The Influence of Player Age on Club Soccer Coaches' Perceptions of Injury Risk and Lower Extremity Injury Prevention Program Use

by
Elle Alexa Morgan

A THESIS

submitted to

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Abstract approved: _____

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Background: The use of a lower extremity injury prevention program (IPP) by female athletes before the completion of puberty may mitigate movement changes that develop during puberty and contribute to greater injury risk. It is unknown whether player age influences coaches' knowledge, attitudes, and behaviors surrounding IPPs. **Methods:** Fifty-four female soccer coaches from Oregon and Washington states completed a web-based survey. Associations between team age (U9-U14=57 and U15-U19=19 teams) and coaches' 1) attitudes and perceptions; and 2) IPP awareness, adoption, and implementation fidelity were assessed. **Results:** Coaches of older teams perceived injuries to be more of a problem and soccer to present a high risk of injury; and more strongly agreed that preventive exercises should be performed by their players during training. Despite similar levels of IPP awareness, coaches of older teams were more likely to use an IPP though they were not more likely to do so with high fidelity. **Conclusion:** Player age influenced coaches' perceptions of injury risk and the rate of IPP adoption. Lesser perceived injury risk by coaches of younger teams likely serves as a barrier to wide-scale implementation of IPPs during a crucial developmental period when high-risk motion patterns begin to emerge in female athletes.

Key Words: lower extremity injury, adoption, neuromuscular, implementation, fidelity

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I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

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Introduction

There are 200,000 professional and 240 million amateur soccer players in the world, with 22 of the 38 million officially registered players under the age of 18 (Junge, 2004; FIFA Communications Division, 2007). Youth soccer is becoming increasingly popular, with the number of registered youth players increasing by 7% worldwide from 2000 to 2006 (FIFA Communications Division, 2007). Unfortunately, with soccer participation comes the risk for injury. In a longitudinal study of children ages 8-17, soccer was associated with the fourth highest incidence of injury per 1000 hours of game, after basketball, handball, and korfball (Backx, 1991; Junge, 2004). Furthermore, 6.7% of all injuries in 5 to 18-year-old soccer players were ruptures of the anterior cruciate ligament (ACL) (Shea, 2003).

ACL ruptures are devastating injuries for athletes of all ages; however, females are 4 to 6 times more likely to sustain a non-contact ACL tear than males (Arendt, 1995). ACL injuries typically require reconstructive surgery if the athlete wishes to return to cutting and jumping activities (Hewett, 2011; Parkkari, 2008), and such injuries can lead to a withdrawal from soccer participation and long term complications such as early-onset osteoarthritis (Parkkari, 2008; Myer, 2013; Hewett, 2011). These complications could result in reduced participation in exercise and sports (Schub, 2011). A longitudinal study by Roos et al. (1995) found that 3 years after rupture of their ACL, 70% of organized soccer participants in Sweden had given up soccer. After 7 years, only 25% of the players were still active in their sport (Roos, 1995). Further, a meta-analysis found that only 63% of those with ACL ruptures return to previous levels of physical activity (Arden, 2011). In an effort to understand these injuries, several age and sex-specific factors have been identified that are proposed to contribute to the increased risk of ACL injury in females following maturation (Faigenbaum, 2011; Myer, 2009, 2012; van der Sluis, 2013).

Studies have shown that sports related ACL injury risk increases during adolescence with a peak incidence rate during the mid-to late teens in female athletes (Arendt, 1995;

Faigenbaum, 2011; Myer, 2013). Higher risk of injury in post pubertal females has been attributed to several changes that occur throughout the puberty process, such as structural and anatomic changes, hormonal variations, and lesser strength relative to height and body weight (Myer, 2013). Moreover, sex-specific movement patterns that are associated with greater ACL injury risk also begin to emerge around puberty (Myer, 2013). Neuromuscular control of knee motion and landing force is considerably worse in females than in males beginning during the transition into puberty, and remaining so thereafter (Hewett, 2004). Further, high-risk mechanics such as dynamic knee valgus during landing with less overall control of the lower extremity is most evident in females compared to males during and after puberty (Myer, 2013) and can lead to increased knee abduction loads and strain on the knee ligaments during landing (Hewett, 2011). One potential reason for these sex-specific changes in movement patterns following puberty may be related to the fact that males tend to be stronger relative to their body size post puberty while females are more likely to experience a reduction in strength relative to their body height and weight (Myer, 2013). Although the natural physical maturation process cannot be modified, proper neuromuscular training interventions can reduce the negative puberty-driven changes by facilitating increases in relative strength and coordination (Myer, 2013).

The "neuromuscular spurt" is defined as the "natural adaptation of increased, power, strength, and coordination that occurs with increasing chronological age and maturational stage" (Myer, 2011). This spurt is most evident in males, while a lack of adaptation is common in female athletes (Beunen, 1988) with lesser power, strength, and coordination relative to their height and weight when compared with males of the same age and maturational stage (Myer, 2011, 2013). Participation in integrative neuromuscular training protocols beginning in pre- and early adolescence may prompt the "neuromuscular spurt", specifically related to relative posterior chain strength, postural control, and muscular power (Myer, 2005, 2011). Inducing this "neuromuscular spurt" may reduce the degree of

differences in lower extremity movement mechanics seen between adolescent males and females, thereby potentially lessening the risk of sports-related injury (Myer, 2011).

Neuromuscular training and triggering of the "neuromuscular spurt" can be achieved through the completion of injury prevention programs (IPPs). IPPs, including Sportsmetrics, FIFA 11+, and the Prevent Injury and Enhance Performance program (PEP) have been shown to decrease the risk of ACL injuries (Noyes, 2012; Owoeye, 2014; Sadoghi, 2012) and typically include exercises that address the same possible deficits in lower extremity strength, coordination, and neuromuscular control that are thought to place the post-pubescent female athlete at a higher risk for lower extremity injury (Myer, 2005, 2011). However, most IPPs have traditionally only targeted older adolescent females who have likely already transitioned through puberty (Annex, 2010; Noyes, 2012; Owoeye, 2014). Implementation of an IPP at a time that coincides with maturation-related changes might help to mitigate the observed reductions in relative strength, coordination, and neuromuscular control; thus reducing injury risk in post-pubescent athletes (Myer, 2013). Despite this, it is not known whether younger female athletes are performing injury prevention programs and if so, if these programs are being implemented with the high level of compliance that is necessary to optimize the reduction in ACL injury risk (Sugimoto, 2012). Further, the influence of player age on club soccer coaches' attitudes and perceptions surrounding lower extremity injury and IPPs or their use of these programs is also unknown. The purpose of this investigation was to evaluate the association between player age and club soccer coaches' perceptions of injury risk and benefits of an IPP; and the rate of IPP use.

Methods

This study utilized a cross-sectional design to determine club soccer coaches' knowledge, attitudes, and behaviors surrounding lower extremity IPPs through the use of a web-based survey (Qualtrics, Inc., Provo, Utah, USA). An email explaining the project and providing an embedded link to the online survey was sent to coaches and/or directors of

Oregon Youth Soccer Association (OYSA) and Washington Youth Soccer (WYS) member clubs by either the study team and/or an administrator from the state soccer organization. In an effort to increase the number of respondents, this email was distributed twice - one week apart. The survey was completed during April 2016 with data collection stopped one week following the second distribution. All participants provided informed consent and the study was approved by the Institutional Review Board at Oregon State University (#7347).

The web-based survey instrument that was used was a combination of two previously used surveys described by O'Brien and Finch (2015) and Norcross et al. (2016). In the first section of the survey, participants were asked questions regarding demographic and coaching history information. The second section covered coaches' perceptions of lower extremity injuries and their prevention. Finally, the third section of the survey gathered information about IPP awareness, adoption, and implementation. In the event that respondents were the head coach of more than one team, the questions in sections two and three of the survey were answered independently for all of their teams. Responses in the first two section were collected on a five-point Likert scale from 1 ("strongly agree") to 5 ("strongly disagree"). Coach awareness, adoption, and implementation of efficacious IPPs was assessed as described previously (Norcross 2016). Briefly, coaches provided "Yes/No" responses to questions asking whether they: 1) were aware of any scientifically tested lower extremity IPPs; 2) currently used a lower extremity IPP with their team; and 3) had their athletes perform the IPP exactly as designed. This set of questions was purposefully designed to assess the current level of awareness, adoption, and use of any lower extremity IPP, rather than a specific program. On average, the survey took approximately 15-20 minutes to complete.

Survey results were analyzed using SPSS v 23.0 (IBM, Inc., Armonk, New York). Responses were grouped into two categories (U9-U14 and U15-U19) to represent pre-pubescent/pubescent and post-pubescent females, respectively (Annex, 2010). Associations

between player age and coaches' perceptions of lower extremity injury and IPPs were assessed using Somer's *d*. Two-sided Fisher's exact tests were used to evaluate the association between player age and IPP awareness, adoption, and implementation fidelity, respectively.

Results

Fifty-four coaches (42.8 ± 8.5 years of age) with 10.7 ± 7.8 years of youth club soccer head coaching experience reported information about 57 female U9-U14 teams and 19 female U15-U19 teams. **Table 1** displays coaches' responses to statements about their perception of injury risk and the benefits of using an injury prevention program. Coaches of older teams (U15-U19) reported greater agreement with the statement that their athletes are at a high risk for lower extremity injuries; and were also more likely to agree that lower extremity soccer injuries are a problem for their team ($p < 0.05$). The majority of all teams' coaches agreed that it is possible to prevent lower extremity soccer injuries in players on their team, and that exercises that have been proven to prevent lower extremity injuries should be performed by players on their team and incorporated into their team's training guidelines. However, coaches of older teams exhibited stronger levels of agreement with these statements than coaches of younger teams ($p < 0.05$). Interestingly, there was neither strong agreement nor disagreement with the statements that lower extremity injuries can cause physical problems later in life or have a negative impact on the quality of life of players, and no differences in the level of agreement was identified between age groups ($p > 0.05$).

Table 2 shows the percentage of female club soccer teams with a coach that is aware of an IPP, reports using an IPP, and reports using an IPP exactly as designed. Of the 76 teams about which information was provided, 49 (65%) had a coach that was aware of an efficacious lower extremity IPP, 23 (30%) had a coach that reported using a proven IPP, and 13 (17%) had a coach that reported using the IPP exactly as designed. There was no association between player age and coach awareness of an IPP ($p = 0.170$), but coaches of

older teams that were aware of an IPP were more likely to report using one than IPP-aware coaches of younger teams ($p = 0.021$). However, there was no association between player age and the use of the IPP exactly as designed (U15-19: 60.0% vs. U9-14: 53.8%, $p > 0.05$) among teams whose coach reported the use of an IPP ($n = 23$).

Discussion

The primary finding of this investigation is that despite similar levels of IPP awareness, U15-U19 female soccer players were more likely to have a coach that used an IPP with their team than players on U9-U14 teams. Though the reason for this is likely multifactorial, one reason may be that coaches of older teams (U15-U19) were more likely to perceive lower extremity injuries to be a problem for their team and their athletes to be at a high risk for lower extremity injuries than coaches of younger teams (U9-U14.)

According to Rogers' Diffusion of preventive innovations, *compatibility* – the degree to which an innovation is thought to be similar to the values and needs of potential users– is an important factor that influences the adoption of an intervention. Coaches need to believe that an intervention addresses the issues they perceive their team to have. A study by Norcross et al. (2016) revealed that 90% of high school coaches who did not choose to implement an IPP reported believing that an IPP would reduce injury, "indicating that negative attitudes toward injury prevention in general, or doubt about the effectiveness of IPPs to prevent injury, were not the primary barriers to IPP adoption". Similarly, coaches of both older and younger age teams in this study tended to agree that exercises which have been scientifically proven to prevent lower extremity injuries should be performed by their athletes and incorporated into the training guidelines of their teams. However, coaches of older teams more strongly agreed that female soccer players on their team were at a high risk for injury and that injuries were a problem for their team.

The greater perceived injury risk in older female soccer players by coaches is reasonable given that, in general, match injury incidence tends to increase with age, as does

the number of sprains/strains and risk for lower extremity injury (Faude, 2013; Leininger 2007). Furthermore, the incidence of sports-related ACL injury increases during adolescence and peaks during the mid-to late teens in female athletes (Myer, 2013). Previous studies have suggested that the increased incidence of lower extremity injury in adolescent females could potentially be due in part to puberty driven changes that reduce relative strength, coordination, and neuromuscular control in female athletes; and that interventions that coincide with the timing of these changes might mitigate the negative effects seen in maturing female athletes, thereby reducing their risk of lower extremity injury (Myer, 2005, 2011). Unfortunately, despite the impact that implementing IPPs during pre- or early adolescence might have on lower extremity injury prevention, only 23% of U9-U14 teams had a coach that reported using an IPP. As coaches of younger teams were less likely to agree that lower extremity injuries are a problem for their team, or that there is a high risk of suffering a lower extremity injury for players on their team, they may not have adopted an IPP because an IPP addresses a need that they do not perceive to have.

In addition to short-term injury risk perceptions, coaches of teams in both age groups were mixed in their agreement about whether lower extremity injuries have a negative impact on the quality of life of their players or if these injuries can cause physical problems later in life. This suggests that many soccer coaches are not aware of long term ramifications of lower extremity joint injuries, such as early-onset osteoarthritis, that can contribute to decreased levels of physical activity and cessation of competitive play (Roos, 1995). Therefore, without a perceived short-or long-term need for an intervention, it would make sense that coaches of younger teams would not adopt IPPs as often as coaches of older teams. Roger's idea of *preventive innovations* – new ideas that require action at one point in time in order to avoid unwanted consequences at some future time – could also help explain why coaches of younger teams do not implement IPPs. In a preventive innovation, not only is the effect delayed in time, but the unwanted consequence of a lower extremity injury may never

occur anyway. Implementing an injury prevention program with a team of younger athletes may not actually result in an immediate reduction of injury risk, but the idea is that the IPP helps to prepare the athletes' bodies for the time when injury risk is the highest – post puberty. However, without immediate results or appreciation of the potential benefits to their athletes a few years down the line, coaches of younger teams may not be motivated to adopt an injury prevention program.

Despite an overall level of IPP awareness of 65% that is slightly higher than has been reported previously (Norcross, 2016), only 53% of U15-U19 teams and 23% of U9-U14 teams had coaches that reported adopting an IPP. Further, of the 23 teams whose coach had adopted an IPP, just 13 (57%) reported using the program exactly as designed. Though our results indicate that there is likely no association between player age and the use of an IPP exactly as designed, this result should be interpreted with caution given the small sample size for this analysis. Nevertheless, high compliance to a program results in the greatest reduction in ACL injury risk, and athletes with low compliance to an IPP exhibit a 4.9 times greater relative risk of ACL injury than athletes who are highly compliant with the IPP (Sugimoto, 2012). Therefore, while adopting an IPP is a step in the right direction, not completing the program as designed reduces the benefit offered by completing the intervention. As a result, further research is needed to identify barriers that may be preventing coaches from implementing injury prevention programs with a high degree of fidelity with teams of all ages.

Moving forward, educating coaches on the puberty driven changes seen in female athletes may have the greatest potential for increasing IPP implementation in young athletes. Making coaches aware of the changes in relative strength, coordination, and neuromuscular control, and how injury prevention programs performed before and during puberty may reduce these unwanted changes and possibly reduce injury risk in the mature female athlete, may make coaches more inclined to adopt an IPP. With more knowledge on the issue,

coaches might see injury prevention programs as being more compatible with their situation, while recognizing the relative advantage of IPPs. Education on the negative repercussions of lower extremity injuries such as an ACL tear is promising as well. Knowing the long term effects of such injuries, coaches may disregard the fact that they might not see immediate results, with the idea in mind that IPPs will benefit their athletes in the long term. Future longitudinal studies should evaluate the effect of completing an injury prevention program before and during puberty on post-pubertal injury risk as this would provide much needed evidence that would support earlier IPP implementation.

Conclusion

Despite similar levels of IPP awareness, we found that coaches of U15-U19 female soccer teams are more likely to use an IPP with their athletes than coaches of U9-U14 teams. However, player age did not seem to influence whether or not an IPP was implemented with a high rate of fidelity. This study indicates that the age of female athletes may influence coaches' perceptions of injury risk and the use of lower extremity injury prevention programs. This can potentially be due to IPPs addressing issues that coaches of younger teams do not perceive their teams to have, seeing that they are less likely to agree that lower extremity injuries are a problem for their team or to perceive their athletes to be at high risk for injury. Coaches of younger teams may not see the relative advantage of IPPs because the benefits do not appear until years later. We propose that lack of knowledge on the benefits of IPPs, the timing of IPP implementation, and the long term ramifications of lower extremity injuries may be inhibiting appropriate adoption of IPPs, while further research is needed to identify barriers to high fidelity IPP implementation.

Table 1. Coaches' perceptions surrounding lower extremity injuries, injury risk, and the benefits of using preventive exercises with their team(s). A negative association (Somer's *d)* indicates greater agreement with the statement by coaches of U15-U19 teams.

	Team Age	**Strongly Agree**	**Agree**	**Neither Agree or Disagree**	**Disagree**	**Strongly Disagree**	**Somer's *d***	***P*-value**
There is a high risk of suffering a lower extremity injury for players on my team.	U9-U14	3, (5.3%)	29, (50.9%)	13, (22.8%)	12, (21.1%)	-	-.382	.014*
	U15-U19	8, (42.1%)	6, (31.6%)	3, (15.8%)	2, (10.5%)	-		
Lower extremity soccer injuries are a problem for my team.	U9-U14	1, (1.8%)	11, (19.3%)	15, (26.3%)	26, (45.6%)	4, (7.0%)	-.473	0.001*
	U15-U19	4, (21.1%)	7, (36.8%)	4, (21.1%)	4, (21.1%)	-		
Lower extremity soccer injuries can cause physical problems later in life for players on my team.	U9-U14	5, (8.8%)	31, (54.4%)	13, (22.8%)	8, (14.0%)	-	-.238	.116
	U15-U19	6, (31.6%)	8, (42.1%)	3, (15.8%)	2, (10.5%)	-		
Lower extremity injuries have a negative impact on the quality of life of my players.	U9-U14	2, (3.5%)	18, (31.6%)	25, (43.9%)	11, (19.3%)	1, (1.8%)	-.029	.867
	U15-U19	3, (15.8%)	6, (31.6%)	3, (15.8%)	6, (31.6%)	1, (5.3%)		
It is possible to prevent lower extremity soccer injuries in players on my team.	U9-U14	12, (21.1%)	31, (54.4%)	8, (14.0%)	6, (10.5%)	-	-.317	.013*
	U15-U19	8, (42.1%)	10, (52.6%)	1, (5.3%)	-	-		
Exercises which have been scientifically proven to prevent lower extremity injuries should be performed by players on my team.	U9-U14	19, (33.3%)	32, (56.1%)	4, (7.0%)	2, (3.5%)	-	-.384	.003*
	U15-U19	13, (68.4%)	6, (31.6%)	-	-	-		
Exercises which have been scientifically proven to prevent lower extremity injuries should be incorporated into the training guidelines of my team.	U9-U14	24, (42.1%)	28, (49.1%)	5, (8.8%)	-	-	-.308	.020*
	U15-U19	14, (73.7%)	4, (21.1%)	1, (5.3%)	-	-		

Table 2. Female club soccer coaches' self-reported knowledge and behaviors related to lower extremity injury prevention programs (IPPs) [*n* (% of Number of teams)].

Team Age	Number of teams	Number of teams with a coach that reported…		
		Being aware of an IPP shown to reduce the risk of lower extremity injury	Using a lower extremity IPP with their team	Using a lower extremity IPP with their team exactly as designed
U9-U14	57	34 (60%)	13 (23%)	7 (12%)
U15-U19	19	15 (79%)	10 (53%)	6 (32%)
Total	76	49 (65%)	23 (30 %)	13 (17%)

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Appendix

Review of Literature

There are 200,000 professional and 240 million amateur soccer players in the world, with 22 of the 38 million officially registered players under the age of 18 (Junge, 2004; FIFA Communications Division, 2007). In children ages 8-17, soccer was associated with the fourth highest incidence of injury per 1000 hours of game, with 77% of soccer related injuries occurring at the lower extremities (Backx, 1991; Junge, 2004). Almost 7% of all injuries in 5 – 18-year-old soccer players were ruptures of the anterior cruciate ligament (ACL) (Shea, 2003). ACL injuries increase the risk for radiographic osteoarthritis (OA) by 105 times, and there may be a 100% chance of OA 20 years after injury (Parkkari, 2008; Fleming, 2003). These injuries can be detrimental to a young athlete, and are occurring more and more frequently.

Sports related ACL injuries increase during adolescence and peak in incidence during the mid- to late teens in female athletes, and if not influenced at an ideal age, low levels of physical fitness and improper mechanics may predispose females to an increased risk of injury (Arendt, 1995; Faigenbaum, 2011). It may be optimal to implement these prevention programs during pre or early adolescence, before the period of altered biomechanics that increases injury risk (Myer, 2013). Although some risk factors predispose athletes to an increased risk of injury, there are modifiable factors than can be influenced with injury prevention programs – if these programs are implemented at the correct time in an athlete's development.

Inducing the "neuromuscular spurt" may help to reduce injury risk as both males and females physically mature (Myer, 2005). However, through puberty, boys and girls diverge from one another in development, putting females at a greater risk for injury (Myer, 2013). A greater knee injury risk reduction has been seen in female athletes who were ≤18 years old, with an ACL injury risk reduction of 72% - compared to a 16% reduction in females older

than 18 (Myer 2013). The development of proper biomechanics and neuromuscular connections before physical maturity may reduce injury risk in both boys and girls, while strength training is useful for skeletally mature boys in reducing injury risk.

Injury prevention programs (IPPs), including Sportsmetrics, FIFA 11+, and the Prevent Injury and Enhance Performance program (PEP) have been developed to decrease the risk of lower extremity injuries. All three of these programs have been shown to significantly reduce the overall rate of injury when implemented to an intervention group (Owoeye, 2014; Noyes, 2012). IPPs have been described as substantially beneficial by reducing the risk of ACL tears by 52% in female and 85% in male athletes (Sadoghi, 2012). A structured program can prevent knee and other lower extremity injuries, however they are not being properly implemented by coaches with compliance a potential limiting factor to overall IPP success (Alentron-Geli, 2009).

There is a need to improve the translation of the latest scientific evidence about effective injury prevention in coaching practices (Twomey, 2009). It is known that the use of neuromuscular training and IPPs reduces the risk of ACL injuries; however, coaches are not using them in an effective manner (Sugimoto, 2012). Low ACL incidence rate is seen with high compliance; moderate compliance results in a risk that is 3.1 times higher than high compliance, and low compliance increases relative risk by 4.9 times (Sugimoto, 2012). Identifying ways that may increase the likelihood of implementation will help reduce injury risk in young athletes. The purpose of this investigation was to evaluate the association between player age and club soccer coaches' perceptions of injury risk and benefits of an IPP; and the rate of IPP use.

Injury Incidence: With 200,000 professional and 240 million amateur participants, soccer is the most popular sport in the world (Junge, 2004). It is becoming increasingly popular at the amateur level through earlier participation of young athletes, and a developing trend of sport specialization. The highest proportion of participants, 22 of 38 million

officially registered players, are under the age of 18 years, and from 2000 to 2006, the number of registered youth players increased by 7% worldwide (FIFA Communications Division, 2007). With this growing number of young participants, the rate of injury and injury risk is increasing. Participation at a younger age may place athletes at a greater risk of injury if they do not possess the adequate strength and proper conditioning to prevent devastating injuries (Myer, 2011). A longitudinal study conducted by Backx *et al* determined that in Dutch school children aged 8-17 years, in both organized and unorganized soccer, the sport was associated with the fourth highest incidence of injuries per 1000 hours of game (Backx, 1991). Lower extremity injuries are commonly caused by movements such as jumping, landing, side-cutting, and running; all actions that can be associated with soccer. According to Junge *et al*, 77% of soccer related injuries occur at the lower extremities, predominately affecting the ankle and knee as well as the muscles of the thigh and calf. In a US report by Shea *et al* of 5 to 18-year-old soccer players, 30.8% of all injuries involved the knee, and 6.7% of all injuries were ruptures of the anterior cruciate ligament (ACL). ACL ruptures are devastating injuries for athletes of all ages. With injury, the risk of radiographic osteoarthritis (OA) later in life increases by 105 times (Parkkari J, 2008), and there may be a nearly 100% chance of OA 20 years after ACL injury (Fleming, 2003). ACL rupture typically requires reconstructive surgery if the athlete wishes to return to activity. ACL reconstructions in younger patients, with significant growth remaining, carry a risk of growth plate injury and growth disruption (AlHardy, 2010). If not managed properly, youth sports injuries can lead to long term complications which could negatively affect the individual's ability to participate in exercise and sports (Schub, 2011). After surgery, the athlete then must undergo several months of physical therapy and rehabilitation before returning to play.

Nearly 350,000 ACL reconstructions are performed annually in the US, and the annual cost of care is estimated to be more than $2 billion (Wojtys, 2010). Age, sex-specific factors, and previous injury are some non-modifiable risk factors for lower extremity injuries,

while poor endurance, lack of preseason training, and psychosocial factors are important modifiable risk factors (Myer, 2013). The latter are factors that can be impacted through injury prevention programs. In a study conducted by Junge *et al*., incidence of injury in both rugby and soccer players in New Zealand was analyzed. The authors found that rugby players had a higher incidence of injury, and thought this to be due to a low ratio of hours spent in training relative to hours spent playing matches (Junge, 2004). The authors recommended the development and implementation of preventive interventions to reduce the rate and severity of injury. Soccer is a high-intensity sport with frequent changes in movement, velocity, and direction, posing the risk of injury. It is necessary to implement preventive measures to reduce the risk of injury, and to support the participation in soccer as well as other competitive sports.

Age and Sex-Related Factors: It may be optimal to implement these prevention programs during pre or early adolescence, before the period of altered biomechanics that increases injury risk (Myer, 2013). Sports related ACL injuries increase during adolescence and peak in incidence during the mid- to late teens in female athletes (Arendt, 1995). The "neuromuscular spurt" is defined as the natural adaptation of increased power, strength, and coordination that occurs with increasing chronological age and maturational stage in adolescent boys (Myer, 2011). Integrative neuromuscular training implemented in preadolescence and early adolescence may artificially induce this neuromuscular spurt, especially related to relative posterior chain strength, postural control, and neuromuscular power, which is often reduced as young female athletes mature (Myer, 2005). Inducing this spurt may help to reduce injury risk as both males and females physically mature. Interventions focused to reduce knee injury appear to be effective when implemented in boys and girls (Sadoghi, 2012); however, through the pubertal transformation during the adolescent years, boys and girls diverge from one another in development, inherently putting female athletes at a greater risk of a devastating injury such as an ACL rupture in the post

pubertal years. Power, strength, and coordination have been shown to increase with puberty in boys, but the same changes have not been seen in girls (Myer, 2013). Once boys have reached skeletal maturity, if they are muscularly weak, they are more susceptible to injury compared to peers of the same chronological age (Backous, 1988). There has not been significant evidence of this sex difference in injury incidence for altered biomechanics in prepubertal female athletes, but only postpubertal female athletes (Myer, 2013). If not addressed at the proper time, low levels of physical fitness and abnormal mechanics may predispose female athletes to an increased risk of musculoskeletal injuries. Integrating neuromuscular training at an early age might increase physical fitness and enhance motor skills (Faigenbaum, 2011). A study by Myer *et al* showed statistically greater knee injury risk reduction in female athletes who were ≤18 years of age compared with those who were >18 years old. ACL injury risk was reduced by 72% in female athletes under 18, but for females over 18 years old the reduction was only 16% (Myer, 2013). There seems to be a higher risk of injury in postpubertal athletes that may be attributed to several changes that occur throughout the pubertal period, such as structural/anatomical changes, hormonal variations, and decreased strength (Myer, 2013). Altered mechanics associated with increased risk of injury in female athletes emerge after the pubertal growth spurt, and seem to coincide with peak incidence of ACL injury (Myer, 2009). Biomechanical and neuromuscular differences have been identified throughout the trunk and lower extremity that may increase noncontact ACL injury risk in female athletes (Bien, 2011), but these noted biomechanical risk factors are sensitive to modification with neuromuscular training interventions (Myer, 2013). The adolescent growth spurt seems to result in increased vulnerability for traumatic injuries (van der Sluis, 2013). The onset of puberty in the skeletally immature athlete presents challenges for athletes and appears to influence the injury rate in both boys and girls. Both experience a spike in the number of injuries in the early teenage years (Wojtys, 2010). The skeletally immature population appears to be sustaining rising numbers of ACL injuries (Kocher, 2002),

and higher rates of midsubstance tears (Lipscomb, 1986). The development of proper biomechanics and neuromuscular connections before physical maturity may reduce injury risk in both boys and girls, but seems especially important in the prepubescent female.

Injury Prevention Programs (IPPs): Although these factors of strength and neuromuscular training pertain to the individual athlete, injury risk may be more specific to the team, and, thus, preventive measures may also target the teams and their environments (Inklaar, 1996). IPPs have been developed for the use of teams to decrease their risk of lower extremity injuries. These programs, including Sportsmetrics, FIFA 11+, and the Prevent Injury and Enhance Performance program (PEP) are structured warm-ups that incorporate exercises such as stretching, strengthening, plyometrics, and sport specific agility exercises. The goal is to address potential deficits in the strength and coordination of the stabilizing muscles around the knee joint. Hip and hamstring training, core stabilization, plyometrics, balance, agility, neuromuscular training, stretching, and verbal feedback to modify technique appear to be essential components of these programs (Bien, 2011). Maneuvers that result in ACL injuries tend to be sudden and unexpected, resulting in injury because the athlete cannot respond to the perturbation quickly enough to activate appropriate muscles. Stability and balance training, and plyometric training produce reductions in voluntary activation times, which may decrease muscle response times so that players are more able to perform these rapid and unexpected sports maneuvers. Training programs that emphasize these neuromuscular mechanisms may enhance protection of the ACL and reduce the incidence of injury (Lloyd, 2001). Through a systematic review of comparative studies testing the effect of neuromuscular and educational interventions on the incidence of ACL injuries, Gagnier et al found that neuromuscular and educational interventions appear to reduce the incidence rate of ACL injuries by approximately 50%. Through a cluster randomized controlled trial, Owoeye et al (2014) administered the FIFA 11+ program to an intervention group of ten teams. They found that the FIFA 11+ program significantly reduced the overall rate of injury

in the intervention group by 41% and all lower extremity injuries by 48% in male youth soccer players (Owoeye, 2014). Similar results have been found in studies of other IPPs including Sportsmetrics and the PEP program. In a review of studies on the effectiveness of IPPs, it was found that the Sportsmetrics and PEP programs resulted in statistically significant decreases in the ACL injury incidence rates as determined by athlete-exposure in high school female athletes participating in basketball and soccer (Noyes, 2012). Sadoghi et al (2012) pooled data from various studies and found that athletes in the prevention programs had a 62% reduction risk of ACL rupture compared with athletes in the control groups. Although these studies did not involve specific programs such as Sportsmetrics and PEP, it was concluded that an ACL injury prevention program should include at least ten minutes of exercises three times per week, with a focus on neuromuscular training (Sadoghi, 2012. Pooled estimates suggested a substantial beneficial effect of ACL prevention programs, with a 52% reduction in the risk of an ACL tear in female athletes, and an 85% reduction in male athletes (Sadoghi, 2012). Noyes et al found that Sportsmetrics and the PEP program significantly reduced ACL injury rates and improved athletic performance tests. Sportsmetrics produced significant increases in lower extremity and abdominal strength, vertical jump height, estimated maximal aerobic power, speed, and agility, while PEP improved isokinetic knee flexion strength. Both programs had a positive influence on injury reduction and athletic performance (Noyes, 2012). The increased athletic performance may be an important factor in implementation, as coaches may be more likely to use a program if it is known to improve the performance of their athletes. These studies show that a structured program of warm-up exercises can prevent knee and other lower extremity injuries in young people playing sports, however they are not readily being implemented by coaches. Compliance may be the limiting factor to the overall success of ACL injury interventions targeted to soccer players (Alentron-Geli, 2009).

IPP Implementation: Twomey et al (2009) found that in Australia, current football training sessions do not give adequate attention to the development of skills most likely to reduce the risk of lower extremity injury in players. The authors declared a need to improve the translation of the latest scientific evidence about effective injury prevention in coaching practices (Twomey, 2009). Poor compliance is considered to be the main reason for an IPP to fail. Steffen et al conducted a study in which they taught an intervention group select preventive exercises that included core stability, lower extremity strength, and neuromuscular control and agility. There was no difference observed in the overall injury rate between the intervention and control group (Steffen, 2008). This was thought to be due to noncompliance. During the first 4 months of the season, the training program was used during 60% of the training sessions, but only 14 out of 58 intervention teams completed more than 20 preventive training sessions (Steffen, 2008). Sugimoto et al (2012) systematically reviewed and synthesized published literature on compliance with neuromuscular training being associated with reduced incidence of ACL injury. They found an inverse association between neuromuscular training (NMT) and ACL injury rates (Sugimoto, 2012). It has been seen that the use of NMT and IPPs reduces the risk and rate of ACL injuries; however, coaches and teams are not implementing these programs in a way that will optimize their effectiveness. Consistent attendance by involved athletes and commitment to the completion of sessions contribute to the effectiveness of an IPP (Sugimoto, 2012). After gathering compliance rates from several studies of NMT and IPPs, Sugimoto et al found lower ACL incidence rates in studies with high compliance rates than the studies with low compliance rates. High compliance was considered >66.6% of participants completing the sessions, moderate 66.6% - 33.3%, and low compliance was <33.3% (Sugimoto, 2012). Participants in the studies with moderate compliance rates had a risk of injuring their ACLs that was 3.1 times higher than participants in the studies with high compliance rates. Furthermore, participants in the studies with low compliance rates demonstrated a relative ACL injury risk that was 4.9 times greater

than that of participants in the studies with high compliance rates (Sugimoto, 2012). It was concluded that higher compliance rates are associated with lower ACL injury rates. Studies reviewed by Sugimoto et al commented that a lack of available scheduling for the intervention program due to a short preseason, constant competition, infrequent practice days, and occasional academic and holiday breaks might contribute to low compliance. The fact that scientific study shows that an injury prevention measure works does not guarantee it will actually prevent injuries in the real world context of sport, if it is not adopted by players and coaches (Twomey, 2009). Identifying ways that may increase the likelihood of implementation of these programs will help to reduce the risk of injuries to young athletes. ACL injuries are detrimental to an athlete, and are often accompanied by lifelong negative effects such as osteoarthritis and a decreased level of physical activity, as well as a large financial cost. A greater involvement in sport at a younger age and sport specialization is leaving young athletes susceptible to these injuries if not trained properly. There is evidence for the need to implement IPPs with athletes of all ages, but with a growing number of prepubescent athletes, the need for earlier intervention seems to be emerging. Despite this evidence and the availability of IPPs, it unknown if these programs are being used by coaches with females as they move through puberty. Therefore, the purpose of this investigation was to evaluate the association between player age and club soccer coaches' perceptions of injury risk and benefits of an IPP; and the rate of IPP use.

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