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Injury risk and maturity status in Italian elite young football players

Injury risk in Italian youth soccer players

KEY WORDS: adolescent; biological age; individualized loads; trauma; youth sport.

LEVEL OF EVIDENCE: 2B

BACKGROUND

Soccer is a complex contact sport that involves relatively high risks and rates of injury at all levels (young athletes, amateur, and professional), during training and match. A specific attention needs to be paid to sport injuries in youth athletes since it is very common for them to encounter an injury during competitive season, which determines restricted participation or training modifications and often a long time of absence from normal training (1). This, as a consequence, imply a substantial reduction of the chances of reaching high levels of performance (2).

As regards the nature and incidence of injuries in young soccer players, precise conclusions are difficult to draw from the available literature (3). Injury represents a central topic for sport science, where is thus fundamental to acquire a clear framework about injury risk factors, to the aim of planning preventive strategies.

The adolescence represents a sensitive phase, in which a great variability in growth and maturation is observed between individuals. Growth rates show a significant increase during the adolescent growth spurt, with the peak height velocity (PHV) observed in average from 13 to 14 years in boys, although with a certain inter-individual variability (4). PHV can be reached at different age, since individuals present a great variation the timing and tempo of biological maturation, so that within a specific age class it is possible to find subjects in different maturation stage, which can be classified as early, average or late maturers.

27 The difference in biological maturation and the discrepancies in size and performance
28 observed in youth who play sports are the subject of great discussions regarding competitive
29 disadvantages and the risk of injury. The rapid growth and, as a consequence, the period around PHV
30 have been generally associated with an increased risk of injury in elite youth athletes,(5) even if not
31 all studies agree (6,7). The higher incidence at PHV has been interpreted as being due to the reduction
32 of the concentration of bone mineral, increased tensile forces on vulnerable muscle attachments,
33 decreased neuromuscular control and reduced flexibility that occurs in this period (4,5,8).

34 These factors combined with excessive functional overload result in an inflammatory
35 degenerative process that can cause injury.

36 Injuries are of two types: traumatic and overuse injuries.

37 Muscle injuries, joint dislocations and bone fractures are considered acute traumatic injuries.
38 This type of trauma is generally due to a single event, which exceeds the resistance capacity of the
39 structure, generating an injury (5,6,9).

40 Chronic pathologies due to functional overload, therefore microtraumas that recur over time,
41 are defined as overuse injuries (10). Somato-anthropometric changes and changes in body
42 composition have been identified among the possible causes of overuse injuries (8). Studies
43 investigating the etiology of growing-up injuries in young players have documented that the majority
44 of overuse injuries caused an absence from play of more than 28 days (severe injury) (8,11). Most of
45 the functional overload injuries recorded in the literature were Osgood Schlatter and Sinding Larsen
46 Johansson syndrome, caused by excessive overload of the myotendon complex and highly associated
47 with growth. Microtraumas are observed not only in the muscle-tendon system, but also in the bone,
48 cartilage and ligament (12). Non-individualized loads bring excessive overload to the anatomical
49 structures mentioned above, generating a degenerative-inflammatory process that is at the basis of
50 overuse injuries. This happens very frequently in the elite youth sectors, where incorrect load
51 management combined with excessively intensive training can cause overuse injuries (3,6).

52 Traumatic and overuse injuries occur mainly during PHV and this may be due to a double
53 factor: the first of a mechanical nature, namely the functional overload imposed on the structure; the
54 second of a physiological nature, since the bone tissue and the myotendon complex which are
55 developing during the PHV cannot tolerate high forces; therefore, an overload combined with
56 excessive shear and compression forces on the previously mentioned tissues can cause trauma.

57 Having found in the literature a lack of uniformity about the peaks of incidence of the different
58 types of injuries, it is necessary to proceed with further investigations. In addition, no data are at
59 disposal for Italian elite young football player. The aim of the present study was to analyze differences
60 in the incidence of injuries in Italian young elite soccer players belonging to different maturation
61 stage (pre-PHV, PHV and post-PHV) in order to identify the relationship between injuries (traumatic
62 and overuse) and maturity.

63

64 **MATERIALS AND METHODS**

65 This cross-sectional study included 141 elite male youth soccer players (age 13.9 ± 0.8) from
66 the U13-U15 categories (U13, N = 26; U14, N = 64; U15, N = 51), associated with an Italian Serie A
67 professional soccer team (Bologna F.C. 1909). Participants were selected from the season 2018/2019.
68 The eligibility criteria for this study were athletes who had been playing for at least a full season and
69 were to be in one of the following maturity stages: 1 year before, 1 year during and 1 year after their
70 predicted PHV. The players voluntarily decided to participate, and their parents provided informed
71 consent after a detailed description of the study procedures. The study was carried out in conformity
72 with the ethical standards laid down in the 1975 declaration of Helsinki and was approved by the
73 local Bioethics Committee of the University of Bologna (Approval Code: 25027) and were in
74 accordance with the MLTJ guidelines (13).

75 All anthropometric data were collected by a specifically trained physician. Height, sitting
76 height, body weight were collected with participants wearing only shorts. Height and sitting height

77 were recorded to the nearest 0.1 cm with a standing stadiometer (Raven Equipment Ltd. Great
78 Donmow, UK) and body weight was measured to the nearest 0.1 kg with a high-precision mechanical
79 scale (Seca, Basel, Switzerland). Leg length was derived as the difference between height and sitting
80 height. An estimation of the years from peak height velocity (YPHV), which is an indicator for the
81 adolescent growth spurt, was made using Mirwald's equation for boys, which can predict maturity
82 offset in youth athletes (14,15). Maturity offset = $-9.236 + 0.0002708 (\text{leg length} \times \text{sitting height}) -$
83 $0.001663 (\text{age} \times \text{leg length}) + 0.007216 (\text{age} \times \text{sitting height}) + 0.02292 (\text{weight} : \text{height})$. Since
84 maturity offset represents the years of distance from peak height velocity (PHV), predicted age at
85 PHV (years) was calculated as the difference between chronological age and maturity offset.

86 To compare injuries between players of different maturation status, the year of PHV was set
87 by taking 6 months before and 6 months after the age at PHV. The 12 months before this year were
88 allocated as the year before PHV (Pre-PHV); the 12 months after this year were allocated as the year
89 after PHV (Post-PHV). Based on these classifications the subjects were divided into three groups:
90 Pre-PHV, N=51; PHV, N= 81; Post-PHV, N=31 (5).

91 Injuries have been recorded and diagnosed by the medical staff of the team. According to the
92 consensus statement for soccer injury studies, i.e., the FIFA registration system,(10) an injury was
93 defined as: “any physical complaint sustained by a player that results from a football match or football
94 training, irrespective of the need for medical attention or time loss from football activities”. The
95 physician recorded “time–loss” injury that results in a player being unable to take a full part in future
96 football training or match the injuries.

97 Injuries can be classified by location, type, body-site and mechanism of injury (traumatic or
98 overuse). Traumatic injuries refer to “an injury resulting from a specific, identifiable event”; while
99 overuse injuries are caused by repeated micro-trauma without a single, identifiable event responsible
100 for the injury.

101 The location of injuries is divided in four main groups: head and neck, upper limbs, trunk and
102 lower limbs. The type of injuries is recorded in 6 main groups: fracture and bone stress, joint and

103 ligament, muscle and tendon, contusions, center / peripheral nervous system and other. The severity
104 of the injury was defined as the number of days that the player was not able to take full part in
105 competition or training: minimal (1 –3 days' time loss), mild (4–7 days' time loss), moderate (8–28
106 days' time loss), severe (more than 28 days' time loss).

107 The hours of training and matches were recorded by the athletic trainers of the respective
108 categories. In case of missing data, training and match hours were replaced by the average amount of
109 training hours or match hours for the corresponding age category in that year. Traumatic and overuse
110 injuries was calculated as the number of injuries per 1000 h of total exposure (training exposure plus
111 match exposure); training and match injury incidence was calculated as the number of injuries per
112 1000 h of exposure in training and matches.

113 Descriptive statistics were calculated for all outcome variables. Differences between the
114 groups were investigated using the one-way analysis of variance (ANOVA). When a significant F
115 ratio was obtained, the Bonferroni post-hoc test was used to assess the differences among the groups.
116 Cohen's d was calculated as a measure for interpreting the scores. An effect size of approximately
117 0.20 was considered small, 0.50 moderate or 0.80 large (16). Chi-square test was carried out to value
118 the difference among injury frequencies observed among the three maturity groups. Statistical
119 significance was determined as $p < 0.05$. The software used to carry out the statistical analyzes was
120 STATA (16.1. StataCorp, College Station, Texas, USA).

121

122

123

124 **RESULTS**

125 The original cohort consisted of 350 soccer players. Of these, 209 players were excluded (51
126 players for U13, 4 players for U14 and 7 players for U15) because they had no anthropometric

127 measurement taken to estimate PHV or because their PHV was not within the target stated above or
128 an in-season transfer to another club. The remaining 141 players were observed for the season
129 2018/2019 (Fig. 1).

130 During the period of data collection, 83 injuries were recorded. Most of the injuries were
131 recorded in the lower limb (77%) (Fig.2). The most common injuries were joint / ligament injuries
132 (36%) and muscle injuries (33%); followed by fracture / bone stress (13%); contusions and
133 hematomas (6%); concussion / nerve injuries (4%); wound / laceration (2%); while 6% were
134 classified as other injuries (Fig.3). Across all groups, the overall exposure to football was 25214 hours
135 (22388 training hours and 2826 match hours). The mean injury incidence for the total cohort was 3.29
136 injuries per 1000 hours (0.83 injuries per 1000 hours during matches; 2.46 injuries per 1000 hours
137 during trainings). On a total of 83 injuries, 63 were traumatic and 20 were overuse injuries; 62 injuries
138 occurred in training and 21 in matches. There was a total of 2901 lost days.

139 As regards age groups, the category where most of the injuries occurred was U13 (81% of the
140 sample suffered injuries); followed by U15 (63%) and finally by U14 (47% of the sample was
141 injured). Chi square test showed a statistically significant differences in injuries frequencies between
142 the three age groups categories ($\chi=9.2686$; $p=0.010$).

143 Considering the subjects according to their maturity status, the athletes at PHV presented the
144 highest incidence of injury (56%), followed by subjects in Post-PHV phase (48%) and then by
145 subjects in Pre-PHV (45%); Chi square test did not show statistically significant differences in
146 injuries frequencies between the three groups ($\chi=1.4677$; $p=0.480$).

147 Traumatic injury incidence, overuse injury incidence, training injury incidence, match injury
148 incidence, missed days due to injuries and mean hours of exposure in the athletes in the three-maturity
149 status are reported in Table I.

150 Traumatic injury showed a tendency to increase from the year before PHV to the year of PHV,
151 after this period a decrease can be observed, without any significant differences among groups. The

152 effect size between Pre-PHV and PHV, PHV and Post-PHV, Pre-PHV and Post-PHV was small
153 (Table I; Fig. 4).

154 Overuse injuries incidence remained constant until PHV, and then decreased in the year after
155 PHV. The differences between the groups were not significant (Table I). Furthermore, functional
156 overload trauma between Pre-PHV and PHV, PHV and Post-PHV, Pre-PHV and Post-PHV showed
157 a small effect size (Fig. 4).

158 Training injury incidence per player showed an increase from the year before PHV to the year
159 of PHV, period in which it reached its peak, and after which it decreased. No statistically significant
160 differences were found; moreover, the differences between Pre-PHV and PHV, PHV and Post-PHV,
161 Pre-PHV and Post-PHV showed a small effect size (Table I; Fig. 5). Match injury incidence per player
162 decreased from the year before PHV to the year of PHV; after this period, an increase was observed;
163 also, in this case; no statistically significant differences were observed. Furthermore, injuries in
164 matches between Pre-PHV and PHV, PHV and Post-PHV, Pre-PHV and Post-PHV showed a small
165 effect size (Table I; Fig. 5).

166 Days missed due to injury showed an increase up to PHV, and then a considerable decrease
167 in the year after PHV; the difference among groups were statistically significant and Post-hoc tests
168 revealed that days missed due to injury were significantly higher in the year of PHV than in the year
169 after PHV (Table I; Fig. 6). The effect size regarding this type of injuries between Pre-PHV and PHV,
170 Pre-PHV and Post-PHV was small, instead the effect size between PHV and Post-PHV was moderate.

171 The Post-PHV group recorded the largest mean exposure with 176.78 ± 63.33 hours
172 (Table I; Fig. 7). The mean of exposure showed an increase from the year before PHV to the year
173 after PHV; furthermore, statistically significant differences were found among these groups
174 ($p=0.0089$). Post-hoc tests revealed that mean of exposure was significantly higher in the year after
175 PHV than in the year before PHV, $p=0.010$. The mean of exposure between Pre-PHV and PHV
176 showed a moderate effect size; the effect size between PHV and Post-PHV was small; instead, the
177 effect size between Pre-PHV and Post-PHV was large (Table I).

178

179 Insert Table I

180 Insert Figure 1

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194 **DISCUSSION**

195 The aim of the present study was to investigate how maturity status (pre-PHV, PHV, post-
196 PHV) influenced injury risk in Italian élite football players. To our knowledge, there are no data
197 regarding Italian young player according to this aspect. In addition, the effects of maturity timing on
198 injury risk are still unclear regarding how maturity status influence injury risk.

199 We considered the differences in traumatic and overuse injuries, as well as the incidence in
200 training and match injury before, during and after the peak height velocity (PHV), which represents
201 the period of maximal rate of growth.

202 The percentage variation in injury incidence between the Pre-PHV and the PHV in our study
203 amounted to 29% and is in line with what reported by Van der Sluis et al. (2013) and Bult et al.
204 (2018), which reported an amount of 37% and 26% respectively, while it considerably differed from
205 the results of Johnson et al. (2019) (115%). The part of the body more susceptible to injuries was the
206 lower limb; this is consistent with other studies regarding youth soccer from different countries (5,6).

207 The most common types of injury in this study were muscle injuries; a finding similar to the
208 results obtained by Price et al. (2004), Le Gall et al. (2006) on elite English and French youth football
209 players respectively (11,17,18).

210 Considering age groups, significant differences were observed between groups, but without a
211 specific trend: the highest incidence was reported in U13, followed by U15 and finally by U14.

212 Regarding the state of maturity, it was possible to find a tendency to the increase in the
213 incidence of injuries during the PHV, even if not significant. The higher incidence at PHV was
214 reported also by other authors (6,19). According to Towlson et al. (2020) during adolescent growth
215 spurt, boys show a rapid growth (also between 7 and 12 cm per year), which may partially explain
216 the phenomenon “adolescent awkwardness,” whereby the trunk and lower limb length have increased
217 but soft tissues have yet to adapt to the size and weight of the frame, causing abnormal movement
218 mechanics that negatively impact performance. This rapid change in musculoskeletal structure and
219 apparent lag time to adequate relative strength is individually variable based on maturity tempo,
220 which likely corresponds to a variation in readiness to perform and, by inference, to vulnerability to
221 injuries.

222 Taking into account the specific nature of injuries, traumatic injury and overuse injuries did
223 not show a significant difference among the three maturity groups. Traumatic injury incidence
224 showed a tendency to increase from the year before PHV to the year of PHV, while after this period
225 a decrease was observed; overuse injury incidence remained constant until PHV, after which a
226 decrease was recorded. The result regarding traumatic injury and overuse injury were greater from

227 what reported by van der Sluis et al. (2013), even if they did not report any significant difference for
228 these types of injuries, too.

229 It should be considered that traumatic injuries may be related to factors such as, but not limited
230 to, tendon maturity, reduced joint stiffness, decreased movement efficiency and decreased bone
231 density. On the other hand, overuse injuries, can be attributed to disproportionate development of
232 skeletal maturity in relation to muscle development (20). These maturation-dependent differences in
233 injury risk should be a point of attention for practitioners, with particular regard to the highly
234 demanding mechanical loading of training practices and intensified bouts of match-play often
235 experienced during match-format football. Training injury showed a tendency to increase at PHV too,
236 while match injury tended to show higher incidence in pre-PHV. Injury rate was considerably higher
237 during matches (6.6-17.1 injuries per 1000 h) than during training (3.4-4.9 injuries per 1000 h), with
238 the majority of injuries being traumatic in nature. The incidence both in training and in matches
239 injuries recorded in our study is comparable to that observed by Le Gall et al. (2006) on elite French
240 youth football players (17).

241 The general tendency to the increase of injuries at PHV found in the present study highlights
242 the increased vulnerability of athletes at this stage, as demonstrated by other authors. This has been
243 reconducted to a functional overload that acts on a bone tissue and on the myo-tendon complex, both
244 not yet fully developed, which are not able to withstand such high shear and compression forces,
245 leading to fractures and muscle injuries (8,21). Regarding bone tissue, the acquisition of bone mineral
246 content (BMC) and bone mineral density (BMD) occurs during PHV, this osteogenic reorganization
247 and remodelling leads to a greater risk of both traumatic and overuse injuries during this state of
248 maturity. Regarding the myo-tendon complex, the increase in terms of volume and strength is
249 recorded approximately at the PHV. This means that the tissue is particularly susceptible to trauma
250 in this phase, not being able to deliver sufficient force instead of what it would be at Post-PHV;
251 alongside this aspect, low joint stiffness and reduced neuromuscular efficiency leads to greater
252 exposure to both acute and chronic injuries (21).

253 The days missed due to injuries in talented youth soccer players were significantly higher in
254 the athletes at PHV, who significantly differed from post-PHV athletes. These results are in
255 accordance with those of van der Sluis et al. (2014), even if in their study the differences were not
256 significant. These suggest how during the PHV the injuries are more severe, causing more days of
257 absence from training and/or competition. In this period of growth, the athletes are more susceptible
258 and less receptive to recovery.

259 The rapid growth and, as a consequence, the period around PHV have been associated with
260 an increased risk of injury in elite youth athletes (22). This has been interpreted as being due to the
261 reduction of the concentration of bone mineral, increased tensile forces on vulnerable muscle
262 attachments, decreased neuromuscular control and reduced flexibility (4,8,9,23).

263 There are various possible reasons for an increased injury occurrence and burden at PHV.
264 Firstly, during PHV the vulnerability of bodily tissues increases, including changes to muscle-tendon
265 junctions, bone-tendon junctions, ligaments, growth cartilage and bone density (9,23). This could be
266 due to the many changes in size, shape and function that accompany the pubertal growth spurt (8,
267 24,25).

268 The mean of hours of exposure grows linearly from Pre-PHV to Post-PHV, showing
269 statistically significant differences in the Pots-PHV group compared to the Pre-PHV group.

270 It is to consider that the athletes in the Pre-PHV group are likely to be those who belonged
271 to the youngest category (U13); while the athletes who are in the Post-PHV are those who belong to
272 the category of the oldest (U15), which also presented a higher hour of exposure. The mean of
273 hours of exposure increased linearly from Pre-PHV to Post-PHV, recording statistically significant
274 differences.

275 The strength of this study was the accuracy with which musculoskeletal injuries were tracked
276 and determined during the study. This made it possible to evaluate and study with greater precision
277 and accuracy the relationships between the risk of injuries and the state of maturity in young elite
278 athletes. The analyzes show that the key factor in reducing the incidence of accidents is to

279 individualize the volume of work. This would help reduce the risk of injury and maximize physical
280 performance. The hope for the future will be to develop working strategies that take into account the
281 biological maturity, raising awareness, moreover, a proper work by professionals in this field.
282 However, a limitation is represented by the numerosity and cross-sectional nature of the sample.

283 In conclusion, the results of this study on young Italian football players confirm the overall
284 increased vulnerability of the athletes in the PHV period. To try to limit injuries, training programs
285 should be calibrated on the state of maturity and not on the chronological age of the group. As the
286 chronological age groups increase, the external training load increases. The same training stimulus
287 can improve performance in one player, maintain performance in another and cause injury to a third
288 player. The same considerations could be applied to playing time: the total distance, the high and
289 very high intensity distance that players cover increases with increasing age, and to acceleration,
290 maximum running speed and repeated sprinting skills.

291 Further research is, however, warranted to confirm this speculation, moreover longitudinal.
292 This could allow to follow the athletes in time, highlighting with greater detail the criticalities.

293

294

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297 **CONFLICT OF INTERESTS**

298 The authors declare that they have no conflict of interests.

299

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368
369 Figure 1: (A) Flowchart of inclusion and exclusion and numbers of observed players for the season
370 2018/2019. 209 players were excluded because they had no anthropometric measurement taken to
371 estimate PHV or because their PHV was not within the target stated above or an in-season transfer to
372 another club. (B) Numbers of observed players for the season 2018/2019 and per team. For U13, 51
373 players were excluded; for U14, 4 players were excluded and for U15, 7 players were excluded.

374
375 Figure 2: Injury location and severity in the 3 periods around PHV.

376
377 Figure 3: Type of injuries in the 3 periods around PHV.

378
379 Figure 4: Means and standard deviations for traumatic and overuse injuries incidence per player in
380 talented youth soccer players.

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382 Figure 5: Means and standard deviations for training and match injuries incidence per player in
383 talented youth soccer players.

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385 Figure 6: Number of days missed in the 3 periods around PHV (bar represent standard deviation).

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387 Figure 7: Hours of exposure in the 3 periods around PHV (bar represent standard deviation).