



UNIVERSITY OF
GLOUCESTERSHIRE

This is a peer-reviewed, post-print (final draft post-refereeing) version of the following published document, This is an Accepted Manuscript of an article published by Taylor & Francis in Journal of Sports Sciences on December 2016, available online:

<http://www.tandfonline.com/10.1080/02640414.2016.1173221> and is licensed under All Rights Reserved license:

Read, Paul J, Oliver, Jon L, De Ste Croix, Mark B ORCID: 0000-0001-9911-4355, Myer, Gregory D and Lloyd, Rhodri S (2016) The scientific foundations and associated injury risks of early soccer specialisation. Journal of Sports Sciences, 34 (24). pp. 2295-2302. doi:10.1080/02640414.2016.1173221

Official URL: <http://www.tandfonline.com/doi/full/10.1080/02640414.2016.1173221>

DOI: <http://dx.doi.org/10.1080/02640414.2016.1173221>

EPrint URI: <https://eprints.glos.ac.uk/id/eprint/3425>

Disclaimer

The University of Gloucestershire has obtained warranties from all depositors as to their title in the material deposited and as to their right to deposit such material.

The University of Gloucestershire makes no representation or warranties of commercial utility, title, or fitness for a particular purpose or any other warranty, express or implied in respect of any material deposited.

The University of Gloucestershire makes no representation that the use of the materials will not infringe any patent, copyright, trademark or other property or proprietary rights.

The University of Gloucestershire accepts no liability for any infringement of intellectual property rights in any material deposited but will remove such material from public view pending investigation in the event of an allegation of any such infringement.

PLEASE SCROLL DOWN FOR TEXT.

This is a peer-reviewed, post-print (final draft post-refereeing) version of the following published document:

Read, Paul J and Oliver, Jon L and De Ste Croix, Mark B and Myer, Gregory D and Lloyd, Rhodri S (2016). *A review of the scientific foundations and associated injury risks of early soccer specialisation*. Journal of Sports Sciences. ISSN 0264-0414

Published in Journal of Sports Sciences, and available online at:

<http://www.tandfonline.com/doi/full/10.1080/026404...>

We recommend you cite the published (post-print) version.

The URL for the published version is

<http://www.tandfonline.com/doi/full/10.1080/026404...>

Disclaimer

The University of Gloucestershire has obtained warranties from all depositors as to their title in the material deposited and as to their right to deposit such material.

The University of Gloucestershire makes no representation or warranties of commercial utility, title, or fitness for a particular purpose or any other warranty, express or implied in respect of any material deposited.

The University of Gloucestershire makes no representation that the use of the materials will not infringe any patent, copyright, trademark or other property or proprietary rights.

The University of Gloucestershire accepts no liability for any infringement of intellectual property rights in any material deposited but will remove such material from public view pending investigation in the event of an allegation of any such infringement.

PLEASE SCROLL DOWN FOR TEXT.

1 ***A REVIEW OF THE SCIENTIFIC FOUNDATIONS AND ASSOCIATED***
2 ***INJURY RISKS OF EARLY SOCCER SPECIALISATION***

3
4 **RUNNING TITLE**

5 Early Soccer Specialisation and Injury Risk

6
7 **KEY WORDS**

8 Soccer, Injury, Overuse, Elite Player Performance, Early specialisation

9
10 **AUTHORS**

11 PAUL J. READ ¹ JON L. OLIVER ^{2,3} MARK B.A. DE STE CROIX ⁴

12 GREGORY D. MYER ^{5,6,7,8} RHODRI S. LLOYD ^{2,3}

13
14 **AFFILIATIONS**

- 15 1. School of Sport, Health and Applied Science, St Mary's University, London, UK
16 2. Youth Physical Development Unit, School of Sport, Cardiff Metropolitan University, UK
17 3. Sport Performance Research Institute, New Zealand (SPRINZ), AUT University, Auckland,
18 New Zealand
19 4. School of Sport and Exercise, University of Gloucestershire, UK
20 5. Division of Sports Medicine, Cincinnati Children's Hospital, Cincinnati, Ohio, USA
21 6. Department of Pediatrics and Orthopaedic Surgery, College of Medicine, University of
22 Cincinnati, Cincinnati, Ohio, USA
23 7. The Micheli Center for Sports Injury Prevention, Boston, MA, USA
24 8. Department of Orthopaedics, University of Pennsylvania, Philadelphia, Pennsylvania, USA.

25
26
27
28 **CORRESPONDENCE**

29
30 Name: Paul Read
31 Address: St Mary's University, Waldegrave Road, Twickenham, London, TW1 4SX
32 Email: paul.read@stmarys.ac.uk

33 **ABSTRACT**

34 Early specialisation is characterised by formal participation in a single sport at the exclusion
35 of others. Limited data are available to support this approach in the development of soccer
36 players who attain elite status later in life. Of growing concern is the associated increased risk
37 of injury and suggestions that single sport specialisation is a risk factor independent of age,
38 growth, biological maturation and training volumes In the United Kingdom, elite soccer
39 organisations have recently adopted an early sport specialisation approach following the
40 introduction of the Elite Player Performance Plan. A key tenet of this programme is increased
41 opportunities for training through a marked rise in the specified on-pitch hours per week. The
42 accumulation of high training hours may be less of a relevant marker for success, and the
43 impact of such a significant increase in training volume for young athletes who are
44 experiencing a range of growth and maturational processes is currently unknown. This critical
45 commentary includes an evidence based discussion of the effectiveness of early sport
46 specialisation and the potential injury risks associated with such programmes placing a specific
47 focus on elite male youth soccer players. Available data indicate that modifications to the
48 existing EPPP framework could enhance player development and reduce injury risk. Proposed
49 alterations include reduced volume of soccer specific training at key stages of growth and
50 maturation and guidelines for the provision of a greater variety of physical activities that are
51 integrated within other programme components.

52

53

54

55

56

57

58 **INTRODUCTION**

59 A common dilemma in developmental sport has centred on the efficacy and effectiveness of
60 child athletes applying deliberate focus to just one sport at the expense of participating in a
61 range of activities (Baker, 2003). The path of early sport specialisation has been recognised as
62 early age involvement in one chosen sport during the period of early to middle childhood (up
63 to age 13 years) with no subsequent participation in the other sports or activities available
64 (Moesch et al., 2011). Specifically, this has included talent identification/development
65 programmes focused on the attainment of professional sports or Olympic success, which in
66 turn has increased the frequency of high volume, intense competitive activities that are highly
67 structured and focused on a single sport without sufficient time for rest and recovery (Bergeron
68 et al., 2015).

69

70 Historically, this has been applied in sports such as gymnastics and diving due to the
71 added advantage of a smaller body mass for rotational movements. The application of
72 systematic training in a single sport from a young age is based on the goal of attaining elite
73 status due to increased exposure and practice (Malina, 2010). Early research suggested that
74 mastery and elite performances in a range of activities was achieved by accruing more
75 deliberate practice time (Ericsson, 1993); however, this research has often been incorrectly
76 interpreted (Ericsson, 2013) and there is a paucity of literature to support this notion in sporting
77 activities. For example, Vaeyens *et al.* (2009) reported that no evidence currently exists to
78 confirm earlier exposures and greater volumes of sport-specific training are associated with
79 heightened success later in their sporting career.

80

81 The risks associated with specialising early within a given sport include the potential for
82 increased injury risk; social isolation and burnout (Malina et al., 2010; Lloyd et al., 2014).
83 Furthermore, a recent position statement from the American Medical Society of Sports

84 Medicine concluded that early sport specialisation may not lead to long-term sporting success
85 and may increase the risk of overuse injury and burnout (Di Fiori et al., 2014). The
86 commencement of formalised intensive training during the pre-pubertal years in one chosen
87 sport by excluding others imposes demands on young children that are exhaustive and entail
88 high psychological pressures reflective of those often undertaken by adults (Borms, 1986). This
89 may increase the likelihood of withdrawing from their chosen sport due to injury or burnout
90 (Gould et al., 1996; Wall and Cote, 2007). Early sport specialisation has also recently been
91 identified as an independent injury risk factor even after accounting for age and hours of total
92 training and competitions completed each week via the use of multivariate regression
93 modelling (Jayanthi et al., 2015). The increased injury risk for youth athletes who engage in a
94 single sport could be attributed to repeated exposures of submaximal loading on the
95 musculoskeletal system (Stein and Michelli, 2010; Di Fiori, 2014), whereby, sufficient time
96 for recovery and adaptation or variety in movement patterns is not provided (Di Fiori et al.,
97 2014). There is a paucity of literature to confirm this notion in soccer; however, available
98 evidence suggests that both athletes and coaches should proceed with caution before adopting
99 an early sport specialisation approach.

100

101 In the sport of soccer, an inherent risk of sports-related injury exists where a concomitant
102 increase in a child's age results in greater exposures to repetitive loading patterns that occur in
103 training and competitions, (Hogan and Gross, 2003). Recent investigations have also reported
104 that youth male soccer players display a heightened risk of overuse and sport-related injuries
105 at various stages of growth and maturation, specifically during the year of peak height velocity
106 (van der Sluis et al., 2014; van der Sluis et al., 2015). Possible mechanisms which contribute
107 to increased risk of injury during this period include changes in joint stiffness, and aberrant
108 movement patterns such as high knee abduction moments (Ford et al., 2010). Therefore,

109 practitioners should be cognisant of the potential negative implications of early sport
110 specialisation and avoid repeated exposures to solely sport-specific skills, which may increase
111 injury risk and limit motor skill enhancement. Also, an understanding of physiological changes
112 associated with key developmental periods during a child's growth and how this effects
113 movement skill and injury risk is required to effectively devise long-term soccer development
114 programmes. In the United Kingdom, elite soccer organisations have recently adopted an early
115 sport specialisation approach following the introduction of the Elite Player Performance Plan
116 (EPPP, 2011). This programme requires an increased volume of on-pitch training hours per
117 week in comparison to previous guidelines (EPPP, 2011). The accumulation of high training
118 hours appears to be an inaccurate measure of determining which players achieve elite
119 professional status later in their career (Haugaasen et al., 2012), and may impose a greater risk
120 of injury (Brink et al., 2010; Jayanthi et al., 2015); however, the impact of this programme is
121 currently unknown. The two key aims of this article are to; 1) review the available literature to
122 determine the effectiveness of early sports specialisation, 2) outline the potential injury risks
123 associated with early sport specialisation with a specific focus on elite male youth soccer
124 players.

125

126 *Is Early Sport Specialisation Effective?*

127 Cumulative findings from the available literature suggest that in most sports, athletes who
128 experience greater diversification in their younger years increase their chances of sporting
129 success later in life (Jayanthi et al., 2012). For example, athletes attaining elite status intensified
130 their involvement with their specialist sports later than non-elites (Lidor and Lavyan, 2002).
131 This has been confirmed in ice hockey (Soberlak and Cote, 2003), tennis (Carlson, 1988), and
132 swimming (Barynina and Vaitsekhovski, 1992); however, when interpreting the findings from
133 these studies it should also be considered that regular participation in their primary sport was

134 also reported during childhood. More recent reports have revealed that elite adult athletes
135 commenced intensified training schedules later than those who were near elite (Moesch et al.,
136 2011). Retrospective analysis of the accumulation of training also identified that near elites had
137 undertaken more hours by ages 9, 12 and 15 years, whereas, the elite group accumulated greater
138 training hours by age 21. This suggests elite adult athletes specialise in their chosen sport later
139 than their non-elite counterparts. Also, a consistent finding from the available literature is that
140 elite adult athletes also played a greater variety of other sports during their developmental years
141 than non-elites (Jayanthi et al., 2012). More diverse sports participation has also been reported
142 to increase gross motor coordination and lower body explosive strength in the form of a
143 standing broad jump versus young boys who specialised in a single sport (Fransen et al., 2012).
144 This is likely as a result of increased exposures to a greater number of physical, cognitive,
145 affective and psychosocial environments and thus, the development of a broader range of skills
146 that are required for sport specialisation during adolescence (Côté et al., 2009; Fransen et al.,
147 2012). However, practitioners should be cognisant that there is currently a lack of available
148 evidence to describe the mechanisms underpinning the effects of greater diversification in the
149 developmental years and longitudinal research is needed to more clearly examine the causal
150 relationship between greater sports diversification and enhancements in motor skill and
151 physical fitness development (Fransen et al., 2012).

152

153 Available data to confirm the effectiveness of early sport specialisation in soccer are
154 limited. A review of literature highlighted that the age at which participation commenced
155 appears to range between 5 and 14 years of age (Haugaasen and Jordet, 2012). Some studies
156 have reported that elite English players started earlier than their non-elite peers (Ward et al.,
157 2007), whereas, other studies reported no difference in starting age in players from Belgium
158 and Holland (Helsen et al., 2000; Huijgen et al., 2009). Participation differences between

159 players classified as either recreational, formerly-elite, or those still competing at the elite level
160 have also reported the importance of unstructured soccer play activities (Ford et al., 2009). In
161 both elite groups, players averaged more cumulative hours than recreational players, but no
162 differences were identified in soccer practice, competition or other sporting activities prior to
163 age 12. However, the players progressing to professional status accumulated more unstructured
164 *'play'* hours than their ex-elite counterparts. Thus, while early specialisation is not
165 recommended, the importance of practice and play in soccer type activities from a young age
166 has been shown to contribute to the attainment of elite performance in soccer (Ford et al., 2009).
167 This supports the early engagement hypothesis, whereby children who achieve expert status
168 later in life undertake more *'play'* activities in their chosen sport (Côté et al., 2007), and this
169 has been further described in German professional soccer players with up to 86% of soccer
170 type activities comprised of a non-organised structure (Hornig et al., 2014). This type of
171 activity may be important for developing a range of skills including anticipation and decision
172 making (Bell-Walker & Williams, 2008), and psycho-social aspects such as motivation and
173 enjoyment (Côté et al., 2007). Thus, authors have proposed the importance of early engagement
174 during the childhood years rather than structured repetitive practice as this may lead to greater
175 skill levels later in their career (Ford et al., 2009). It should also be considered that successful
176 application of long-term athlete physical development approaches are largely determined by
177 education and quality instruction from appropriately qualified coaches highlighting the
178 importance of coach-athlete interaction from an early age (Myer et al., 2011; Lloyd and Oliver,
179 2012). A more recent study using Portuguese futsal players reported that elite players dedicated
180 themselves to the sport earlier than their non-elite counterparts (Serrano et al., 2013). These
181 results are in conflict with an investigation that assessed the contribution of diverse
182 participation towards the attainment of elite youth and senior professional status in soccer
183 players (Haugaasen et al., 2014). A retrospective questionnaire was utilised and reported the

184 amount of time spent partaking in sports other than soccer and their perceived contribution of
185 non-soccer related activities. No significant differences were shown between the engagement
186 history of professional and non-professional players. However, participating in similar sports
187 was rated as important to compliment the development of soccer skills.

188

189 There is also conflict within the available literature regarding the requirement for
190 accumulation of soccer practice hours in becoming an elite adult player (Haugaasen et al.,
191 2012), which is a fundamental principle of recently adopted youth soccer development
192 programmes (EPPP, 2011). Case histories of players from English Premier League academies
193 identified a greater volume of practice than a sub-elite control group (6500 hours versus 4990
194 hours) (Ward et al., 2007); however, the number of years of participation displayed minor
195 differences (11 versus 10.5 years respectively). Furthermore, the subjects in this study were
196 elite youth players; therefore, these data do not support the application that greater
197 accumulation of training hours present in elite academy players increases the likelihood of
198 achieving elite status as a senior professional. Other studies have also shown no differences in
199 accumulated soccer practice time between elite and sub-elite players (Koslowsky and Da
200 Conceicao Bothelo, 2010).

201

202 The age at which accumulated practice differentiates between elite and non-elite players
203 is also a point of contention. Using a retrospective questionnaire, the majority of Portuguese
204 national team players (90.5%) have been reported to undertake significantly greater soccer-
205 specific practice by age 10 years (Leite et al., 2009). Conversely, Dutch professional players
206 were reported to partake in an additional hour per week of soccer-specific practice from age 14
207 years (Huijgen et al., 2009). Although not directly linked to early sport specialisation, the
208 period of time for accumulation should also be considered, because prior research has failed to

209 show significant differences in accumulated practice time between elite and sub-elite players
210 until 10 years into their adult careers (Helsen et al., 1998). Variations reported within the
211 aforementioned literature could be due to recall bias which can occur with both long and short
212 term retrospective reporting (Junge and Dvorak, 2000).

213

214 Currently, there are inconsistencies within the available literature as to the effectiveness
215 of early soccer specialisation in developing elite adult professional players, which may be
216 attributed to high drop-out rates (Haugaasen and Jordet, 2012); a key factor affecting continued
217 participation (Vaeyens et al., 2009). Opportunities to partake in unstructured play and a wider
218 range of sporting activities appear to be useful and should be encouraged. Engaging in intensive
219 specialised soccer training with high levels of structure does not guarantee the likelihood of
220 higher performance levels later in life but may lead to an increased risk of overuse injuries.
221 Also, data available from Portuguese national athletes (including soccer players) showed that
222 the path to expertise were non-uniform, which reflects the complexity of skill acquisition (Leite
223 et al., 2009). Furthermore, in former Swiss professional soccer players, although all players
224 retrospectively reported above average volumes of in-club training, some showed above
225 average participation rates of informal soccer outside the club, whereas, others described
226 greater than average activity in other sports (Zibung and Conzelmann, 2012). Cumulatively,
227 while not always consistent, the existing literature indicates a more diverse approach to sports
228 participation is preferable.

229

230 ***Injury risk associated with early soccer specialisation***

231 The incidence of traction apophyseal injuries in youth athletes warrants consideration. Such
232 injuries are particularly prevalent in soccer between the ages of 11-14; with peak incidence
233 occurring in males for the under 13 and under 14 age groups (Price et al., 2004). A delay

234 between growth in muscle length and cross-sectional area has been reported (Xu et al., 2009)
235 and may result in altered neuromuscular control, which requires accurate sensory input and
236 appropriate motor responses to maintain correct alignment in response to rapid adjustments of
237 the bodies centre of mass that can occur during cutting and landing movements (Lephart et al.,
238 2002; Zazulak et al., 2007). Available data in female athletes show that this interaction can
239 affect dynamic stabilisation, leading to aberrant patterns of neuromuscular control (Hewett et
240 al., 2004; Ford et al., 2010). The presence of these musculoskeletal growth lags following the
241 onset of a growth spurt up to, and around the period of peak height velocity (PHV), needs to
242 be considered in the management of male youth soccer players. During these sensitive periods
243 of growth, players should be monitored and training volume and/or intensity may need to be
244 adjusted to reduce the risk of apophyseal and overuse type injuries.

245

246 High exposures to the repetitive patterning of soccer activities such as kicking from a
247 young age may also lead to morphological adaptations. An example is radiographic changes
248 and the development of Cam-Type deformity combined with femoral acetabular impingement
249 in male youth soccer players (Agricola et al., 2012; Tak et al., 2015). A recent finding is that a
250 cam deformity in soccer players only develops during the period of skeletal maturation when
251 the proximal femoral growth plate is open (Agricola et al., 2014). Although not all studies have
252 reported significant associations between skeletal immaturity and a higher risk of cam
253 deformity (Johnson et al., 2012), there is a high prevalence in young adult males who
254 participate in soccer activities (Johnson et al., 2012; Agricola et al., 2012; Tak et al., 2015).
255 This risk of cam deformity increases in males who played intensive soccer versus controls
256 (Agricola et al., 2012; Tak et al., 2015). Specifically, a cam deformity appears to be less likely
257 to develop in youth players who do not participate in frequent practice (defined as ≥ 4 times per
258 week) prior to 12 years of age. This could be linked to increases in growth hormone and insulin

259 growth factor-1 in boys aged between 12-14 years, increasing bone responses to hip loading
260 (Ferguson and Patricios, 2014). Confounding this, accumulated years of practice demonstrate
261 weak associations with the presence of the specified morphological adaptations; reducing the
262 volume of soccer-specific training and competitions during this period may be warranted (Tak
263 et al., 2015). Therefore, the intensity, type, duration, and frequency of training and competition
264 loads should be adjusted during skeletal growth to minimise the risk of developing groin pain,
265 limitations in hip function and osteoarthritis. Also, participation in a wider range of diverse
266 sports and activities will increase their movement variability and alter the point of force
267 absorption/production, stressing a greater range of anatomical structures which in turn may
268 provide a more even distribution of stress/adaptation and reduce the risk of overuse injury.

269

270 There is currently a paucity of literature available to examine the relationship between
271 workloads and injury incidence in elite male youth soccer players. Gabbett *et al.* (2012)
272 identified that of the few studies available; an increased external training load as measured by
273 a global positioning system (GPS) resulted in heightened injury rates and longer training
274 durations was associated with a greater incidence of illness. The authors highlighted that
275 undertaking greater workloads may be necessary in elite sport to stimulate an adaptive response
276 but this increases injury risk. The physical stress associated with training has also demonstrated
277 relationships with injury in elite male youth soccer players. Measured across a period of two
278 seasons, physical stress was related to both injury and illness (range odds ratio, 0.56 - 2.27)
279 (Brink et al., 2010). Specifically, increased exposure has been identified as the most important
280 risk factor for injury in high school athletes (Rose et al., 2008), and a training threshold of more
281 than 16 hours per week has been associated with a significantly increased risk of injury (Rose
282 et al., 2008). This volume of intensive, specialised sports participation was also identified by
283 Jayanthi *et al.* (2015), whereby, young athletes who completed more hours of sport per week

284 than their age in years, or whose ratio of organised sports versus free play time was >2:1, were
285 at a greater risk of serious overuse injury (odds ratio, 1.87, $P < .01$). Risk was also greater in
286 youth athletes who undertook highly specialised sports practice suggesting this is a risk factor
287 for serious overuse injury, independent of age, growth, biological maturation and training
288 volumes.

289

290 In summary, the available literature suggests that engaging in soccer specialisation
291 programmes from an early age does not guarantee success or predict the achievement of elite
292 status later in their career (Vayens et al., 2009; Haugaasen and Jordet, 2012).). From a
293 population of approximately 10,000 aspiring players, data reported by the Professional
294 Footballers Association (PFA) has estimated that <1% of young boys who are involved in
295 soccer development programmes establish a career as a professional player (Green, 2009).
296 Furthermore, data from the PFA indicate that of adolescents entering full-time scholarship
297 programmes after leaving school, 50% will no longer be involved in football two years later,
298 and at age 21, the attrition rate rises to >75%. There is also a considerable risk of injury in early
299 soccer specialisation programmes (Brink et al., 2010; Agricola et al., 2012; Tak et al., 2015)
300 and reports in other sports of high athlete attrition due to burnout (approximately 30%) (Matos
301 et al., 2011). While it is acknowledged that deliberate play, practice and formalised sports
302 training is required to achieve sporting success, safeguarding the welfare of youth players is of
303 paramount importance. Therefore, a review of the predominant youth development programme
304 for soccer is warranted to critique its scientific foundations and identify potential injury risks.

305

306 *The Elite Player Performance Plan (EPPP): a modern-day example of early sport*
307 *specialisation*

308 Elite soccer in the United Kingdom (UK) has recently adopted an early sport specialisation
309 approach. Following the introduction of the Elite Player Performance Plan (EPPP, 2011), youth
310 boys participating in such programmes are now required to attend multiple weekly training
311 sessions and competitions, with formal registration commencing at the age of 9 years (EPPP,
312 2011). This model is based on the theory of 10,000 accumulated practice hours (Gladwell,
313 2008); a time-frame suggested following observations that performance is gradually improved
314 over time as a result of engaging in extended periods of deliberate practice (Ericson, 1993). In
315 the original UK soccer academy system set out in 1998, the number of required contact hours
316 for coaching was approximately 3,760 (accumulated incrementally from age 9-21) (EPPP,
317 2011). Under the new regulations set out in the EPPP, this number has been increased to 8,500
318 contact hours for clubs in the highest academy classification category. Specific requirements
319 for player contact hours as per the EPPP guidance framework are presented in *table 1* (EPPP,
320 2011).

321

322 ***** *Table 1 near here* *****

323

324 The increased opportunities for training time required in the EPPP are thought to enhance
325 technical proficiency and enable a better progression towards higher levels of performance
326 (EPPP, 2011). Whilst intuitively, accumulating more playing time in a particular sport would
327 appear a valid concept, it should be considered that the original work of Ericsson (1993) has
328 often been incorrectly interpreted (Ericsson, 2013). For example, the observational analysis by
329 Ericsson (1993) identified that not all of the participants accrued the arbitrary 10,000 hours.
330 Four expert violinists averaged only 5,000 hours of deliberate practice; international pianists
331 accumulated in the region of 25,000 hours, and mastery of less competitive activities including
332 memory tasks may require less practice (Ericson and Kintsch, 1995). Additionally, Ericsson

333 (1993) utilised musicians who perform finite motor skills that may require more specific
334 practice. These tasks are not reflective of the multi-faceted range of technical and physical
335 qualities required for successful performance in soccer; the accumulation of high training hours
336 may be less of a pertinent marker for success in soccer.

337

338 The impact of such a significant increase in training volume for young athletes that are
339 experiencing a range of growth and maturational processes is currently unknown. This requires
340 further investigation to determine the potential for injury risk. In the framework of the EPPP,
341 contact hours increase significantly from age 12-16 years coinciding with the peak adolescent
342 growth spurt, which occurs at approximately age 14 years in boys (Malina et al., 2004). This
343 time period may occur earlier in elite youth soccer players due to the high representation of
344 early maturation in elite youth soccer programmes (Malina et al., 2000). The reported risk of
345 injury in youth soccer is also highest during this period, with incidence rising from 8.0 injuries
346 per 1000 hours of exposure in 9-12 year olds, to 65.8 per 100 hours in 13-15 year olds (Rumpf
347 and Cronin, 2012). This concomitant increase in a child's advanced age and greater exposure
348 to training and competition involves high levels of repetitive loading which can increase injury
349 risk (Hogan and Gross, 2003). Further, a linear increase in injury rates has been reported from
350 9 to 15 years of age in elite male youth players (Price et al., 2004), with a marked increase
351 around the age of 13 years of age (Emery, 2003; Rumpf and Cronin, 2012). Due to rapid growth
352 in skeletal structures, the muscular system must simultaneously develop both in length (to
353 normalize tension from bone growth), and also in size, so that greater levels of force production
354 are possible to support and move the larger and heavier skeleton (Williams et al., 2012). An
355 inherent time lag is present between the rate of bone growth and subsequent muscle lengthening
356 during the growth spurt and around PHV, normalizing to safer ranges during late adolescence.
357 Recent research also shows that elite male youth soccer players experience more traumatic

358 injuries in the year of PHV (van der Sluis et al., 2014), which underlines the greater occurrence
359 of sports injuries in school aged youths with later stages of maturation (Michaud et al., 2001).

360

361 Maturation status should also be accounted for in the planning and delivery of training
362 loads during key periods of growth and development. Recent data indicate that later-maturing
363 youth soccer players demonstrate significantly greater injury incidence than those who are
364 early maturers in both the year prior to (3.53 vs. 0.49 overuse injuries/1000 h of exposure) and
365 year of (3.97 vs.1.56 overuse injuries/1000 h of exposure) PHV (van der Sluis et al., 2015).
366 This may be due to increased levels of exposure, and a lack of physical readiness (Carter and
367 Michelli, 2011) and highlights that children participating in organised sports competition in the
368 circa-PHV age group are at a greater risk of certain types of injury. Therefore, the subsequent
369 volume of repetitive movements should be reduced during such periods due to a
370 disproportionate growth of skeletal and muscle tissue, and changes in neuromuscular
371 functioning (De Ste Croix and Deighan, 2012). Enforcing training and match loads on players
372 who are not physically able to withstand the repeated stressors will likely increase injury risk.
373 Further, a structure should be included which is relative to the maturity levels, technical
374 competency and training age of each individual player to minimise injury risk and maximise
375 their long-term athlete development. This is especially true for players in the year prior to and
376 during their maximal accelerated growth spurt ((van der Sluis et al., 2014). Clear guidelines
377 and provision for this are not currently included in the EPPP which suggests a linear increase
378 in training volume during this period. While currently no published research is available to
379 report injury incidence since the inception of the EPPP, this requires further investigation.
380 Practitioners should also consider frequently monitoring the rates of growth and maturation of
381 individual players approximately every three months (Lloyd et al., 2014) and adapting the
382 volume loads of their players accordingly.

383

384 The required participation hours each week set out in the EPPP relate only to on-pitch
385 time (structured training and competitions), and no provision or recommendations have been
386 included for athletic development activities which are required in addition to the accumulation
387 of the designated soccer hours (EPPP, 2011). This adds further training loads to youth players
388 involved in such programmes who may also be participating in additional sports at school and
389 has connotations for the development of overuse injuries. A more effective approach may be
390 to place greater emphasis on quality practice in a range of learning environments, and the
391 inclusion of activities which target strength and motor skill development from a young age
392 (Myer et al., 2011) as opposed to simply the accumulation of more sport-specific training hours.
393 An example is integrative neuromuscular training (INT) which consists of exercises to enhance
394 fundamental movement skills, muscular power, lower body and core strength (Myer et al.,
395 2011). The inclusion of preparatory conditioning is essential and can assist in the reduction of
396 injuries. In adolescent athletes, available literature has shown the effectiveness of strength
397 training and movement preparation programmes in decreasing injuries and enhancing recovery
398 times during rehabilitation (Hejna et al., 1982), in lowering the occurrence of both overuse
399 injuries (Soligard et al., 2008) and in decreasing acute trauma (Emery and Meeuwisse, 2010).
400 Targeted interventions which address prevalent risk factors associated with youth sports
401 participation may reduce overuse injuries by approximately 50% in youth athletes (Micheli et
402 al., 2013). Regular participation in varied strength and conditioning programmes that are
403 developmentally appropriate, technique driven, safe and enjoyable has also recently been
404 recommended for youth athletes (Bergeron et al., 2015).

405

406 Opportunities to enhance fundamental movement skills during developmental years are
407 also deemed critical due to the accelerated periods of neural plasticity resulting from the natural

408 development of the neuromuscular system (Borms, 1986). This supports the notion of early
409 engagement and variety in athletic development and sporting activities. Importantly for
410 developmental athletes, such preparatory conditioning programmes aimed at youth athletes,
411 still affords the opportunity for children to create exercises, optimising engagement while
412 enhancing physical performance (Faigenbaum et al., 2015). Thus, while the integration of
413 deliberate play which is characterised by sporting activities that are unstructured, play like and
414 enjoyable is recommended (Berry et al., 2008), practitioners should also adopt a strategy of
415 deliberate preparation. This approach includes planned training and qualified instruction to
416 enhance athletic skill competency and prevent the accumulation of neuromuscular deficits
417 during the developmental years (Faigenbaum et al., in press) that can develop as a result of
418 soccer training and competitions (Atkins et al., 2013; Danshjo et al., 2013). Furthermore, a
419 recent systematic review demonstrated that participation in neuromuscular type training
420 activities was not a cause for dropout, whereas, a perceived lack of physical competence was
421 (Crane and Temple, 2015). Guidelines are required within the framework of the EPPP to
422 demonstrate more clearly the interaction between technical and physical development sessions
423 to ensure effective implementation and appropriate dosage as part of the holistic development
424 of young soccer players.

425

426 While the authors acknowledge that the EPPP is only reflective of a single model from
427 the United Kingdom, based on the available evidence, it is suggested that a range of
428 modifications and provisions should be included within the framework of future long-term
429 athletic development programmes for youth soccer players. These recommendations are
430 outlined below and are designed to enhance the potential for future success and to reduce the
431 risk of traumatic and overuse injuries.

432

- 433 1. Adjustment of the age for which formalised soccer registration is permitted.
434 Specifically, the entry age into formalised academy soccer programmes may be most
435 beneficial after age 12 years and deliberate play should be emphasised prior to this
436 point.
- 437 2. Limiting frequent specialised practice sessions (<4 x p/wk) and providing variation
438 and diversity in physical activity and sports is essential in the early years of a child's
439 development to avoid risks of morphological abnormalities.
- 440 3. Provisions should be included to monitor and reduce soccer training workloads and
441 increase exposure to neuromuscular training during periods of rapid growth with a
442 particular focus around the time of peak height velocity, especially for late maturers.
- 443 4. The ratio of organised sports versus free play time should be <2:1 to reduce the risk of
444 serious overuse injury and at no time should a training threshold of >16 hours of
445 organised soccer and supplemental sports training be completed per week.
- 446 5. Guidelines should be included in the framework of long-term soccer development plans
447 to account for the provision of physical development activities that are age-appropriate
448 to assist in the reduction of injury risk and ensure effective integration with all other
449 programme components.

450

451 **PERSPECTIVES**

452 Limited data is available to support the application of structured early specialisation
453 programmes in the development of soccer players who attain elite status later in life.
454 Conversely, in a wide range of sports a more diverse approach to sports participation appears
455 to be associated with heightened adult performances. Intense participation in a single sport such
456 as soccer prior to physical maturation may also increase the risk of overuse injury. Although
457 data is currently unavailable to report the incidence of injury since the inception of early

458 specialisation programmes such as the EPPP, further investigation is warranted to determine
459 both its effectiveness and the potential injury risks associated with the marked increase in
460 required training volume. Modifications to the existing EPPP framework should also be
461 considered for future long-term athletic development programmes for youth soccer players.

462

463

464

465

466

467

468

469

470

471

472

473

474

475

476

477 REFERENCES

478 1. Agricola, R, Bessems, J, Ginai, A, Heijboer, MP, van der Heijden, RA, Verhaar, J, Weinans,
479 H, Waarsing, JH. (2012). The Development of Cam-Type Deformity in Adolescent and
480 Young Male Soccer Players. *AM J Sports Med*, 40: 1099-1066.

481 2. Agricola, R, Waarsing, JH, Thomas, GE, Carr, JE, Reijman, M, Bierma-Zeinstra, SMA,
482 Glyn-Jones, S, Weinans, H, Arden, NK. (2014). Cam impingement: defining the presence
483 of a cam deformity by the alpha angle: Data from the CHECK cohort and Chingford cohort.
484 *Osteoarthritis and Cartilage*, 22: 218-225.

- 485 3. Atkins, SJ, Hesketh, C, and Sinclair, JK. (in press). The presence of bilateral imbalance of
486 the lower limbs in elite youth soccer players of different ages. *J Strength Cond Res*.
- 487 4. Baker, J, Côté, J, Abernethy, B. (2003). Sport-specific practice and the development of
488 expert decision-making in team ball sports. *J Appl Sport Psychol*, 15: 12 – 25.
- 489 5. Barynina, II., & Vaitsekhovskii, SM. (1992). The aftermath of early sports specialization
490 for highly qualified swimmers. *Fitness and Sports Review International*, 27: 132–133.
- 491 6. Bell-Walker, J, & Williams, A.M. (2008). The effect of memory recall on perceptual–
492 cognitive skill in elite soccer: Development of long term working memory. In T. Reilly, F.
493 Korkusuz, & E. Ergen (Eds.), *Science and football VI* (pp. 340–343). London: Taylor &
494 Francis.
- 495 7. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Cote J, Emery CA, Faigenbaum A, Hall
496 G, Jr., Kriemler S, Leglise M, Malina RM, Pensgaard AM, Sanchez A, Soligard T, Sundgot-
497 Borgen J, van Mechelen W, Weissensteiner JR, and Engebretsen L. (2015). International
498 Olympic Committee consensus statement on youth athletic development. *Br J Sports Med*,
499 49: 843-851.
- 500 8. Berry J, Abernethy B, Côté J. (2008). The contribution of structured activity and deliberate
501 play to the development of expert perceptual and decision-making skill. *J Sport Exerc*
502 *Psychol*, 30:685–708.
- 503 9. Borms J. (1986). The child and exercise: An overview. *J Sports Sci*, 4: 4-20.
- 504 10. Brink, MS, Visscher, C, Arends, S, Zwerver, J, Post, WJ, Lemmink, K. (2010). Monitoring
505 stress and recovery: new insights for the prevention of injuries and illnesses in elite youth
506 soccer players. *Br J Sports Med*, 44:809–815.
- 507 11. Carlson, RC. (1988). The socialization of elite tennis players in Sweden: An analysis of
508 players' backgrounds and development. *Sociology of Sport Journal*, 5: 241–256.

- 509 12. Carter, CW, and Michelli, LJ. (2011). Training the child athlete: physical fitness, health and
510 injury. *BJSM*, 45: 880-885,.
- 511 13. Côté, J, Baker, J, & Abernethy, B. (2007). Practice and play in the development of sport
512 expertise. In G. Tenenbaum & R.C. Eklund (Eds.), *Handbook of sport psychology* (pp. 184–
513 202). New Jersey: John Wiley & Sons.
- 514 14. Côté, J, Lidor, R, and Hackfort D. (2009). ISSP position stand: to sample or to specialize?
515 Seven postulates about youth sport activities that lead to continued participation and elite
516 performance. *International Journal of Sport and Exercise Psychology*, 9: 7-17.
- 517 15. Crane, J and Temple V. (in press). A systematic review of dropout from organized sport
518 among children and youth. *Eur Phys Educ Rev*.
- 519 16. Daneshjoo, A, Rahnama, N, Mokhtar, AH, Yusof, A. (2013). Bilateral and Unilateral
520 Asymmetries of Isokinetic Strength and Flexibility in Male Young Professional Soccer
521 Players. *J Hum Kinet*, 36: 45-53.
- 522 17. De Ste Croix, M and Deighan, M. (2012). Dynamic knee stability during childhood. In;
523 Paediatric Biomechanics and Motor Control: Theory and Application. Edited by De Ste
524 Croix, M and Korf, T. Routledge, Oxford, England, 233-258.
- 525 18. DiFiori, JP, Benjamin, HJ, Brenner, J, Gregory, A. (2014). Overuse Injuries and Burnout in
526 Youth Sports: A Position Statement from the American Medical Society for Sports
527 Medicine. *Clin J Sport Med*, 24: 3–20.
- 528 19. Elite Player Performance Plan. (2011). Document prepared by the English Premier League.
- 529 20. Emery, C.A. (2003). Risk factors for Injury in Child and Adolescent sport: a systematic
530 review of the literature. *Clin J Sports Med*, 13: 256-268.

- 531 21. Emery, CA, Meeuwisse, W. (2010). The effectiveness of a neuromuscular prevention
532 strategy to reduce injuries in youth soccer: a cluster-randomised controlled trial. *Br J Sports*
533 *Med*, 44: 555–62.
- 534 22. Ericsson, KA, Krampe, RT, Tesch-Romer, C. (1993). The role of deliberate practice in the
535 acquisition of expert performance . *Psychol Rev*, 100: 363 – 406.
- 536 23. Ericsson, KA, Kintsch, W. (1995). Long working memory. *Psychological Review*, 102: 211-
537 245.
- 538 24. Ericsson, KA. (2013). Training history, deliberate practice and elite sports performance: an
539 analysis in response to Tucker and Collins review - what makes champions?. *BJSM*, 47: 533-
540 535.
- 541 25. Faigenbaum, AD, Bush, JA, McLoone, RP, Kreckel, MC, Farrell, A, Ratamess, NA, and
542 Kang, J. (2015). Benefits of strength and skill-based training during primary school physical
543 education. *J Strength Cond Res*, 29: 1255–1262.
- 544 26. Faigenbaum, AD, Lloyd, RS, MacDonald, J, Myer, GD. (in press). Citius, Altius, Fortius:
545 beneficial effects of resistance training for young athletes. *BJSM*.
- 546 27. Ford, PR, Ward, P, Hodges, N, Williams, AM. (2009). The role of deliberate practice and
547 play in career progression in sport: the early engagement hypothesis. *High Ability Studies*,
548 20: 65 – 75.
- 549 28. Ford, KR, Shapiro, R, Myer, GD, Van Den Bogert AJ, Hewett TE. (2010). Longitudinal sex
550 differences during landing in knee abduction in young athletes. *Med Sci Sports Exerc*,
551 42:1923-31.
- 552 29. Ferguson, M, Patricios. J (2014). What is the relationship between groin pain in athletes and
553 femoroacetabular impingement? *Br J Sports Med*, 48:1074–5.

- 554 30. Fransen, J, Pion, J, Vandendriessche, J, Vandorpe, B, Vaeyens, R, Lenoir, M & Renaat,
555 M. (2012). Differences in physical fitness and gross motor coordination in boys aged 6–12
556 years specializing in one versus sampling more than one sport. *J Sports Sci*, 30: 379-386.
- 557 31. Gabbett, TJ, Shahid, U. (2012). Relationship Between Running Loads and Soft-Tissue
558 Injury in Elite Team Sport Athletes. *J Strength Cond Res*, 26: 953-960.
- 559 32. Gladwell, M. (2008). *Outliers: The story of success*. New York, NY: Little, Brown.
- 560 33. Gould, D, Udry, E, Tuffey, S. (1996). Burnout in competitive junior tennis players: Pt. 1. A
561 quantitative psychological assessment. *Sport Psychol*, 10: 322–340.
- 562 34. Green, C. (2009). *Every boy's dream*. London: A & C Black Publishers.
- 563 35. Hugaasen, M and Jordet, G. (2012). Developing football expertise: a football specific
564 research review. *Int Rev Sport Exerc Psych*, 5: 177-201.
- 565 36. Hugaasen, M, Toering, T, Jordet, G. (2014) From childhood to senior professional football:
566 elite youth players' engagement in non-football activities. *Journal Sports Sci (Science and*
567 *Medicine in Football Special Edition*, 32: 1940-1949.
- 568 37. Hejna, WF, Rosenberg, A, Buturusis, DJ. (1982). The prevention of sports injuries in high
569 school students through strength training. *Natl Strength Coaches Assoc, J* 4:28–31.
- 570 38. Helsen, W, Starkes, JL, van Winkel, J. (1998). The influence of relative age on success and
571 drop out in male soccer players. *AM J Human Biol*, 10: 791-798.
- 572 39. Helsen, WF, Strakes, JL, Van Winckel, J. (2000). Effect of a Change in Selection Year on
573 Success in Male Soccer Players. *AM J Hum Biol*, 12:729–735.
- 574 40. Hewett, TE, Myer, GD and Ford, KR. (2004). Decreases in neuromuscular control about the
575 knee with maturation in female athletes. *J Bone Joint Surgery AM*, 86: 1601-1608.

- 576 41. Hogan, KA, Gross, RH. (2003). Overuse injuries in pediatric athletes. *Orthop Clin North*
577 *Am*, 34: 405-1.
- 578 42. Hornig, M, Aust, F, Güllich, A. (2014). Practice and play in the development of German
579 top-level professional football players. *Eur Journ Sport Sci*, 2: 1-10.
- 580 43. Huijgen, BCH, Elferink-Gemser, MT, Post, WJ, Visscher, C. (2009). Soccer skill
581 development in professionals. *Int J Sports Med*, 30: 585-591.
- 582 44. Jayanthi, N, Pinkham, P, Dugas, L, Patrick, B and LaBella, C, (2012). Sports Specialization
583 in Young Athletes: Evidence-Based Recommendations. *Sports Health*, 5: 251-257.
- 584 45. Jaynathi, NA, LaBella, CR, Fischer,D, Pasulka, J and Dugas, LR. (2015). Sports-Specialized
585 Intensive Training and the Risk of Injury in Young Athletes: A Clinical Case-Control Study.
586 *AM J Sports Med*, 43: 794-801.
- 587 46. Johnson, AC, Shaman, MA, Ryan, TG. (2012). Femoroacetabular Impingement in Former
588 High-Level Youth Soccer Players *Am J Sports Med*, 40: 1342-1346.
- 589 47. Junge, A, and Dvorak, J. (2000). Influence of Definition and Data Collection on the
590 Incidence of Injuries in Football. *AM J Sports Med*, 20: 40-46.
- 591 48. Koslowsky, M and Da Conceicao Bothelo, MF. (2010). Domains in the practice of football
592 learning: Comparative study among football athletes of junior category in Portugal and
593 Brazil. *J Human Sport and Exerc*, 5: 400-410.
- 594 49. Leite, N, Baker, J, Sampiao, J. (2009). Paths to expertise in the Portugese national team
595 athletes. *J Sports Sci Med*, 8: 560-566.
- 596 50. Lephart SM, Riemann BL, Fu FH. (2000). Introduction to the sensorimotor system. In:
597 Lephart SM, Fu FH, editors. Proprioception and neuromuscular control in joint stability.
598 Champaign, IL: Human Kinetics.

- 599 51. Lidor, R, Lavyan, Z. (2002). A retrospective picture of early sport experiences among elite
600 and near-elite Israeli athletes: developmental and psychological perspectives. *Int J Sport*
601 *Psychol*, 33:269-289.
- 602 52. Lloyd, RS, and Oliver, JL. (2012). The Youth Physical Development Model: A New
603 Approach to Long-Term Athletic Development. *Strength Cond J*, 34: 61-72.
- 604 53. Lloyd, RS, Oliver, JL, Faigenbaum, AD, Myer, GD, De Ste Croix, MBA. (2014).
605 Chronological Age vs. Biological Maturation: Implications for Exercise Programming in
606 Youth. *J Strength Cond Res*, 28: 1454–1464.
- 607 54. Malina, RM Peña Reyesa, ME, Eisenmanna, JC, Hortab, L, Rodriguesc, J & Miller, R.
608 (2000). Height, mass and skeletal maturity of elite Portuguese soccer players aged 11–16
609 years. *J Sports Sci*, 18: 685-693.
- 610 55. Malina, R.M, Eisenmann, J.C, Cumming, S.P, Riberio, B, Aroso, J. (2004). Maturity-
611 associated variation in the growth and functional capacities of youth football (soccer)
612 players 13-15 years. *Eur J Appl Physiol*, 91: 555-562.
- 613 56. Malina RM. (2010). Early sport specialization: roots, effectiveness, risks. *Curr Sports Med*
614 *Rep*, 9:364-371.
- 615 57. Matos, NF, Winsley, RJ, Williams, CA. (2011). Prevalence of non-functional
616 overreaching/overtraining in young English athletes. *Med Sci Sports Exerc*, 43:1287–1294.
- 617 58. Michaud, PA, Renaud, A and Narring, F. (2001). Sports activities related to injuries? A
618 survey among 9-19 year olds in Switzerland. *Inj Prev*, 7: 41-45.
- 619 59. Micheli, L, Natsis, KI. (2013). Preventing injuries in team sports: what the team physician
620 needs to know. In: Micheli LJ, Pigozzi F, Chan KM, et al. eds. F.I.M.S. Team Physician
621 Manual. 3rd edn. London: Routledge, pp. 505–20.

- 622 60. Moesch, K, Elbe, AM, Hauge, ML, Wikman, JM. (2011). Late specialization: the key to
623 success in centimeters, grams, or seconds (cgs) sports. *Scand J Med Sci Sports*, 21: 282-290.
- 624 61. Myer, GD, Faigenbaum, AD, Ford, KR, Best, TM, Gergeron, MF, Hewett, TE. (2011).
625 When to initiate integrative neuromuscular training to reduce sports-related injuries in
626 youth? *Curr Sports Med Rep*, 10: 155–166.
- 627 62. Price, RJ, Hawkins, RD, Hulse, MA and Hodson, A. (2004). The Football Association and
628 medical research programme: an audit of injuries in academy youth football. *BR J Sports
629 Med*, 38: 466-471.
- 630 63. Rose, MS, Emer,y CA, Meeuwisse, WH. (2008). Sociodemographic predictors of sport
631 injury in adolescents. *Med Sci Sports Exerc*, 40:444-450.
- 632 64. Rumpf, M, and Cronin, J. (2012). Injury Incidence, Body Site, and Severity in Soccer
633 Players Aged 6–18 Years: Implications for Injury Prevention. *Strength Cond J*, 34: 20-31.
- 634 65. Serrano, João Manuel Pereira Ramalho; Santos, Sara Diana Leal dos; Sampaio, António
635 Jaime Eira and LEITE, Nuno Miguel Correia. Iniciação desportiva, actividades prévias e
636 especialização no treino de futsal em Portugal. *Motriz: rev. educ. fis.* [online]. 2013, vol.19,
637 n.1 [cited 2015-03-10], pp. 99-113.
- 638 66. Soberlak, P and Cote, J. (2003). The developmental activities of elite ice hockey players. *J
639 Appl Sport Psych*, 15: 41-49.
- 640 67. Soligard, T, Mycklebust, G, Steffen, K. (2008). Comprehensive warm-up programme to
641 prevent injuries in young female footballers: cluster randomized controlled trial. *BMJ* 37:
642 a2469.
- 643 68. Stein, CJ, Michelli, LJ. (2010). Overuse Injuries in Youth Sports. *The Physician and
644 Sportsmedicine*, 38: 102-108.

- 645 69. Tak, I, Weir, A, Langhout, R, Waarsing, J, Stubbe, J, Kerkhoffs, G, Agricola, R. (2015).
646 The relationship between the frequency of football practice during skeletal growth and the
647 presence of a cam deformity in adult elite football players. *Br J Sports Med*, 49:630-634.
- 648 70. van der Sluis, A, Elferink-Gemser, MT, Coelho-e-Sliva, MJ, Nijboer, JA, Brink, MS and
649 Visscher, C (2014). Sports Injuries Aligned to Peak Height Velocity in Talented Pubertal
650 Soccer Players. *Int J Sports Med*, 35: 351–355.
- 651 71. van der Sluis, A, Elferink-Gemser, MT, Brink, MS, Visscher, C. (in press). Importance of
652 Peak Height Velocity Timing in Terms of Injuries in Talented Soccer Players. *Clin J Sports
653 Med.*
- 654 72. Vaeyens, R, Gullich, A, Warr, CR, Philippaerts, R. (2009). Talent identification and
655 promotion programmes of Olympic athletes. *J Sports Sci*, 27:1367-1380.
- 656 73. Wall M, Côté J. (2007). Developmental activities that lead to dropout and investment in
657 sport. *Phys Educ Sport Pedagogy*, 12:77–87.
- 658 74. Ward, P, Hidges, NJ, Starkes, JL, and Williams MA. (2007). The road to excellence:
659 Deliberate practice and the development of expertise. *High Ability Studies*, 18: 119-153.
- 660 75. Williams, CA, Wood, L, De Ste Croix, M. Growth and Maturation in childhood. In;
661 Paediatric Biomechanics and Motor Control: Theory and Application. Ed; De Ste Croix M,
662 and Korff T. Routledge, Abingdon, UK, 15-17, 2012.
- 663 76. Xu, L, Nicholson, P, Wang, Q, Alen, M, and Cheng, S. Bone and Muscle Development
664 During Puberty in girls. A seven year longitudinal study. *J Bone Mineral Research* 24: 1963-
665 8, 2009.
- 666 77. Zazulak, BT, Hewett, TE, Reeves, PN, Goldberg, B and Cholewicki, J. Biomechanical-
667 Epidemiologic Study Deficits in Neuromuscular Control of the Trunk Predict Knee Injury
668 Risk: A Prospective. *Am. J. Sports Med.* 35; 1123, 2007

669 78. Zinberg, M. & Conzelmann, A. (2012). The role of specialization in the promotion of young
670 football talents: A person-oriented study. *European Journal of Sport Science*, 13, 452-460

671

672