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

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Workload and injury incidence in elite football academy players.

Abstract

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

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

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

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

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

2

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).

4

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, & Gastin, 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.

8

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.

9

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%.

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

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.

13

298

This study presents some limitations. First of all, the current study identified an

association between absolute workload and injury incidence with players in a football

academy but it does not necessarily mean that there is a causal connection between

workload and injury incidence (Bahr, 2016). Although very complicated to implement

in the real high-level sport world, other studies and randomised controlled trials should

be assessed to analyse the effect of a controlled workload on the injury incidence, in an

isolated way, to confirm a causal connection (Bahr, 2016). As a cohort study, the design

represents a limit. The observation of the players means that the results are influenced

by players sustaining several injuries and as such are considered as repeated

independent observations while these injuries are multifactorial and are linked to a lot of

factors dependent of the player observed, as, for example, the ability to cope with very

high load and/or to large variations in workload. One of the limits of this study is the

low injury incidence in this study with only 182 injuries for 17,778 days of observation

in U19 and 372 injuries for 26,672 days of observation in U21, representing a daily

probability to sustain an injury of 1.02% in U19 and of 1.15% in U21. This low

probability could explain in part the absence of statistical association in U19 as a low

occurrence of an event reduces the probability to find an association between this event

and an independent factor (Bahr and Holme, 2003). Another limit of the study concerns

the practitioners who recorded the data. If they adapted the workload according to the

data recorded to protect some players with very high of low workloads, it would impact

the results. This limit could also partly explain the absence of results in U19 compared

to the results in U21. In U19, the workload was regulated on a weekly basis by the

practitioners. The objective for the practitioners in U19 was to reach a mean weekly

group workload of 2,500 A.U., and was analysed in the end of each week to decide how

14

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

15

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

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

16

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   *Rehabillitation*, *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., & Gastin, 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 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

21

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 (9.66 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

Introduction

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

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

3

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).

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, & Gastin, 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 ± 6.8cm; body

106   mass: 70.9 ± 7.3kg) 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

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

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

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

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

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

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

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

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

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

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., & Gastin, 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 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 (9.66 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