

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

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

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

Abstract

4 5	3	
6 7	4	The aim of this study was to prospectively analyse the relationship between
8 9	5	workloads and injury in elite football academy players.
10	6	
11 12	7	Elite football academy players ( $n = 122$ ) from under-19 (U19) and under-21
13 14	8	(U21) of a professional football team competing in UEFA European Cups were
15	9	followed during 5 seasons. Injuries were collected and absolute workload and
16 17	10	workload ratios (4-weeks, 3-weeks, 2-weeks and week-to-week) calculated using
18 19	11	a rolling days method with the help of the session Rate of Perceived Exertion.
20	12	
21 22	13	There was no association between absolute workload or workload ratio with the
23 24	14	injury incidence in the U19. In the U21, the level of cumulative absolute
25	15	workloads during 3-weeks (RR=1.39, p=0.026) and during 4-weeks (RR=1.40,
26 27	16	p=0.019) were associated with an increase in injury. There was no association
28 29	17	between workload ratio and injury in U21.
30	18	
31 32	19	The significant link between high cumulated 3-weeks and 4 weeks workloads and
33 34	20	injury in U21 confirmed the requirement to monitor the internal subjective
35	21	workload in U21 in order to prevent injury. Further studies exploring the
36 37	22	relationships between workload and injury are required in football academy.
38 39		
40	23	Keywords: Training, Academy, Team Sport, Injury prevention.
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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

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,

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

#### **Materials and Methods**

**Subjects** 

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

*Methodology* 

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

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

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

#### 155 Statistical Analysis

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

161 The daily probability to sustain an injury was calculated by dividing the number of162 injuries by the number of days of observation, multiplied by 100.

#### **Results**

A total of 122 players have been followed during the period of observation. The number of players in each squad, season by season, are described in table 1. In U19 category, a total 52 players were followed (24 players were followed during one season, 26 players were followed during two seasons, 2 players were followed during 3 seasons). In U21 category, a total of 70 players were followed (41 players were followed during one season, 16 players were followed during 2 seasons, 8 players were followed during 3 seasons, 4 players were followed during 4 seasons and one player was followed during the 5 seasons of observation). It represents a total of 200 player-seasons, 17,778 days in 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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188 189 190 191	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the
188 189 190 191 192	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between
188 189 190 191 192 193	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between absolute workload and global, non-contact and contact injuries in U21 are described in
188 189 190 191 192 193 194	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between absolute workload and global, non-contact and contact injuries in U21 are described in table 4. An association was found between the cumulative 3 weeks absolute workload
188 189 190 191 192 193 194 195	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between absolute workload and global, non-contact and contact injuries in U21 are described in table 4. An association was found between the cumulative 3 weeks absolute workload and injury incidence (RR=1.39, p=0.026) and between the cumulative 4 weeks absolute
188 189 190 191 192 193 194 195 196	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between absolute workload and global, non-contact and contact injuries in U21 are described in table 4. An association was found between the cumulative 3 weeks absolute workload and injury incidence (RR=1.39, p=0.026) and between the cumulative 4 weeks absolute workload and injury incidence (RR=1.40, p=0.019). There was no association between

players.

# 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

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

association between absolute or A:C workload ratio with U19 players, while there was

an association between 3 weeks and 4 weeks cumulative absolute workload with U21

1	223	No link between absolute workload, A:C workload ratio and injury incidence
2 3	224	was found for the U19. These results about the lack of significant relationship between
4 5 6	225	absolute workload and the occurrence of injury are different of a previous study led by
6 7 8	226	Brink et al. (2010), who found an association between internal workload calculated
9 10	227	using the sRPE and the injury incidence. However, the methodology used are different.
11 12 13	228	First of all, Brink et al. analysed the sum of the workload week after week, while in the
14 15	229	current study, a rolling days method was used to analyse the workload day after day.
16 17	230	This is a major difference between the two studies as an injury at the beginning of the
18 19 20	231	week or in the end of the week could lead to big changes in the weekly workload with
21 22	232	Brink et al.'s methodology (2010). In the study led by Brink et al. (2010), an odd ratio
23 24 25	233	was calculated, while in the current study, a Poisson regression was used, providing a
26 27	234	relative risk. The injury incidence in Brink et al. study (2010) (37.55 per 1,000h of
28 29 30	235	match and 11.14 per 1,000h of training) was higher than the one in the present study
31 32	236	(7.6 in U19 and 9.6 in U21). The probability to find a significant association between a
33 34 35	237	potential risk factor and an event depends on the event frequency. It means that the
36 37	238	higher the injury incidence is, the higher the probability to find a significant statistical
38 39 40	239	association is (Bahr and Holme, 2003). The method to calculate the workload was not
40 41 42	240	exactly the same as the authors used a 15-point scale to rate the perceived intensity and
43 44	241	multiply the perceived exertion by the number of hours of practice while a 10-point
45 46 47	242	scale was used in the present study and the exertion was multiplied by the number of
48 49	243	minutes of practice. It is therefore difficult to compare the workload data range width
50 51 52	244	while the data range width of the independent factor modifies the results of a regression
53 54	245	(Salgueiro da Silva and Seixas, 2017). Another difference in the results could be
55 56 57	246	explained by a different definition of injury, as Brinks et al. (2010), defined the injury
58 59	247	as any physical complaint sustained by a player that results from a soccer match or
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soccer training and leading to time loss or medical attention. In the present study, only
the complaint leading to time loss were taken into account. Given the very low odd ratio
(OR=1.01, 95% CI 1.00 to 1.02) reported by Brink et al. (2010), these changes in the
methodology could explain the absence of association in the current study and the
differences between the two studies.

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

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

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

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

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

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.

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

### 342 Conclusion

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

1	348	academy in order to potentially reduce the injury incidence. Further studies are required
1 2 3	349	in these age categories to analyse these associations.
4 5	350	
6 7	351	Acknowledgements
8 9	352	The authors thank all the players who took part in the study.
10 11		The autions mank an the prayers who took part in the study.
12 13	353	
14 15	354	Declaration of interest statement
16 17	355	The authors report no conflict of interest.
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	Number of players observed	Number of players observed
	in U19	in U21
2012-2013	Х	21
2013-2014	18	26
2014-2015	16	24
2015-2016	23	28
2016-2017	25	19

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

observation.

501Table 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)

and 28 days (4weeks) in the U19 age category.

	RR	р
	(95% CI)	
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

 $\begin{array}{r} 45\\ 46\\ 47\\ 48\\ 49\\ 50\\ 51\\ 52\\ 53\\ 54\\ 55\\ 56\end{array}$ 

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

	RR (95% CI)	р
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

- 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)	р
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

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

	RR (95% CI)	р
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

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

118

119 Methodology

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

125 The workload was calculated by the sRPE method. This method is valid for its use with athletes and football players (Foster, 1998; Impellizzeri et al., 2004). 126 127 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 <sup>(</sup>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
170 171	season, 16 players were followed during 2 seasons, 8 players were followed during 3 seasons, 4 players were followed during 4 seasons and one player was followed during

## 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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188 189	*** TABLE 3 NEAR HERE
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188 189 190 191	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the
188 189 190 191 192	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between
188 189 190 191 192 193	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between absolute workload and global, non-contact and contact injuries in U21 are described in
188 189 190 191 192 193 194	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between absolute workload and global, non-contact and contact injuries in U21 are described in table 4. An association was found between the cumulative 3 weeks absolute workload
188 189 190 191 192 193 194 195	*** TABLE 3 NEAR HERE In U21, the mean weekly workload was 1979±666 AU; the mean 2 weeks workload was 3783±1211 AU; the mean 3 weeks workload was 5497±1740 AU and the mean 4 weeks workload was 7145±2254 AU. The results concerning the link between absolute workload and global, non-contact and contact injuries in U21 are described in table 4. An association was found between the cumulative 3 weeks absolute workload and injury incidence (RR=1.39, p=0.026) and between the cumulative 4 weeks absolute

199 \*\*\*TABLE 4 NEAR HERE
200 \*\*\*TABLE 5 NEAR HERE
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202

203 **Discussion** 

The aim of this study was to analyse the relationship between workload and injury incidence in elite football academy players. The main findings showed that there was no association between absolute or A:C workload ratio with U19 players, while there was an association between 3 weeks and 4 weeks cumulative absolute workload with U21 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 minutes of practice. It is therefore difficult to compare the workload data range width 243 244 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

soccer training and leading to time loss or medical attention. In the present study, only
the complaint leading to time loss were taken into account. Given the very low odd ratio
(OR=1.01, 95% CI 1.00 to 1.02) reported by Brink et al. (2010), these changes in the
methodology could explain the absence of association in the current study and the
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 was associated with an elevated incidence of overuse injury with elite football players 268 269 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.

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	

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

342

Conclusion

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	

	Number of players observed	Number of players observed
	in U19	in U21
2012-2013	Х	21
2013-2014	18	26
2014-2015	16	24
2015-2016	23	28
2016-2017	25	19

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

499 observation

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)

	RR	р
	(95% CI)	
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

503 and 28 days (4weeks) in the U19 age category.

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)	р
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

- 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)	р
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

- 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)	р
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