

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

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Gregory Dupont

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

Barthélémy Delecroix^{1,2}, Benoit Delaval^{2,3}, Brian Dawson⁴, Serge Berthoin¹, Gregory Dupont⁵

¹*Univ. Lille, Univ. Artois, Univ. Littoral Côte d'Opale, EA 7369 - URePSSS - Unité de Recherche Pluridisciplinaire Sport Santé Société, F-59000 Lille, France.*

²*LOSC Lille Métropole*

³*Université de Picardie Jules Verne, EA 3300 – APERE – Adaptations physiologiques à l'exercice et réadaptation à l'effort, Amiens, France.*

⁴*School of Human Sciences (Sport Science, Exercise and Health), The University of Western Australia, Perth, Australia.*

⁵*The Football Exchange, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool UK.*

Corresponding author:

Gregory Dupont. The Football Exchange, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool UK. email address: G.Dupont@ljmu.ac.uk

1 Workload and injury incidence in elite football academy 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.

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

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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, & 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,

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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.

102

103 **Materials and Methods**

104 *Subjects*

105 One hundred twenty-two elite young football players (height: 178.6 ± 6.8 cm; body
106 mass: 70.9 ± 7.3 kg) from U19 (n=52; age: 16.8 ± 0.9) and U21 (n=70; age: 20.1 ± 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).
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7 127 Players were instructed to rate the global intensity of all sessions and matches using a
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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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14 130 collected 30 minutes after completion of the session/match by a sport clinician working
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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
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21 133 units (AU) was calculated by multiplying the perceived intensity by the session or
22
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24 134 match duration (Foster et al., 2001); all training sessions and all matches were included.
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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
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31 137 workload was calculated based on the preceding days) (Hulin et al., 2016; Bowen et al.,
32
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34 138 2017). The absolute workload was the sum of the load for the last 7 days (one-week
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36 139 workload), 14 days (2-weeks workload), 21 days (3-weeks workload) and 28 days (4-
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39 140 weeks workload) were calculated. To determine A:C ratios, the one-week workload was
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41 141 divided by the total workload of the last 28 days, divided by 4 for the 4-weeks A:C ratio
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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
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58 148 who could use the data to regulate the workload. In U19, the group (and not individual)

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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 ± 705 AU; the mean 2 weeks
181 workload was 3813 ± 1291 AU; the mean 3 weeks workload was 5501 ± 1831 AU and the
182 mean 4 weeks absolute workload was 7104 ± 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

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190 In U21, the mean weekly workload was 1979 ± 666 AU; the mean 2 weeks
191 workload was 3783 ± 1211 AU; the mean 3 weeks workload was 5497 ± 1740 AU and the
192 mean 4 weeks workload was 7145 ± 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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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%.

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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**

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353

354 **Declaration of interest statement**

355 The authors report no conflict of interest.

356

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497

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

	Number of players observed in U19	Number of players observed in U21
2012-2013	X	21
2013-2014	18	26
2014-2015	16	24
2015-2016	23	28
2016-2017	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 (95% CI)	p
1 week workload	1.11 (0.84 - 1.50)	0.44
2 weeks cumulative workload	1.03 (0.77 - 1.38)	0.85
3 weeks cumulative workload	0.97 (0.74 - 1.28)	0.82
4 weeks cumulative workload	1.00 (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 (95% CI)	p
4 weeks A:C workload	1.01 (0.96 - 1.07)	0.73
3 weeks A:C workload	1.00 (0.95 - 1.06)	0.91
2 weeks A:C workload	0.99 (0.90 - 1.09)	0.82
Week to week workload changes	1.00 (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.

	RR (95% CI)	p
1 week workload	1.18 (0.92 to 1.52)	0.19
2 weeks cumulative workload	1.28 (0.97 to 1.69)	0.076
3 weeks cumulative workload	1.39 (1.04 to 1.84)	0.026
4 weeks cumulative workload	1.40 (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.

	RR (95% CI)	p
4 weeks A:C workload	0.89 (0.71 to 1.13)	0.34
3 weeks A:C workload	0.88 (0.66 to 1.16)	0.37
2 weeks A:C workload	0.86 (0.58 to 1.29)	0.47
Week to week workload changes	1.00 (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 ± 6.8 cm; body
106 mass: 70.9 ± 7.3 kg) from U19 (n=52; age: 16.8 ± 0.9) and U21 (n=70; age: 20.1 ± 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 ± 705 AU; the mean 2 weeks
181 workload was 3813 ± 1291 AU; the mean 3 weeks workload was 5501 ± 1831 AU and the
182 mean 4 weeks absolute workload was 7104 ± 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 ± 666 AU; the mean 2 weeks
191 workload was 3783 ± 1211 AU; the mean 3 weeks workload was 5497 ± 1740 AU and the
192 mean 4 weeks workload was 7145 ± 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 of 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

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353

354 **Declaration of interest statement**

355 The authors report no conflict of interest.

356

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497

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

	Number of players observed in U19	Number of players observed in U21
2012-2013	X	21
2013-2014	18	26
2014-2015	16	24
2015-2016	23	28
2016-2017	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 (95% CI)	p
1 week workload	1.11 (0.84 - 1.50)	0.44
2 weeks cumulative workload	1.03 (0.77 - 1.38)	0.85
3 weeks cumulative workload	0.97 (0.74 - 1.28)	0.82
4 weeks cumulative workload	1.00 (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 (95% CI)	p
4 weeks A:C workload	1.01 (0.96 - 1.07)	0.73
3 weeks A:C workload	1.00 (0.95 - 1.06)	0.91
2 weeks A:C workload	0.99 (0.90 - 1.09)	0.82
Week to week workload changes	1.00 (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.

	RR (95% CI)	p
1 week workload	1.18 (0.92 to 1.52)	0.19
2 weeks cumulative workload	1.28 (0.97 to 1.69)	0.076
3 weeks cumulative workload	1.39 (1.04 to 1.84)	0.026
4 weeks cumulative workload	1.40 (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.

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

518

519

520