite football players, one study  
91 identified an association between the one week absolute workload calculated using the  
92 session Rate of Perceived Exertion (sRPE), using a modified perception scale (Borg,  
93 CR-10) and the injury incidence (OR=1.01, 95%CI 1.00 to 1.06) (Brink et al., 2010).  
94 However, in this study, the workload was calculated only for 1 week, while associations  
95 between external workload and injury incidence during 2, 3 or 4 cumulative weeks and  
96 A:C ratios have been identified (Bowen et al., 2017). To our knowledge, no study aimed  
97 at evaluating the association of absolute internal workload during several weeks, and  
98 acute:chronic internal workload ratio and injury in a elite football academy. Therefore,

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99 the aim of this study is to analyse the relationships between several combinations of  
100 internal workload using the sRPE and the injury among football players in an elite  
101 football academy.

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## 103 **Materials and Methods**

### 104 *Subjects*

105 One hundred twenty-two elite young football players (height:  $178.6 \pm 6.8$ cm; body  
106 mass:  $70.9 \pm 7.3$ kg) from U19 (n=52; age:  $16.8 \pm 0.9$ ) and U21 (n=70; age:  $20.1 \pm 0.3$ )  
107 squads of a football academy in an elite football club playing in first French League and  
108 taking part regularly in European competitions were followed during four and five  
109 seasons respectively. All players from the U19 and the U21 squads were included in the  
110 study. The players lived in the academy. If a player joined the team during the  
111 observational period, he was included from the date he joined the team. A player who  
112 left the team during the observational period was excluded from the study from the date  
113 he left the team. If a player was already injured at the start of data collection, he was  
114 included in the study but this injury was excluded (Fuller et al., 2006). All players were  
115 informed and consented to take part in the study. This study was conducted in  
116 accordance with the local ethical committee on biomedical research (CCTIRS#10544)  
117 and the standards of the declaration of Helsinki.

118

### 119 *Methodology*

120 This study was a prospective cohort study. An injury was defined, in accordance with  
121 the FIFA consensus, as any physical complaint sustained by a player that resulted from  
122 a football match or football training, that made the player unable to participate in future  
123 football training or a match (Fuller et al., 2006).

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2 125 The workload was calculated by the sRPE method. This method is valid  
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5 126 for its use with athletes and football players (Foster, 1998 ; Impellizzeri et al., 2004).  
6  
7 127 Players were instructed to rate the global intensity of all sessions and matches using a  
8  
9 128 modified category ratio scale going from 0 to 10 based on the scale developed by Borg  
10  
11 129 (1987) by answering the following question: ‘How was your workout?’. The sRPE was  
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13  
14 130 collected 30 minutes after completion of the session/match by a sport clinician working  
15  
16 131 in the club responsible for the collection of the data. The players were isolated to  
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19 132 answer in order not to be influenced by other players. Workload, expressed in arbitrary  
20  
21 133 units (AU) was calculated by multiplying the perceived intensity by the session or  
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23  
24 134 match duration (Foster et al., 2001); all training sessions and all matches were included.  
25  
26 135 All the training sessions and matches were on natural grass. The workload was  
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29 136 calculated on a daily basis with the methods of rolling days blocks (everyday, a new  
30  
31 137 workload was calculated based on the preceding days) (Hulin et al., 2016; Bowen et al.,  
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33  
34 138 2017). The absolute workload was the sum of the load for the last 7 days (one-week  
35  
36 139 workload), 14 days (2-weeks workload), 21 days (3-weeks workload) and 28 days (4-  
37  
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39 140 weeks workload) were calculated. To determine A:C ratios, the one-week workload was  
40  
41 141 divided by the total workload of the last 28 days, divided by 4 for the 4-weeks A:C ratio  
42  
43 142 (formula: one-week workload / (last 28 days workload/4)), the total load of the last 21  
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46 143 days divided by 3 for the 3-weeks A:C ratio (one-week workload / (last 21 days  
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49 144 workload/3)) and the total load of the last 14 days divided by 2 for the 2 weeks A:C  
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51 145 ratio (one-week workload / (last 14 days workload/2)) (Malone et al., 2017). The week-  
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53 146 to-week load changes were also calculated by dividing the 1-week load by the  
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56 147 accumulated load of the previous 7 days. The workload was known by the practitioners  
57  
58 148 who could use the data to regulate the workload. In U19, the group (and not individual)



149 workload was regulated on a weekly basis by the practitioners. The workload was  
150 analysed in the end of each week and the practitioners aim was to reach a weekly mean  
151 of 2,500 A.U, because they considered it was the optimal workload to reduce the injury  
152 risk while improving players fitness qualities. The data were not taken into account in  
153 U21 to regulate the workload.

154

### 155 *Statistical Analysis*

156 A Poisson regression analysis was performed with IBM SPSS Statistics Version 20 for  
157 the 1-week, 2-weeks, 3-weeks and 4-weeks absolute workload and the A:C workload  
158 ratios to assess the link between these factors and injury incidence and calculate relative  
159 risk (RR). The absolute workload and the A:C workload ratios were log-transformed  
160 when the scores were not normally distributed.

161 The daily probability to sustain an injury was calculated by dividing the number of  
162 injuries by the number of days of observation, multiplied by 100.

163

### 164 **Results**

165 A total of 122 players have been followed during the period of observation. The number  
166 of players in each squad, season by season, are described in table 1. In U19 category, a  
167 total 52 players were followed (24 players were followed during one season, 26 players  
168 were followed during two seasons, 2 players were followed during 3 seasons). In U21  
169 category, a total of 70 players were followed (41 players were followed during one  
170 season, 16 players were followed during 2 seasons, 8 players were followed during 3  
171 seasons, 4 players were followed during 4 seasons and one player was followed during  
172 the 5 seasons of observation). It represents a total of 200 player-seasons, 17,778 days in  
173 the U19 and of 26,672 days in the U21 were recorded.

174 \*\*\* TABLE 1 NEAR HERE

175 A total of 182 injuries were recorded in the U19 category (119 non-contact + 63  
176 contact injuries) and of 307 injuries (215 non-contact + 92 contact injuries) were  
177 recorded in the U21 category. It represents a global injury incidence of 7.6 injuries per  
178 1,000h of exposition for the U19 and of 9.6 injuries per 1,000h of exposition for the  
179 U21. The daily probability to sustain an injury was 1.02% in U19 and 1.15% in U21.

180 In U19, the mean weekly workload was  $2046 \pm 705$  AU; the mean 2 weeks  
181 workload was  $3813 \pm 1291$  AU; the mean 3 weeks workload was  $5501 \pm 1831$  AU and the  
182 mean 4 weeks absolute workload was  $7104 \pm 2334$  AU. No link was found between  
183 absolute workload, cumulative absolute workload (2 weeks, 3 weeks, 4 weeks) and  
184 global, non-contact or contact injuries with U19 players. These results are described in  
185 table 2. No link was found between none of the A:C workload ratio and global, non-  
186 contact and contact injuries with U19 players, as described in table 3.

187 \*\*\* TABLE 2 NEAR HERE

188 \*\*\* TABLE 3 NEAR HERE

189  
190 In U21, the mean weekly workload was  $1979 \pm 666$  AU; the mean 2 weeks  
191 workload was  $3783 \pm 1211$  AU; the mean 3 weeks workload was  $5497 \pm 1740$  AU and the  
192 mean 4 weeks workload was  $7145 \pm 2254$  AU. The results concerning the link between  
193 absolute workload and global, non-contact and contact injuries in U21 are described in  
194 table 4. An association was found between the cumulative 3 weeks absolute workload  
195 and injury incidence ( $RR=1.39$ ,  $p=0.026$ ) and between the cumulative 4 weeks absolute  
196 workload and injury incidence ( $RR=1.40$ ,  $p=0.019$ ). There was no association between  
197 the A:C workload ratio and the injury incidence with U21 players. The results are  
198 described in table 5.

199 \*\*\*TABLE 4 NEAR HERE

200 \*\*\*TABLE 5 NEAR HERE

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202

203 **Discussion**

204 The aim of this study was to analyse the relationship between workload and injury  
205 incidence in elite football academy players. The main findings showed that there was no  
206 association between absolute or A:C workload ratio with U19 players, while there was  
207 an association between 3 weeks and 4 weeks cumulative absolute workload with U21  
208 players.

209  
210 In the current study, the overall injury incidence was 7.6 injuries per 1,000h of  
211 exposition with U19 and 9.6 injuries per 1,000h of exposition with U21 players. These  
212 results confirm those of previous studies with an overall injury incidence between 6 and  
213 10 injuries per 1,000h of exposition with players in U18 and U19 categories (Nilsson et  
214 al., 2016; Renshaw & Goodwin, 2016). This injury incidence is also close to the injury  
215 incidence of elite professional football teams (8 injuries per 1,000h of exposition)  
216 (Ekstrand, Hagglund, & Walden, 2011). When transforming these results into daily  
217 probability, the overall daily probability to sustain an injury in U19 is 1.02% per player  
218 and in U21 is 1.15% per player. The daily probability to sustain an injury per player  
219 highlights that even if the injury incidence is very high compared to other activities  
220 (Ekstrand, 2013), the daily probability to sustain an injury in a youth academy is low,  
221 being approximately 1%.

222

223 No link between absolute workload, A:C workload ratio and injury incidence  
224 was found for the U19. These results about the lack of significant relationship between  
225 absolute workload and the occurrence of injury are different of a previous study led by  
226 Brink et al. (2010), who found an association between internal workload calculated  
227 using the sRPE and the injury incidence. However, the methodology used are different.  
228 First of all, Brink et al. analysed the sum of the workload week after week, while in the  
229 current study, a rolling days method was used to analyse the workload day after day.  
230 This is a major difference between the two studies as an injury at the beginning of the  
231 week or in the end of the week could lead to big changes in the weekly workload with  
232 Brink et al.'s methodology (2010). In the study led by Brink et al. (2010), an odd ratio  
233 was calculated, while in the current study, a Poisson regression was used, providing a  
234 relative risk. The injury incidence in Brink et al. study (2010) (37.55 per 1,000h of  
235 match and 11.14 per 1,000h of training) was higher than the one in the present study  
236 (7.6 in U19 and 9.6 in U21). The probability to find a significant association between a  
237 potential risk factor and an event depends on the event frequency. It means that the  
238 higher the injury incidence is, the higher the probability to find a significant statistical  
239 association is (Bahr and Holme, 2003). The method to calculate the workload was not  
240 exactly the same as the authors used a 15-point scale to rate the perceived intensity and  
241 multiply the perceived exertion by the number of hours of practice while a 10-point  
242 scale was used in the present study and the exertion was multiplied by the number of  
243 minutes of practice. It is therefore difficult to compare the workload data range width  
244 while the data range width of the independent factor modifies the results of a regression  
245 (Salgueiro da Silva and Seixas, 2017). Another difference in the results could be  
246 explained by a different definition of injury, as Brinks et al. (2010), defined the injury  
247 as any physical complaint sustained by a player that results from a soccer match or

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248 soccer training and leading to time loss or medical attention. In the present study, only  
249 the complaint leading to time loss were taken into account. Given the very low odd ratio  
250 (OR=1.01, 95% CI 1.00 to 1.02) reported by Brink et al. (2010), these changes in the  
251 methodology could explain the absence of association in the current study and the  
252 differences between the two studies.

253

254 In the U21, no association was found between none of the A:C workload while  
255 an association was found between the cumulative absolute 3 weeks and 4 weeks  
256 workload and the injury incidence. In the current study, no association has been found  
257 with none of the workload calculated over the last 7 days (absolute 1 week workload or  
258 A:C workload ratio). These results does not allow to identify a link between the internal  
259 A:C workload ratios calculated with sRPE and injury incidence with academy players  
260 while this association has been identified with professional players (Malone et al.,  
261 2017). In professional football, an A:C ratio between 1.00 and 1.25 has been identified  
262 as an injury protective factor (Malone et al., 2017). An elevated A:C workload ratio is  
263 the result of the combination of a low chronic workload and a high acute workload  
264 (Blanch & Gabbett, 2016). It means that a low chronic workload or spikes in the  
265 workload calculated with sRPE should be avoided in elite level football players in  
266 order to reduce the injury incidence (Blanch & Gabbett, 2016). Jaspers et al. (2018)  
267 identified that an elevated workload calculated with the help of sRPE during two weeks  
268 was associated with an elevated incidence of overuse injury with elite football players  
269 while a medium workload during four weeks was associated with a decrease in injury  
270 incidence in comparison with a low workload calculated with sRPE. This result  
271 indicates that a minimum level workload should be necessary to avoid an increase in  
272 injury risk, and that a chronic workload too low could be an injury risk factor among

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273 professional football players. These results highlight the association between injury  
274 incidence and acute and chronic workload calculated with sRPE in professional  
275 football. This association has not been found in the present study with academy players.  
276 Differences between players playing in a youth football academy and professional  
277 football players playing in European competitions could be explained by differences in  
278 the changes in acute workload. Large changes in workload sustained by professional  
279 football players could occur during the congested schedule with two to three-games per  
280 week. The schedule in youth category seems to be more regular without congested  
281 periods, leading to smaller changes in the acute workload. These differences in the  
282 competitions schedules could explain the absence of association between A:C workload  
283 ratio and injury incidence in the U19 and U21 age categories.

284

285         The difference in results between U19 and U21 in the present study could be  
286 explained in part by the smaller number of injuries recorded in U19 compared to U21  
287 (182 vs 307), which is explained by a lower incidence (7.6 vs 9.6) and shorter period of  
288 observation in U19 in comparison with the U21 (4 seasons vs 5 seasons). There was a  
289 similar proportion of non-contact injuries between U19 and U21 (65% in U19 vs 71%  
290 in U21), but a lower number of non-contact injuries recorded in U19 (119 vs 215),  
291 which also could explain the absence of association in U19 as non-contact injuries are  
292 considered easier to prevent than contact injuries (Gabbett et al., 2010). As explained in  
293 the introduction, a previous injury is the strongest injury risk factor. In future studies, it  
294 may be interesting to evaluate the effect of a previous injury on the ability of a player to  
295 sustain high workload, as the present results indicate that older players (U21) are more  
296 sensitive to high workload, which may be linked to a higher proportion of previously  
297 injured players with older players.

298

299           This study presents some limitations. First of all, the current study identified an  
300 association between absolute workload and injury incidence with players in a football  
301 academy but it does not necessarily mean that there is a causal connection between  
302 workload and injury incidence (Bahr, 2016). Although very complicated to implement  
303 in the real high-level sport world, other studies and randomised controlled trials should  
304 be assessed to analyse the effect of a controlled workload on the injury incidence, in an  
305 isolated way, to confirm a causal connection (Bahr, 2016). As a cohort study, the design  
306 represents a limit. The observation of the players means that the results are influenced  
307 by players sustaining several injuries and as such are considered as repeated  
308 independent observations while these injuries are multifactorial and are linked to a lot of  
309 factors dependent of the player observed, as, for example, the ability to cope with very  
310 high load and/or to large variations in workload. One of the limits of this study is the  
311 low injury incidence in this study with only 182 injuries for 17,778 days of observation  
312 in U19 and 372 injuries for 26,672 days of observation in U21, representing a daily  
313 probability to sustain an injury of 1.02% in U19 and of 1.15% in U21. This low  
314 probability could explain in part the absence of statistical association in U19 as a low  
315 occurrence of an event reduces the probability to find an association between this event  
316 and an independent factor (Bahr and Holme, 2003). Another limit of the study concerns  
317 the practitioners who recorded the data. If they adapted the workload according to the  
318 data recorded to protect some players with very high or low workloads, it would impact  
319 the results. This limit could also partly explain the absence of results in U19 compared  
320 to the results in U21. In U19, the workload was regulated on a weekly basis by the  
321 practitioners. The objective for the practitioners in U19 was to reach a mean weekly  
322 group workload of 2,500 A.U., and was analysed in the end of each week to decide how

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323 to manage the group workload in the following week. It could explain why the  
324 workload is not associated with the injury incidence in U19. In U21, the data were  
325 known by the practitioners but not used to regulate the workload, which could partly  
326 explain the differences in the results between the two categories.

327  
328           Despite these limits, this study presents some interesting strengths. First of all,  
329 to our knowledge, this is the first study with elite football academy players analyzing  
330 the associations of multiple combinations of internal absolute workload and workload  
331 ratios with injury incidence.

332  
333           With 122 players followed and 200 player-seasons, the cohort of this study was  
334 large compared to other studies in the same topic. It is, to our knowledge, the first  
335 longitudinal study concerning young football players led during a period as long as five  
336 full seasons. The players followed were football players from an elite football academy.  
337 It means that there was a very good control about the workload with no missing data  
338 and a very good control of the outside activities of the players as most of the players  
339 were staying in the academy. It gives a very high level of confidence to the recorded  
340 workload.

341

### 342           *Conclusion*

343 In conclusion, the results of this study indicated that the internal workload calculated  
344 using the sRPE was not associated with injury incidence in U19. In the U21 category,  
345 the absolute workload cumulated during 21 or 28 days is positively associated with the  
346 injury incidence. This result indicates that practitioners working with young football  
347 players could calculate the internal workload and use the sRPE during their late years of



348 academy in order to potentially reduce the injury incidence. Further studies are required  
349 in these age categories to analyse these associations.

350

### 351 **Acknowledgements**

352 The authors thank all the players who took part in the study.

353

### 354 **Declaration of interest statement**

355 The authors report no conflict of interest.

356

### 357 **References**

358 Akenhead, R., & Nassis, G. P. (2016). Training load and player monitoring in high-  
359 level football: current practice and perceptions. *International Journal of Sports*  
360 *Physiology and Performance, 11*, 587-793.

361

362 Bahr R., & Holme I. (2003). Risk factors for sports injuries – a methodological  
363 approach. *British Journal of Sports Medicine, 37*, 384-392.

364

365 Bahr, R. (2016). Why screening tests to predict injury do not work and probably never  
366 will...: a critical review. *British Journal of Sports Medicine, 50*, 776-780.

367

368 Blanch, P., & Gabbett, T. J. (2016). Has the athlete trained enough to return to play  
369 safely? The acute:chronic workload ratio permits clinicians to quantify a  
370 player's risk of subsequent injury. *British Journal of Sports Medicine, 50*, 471-  
371 475.

372

373 Borg, G., Hassmen, P., & Lagerstrom, M. (1987). Perceived exertion related to heart  
374 rate and blood lactate during arm and leg exercise. *European Journal of Applied*  
375 *Physiology and Occupational Physiology, 56*, 670-685.

376

1 377 Bowen, L., Gross, A. S., Gimpel, M., & Li, F. X. (2017). Accumulated workloads and  
2 378 the acute:chronic workload ratio relate to injury risk in elite youth football  
3 379 players. *British Journal of Sports Medicine*, 51, 452-459.  
4 380

5 381 Brink, M. S., Visscher, C., Arends, S., Zwerver J., Post W. J., & Lemmink K. A. P. M.  
6 382 (2010). Monitoring stress and recovery: new insights for the prevention of  
7 383 injuries and illnesses in elite youth soccer players. *British Journal of Sports*  
8 384 *Medicine*, 44, 809-815.  
9 385

10 386 Carey, D. L., Blanch, P., Ong, K. L., Crossley, K. M., Crow, J., & Morris, M. E. (2016).  
11 387 Training loads and injury risk in Australian football-differing acute:chronic  
12 388 workload ratios influence match injury risk. *British Journal of Sports Medicine*,  
13 389 51, 1215-1220  
14 390

15 391 Ekstrand J., Hagglund M., & Walden M. (2011). Epidemiology of muscle injuries in  
16 392 professional football (soccer). *American Journal of Sports Medicine*, 39, 1226-  
17 393 1232.  
18 394

19 395 Ekstrand, J., Hagglund, M., & Walden, M. (2011). Injury incidence and injury patterns  
20 396 in professional football: the UEFA injury study. *British Journal of Sports*  
21 397 *Medicine*, 45, 553– 558.  
22 398

23 399 Ekstrand, J. (2013). Keeping your top players on the pitch: the key to football medicine  
24 400 at the professional level. *British Journal of Sports Medicine*, 47, 723-724.  
25 401

26 402 Foster, C. (1998). Monitoring training in athletes with reference to overtraining  
27 403 syndrome. *Medicine & Science in Sports & Exercise*, 30, 1164-1168.  
28 404

29 405 Foster, C., Florhaid, J. A., Franklin, J., Gottschall, L., Hrovantin, L. A., Parker, S.,  
30 406 Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise  
31 407 training. *Journal of Strength and Conditioning Research*, 15, 109-115.  
32 408

33 409 Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., Hägglund,  
34 410 M., McCrory, P., & Meeuwisse, W. H. (2006). Consensus statement on injury

1 411 definitions and data collection procedures in studies of football (soccer) injuries.  
2 412 *British Journal of Sports Medicine*, 40, 193-201.  
3 413  
4 414 Gabbett, T. J. (2010). The development and application of an injury prediction model  
5 415 for noncontact, soft-tissue injury in elite collision sport athletes. *Journal of*  
6 416 *Strength and Conditioning Research*, 24, 2593-2603.  
7 417  
8 418 Hagglund, M., Walden, M., & Ekstrand, J. (2006). Previous injury as a risk factor for  
9 419 injury in elite football: a prospective study over two consecutive seasons. *British*  
10 420 *Journal of Sports Medicine*, 40, 767-772.  
11 421  
12 422 Hagglund, M., Walden, M., & Ekstrand, J. (2013). Risk factors for lower extremity  
13 423 muscle injury in professional soccer. *American Journal of Sports Medicine*, 41,  
14 424 327-335.  
15 425  
16 426 Harbour, R., & Miller, J. (2001). A new system for grading recommendations in  
17 427 evidence based guidelines. *British Medical Journal*, 323, 334-336.  
18 428  
19 429 Hulin, B. T., Gabbett, T. J., Lawson D. W., Caputi P., & Sampson J. A. (2016). The  
20 430 acute:chronic workload ratio predicts injury: high chronic workload may  
21 431 decrease injury risk in elite rugby players. *British Journal of Sports Medicine*,  
22 432 50, 231-236.  
23 433  
24 434 Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004).  
25 435 Use of RPE-based training load in soccer. *Medicine & Science in Sports &*  
26 436 *Exercise*, 36, 1042-1047.  
27 437  
28 438 Jaspers, A., Brink M. S., Probst, S. G., Frenken W. G., & Helsen W. F. (2017).  
29 439 Relationships between training load indicators and training outcomes in  
30 440 professional soccer. *Sports Medicine*, 47, 533-544.  
31 441  
32 442 Jaspers, A., Kuyvenhoven, J. P., Staes, F., Frencken, W. G. P., Helsen, W. F., & Brink,  
33 443 M. S. (2018). Examination of the external and internal load indicators

1 444 association with overuse injuries in professional soccer players. *Journal of*  
2 445 *Science and Medicine in Sport*, 21, 579-585

3 446

4 447 Jones, C. M., Griffiths, P. C., & Mellalieu, S. D. (2017). Training load and fatigue  
5 448 marker associations with injury and illness: A systematic review of longitudinal  
6 449 studies. *Sports Medicine*, 47, 943-974.

7 450

8 451 Lu, D., Howle, K., Waterson, A., Duncan, C., & Duffield, R. (2017). Workload profiles  
9 452 prior to injury in professional soccer players. *Science and Medicine in Football*,  
10 453 3, 237-243.

11 454

12 455 Malone, S., Owen, A., Newton, M., Mendes, B., Collins, K. D., & Gabbett, T. J. (2017).  
13 456 The acute:chronic workload ratio in relation to injury risk in professional soccer.  
14 457 *Journal of Science and Medicine in Sport*, 20, 561-565.

15 458

16 459 McCall, A., Carling, C., Nedelec, M., Davison, M., Le Gall, F., Berthoin, S., & Dupont,  
17 460 G. (2014a). Risk factors, testing and preventative strategies for non-contact  
18 461 injuries in professional football: current perceptions and practices of 44 teams  
19 462 from various premier leagues. *British Journal of Sports Medicine*, 49, 583-589.

20 463

21 464 McCall, A., Carling, C., Michael, D., Nedelec, M., Le Gall, F., Berthoin, S., & Dupont,  
22 465 G. (2014b). Injury risk factors, screening tests and preventative strategies: a  
23 466 systematic review of the evidence that underpins the perceptions and practices of  
24 467 44 football (soccer) teams from various premier leagues. *British Journal of*  
25 468 *Sports Medicine*, 49, 583-589.

26 469

27 470 Nilsson, T., Ostenberg, A. H., & Alricsson, M. (2016). Injury profile among elite male  
28 471 youth soccer players in a Swedish first league. *Journal of Exercise*  
29 472 *Rehabilitation*, 12, 83-89.

30 473

31 474 Pfirrmann, D., Herbst, M., Ingelfinger, P., Perikles, S., & Tug, S. (2016). Analysis of  
32 475 injury incidences in male professional adult and elite youth soccer players: A  
33 476 systematic review. *Journal of Athletic Training*, 51, 410-424.

34 477

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55  
56  
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59  
60  
61  
62  
63  
64  
65

478 Renshaw, A., & Goodwin P. C. (2016). Injury incidence in a Premier League youth  
479 soccer academy using the consensus statement: a prospective cohort study.  
480 *British Medicine Journal Open Sport and Exercise Medicine*, 2, e000132.  
481

482 Salgueiro da Silva, M. A., & Seixas, T. M. (2017). The role of data range in linear  
483 regression. *The Physics Teacher*, 55, 371-372.  
484

485 Saw, A. E., Main, L. C., & Gatin, P. B. (2016). Monitoring the athlete training  
486 response: subjective self-reported measures trump commonly used objective  
487 measures: a systematic review. *British Journal of Sports Medicine*, 50, 281-291.  
488

489 van Mechelen, M., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology  
490 and prevention of sports injuries. *A review of concepts. Sports Medicine*, 14, 82-  
491 89.  
492

493 Walden M., Hagglund M., & Ekstrand J. (2005) UEFA Champions League study: a  
494 prospective study on injuries in professional football during the 2001-2002  
495 season. *British Journal of Sports Medicine*, 39, 542-546.  
496  
497

498 Table 1: Number of players observed in U19 and U21 during the 5 seasons of  
 499 observation.

|                  | Number of players observed<br>in U19 | Number of players observed<br>in U21 |
|------------------|--------------------------------------|--------------------------------------|
| <b>2012-2013</b> | X                                    | 21                                   |
| <b>2013-2014</b> | 18                                   | 26                                   |
| <b>2014-2015</b> | 16                                   | 24                                   |
| <b>2015-2016</b> | 23                                   | 28                                   |
| <b>2016-2017</b> | 25                                   | 19                                   |

500

501 Table 2: Relative risk RR (95% confidence interval) and p-value for an increase in  
 502 cumulative workload for the last 7 days (1 week), 14 days (2 weeks), 21 days (3 weeks)  
 503 and 28 days (4weeks) in the U19 age category.

|                                    | RR<br>(95% CI)        | p    |
|------------------------------------|-----------------------|------|
| <b>1 week workload</b>             | 1.11<br>(0.84 - 1.50) | 0.44 |
| <b>2 weeks cumulative workload</b> | 1.03<br>(0.77 - 1.38) | 0.85 |
| <b>3 weeks cumulative workload</b> | 0.97<br>(0.74 - 1.28) | 0.82 |
| <b>4 weeks cumulative workload</b> | 1.00<br>(0.76 - 1.33) | 0.97 |

504

505 Table 3: Relative risk RR (95% confidence interval) and p-value for an increase in  
 506 Acute:Chronic workload with a chronic workload calculated over the last the last 28  
 507 days (4weeks), the last 21 days (3 weeks), the last 14 days (2 weeks) and the week to  
 508 week changes in workload in the U19 age category.

|                                      | RR<br>(95% CI)        | p    |
|--------------------------------------|-----------------------|------|
| <b>4 weeks A:C workload</b>          | 1.01<br>(0.96 - 1.07) | 0.73 |
| <b>3 weeks A:C workload</b>          | 1.00<br>(0.95 - 1.06) | 0.91 |
| <b>2 weeks A:C workload</b>          | 0.99<br>(0.90 - 1.09) | 0.82 |
| <b>Week to week workload changes</b> | 1.00<br>(0.96 - 1.04) | 0.93 |

509

510 Table 4: Relative risk RR (95% confidence interval) and p-value for an increase in  
 511 cumulative workload for the last 7 days (1 week), 14 days (2 weeks), 21 days (3 weeks)  
 512 and 28 days (4weeks) in the U21 age category.

|                                    | <b>RR<br/>(95% CI)</b> | <b>p</b> |
|------------------------------------|------------------------|----------|
| <b>1 week workload</b>             | 1.18<br>(0.92 to 1.52) | 0.19     |
| <b>2 weeks cumulative workload</b> | 1.28<br>(0.97 to 1.69) | 0.076    |
| <b>3 weeks cumulative workload</b> | 1.39<br>(1.04 to 1.84) | 0.026    |
| <b>4 weeks cumulative workload</b> | 1.40<br>(1.06 to 1.86) | 0.019    |

513

514 Table 5: Relative risk RR (95% confidence interval) and p-value for an increase in  
 515 Acute:Chronic workload with a chronic workload calculated over the last the last 28  
 516 days (4weeks), the last 21 days (3 weeks), the last 14 days (2 weeks) and the week to  
 517 week changes in workload in the U21 age category.

|                                      | <b>RR<br/>(95% CI)</b> | <b>p</b> |
|--------------------------------------|------------------------|----------|
| <b>4 weeks A:C workload</b>          | 0.89<br>(0.71 to 1.13) | 0.34     |
| <b>3 weeks A:C workload</b>          | 0.88<br>(0.66 to 1.16) | 0.37     |
| <b>2 weeks A:C workload</b>          | 0.86<br>(0.58 to 1.29) | 0.47     |
| <b>Week to week workload changes</b> | 1.00<br>(0.95 to 1.06) | 0.91     |

518

519

520

**Title: Workload and injury incidence in elite football academy players.**



# 1 **Workload and injury incidence in elite youth football players.**

2 Abstract

3  
4 The aim of this study was to prospectively analyse the relationship between  
5 workloads and injury in elite football academy players.

6  
7 Elite football academy players (n = 122) from under-19 (U19) and under-21  
8 (U21) of a professional football team competing in UEFA European Cups were  
9 followed during 5 seasons. Injuries were collected and absolute workload and  
10 workload ratios (4-weeks, 3-weeks, 2-weeks and week-to-week) calculated using  
11 a rolling days method with the help of the session Rate of Perceived Exertion.

12  
13 There was no association between absolute workload or workload ratio with the  
14 injury incidence in the U19. In the U21, the level of cumulative absolute  
15 workloads during 3-weeks (RR=1.39, p=0.026) and during 4-weeks (RR=1.40,  
16 p=0.019) were associated with an increase in injury. There was no association  
17 between workload ratio and injury in U21.

18  
19 The significant link between high cumulated 3-weeks and 4 weeks workloads and  
20 injury in U21 confirmed the requirement to monitor the internal subjective  
21 workload in U21 in order to prevent injury. Further studies exploring the  
22 relationships between workload and injury are required in football academy.

23 Keywords: Training, Academy, Team Sport, Injury prevention.

24

## 25 **Introduction**

26 Mean injury incidence (match and training) across seven UEFA clubs during seven  
27 seasons was reported as eight injuries per 1,000 hours of exposure, which corresponds  
28 to 50 injuries per season in a team of 25 players, or two injuries per player per season  
29 (Ekstrand, Hagglund, & Walden, 2011). ~~This injury incidence is 1,000 times higher than~~  
30 ~~in typical industrial occupations considered as highly risked (Drawer and Fuller, 2002).~~  
31 ~~During the 2012 Olympics, the football competition represented the highest level of~~  
32 ~~injury, with 35.2% of total number of injuries during the Olympics (Engebretsen et al.,~~  
33 ~~2013).~~ This high injury incidence highlights the importance of injury prevention in elite  
34 football.

35

36 According to the model of van Mechelen (1992) about the prevention of sports  
37 injuries, once the injury incidence and severity have been evaluated through  
38 epidemiological studies, the second step to prevent injury risk is to identify the risk  
39 factors and injury mechanisms. The third step is to introduce measures that are likely to  
40 reduce the future risk and/or severity of injuries. The last step is characterised by  
41 assessing the effect of the measures by repeating the first step (Van Mechelen, Hlobil,  
42 & Kemper, 1992). According to this model, several injury risk factors have been  
43 identified. In a survey, McCall et al. (2014a) reported that elite football  
44 medicine/science practitioners considered previous injury as the most important injury  
45 risk factor (121 points of importance on a score of 132). In their systematic review,  
46 McCall et al. (2014b) confirmed the practitioners' perceptions: previous injury was the  
47 injury risk factor with the highest level of scientific evidence (level 2++ according to  
48 the system for graded recommendations guidelines published in British Medical  
49 Journal) (Harbour and Miller, 2001). A previous hamstring, calf, groin or knee injury

50 increases two to three times the risk to sustain a new injury in the same body part during  
51 the following season (Hagglund et al., 2013). A previous injury also increases the  
52 overall injury risk, and not only in the previously injured body part (hazard ratio = 2.7,  
53 CI95% 1.7 to 4.3) (Hagglund et al., 2006). As a previous injury is a non-modifiable  
54 internal injury risk factor, it is important to prevent initial injuries which occur during  
55 the youth academy period. The fact to have already been injured during this period  
56 would become a non-modifiable risk factor in their future professional career.

57 Moreover, during an injury period, youth players do not have the same training  
58 protocol, it could represent an additional gap to bridge in their improvements. Several  
59 studies examined the injury incidence in elite youth football academy. In a systematic  
60 review of literature, Pfirrmann et al. (2016) reported, in youth academies, an overall  
61 injury incidence from 2.0 to 19.4 injuries per 1,000h of exposition and a training injury  
62 incidence in youth academies from 3.7 to 11.4 injuries per 1,000h of training. For the  
63 last year spent in the academy, the overall injury incidence of U18 and U19 (between  
64 6.8 and 10 per 1,000h of exposition) (Nilsson et al., 2016 ; Renshaw & Goodwin, 2016)  
65 is comparable to the one reported in elite professional football players (7.6 injuries per  
66 1,000h of exposition) (Ekstrand, Hagglund, Kristenson, Magnusson & Walden, 2013).

67 These results concerning the high injury incidence in youth football academy highlights  
68 the needs to identify injury risk factors with this population in order to implement injury  
69 prevention strategies, especially to reduce the risk to sustain a first injury. Although a  
70 few studies have already dealt on the identification of the risk factors and injury  
71 prevention in youth academy (Bowen et al., 2017), most of the studies dealt on high-  
72 level professional players (Ekstrand, Hagglund, & Walden, 2011; Hagglund, Walden, &  
73 Ekstrand, 2013).

74 In their survey, McCall et al. (2014a) reported that the practitioners considered  
75 the fatigue (105 points of importance on a maximal score of 132) as the second most  
76 important injury risk with professional football players. Fatigue could come from the  
77 repetition of training and matches. Several studies found a significant association  
78 between workload and injury incidence among professional football players (Malone et  
79 al., 2017; Lu et al., 2017 ; Jaspers et al., 2017). Two reviews of literature concluded that  
80 internal/subjective tools were more sensitive and related to injury incidence than  
81 external and/or objective tools (Saw, Main, & Gatin, 2016; Jones, Griffiths, &  
82 Mellalieu, 2017). Jones, Griffiths, & Mellalieu (2017) included 21 studies evaluating  
83 the association between internal workload and injury incidence in sports in a systematic  
84 review of literature. The majority (90%) of these studies concerned team sports. The  
85 authors concluded that there was a moderate evidence that the internal workload was  
86 associated with injury incidence. In professional football, Malone et al. (2017)  
87 identified that an absolute workload calculated with sRPE higher than 1,500 arbitrary  
88 units (A.U.) was associated with an elevated injury risk, and that an acute:chronic  
89 workload ratio calculated with the sRPE between 1.00 and 1.25 was associated with a  
90 lower injury incidence in elite football players. In youth elite football players, one study  
91 identified an association between the one week absolute workload calculated using the  
92 session Rate of Perceived Exertion (sRPE), using a modified perception scale (Borg,  
93 CR-10) and the injury incidence (OR=1.01, 95%CI 1.00 to 1.06) (Brink et al., 2010).  
94 However, in this study, the workload was calculated only for 1 week, while associations  
95 between external workload and injury incidence during 2, 3 or 4 cumulative weeks and  
96 A:C ratios have been identified (Bowen et al., 2017). To our knowledge, no study aimed  
97 at evaluating the association of absolute internal workload during several weeks, and  
98 acute:chronic internal workload ratio and injury in a elite football academy. Therefore,

99 the aim of this study is to analyse the relationships between several combinations of  
100 internal workload using the sRPE and the injury among football players in an elite  
101 football academy.

102

### 103 **Materials and Methods**

#### 104 *Subjects*

105 One hundred twenty-two elite young football players (height:  $178.6 \pm 6.8$ cm; body  
106 mass:  $70.9 \pm 7.3$ kg) from U19 (n=52; age:  $16.8 \pm 0.9$ ) and U21 (n=70; age:  $20.1 \pm 0.3$ )  
107 squads of a football academy in an elite football club playing in first French League and  
108 taking part regularly in European competitions were followed during four and five  
109 seasons respectively. All players from the U19 and the U21 squads were included in the  
110 study. The players lived in the academy. If a player joined the team during the  
111 observational period, he was included from the date he joined the team. A player who  
112 left the team during the observational period was excluded from the study from the date  
113 he left the team. If a player was already injured at the start of data collection, he was  
114 included in the study but this injury was excluded (Fuller et al., 2006). All players were  
115 informed and consented to take part in the study. This study was conducted in  
116 accordance with the local ethical committee on biomedical research (CCTIRS#10544)  
117 and the standards of the declaration of Helsinki.

118

#### 119 *Methodology*

120 This study was a prospective cohort study. An injury was defined, in accordance with  
121 the FIFA consensus, as any physical complaint sustained by a player that resulted from  
122 a football match or football training, that made the player unable to participate in future  
123 football training or a match (Fuller et al., 2006).

124

125           The workload was calculated by the sRPE method. This method is valid  
126   for its use with athletes and football players (Foster, 1998 ; Impellizzeri et al., 2004).  
127   Players were instructed to rate the global intensity of all sessions and matches using a  
128   modified category ratio scale going from 0 to 10 based on the scale developed by Borg  
129   (1987) by answering the following question: ‘How was your workout?’. The sRPE was  
130   collected 30 minutes after completion of the session/match by a sport clinician working  
131   in the club responsible for the collection of the data. The players were isolated to  
132   answer in order not to be influenced by other players. Workload, expressed in arbitrary  
133   units (AU) was calculated by multiplying the perceived intensity by the session or  
134   match duration (Foster et al., 2001); all training sessions and all matches were included.  
135   All the training sessions and matches were on natural grass. The workload was  
136   calculated on a daily basis with the methods of rolling days blocks (everyday, a new  
137   workload was calculated based on the preceding days) (Hulin et al., 2016; Bowen et al.,  
138   2017). The absolute workload was the sum of the load for the last 7 days (one-week  
139   workload), 14 days (2-weeks workload), 21 days (3-weeks workload) and 28 days (4-  
140   weeks workload) were calculated. To determine A:C ratios, the one-week workload was  
141   divided by the total workload of the last 28 days, divided by 4 for the 4-weeks A:C ratio  
142   (formula: one-week workload / (last 28 days workload/4)), the total load of the last 21  
143   days divided by 3 for the 3-weeks A:C ratio (one-week workload / (last 21 days  
144   workload/3)) and the total load of the last 14 days divided by 2 for the 2 weeks A:C  
145   ratio (one-week workload / (last 14 days workload/2)) (Malone et al., 2017). The week-  
146   to-week load changes were also calculated by dividing the 1-week load by the  
147   accumulated load of the previous 7 days. The workload was known by the practitioners  
148   who could use the data to regulate the workload. In U19, the group (and not individual)

149 workload was regulated on a weekly basis by the practitioners. The workload was  
150 analysed in the end of each week and the practitioners aim was to reach a weekly mean  
151 of 2,500 A.U, because they considered it was the optimal workload to reduce the injury  
152 risk while improving players fitness qualities. The data were not taken into account in  
153 U21 to regulate the workload.

154

### 155 *Statistical Analysis*

156 A Poisson regression analysis was performed with IBM SPSS Statistics Version 20 for  
157 the 1-week, 2-weeks, 3-weeks and 4-weeks absolute workload and the A:C workload  
158 ratios to assess the link between these factors and injury incidence and calculate relative  
159 risk (RR). The absolute workload and the A:C workload ratios were log-transformed  
160 when the scores were not normally distributed.

161 The daily probability to sustain an injury was calculated by dividing the number of  
162 injuries by the number of days of observation, multiplied by 100.

163

### 164 **Results**

165 A total of 122 players have been followed during the period of observation. The number  
166 of players in each squad, season by season, are described in table 1. In U19 category, a  
167 total 52 players were followed (24 players were followed during one season, 26 players  
168 were followed during two seasons, 2 players were followed during 3 seasons). In U21  
169 category, a total of 70 players were followed (41 players were followed during one  
170 season, 16 players were followed during 2 seasons, 8 players were followed during 3  
171 seasons, 4 players were followed during 4 seasons and one player was followed during  
172 the 5 seasons of observation). It represents a total of 200 player-seasons, 17,778 days in  
173 the U19 and of 26,672 days in the U21 were recorded.

174 \*\*\* TABLE 1 NEAR HERE

175 A total of 182 injuries were recorded in the U19 category (119 non-contact + 63  
176 contact injuries) and of 307 injuries (215 non-contact + 92 contact injuries) were  
177 recorded in the U21 category. It represents a global injury incidence of 7.6 injuries per  
178 1,000h of exposition for the U19 and of 9.6 injuries per 1,000h of exposition for the  
179 U21. The daily probability to sustain an injury was 1.02% in U19 and 1.15% in U21.

180 In U19, the mean weekly workload was  $2046 \pm 705$  AU; the mean 2 weeks  
181 workload was  $3813 \pm 1291$  AU; the mean 3 weeks workload was  $5501 \pm 1831$  AU and the  
182 mean 4 weeks absolute workload was  $7104 \pm 2334$  AU. No link was found between  
183 absolute workload, cumulative absolute workload (2 weeks, 3 weeks, 4 weeks) and  
184 global, non-contact or contact injuries with U19 players. These results are described in  
185 table 2. No link was found between none of the A:C workload ratio and global, non-  
186 contact and contact injuries with U19 players, as described in table 3.

187 \*\*\* TABLE 2 NEAR HERE

188 \*\*\* TABLE 3 NEAR HERE

189

190 In U21, the mean weekly workload was  $1979 \pm 666$  AU; the mean 2 weeks  
191 workload was  $3783 \pm 1211$  AU; the mean 3 weeks workload was  $5497 \pm 1740$  AU and the  
192 mean 4 weeks workload was  $7145 \pm 2254$  AU. The results concerning the link between  
193 absolute workload and global, non-contact and contact injuries in U21 are described in  
194 table 4. An association was found between the cumulative 3 weeks absolute workload  
195 and injury incidence (RR=1.39, p=0.026) and between the cumulative 4 weeks absolute  
196 workload and injury incidence (RR=1.40, p=0.019). There was no association between  
197 the A:C workload ratio and the injury incidence with U21 players. The results are  
198 described in table 5.



199 \*\*\*TABLE 4 NEAR HERE

200 \*\*\*TABLE 5 NEAR HERE

201

202

203 **Discussion**

204 The aim of this study was to analyse the relationship between workload and injury  
205 incidence in elite football academy players. The main findings showed that there was no  
206 association between absolute or A:C workload ratio with U19 players, while there was  
207 an association between 3 weeks and 4 weeks cumulative absolute workload with U21  
208 players.

209

210 In the current study, the overall injury incidence was 7.6 injuries per 1,000h of  
211 exposition with U19 and 9.6 injuries per 1,000h of exposition with U21 players. These  
212 results confirm those of previous studies with an overall injury incidence between 6 and  
213 10 injuries per 1,000h of exposition with players in U18 and U19 categories (Nilsson et  
214 al., 2016; Renshaw & Goodwin, 2016). This injury incidence is also close to the injury  
215 incidence of elite professional football teams (8 injuries per 1,000h of exposition)  
216 (Ekstrand, Hagglund, & Walden, 2011). When transforming these results into daily  
217 probability, the overall daily probability to sustain an injury in U19 is 1.02% per player  
218 and in U21 is 1.15% per player. The daily probability to sustain an injury per player  
219 highlights that even if the injury incidence is very high compared to other activities  
220 (Ekstrand, 2013), the daily probability to sustain an injury in a youth academy is low,  
221 being approximately 1%.

222

223 No link between absolute workload, A:C workload ratio and injury incidence  
224 was found for the U19. These results about the lack of significant relationship between  
225 absolute workload and the occurrence of injury are different of a previous study led by  
226 Brink et al. (2010), who found an association between internal workload calculated  
227 using the sRPE and the injury incidence. However, the methodology used are different.  
228 First of all, Brink et al. analysed the sum of the workload week after week, while in the  
229 current study, a rolling days method was used to analyse the workload day after day.  
230 This is a major difference between the two studies as an injury at the beginning of the  
231 week or in the end of the week could lead to big changes in the weekly workload with  
232 Brink et al.'s methodology (2010). In the study led by Brink et al. (2010), an odd ratio  
233 was calculated, while in the current study, a Poisson regression was used, providing a  
234 relative risk. The injury incidence in Brink et al. study (2010) (37.55 per 1,000h of  
235 match and 11.14 per 1,000h of training) was higher than the one in the present study  
236 (7.6 in U19 and 9.6 in U21). The probability to find a significant association between a  
237 potential risk factor and an event depends on the event frequency. It means that the  
238 higher the injury incidence is, the higher the probability to find a significant statistical  
239 association is (Bahr and Holme, 2003). The method to calculate the workload was not  
240 exactly the same as the authors used a 15-point scale to rate the perceived intensity and  
241 multiply the perceived exertion by the number of hours of practice while a 10-point  
242 scale was used in the present study and the exertion was multiplied by the number of  
243 minutes of practice. It is therefore difficult to compare the workload data range width  
244 while the data range width of the independent factor modifies the results of a regression  
245 (Salgueiro da Silva and Seixas, 2017). Another difference in the results could be  
246 explained by a different definition of injury, as Brinks et al. (2010), defined the injury  
247 as any physical complaint sustained by a player that results from a soccer match or

248 soccer training and leading to time loss or medical attention. In the present study, only  
249 the complaint leading to time loss were taken into account. Given the very low odd ratio  
250 (OR=1.01, 95% CI 1.00 to 1.02) reported by Brink et al. (2010), these changes in the  
251 methodology could explain the absence of association in the current study and the  
252 differences between the two studies.

253

254 In the U21, no association was found between none of the A:C workload while  
255 an association was found between the cumulative absolute 3 weeks and 4 weeks  
256 workload and the injury incidence. In the current study, no association has been found  
257 with none of the workload calculated over the last 7 days (absolute 1 week workload or  
258 A:C workload ratio). These results does not allow to identify a link between the internal  
259 A:C workload ratios calculated with sRPE and injury incidence with academy players  
260 while this association has been identified with professional players (Malone et al.,  
261 2017). In professional football, an A:C ratio between 1.00 and 1.25 has been identified  
262 as an injury protective factor (Malone et al., 2017). An elevated A:C workload ratio is  
263 the result of the combination of a low chronic workload and a high acute workload  
264 (Blanch & Gabbett, 2016). It means that a low chronic workload or spikes in the  
265 workload calculated with sRPE should be avoided in elite level football players in  
266 order to reduce the injury incidence (Blanch & Gabbett, 2016). Jaspers et al. (2018)  
267 identified that an elevated workload calculated with the help of sRPE during two weeks  
268 was associated with an elevated incidence of overuse injury with elite football players  
269 while a medium workload during four weeks was associated with a decrease in injury  
270 incidence in comparison with a low workload calculated with sRPE. This result  
271 indicates that a minimum level workload should be necessary to avoid an increase in  
272 injury risk, and that a chronic workload too low could be an injury risk factor among

273 professional football players. These results highlight the association between injury  
274 incidence and acute and chronic workload calculated with sRPE in professional  
275 football. This association has not been found in the present study with academy players.  
276 Differences between players playing in a youth football academy and professional  
277 football players playing in European competitions could be explained by differences in  
278 the changes in acute workload. Large changes in workload sustained by professional  
279 football players could occur during the congested schedule with two to three-games per  
280 week. The schedule in youth category seems to be more regular without congested  
281 periods, leading to smaller changes in the acute workload. These differences in the  
282 competitions schedules could explain the absence of association between A:C workload  
283 ratio and injury incidence in the U19 and U21 age categories.

284

285         The difference in results between U19 and U21 in the present study could be  
286 explained in part by the smaller number of injuries recorded in U19 compared to U21  
287 (182 vs 307), which is explained by a lower incidence (7.6 vs 9.6) and shorter period of  
288 observation in U19 in comparison with the U21 (4 seasons vs 5 seasons). There was a  
289 similar proportion of non-contact injuries between U19 and U21 (65% in U19 vs 71%  
290 in U21), but a lower number of non-contact injuries recorded in U19 (119 vs 215),  
291 which also could explain the absence of association in U19 as non-contact injuries are  
292 considered easier to prevent than contact injuries (Gabbett et al., 2010). As explained in  
293 the introduction, a previous injury is the strongest injury risk factor. In future studies, it  
294 may be interesting to evaluate the effect of a previous injury on the ability of a player to  
295 sustain high workload, as the present results indicate that older players (U21) are more  
296 sensitive to high workload, which may be linked to a higher proportion of previously  
297 injured players with older players.

298

299           This study presents some limitations. First of all, the current study identified an  
300 association between absolute workload and injury incidence with players in a football  
301 academy but it does not necessarily mean that there is a causal connection between  
302 workload and injury incidence (Bahr, 2016). Although very complicated to implement  
303 in the real high-level sport world, other studies and randomised controlled trials should  
304 be assessed to analyse the effect of a controlled workload on the injury incidence, in an  
305 isolated way, to confirm a causal connection (Bahr, 2016). As a cohort study, the design  
306 represents a limit. The observation of the players means that the results are influenced  
307 by players sustaining several injuries and as such are considered as repeated  
308 independent observations while these injuries are multifactorial and are linked to a lot of  
309 factors dependent of the player observed, as, for example, the ability to cope with very  
310 high load and/or to large variations in workload. One of the limits of this study is the  
311 low injury incidence in this study with only 182 injuries for 17,778 days of observation  
312 in U19 and 372 injuries for 26,672 days of observation in U21, representing a daily  
313 probability to sustain an injury of 1.02% in U19 and of 1.15% in U21. This low  
314 probability could explain in part the absence of statistical association in U19 as a low  
315 occurrence of an event reduces the probability to find an association between this event  
316 and an independent factor (Bahr and Holme, 2003). Another limit of the study concerns  
317 the practitioners who recorded the data. If they adapted the workload according to the  
318 data recorded to protect some players with very high or low workloads, it would impact  
319 the results. This limit could also partly explain the absence of results in U19 compared  
320 to the results in U21. In U19, the workload was regulated on a weekly basis by the  
321 practitioners. The objective for the practitioners in U19 was to reach a mean weekly  
322 group workload of 2,500 A.U., and was analysed in the end of each week to decide how

323 to manage the group workload in the following week. It could explain why the  
324 workload is not associated with the injury incidence in U19. In U21, the data were  
325 known by the practitioners but not used to regulate the workload, which could partly  
326 explain the differences in the results between the two categories.

327

328         Despite these limits, this study presents some interesting strengths. First of all,  
329 to our knowledge, this is the first study with elite football academy players analyzing  
330 the associations of multiple combinations of internal absolute workload and workload  
331 ratios with injury incidence.

332

333         With 122 players followed and 200 player-seasons, the cohort of this study was  
334 large compared to other studies in the same topic. It is, to our knowledge, the first  
335 longitudinal study concerning young football players led during a period as long as **five**  
336 full seasons. **The players followed were football players from an elite football academy.**  
337 **It means that there was a very good control about the workload with no missing data**  
338 **and a very good control of the outside activities of the players as most of the players**  
339 **were staying in the academy. It gives a very high level of confidence to the recorded**  
340 **workload.**

341

342         *Conclusion*

343 In conclusion, the results of this study indicated that the internal workload calculated  
344 using the sRPE was not associated with injury incidence in U19. In the U21 category,  
345 the absolute workload cumulated during 21 or 28 days is positively associated with the  
346 injury incidence. This result indicates that practitioners working with young football  
347 players could calculate the internal workload and use the sRPE during their late years of

348 academy in order to potentially reduce the injury incidence. Further studies are required  
349 in these age categories to analyse these associations.

350

### 351 **Acknowledgements**

352 The authors thank all the players who took part in the study.

353

### 354 **Declaration of interest statement**

355 The authors report no conflict of interest.

356

### 357 **References**

358 Akenhead, R., & Nassis, G. P. (2016). Training load and player monitoring in high-  
359 level football: current practice and perceptions. *International Journal of Sports*  
360 *Physiology and Performance, 11*, 587-793.

361

362 Bahr R., & Holme I. (2003). Risk factors for sports injuries – a methodological  
363 approach. *British Journal of Sports Medicine, 37*, 384-392.

364

365 Bahr, R. (2016). Why screening tests to predict injury do not work and probably never  
366 will...: a critical review. *British Journal of Sports Medicine, 50*, 776-780.

367

368 Blanch, P., & Gabbett, T. J. (2016). Has the athlete trained enough to return to play  
369 safely? The acute:chronic workload ratio permits clinicians to quantify a  
370 player's risk of subsequent injury. *British Journal of Sports Medicine, 50*, 471-  
371 475.

372

373 Borg, G., Hassmen, P., & Lagerstrom, M. (1987). Perceived exertion related to heart  
374 rate and blood lactate during arm and leg exercise. *European Journal of Applied*  
375 *Physiology and Occupational Physiology, 56*, 670-685.

376

377 Bowen, L., Gross, A. S., Gimpel, M., & Li, F. X. (2017). Accumulated workloads and  
378 the acute:chronic workload ratio relate to injury risk in elite youth football  
379 players. *British Journal of Sports Medicine*, 51, 452-459.  
380

381 Brink, M. S., Visscher, C., Arends, S., Zwerver J., Post W. J., & Lemmink K. A. P. M.  
382 (2010). Monitoring stress and recovery: new insights for the prevention of  
383 injuries and illnesses in elite youth soccer players. *British Journal of Sports  
384 Medicine*, 44, 809-815.  
385

386 Carey, D. L., Blanch, P., Ong, K. L., Crossley, K. M., Crow, J., & Morris, M. E. (2016).  
387 Training loads and injury risk in Australian football-differing acute:chronic  
388 workload ratios influence match injury risk. *British Journal of Sports Medicine*,  
389 51, 1215-1220  
390

391 Ekstrand J., Hagglund M., & Walden M. (2011). Epidemiology of muscle injuries in  
392 professional football (soccer). *American Journal of Sports Medicine*, 39, 1226-  
393 1232.  
394

395 Ekstrand, J., Hagglund, M., & Walden, M. (2011). Injury incidence and injury patterns  
396 in professional football: the UEFA injury study. *British Journal of Sports  
397 Medicine*, 45, 553– 558.  
398

399 Ekstrand, J. (2013). Keeping your top players on the pitch: the key to football medicine  
400 at the professional level. *British Journal of Sports Medicine*, 47, 723-724.  
401

402 Foster, C. (1998). Monitoring training in athletes with reference to overtraining  
403 syndrome. *Medicine & Science in Sports & Exercise*, 30, 1164-1168.  
404

405 Foster, C., Florhaud, J. A., Franklin, J., Gottschall, L., Hrovantin, L. A., Parker, S.,  
406 Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise  
407 training. *Journal of Strength and Conditioning Research*, 15, 109-115.  
408

409 Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., Hägglund,  
410 M., McCrory, P., & Meeuwisse, W. H. (2006). Consensus statement on injury



411 definitions and data collection procedures in studies of football (soccer) injuries.  
412 *British Journal of Sports Medicine*, 40, 193-201.

413

414 Gabbett, T. J. (2010). The development and application of an injury prediction model  
415 for noncontact, soft-tissue injury in elite collision sport athletes. *Journal of*  
416 *Strength and Conditioning Research*, 24, 2593-2603.

417

418 Hagglund, M., Walden, M., & Ekstrand, J. (2006). Previous injury as a risk factor for  
419 injury in elite football: a prospective study over two consecutive seasons. *British*  
420 *Journal of Sports Medicine*, 40, 767-772.

421

422 Hagglund, M., Walden, M., & Ekstrand, J. (2013). Risk factors for lower extremity  
423 muscle injury in professional soccer. *American Journal of Sports Medicine*, 41,  
424 327-335.

425

426 Harbour, R., & Miller, J. (2001). A new system for grading recommendations in  
427 evidence based guidelines. *British Medical Journal*, 323, 334-336.

428

429 Hulin, B. T., Gabbett, T. J., Lawson D. W., Caputi P., & Sampson J. A. (2016). The  
430 acute:chronic workload ratio predicts injury: high chronic workload may  
431 decrease injury risk in elite rugby players. *British Journal of Sports Medicine*,  
432 50, 231-236.

433

434 Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004).  
435 Use of RPE-based training load in soccer. *Medicine & Science in Sports &*  
436 *Exercise*, 36, 1042-1047.

437

438 Jaspers, A., Brink M. S., Probst, S. G., Frenken W. G., & Helsen W. F. (2017).  
439 Relationships between training load indicators and training outcomes in  
440 professional soccer. *Sports Medicine*, 47, 533-544.

441

442 Jaspers, A., Kuyvenhoven, J. P., Staes, F., Frencken, W. G. P., Helsen, W. F., & Brink,  
443 M. S. (2018). Examination of the external and internal load indicators

444 association with overuse injuries in professional soccer players. *Journal of*  
445 *Science and Medicine in Sport*, 21, 579-585

446

447 Jones, C. M., Griffiths, P. C., & Mellalieu, S. D. (2017). Training load and fatigue  
448 marker associations with injury and illness: A systematic review of longitudinal  
449 studies. *Sports Medicine*, 47, 943-974.

450

451 Lu, D., Howle, K., Waterson, A., Duncan, C., & Duffield, R. (2017). Workload profiles  
452 prior to injury in professional soccer players. *Science and Medicine in Football*,  
453 3, 237-243.

454

455 Malone, S., Owen, A., Newton, M., Mendes, B., Collins, K. D., & Gabbett, T. J. (2017).  
456 The acute:chronic workload ratio in relation to injury risk in professional soccer.  
457 *Journal of Science and Medicine in Sport*, 20, 561-565.

458

459 McCall, A., Carling, C., Nedelec, M., Davison, M., Le Gall, F., Berthoin, S., & Dupont,  
460 G. (2014a). Risk factors, testing and preventative strategies for non-contact  
461 injuries in professional football: current perceptions and practices of 44 teams  
462 from various premier leagues. *British Journal of Sports Medicine*, 49, 583-589.

463

464 McCall, A., Carling, C., Michael, D., Nedelec, M., Le Gall, F., Berthoin, S., & Dupont,  
465 G. (2014b). Injury risk factors, screening tests and preventative strategies: a  
466 systematic review of the evidence that underpins the perceptions and practices of  
467 44 football (soccer) teams from various premier leagues. *British Journal of*  
468 *Sports Medicine*, 49, 583-589.

469

470 Nilsson, T., Ostenberg, A. H., & Alricsson, M. (2016). Injury profile among elite male  
471 youth soccer players in a Swedish first league. *Journal of Exercise*  
472 *Rehabilitation*, 12, 83-89.

473

474 Pfirrmann, D., Herbst, M., Ingelfinger, P., Perikles, S., & Tug, S. (2016). Analysis of  
475 injury incidences in male professional adult and elite youth soccer players: A  
476 systematic review. *Journal of Athletic Training*, 51, 410-424.

477

478 Renshaw, A., & Goodwin P. C. (2016). Injury incidence in a Premier League youth  
479 soccer academy using the consensus statement: a prospective cohort study.  
480 *British Medicine Journal Open Sport and Exercise Medicine*, 2, e000132.  
481

482 Salgueiro da Silva, M. A., & Seixas, T. M. (2017). The role of data range in linear  
483 regression. *The Physics Teacher*, 55, 371-372.  
484

485 Saw, A. E., Main, L. C., & Gatin, P. B. (2016). Monitoring the athlete training  
486 response: subjective self-reported measures trump commonly used objective  
487 measures: a systematic review. *British Journal of Sports Medicine*, 50, 281-291.  
488

489 van Mechelen, M., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology  
490 and prevention of sports injuries. *A review of concepts. Sports Medicine*, 14, 82-  
491 89.  
492

493 Walden M., Hagglund M., & Ekstrand J. (2005) UEFA Champions League study: a  
494 prospective study on injuries in professional football during the 2001-2002  
495 season. *British Journal of Sports Medicine*, 39, 542-546.  
496  
497

498 Table 1: Number of players observed in U19 and U21 during the 5 seasons of  
 499 observation.

|                  | Number of players observed<br>in U19 | Number of players observed<br>in U21 |
|------------------|--------------------------------------|--------------------------------------|
| <b>2012-2013</b> | X                                    | 21                                   |
| <b>2013-2014</b> | 18                                   | 26                                   |
| <b>2014-2015</b> | 16                                   | 24                                   |
| <b>2015-2016</b> | 23                                   | 28                                   |
| <b>2016-2017</b> | 25                                   | 19                                   |

500

501 Table 2: Relative risk RR (95% confidence interval) and p-value for an increase in  
 502 cumulative workload for the last 7 days (1 week), 14 days (2 weeks), 21 days (3 weeks)  
 503 and 28 days (4weeks) in the U19 age category.

|                                    | RR<br>(95% CI)        | p    |
|------------------------------------|-----------------------|------|
| <b>1 week workload</b>             | 1.11<br>(0.84 - 1.50) | 0.44 |
| <b>2 weeks cumulative workload</b> | 1.03<br>(0.77 - 1.38) | 0.85 |
| <b>3 weeks cumulative workload</b> | 0.97<br>(0.74 - 1.28) | 0.82 |
| <b>4 weeks cumulative workload</b> | 1.00<br>(0.76 - 1.33) | 0.97 |

504

505 Table 3: Relative risk RR (95% confidence interval) and p-value for an increase in  
 506 Acute:Chronic workload with a chronic workload calculated over the last the last 28  
 507 days (4weeks), the last 21 days (3 weeks), the last 14 days (2 weeks) and the week to  
 508 week changes in workload in the U19 age category.

|                                      | RR<br>(95% CI)        | p    |
|--------------------------------------|-----------------------|------|
| <b>4 weeks A:C workload</b>          | 1.01<br>(0.96 - 1.07) | 0.73 |
| <b>3 weeks A:C workload</b>          | 1.00<br>(0.95 - 1.06) | 0.91 |
| <b>2 weeks A:C workload</b>          | 0.99<br>(0.90 - 1.09) | 0.82 |
| <b>Week to week workload changes</b> | 1.00<br>(0.96 - 1.04) | 0.93 |

509

510 Table 4: Relative risk RR (95% confidence interval) and p-value for an increase in  
 511 cumulative workload for the last 7 days (1 week), 14 days (2 weeks), 21 days (3 weeks)  
 512 and 28 days (4weeks) in the U21 age category.

|                                    | <b>RR<br/>(95% CI)</b> | <b>p</b> |
|------------------------------------|------------------------|----------|
| <b>1 week workload</b>             | 1.18<br>(0.92 to 1.52) | 0.19     |
| <b>2 weeks cumulative workload</b> | 1.28<br>(0.97 to 1.69) | 0.076    |
| <b>3 weeks cumulative workload</b> | 1.39<br>(1.04 to 1.84) | 0.026    |
| <b>4 weeks cumulative workload</b> | 1.40<br>(1.06 to 1.86) | 0.019    |

513

514 Table 5: Relative risk RR (95% confidence interval) and p-value for an increase in  
 515 Acute:Chronic workload with a chronic workload calculated over the last the last 28  
 516 days (4weeks), the last 21 days (3 weeks), the last 14 days (2 weeks) and the week to  
 517 week changes in workload in the U21 age category.

|                                      | <b>RR<br/>(95% CI)</b> | <b>p</b> |
|--------------------------------------|------------------------|----------|
| <b>4 weeks A:C workload</b>          | 0.89<br>(0.71 to 1.13) | 0.34     |
| <b>3 weeks A:C workload</b>          | 0.88<br>(0.66 to 1.16) | 0.37     |
| <b>2 weeks A:C workload</b>          | 0.86<br>(0.58 to 1.29) | 0.47     |
| <b>Week to week workload changes</b> | 1.00<br>(0.95 to 1.06) | 0.91     |

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