Epidemiology of Anterior Cruciate Ligament Injury in Italian First Division Soccer Players

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Background: The burden of anterior cruciate ligament (ACL) injury in professional soccer players is particularly relevant as it represents a potentially career-threatening injury.

Hypothesis: Our hypotheses were that (1) injury incidence rate would be similar to that reported in the literature, (2) we would identify a uniform distribution of the injuries along the season, and (3) injury incidence rate would be similar in high-ranked and lower ranked teams, based on final placement in the league.

Study Design: Descriptive epidemiological study.

Level of Evidence: Level 4.

Methods: Professional male soccer players participating in the Serie A championship league in 7 consecutive seasons (2011-2012 to 2017-2018) were screened to identify ACL injuries through the online football archive transfermarkt.com. Exposure in matches and training were calculated.

Results: There were 84 ACL injuries found (mean player age, 25.3 ± 4.2 years). Overall, 25% of ACL injuries were reruptures (15%) or contralateral injuries (10%). ACL incidence rate was 0.4215 per 1000 hours of play during Serie A matches, 0.0305 per 1000 hours of training (rate ratio [RR], 13.8; 95% CI, 8.4-22.7; $P < 0.0001$), and 0.0618 per 1000 hours of total play. Injury distribution had a bimodal peak, with the highest number of events in October and March. Alternatively, training injuries peaked in June and July. A significantly higher incidence rate was found for the teams ranked from 1st to 4th place compared with those ranked 5th to 20th (0.1256 vs 0.0559 per 1000 hours of play; RR, 2.2; 95% CI, 1.4-3.6; $P = 0.0003$). A similar finding was found for injury incidence proportion (3.76% vs 1.64%; $P = 0.0003$).

Conclusion: The overall incidence rate of ACL injuries in Italian Serie A was 0.062 per 1000 hours, with a 14-fold risk in matches compared with training. Relevantly, 25% were second injuries. Most injuries occurred in October and March, and an almost 2-fold incidence rate and incidence proportion were noted in those teams ranked in the first 4 positions of the championship league.

Clinical Relevance: Knowing the precise epidemiology of ACL injury in one of the most competitive professional football championship leagues could help delineate fields of research aimed to investigate its risk factors.

Keywords: anterior cruciate ligament; ACL; football (soccer); professional; Serie A; epidemiology

Pivoting sports such as soccer are considered high-risk activities for anterior cruciate ligament (ACL) injury[13,16,26] because of the high axial and torsional loads applied to the knee joint during sport-specific tasks like sudden change of direction, rapid deceleration, and landing from a jump or heading.[1,12,32] The burden of ACL injury in professional soccer players is particularly relevant since the time lost is on average between 9 and 12 months.[20,40,41] Moreover, only 65% of injured

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soccer players are able to participate at the same preinjury level 3 years after the injury,[36] and the early onset of osteoarthritis represents a common consequence.[34]

Preventive programs are considered important measures to protect a player's heath and career; however, to optimize the efficacy of these programs, it is important to first define the number of injuries as well as their mechanism, frequency, and severity in an ecologically valid population.[29]

Only a few reports on ACL epidemiology have been published so far, analyzing different populations and different time periods and utilizing various methodologies to collect injuries.[27,29,31,36] At the present time, the most authoritative data derive from the Union of European Football Associations (UEFA) study by Waldén et al,[36] where an ACL injury incidence of 0.309 per 1000 hours of play and 0.013 per 1000 hours of training was reported. While that study represents a valid and generalizable model depicting the average status of the art of European football because of its heterogeneity, the lack of the systematic focus on a single well-defined league during a limited time span represents a potential limitation for studying relevant factors such as injury distribution across the season or within different teams. Seasonal peaks in injury incidence and the role of match overload, number of matches played, and the willingness to compete to higher rank positions still represent pending questions that could be answered by analyzing several consecutive seasons of a single league. In this regard, recently, Eirale et al[10] highlighted the lack of epidemiological studies in the Italian First Division (Serie A), calling for implementation of robust epidemiological surveillance of Italian professional leagues. This is relevant, as the Italian soccer league is one of the best in the world and among the 4 best in Europe, as measured by UEFA club coefficient ranking, and involves more than 13,000 professional players.[10]

Because of the difficulty in implementing official injury-surveillance programs, several researchers performed epidemiological and outcome studies on professional athletes based on publicly available internet news and databases for ACL injury,[27,31] Achilles tendon rupture,[2,33] upper and lower limb fractures,[25,30] meniscal surgery,[25] lumbar disc herniation,[24] and femoroacetabular impingement.[23]

Therefore, the present study was designed with the purpose of evaluating the epidemiology of ACL injury in 7 consecutive seasons of the Italian Serie A championship league, retrieving data from publicly available soccer databases. Our hypotheses were that (1) injury incidence rate would be similar to that reported in the UEFA study,[36] (2) we would be able to identify a uniform distribution of injuries within the season, and (3) injury incidence rate would be similar in high-ranked and lower ranked teams, based on final placement within the league.

METHODS

Screening Process

To investigate the epidemiology of ACL injuries in Italian First Division soccer, all professional male soccer players participating in the Italian First Division League (Serie A) across 7 seasons, from 2011-2012 to 2017-2018, were screened for ACL injuries.

The Italian Serie A is composed of 20 teams; each team plays against the other teams 2 times within the entire season (from August to May), for a total of 38 matches. The teams ending the season in the first 4 positions also participate in the UEFA Champions League (UCL) tournament in the subsequent season, which is the most prestigious European tournament and includes the highest ranked teams of all European leagues. Similarly, the teams concluding the season in the 5th, 6th, and 7th positions participate in the UEFA Europa League tournament, which has a similar format to the UCL but involves lower ranked teams. All Serie A teams are also involved in the National Cup (Coppa Italia), which is a tournament that utilizes a knock-out format. The number of matches played by each team in the Cup (UCL, Europe League, and National Cup) is variable and depends on their progression along the tournaments. All Cup matches are played in parallel with the Serie A official matches. Finally, a variable proportion of players on Serie A teams are involved in an additional number of matches and training with their own national representatives if they are selected to represent their own country in an international competition such as the World Cup or Continental Cups (Euro Cup, Asian Cup, African Cup, or Copa America).

The publicly available media-based platform transfermarkt.com (Transfermarkt GmbH & Co KG) was searched manually by 2 investigators. This website is a broad database of worldwide football statistics, accounting for players' performances, presence, and injuries. A recently published validation study elegantly demonstrated sufficient validity and accuracy of the injury-related data retrieved from Transfermarkt.[21] An interobserver agreement of over 90% between reference sources and Transfermarkt.de and a Cohen kappa of 0.82 for cross-validation were found.

The main page of the website was opened, and 7 consecutive seasons from 2011-2012 to 2017-2018 of the Italian First Division (Serie A) were progressively accessed and analyzed. For each season, the list of the 20 participating teams was assessed separately. The injury history of each player on every team was evaluated, and when report of an ACL injury was encountered, the player was considered eligible for inclusion in the study. A further targeted search was performed to confirm the injury and the treatment through ACL reconstruction.

Data Extraction

For every player in which ACL injury and reconstruction was confirmed, the anthropometric player characteristics, the situation of injury, and the timing of injury were extracted by the same investigators. Injuries were classified based on the occurrence during Serie A matches, Cup matches, involvement with the national representative team, and during training. Injuries that occurred during friendly matches were designated as "in training." Previous contralateral ACL ruptures and ipsilateral graft failures were also noted. Therefore, for all the players included, the medical history before the 2011-2012

season was also analyzed to rule out possible previous ipsilateral or contralateral ACL injuries and reconstruction.

To calculate the risk exposure while playing soccer, the total number of matches played by each team in each season were calculated and subdivided in the different competition in which 1 or more teams participated (Serie A, Champions League, Europa League, and National Cup). The risk exposure of each player during training was approximated considering the annual average exposure of an Italian First Division middle-rank team that participated in more than half of the seasons analyzed. The risk exposure while playing or training with the national representative team was not assessed, since it was impossible to approximate due to nonhomogeneous participation among the players from the 20 First Division teams. Finally, the number of players on each team in each season and the final placement of each team in the seasonal rankings were obtained as well. Since the first 4 teams in the final rank from the Italian Serie A are allowed to participate in the UCL, which is the most prestigious football competition, we arbitrarily defined high-ranked teams as those classified from 1st to 4th position, while low-rank teams were those classified from 5th to 20th position. Based on the data obtained, several epidemiological measures of ACL injuries were calculated, according to Knowles et al[17] (Appendix Table A1, available in the online version of this article). The *incidence rates* were defined as the number of injuries divided by the total person-time at risk (eg, athlete-exposure during matches or training). The *incidence proportions* were defined as the number of new injuries divided by the total number of athletes at risk during a specified time period (eg, team-season or league-season).

Statistical Analysis

Statistical analysis was performed using the statistical software MedCalc. Continuous variables were reported as mean ± SD, while categorical variables were reported as raw number and percentage of the total. Continuous variables were compared using the independent-sample *t* tests and analysis of variance, while categorical variables were compared using the chi-square test. A subanalysis was performed based on the final team ranking in the league: Teams were divided based on position 1 to 4 and 5 to 20. Comparison between the incidence rates was performed using a rate ratio (RR) and 95% confidence interval, and significance was tested using the *z*-statistic,[22,36] while the chi-square test was used to compare categorical variables. Values were considered statistically significant at $P < 0.05$.

RESULTS

Player Characteristics

Overall, 84 ACL injuries were found during the 7 Serie A seasons analyzed, in athletes with a mean age of 25.3 ± 4.2 years. Most of the injuries occurred in defenders (43%), followed by midfielders (31%), forwards (20%), and goalkeepers (6%). A total of 25% of ACL injuries were in athletes who had already sustained a previous ACL injury (15% reinjuries, 10% contralateral injuries) (Figure 1). Most injuries occurred during official Serie A matches (44%) and training (40%).

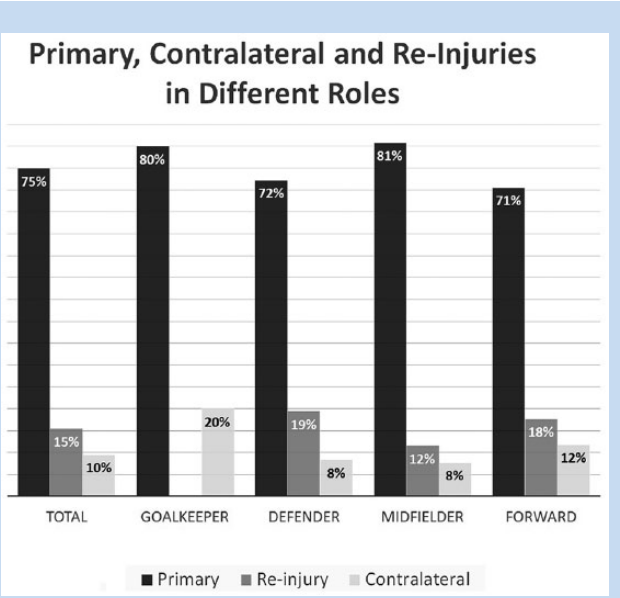

Figure 1. Percentage of primary anterior cruciate ligament (ACL) injuries (black bar), ipsilateral rerupture (dark-gray bar), and contralateral ACL injuries (light gray bar) according to player position.

Incidence Rate

The incidence rate of ACL injuries was 0.4215 per 1000 hours of play during Serie A matches, with no significant differences across the seasons ($P > 0.05$), and 0.0305 per 1000 hours of training (Appendix Table A1, available online). The Serie A injury rate was 14 times higher than the training injury rate (RR, 13.8; 95% CI, 8.4-22.7; $P < 0.0001$). Finally, the overall injury rate per 1000 hours of play (matches and training) was 0.0618 (Figure 2, Table 1).

Incidence Proportion

The overall incidence proportion was 2.04% of the total players involved in the Serie A league, with no significant differences across the seasons ($P > 0.05$). Based on these data, it could be estimated that 0.6 injuries occurred per team every season, which roughly corresponds to 1 injury every 2 seasons (Appendix Table A2, available online). On average, considering 2 teams in each match, an injury is expected every 72 Serie A matches or 7 rounds.

ACL Injury Distribution

Most of the injuries occurred during autumn (31%), especially during official Serie A matches. Summer was the season with the lowest number of injuries (20%), although almost all of them were during training (14% of the total) (Appendix Figure A1, available online). The monthly distribution of ACL injuries revealed a bimodal peak, with the highest number of injuries in

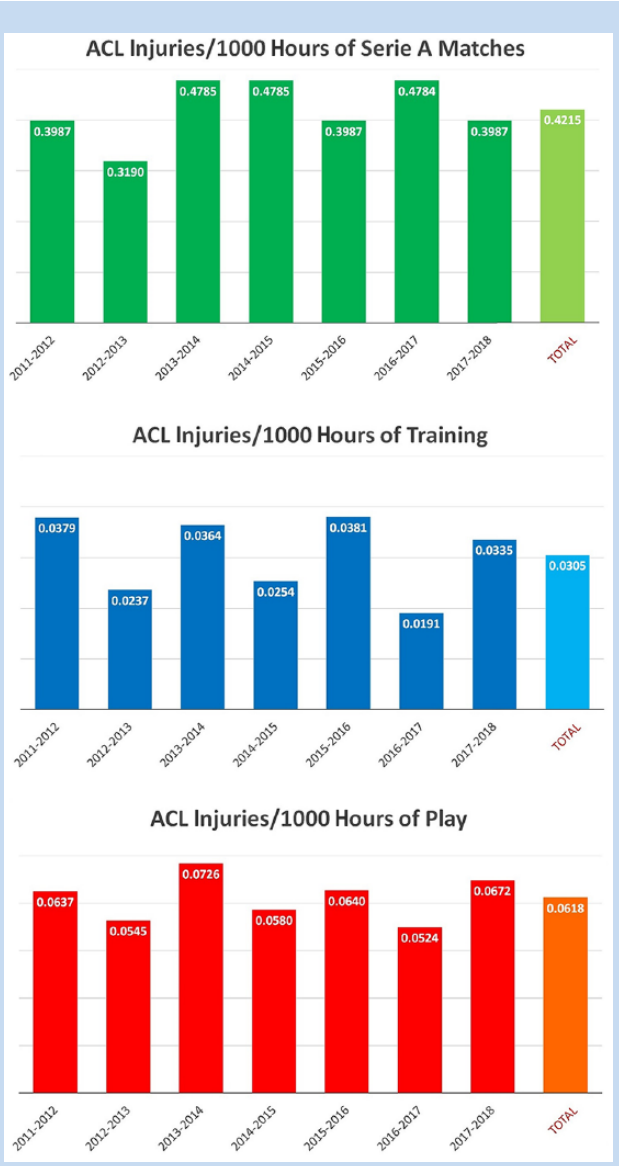

Figure 2. Incidence rates for anterior cruciate ligament (ACL) injury per 1000 hours of Serie A matches (green), 1000 hours of training (blue), and 1000 hours of total play (red).

October and March. In contrast, training injuries peaked in June and July (Figure 3).

Team Rank Comparison

When stratifying injuries based on the final rank of the injured player's team, a significantly higher incidence rate was found for the teams ranked from the 1st to the 4th place compared with those in the 5th to 20th positions (Table 2). Specifically, the incidence rate per 1000 hours of total play and per 1000 hours of training were 2.2 ($P = 0.0003$) and 2.4 ($P = 0.0130$) times higher, respectively. The injury incidence proportion per total number of players was almost double in the team ranked in the 1st to 4th positions (3.76% vs 1.64%; $P = 0.0003$). Moreover, teams with higher rank not only experienced an average of 1 injury per season, compared with 0.5 in teams with lower rank ($P = 0.0009$), but also played, on average, a greater number of matches during the season (49 vs 42; $P = 0.0001$) (Figure 4).

DISCUSSION

According to the epidemiological evaluation of ACL injuries in 7 consecutive seasons of the Italian First Division (Serie A) obtained from publicly available databases, we were able to confirm only 1 of 3 initial study hypotheses. In fact, an ncidence rate similar to the UEFA study by Waldén et al[36] was found, thus supporting the first hypothesis. The second hypothesis was not confirmed, since a nonuniform distribution of injuries across the seasons was found; rather, a bimodal peak was noted, with peaks during the months of October and March. Finally, the third hypothesis was not confirmed either, because higher incidence rates and proportions of ACL injuries were found in those teams placed in the first 4 positions of the final league ranking compared with teams that were placed in the 5th to 20th positions. In addition to the main study hypotheses, other interesting and unexpected considerations could be drawn.

Player Characteristics

First, the profile of players who sustained ACL injuries in the Italian Serie A resembles what has been previously reported in the literature regarding professional soccer players. The mean age of 25.3 years is consistent with what was reported in a European 3-cohort UEFA study (25.2 years),[35] in 132 ACL ruptures from the 4 most important European leagues during the seasons 2010-2011 and 2011-2012 (25.3 years),[27] and in professional Qatar soccer players (25.0 years).[29] Also, the greatest number of injuries occurred in defenders (43%), which could reflect both the generally higher absolute numbers of defenders on normal rosters (which usually utilize modules with 4 defenders) and also indirectly pointing out pressing as one of the most common injury mechanisms.[3,8,15,37]

An important matter of reflection obtained from the current data is that 1 of 4 ACL injuries reported—either ipsilateral or contralateral—occurred in a soccer player who had a previous ACL reconstruction. This is not new, since statistics report a 20-fold rate of ACL injury in those who had ipsilateral ACL reconstruction compared with uninjured controls.[27] The 15% rate of reinjury and 10% rate of contralateral injury reported in the present study is consistent with that reported in a meta-analysis by Wiggins et al,[38] where a 23% rate of second ACL injury (either ipsilateral or contralateral) was found in athletes younger than age 25 years who returned to sport. However, the meta-analysis included heterogeneous studies in terms of sports and level. The evidence that a similar trend is present also in professional top-level soccer players, who are provided with the best treatment options for surgery and rehabilitation, represents an alarming situation since this suggests a certain inherent predisposition to ACL injury and recurrence. In fact, as an

Table 1. Incidence rates of anterior cruciate ligament (ACL) injuries across the 7 seasons according to different exposures

Season	Total Players	Matches		ACL Injuries					Incidence Rate of ACL Injuries				
		Serie A	Cups	Total	Serie A	Cups	Training	National Team	Serie A Matches[a]	Cup Matches[a]	Total Matches[a]	Training[a]	Total Play[a]
2011-2012	586	760	109	11	5	0	6	0	0.3987	0.0000	0.3487	0.0379	0.0637
2012-2013	626	760	118	10	4	2	4	0	0.3190	1.0272	0.4142	0.0237	0.0545
2013-2014	610	760	110	14	6	1	6	1	0.4785	0.5510	0.4876	0.0364	0.0726
2014-2015	584	760	137	12	6	0	4	2	0.4785	0.0000	0.4054	0.0254	0.0580
2015-2016	584	760	95	12	5	0	6	1	0.3987	0.0000	0.3544	0.0381	0.0640
2016-2017	582	760	112	12	6	0	3	3	0.4784	0.0000	0.4170	0.0191	0.0524
2017-2018	552	760	122	13	5	1	5	2	0.3987	0.4968	0.4123	0.0335	0.0672
Total	4124	5320	803	84	37 (44%)	4 (5%)	34 (40%)	9 (11%)	0.4215	0.3019	0.4058	0.0305	0.0618

[a]Incidence rates reported per 1000 hours of given activity. Nonsignificant differences between the seasons ($P > 0.05$).

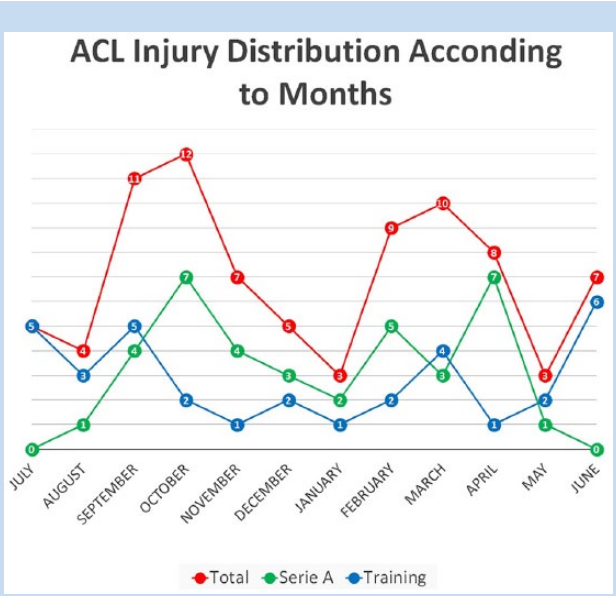

Figure 3. Distribution along the year of total anterior cruciate ligament (ACL) injuries (red), injuries occurred during Serie A matches (green), and injuries occuring during training (blue).

example, a steep posterior tibial slope and an oblong shape of the lateral femoral condyle have been correlated with multiple ACL failures or contralateral ACL injury.[14,28] Further studies should be directed to understanding whether those anatomical risk factors that have been demonstrated to be relevant in the general population are also valid in professional athletes or if the high number of second injuries are due to incomplete recovery after ACL reconstruction.[19]

Incidence Rate and Incidence Proportion of ACL Injuries

The overall incidence rate of ACL injuries per 1000 hours of football play was 0.062 in the present study of Italian First Division (Serie A). This is consistent with the value of 0.058 reported by Waldén et al[36] for several European Clubs monitored between 2001 and 2015. Also, Rekik et al[29] reported an injury rate of 0.076 in Middle East Qatar professional soccer players. It is interesting to note that we did not find relevant differences of the incidence rate within each of the 7 seasons evaluated, thus confirming the worrisome scenario suggested by Waldén et al[36] regarding the lack of injury rate decline over the years despite new preventive strategies. Another interesting consideration concerns the 14-fold higher incidence rate during matches versus training. This is slightly lower compared with the 20-fold higher incidence reported in the UEFA report.[36]

This could be for 2 reasons: First, the use of an approximated exposure training time and the inclusion of injuries that occurred during friendly matches could have overestimated the training injury rate (0.0305 in the present study vs 0.0138 in the UEFA study). Second, a higher incidence rate of training injuries could be effectively present, since 34 of 84 injuries (40%) in Serie A teams occurred during training, as compared with 28 of 140 injuries (20%) in the UEFA study.[36] A similar trend was recently reported in the Qatar League (15/37; 40%),[29] therefore raising a serious concern. In fact, the training environment should be the safest for soccer players, where coaches and athletic trainers are supposed to have the maximum control over players and on possibly dangerous injury situations; therefore, this high percentage of training injuries is worrisome and worthy of further investigation.

An unexpected but not negligible finding was that 1 of 10 injuries occurred while the athlete was playing with the national representative team rather than with his usual club team. This finding has never been investigated and, in our opinion, should be a matter for future studies. A prospective study on a Premier League team reported that only 5% of all the working days lost to injury were due to injuries sustained during national duties.[4] From our study design, it was impossible to calculate the exact exposure to ACL injury risk of the players while playing as a national representative, especially because of the inhomogeneous participation by the players of Serie A teams and complex schedule for international competitions. Therefore, the exact incidence rate of ACL injuries while playing as national representatives is unknown. However, this percentage seems extremely high, and a possible explanation could be overload. In fact, when involved with national representation, soccer players are subjected to multiple training sessions and matches within a limited period.[5,9] Moreover, all the players come from different clubs, each with different styles and methods of training and playing. Finally, competing for one's own country could push the players to play in a more aggressive and risky manner or to be subjected to more psychological pressure. These are all aspects that necessitate further investigation to identify possible correctable risk factors.

ACL Injury Distribution

ACL injuries, both those that occurred during training and those that occurred during official Serie A matches, were not uniformly distributed across the months of the year. In fact, 2 clear peaks were identified in October and March. A similar bimodal peak (November and March) was noted regarding traumatic injuries in a French League for 1 professional team across 4 seasons.[6] Similarly, Falese et al,[11] analyzing 2 seasons of the Italian Serie A, also noted the highest incidence of trauma in October and March. The high incidence during the first months of the competitive season, in addition to the relevant number of injuries that occurred in training during the summer season, could reflect the impact of physical preparation blended with the start of official competitions. The second peak in March, toward the end of the season, could highlight the possible effect of the most stressful and crucial period of the championship, where each match could determine advancement in national and international Cups or achievement of a high position in the league ranking. Based on these findings, athletes and coaches should be aware of this injury

Table 2. Incidence rates and proportions of anterior cruciate ligament (ACL) injuries based on team position in the Serie A league

	Position in Serie A League		
	1 to 4	5 to 20	*P*
ACL injuries			
Total	29	55	NA
Serie A	11	26	NA
Cups	2	2	NA
Training	12	22	NA
National team	4	5	NA
Matches played			
Total	1387	4736	NA
Serie A	1064	4256	NA
Champions League	130	40	NA
Europa League	90	160	NA
National Cup	103	280	NA
Average per season	49	42	0.0001*
Incidence rate of ACL injuries (per 1000 hours)			
Total play	0.1256	0.0559	0.0003*
Serie A matches	0.6266	0.3702	0.1390
Cups matches	0.3848	0.2557	0.6806
Training	0.0576	0.0243	0.0130*
Total matches	0.5713	0.3588	0.1618
Incidence proportion of ACL injuries (per 100 players)			
Total	3.76%	1.64%	0.0003*
Serie A matches	1.43%	0.78%	0.1309
Training	1.56%	0.66%	0.0235*
Cups matches	0.26%	0.06%	0.3345
National team	0.52%	0.15%	0.1202
Incidence proportion of ACL injuries			
Team	1.04	0.49	0.0009*
Serie A match	0.0103	0.0061	0.1390
Cups match	0.0062	0.0042	0.6901
Total matches	0.0094	0.0059	0.1660
No. of matches every ACL injury			
Serie A	97	164	0.1390
Cups	162	240	0.6901
Total matches	107	169	0.1660

NA, not applicable. *$P < 0.05$.

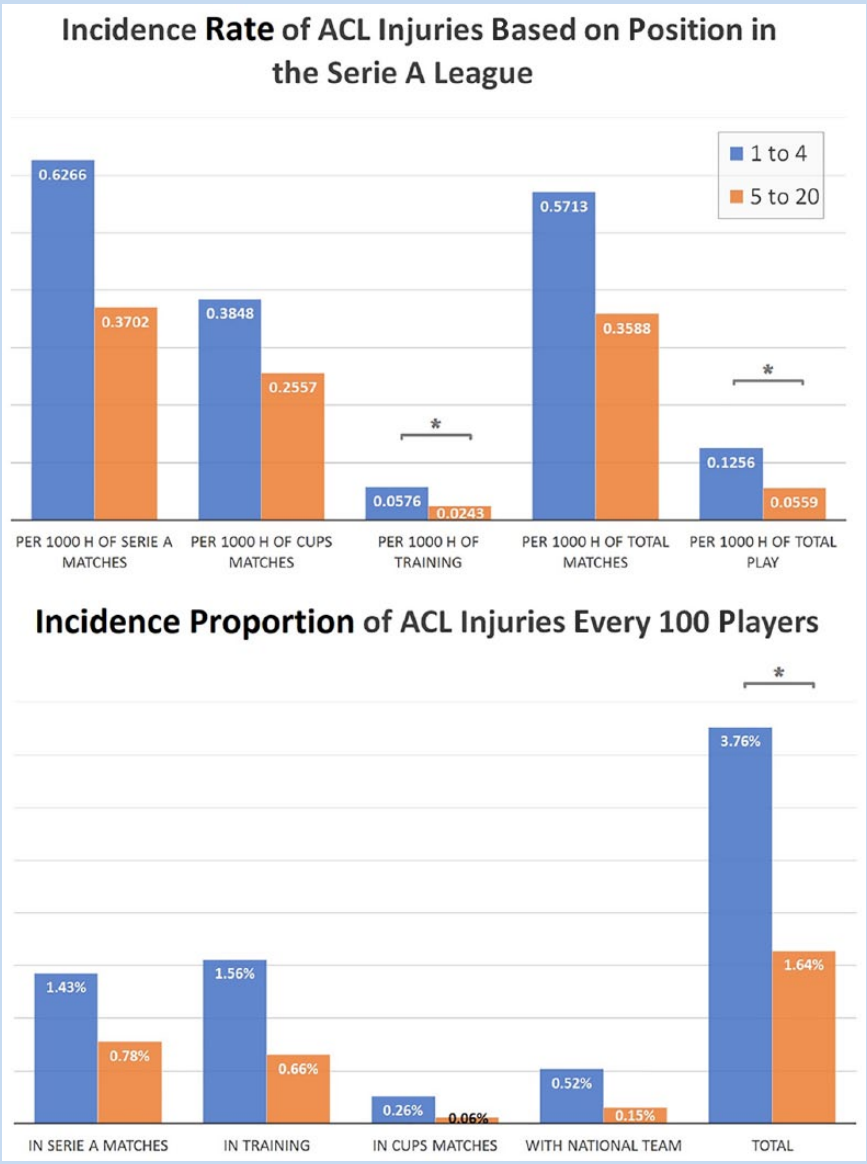

Figure 4. Comparison of incidence rates (top) and incidence proportions (bottom) of anterior cruciate ligament (ACL) injuries between teams ranked in 1st through 4th position (blue) and teams ranked in 5th through 20th position (orange). Asterisk (*) indicates statistically significant difference.

distribution so that preventive and protective measures can be taken.

Team Rank Comparison

Almost double the incidence rate and incidence proportion of ACL injuries was found in teams that secured the first 4 positions in the final Serie A ranking compared with teams in the 5th through 20th positions. In particular, higher ranked teams had 1 injury every season, compared with an average injury every 2 seasons in lower ranked teams. This could be due to the greater number of matches played and the possibly greater number of players involved in national representations. However, since the incidence rate per 1000 hours of total play is also higher, it is possible that the quality of play and training has a role in the overall ACL injury risk. In fact, a higher risk of overall injuries has been reported when 2 matches per week are played,[5,9] which is a common occurrence among high-ranked teams involved in multiple competitions. Moreover, teams that compete for higher positions resort to pressing tactics and high-speed style of play, which have been demonstrated to have an important correlation with ACL injury mechanisms.[3,8,15,18,37] Finally, the fact that greater match intensity has been reported in teams with players' unavailability,[39] it is possible that an ACL injury could begin a vicious circle of player overload and further injuries.

Methodological Considerations and Limitations

The main limitation of this study is related to the inherent study design, which does not utilize direct injury reporting from medical personnel. This could represent a relevant bias, especially for the calculation of injury risk during training, since the exposure time was calculated as an estimation based on a single team; moreover, the comparison based on final rank could be biased as well, since top-ranked teams could have greater media exposure, thus resulting in more reported injuries. However, direct reporting has been also reported to have inherent biases; in fact, a relevant underestimation was noted between head collisions reported by team physicians and the events registered with video analysis of all the matches of the 2014 World Cup.[7] The design utilized in the present study has been validated and considered reliable to assess injuries in soccer players[21,27,31] and should be considered free from detection bias, since the treating physicians were not involved in the collection of data and analysis of the results. Moreover, the use of publicly available data allowed us to retrieve the exact date of trauma, the context of injury (Serie A, cups, training, or national representative games), and the presence of a second ACL injury. Finally, it should be noted that the data presented in this study are not official from the Italian Football Federation and require confirmation through official prospective programs of systematic injury surveillance.

CONCLUSION

According to the epidemiological evaluation of ACL injuries in 7 consecutive seasons of the Italian First Division (Serie A) obtained from publicly available databases, an overall ACL injury rate of 0.062 per 1000 hours of football play was reported, with a 14-fold risk in matches compared with training. Relatedly, 25% of injuries occurred in players with a previous ACL reconstruction, and 10% occurred when the players were involved in national games. Two definite peaks of greater incidence were reported in October and March, and an almost 2-fold increase in incidence rate and incidence proportion were noted in those teams ranked in the top 4 positions of the championship. All these epidemiological data could be used by athletes, coaches, and soccer personnel to implement prevention strategies to reduce ACL injuries.

CLINICAL RECOMMENDATIONS

Knowing the precise epidemiology of ACL injury in one of the most competitive professional soccer championship leagues could help delineate fields of research aimed to investigate its risk factors. Epidemiological information could also be used by athletes, coaches, and soccer team personnel to reduce ACL injuries, for instance, implementing prevention programs to reduce training injuries, identification of risk factors for secondary injuries, paying particular attention to training and player management during the months of March and October, and greater use of player turnover in teams competing for the first position of the league.

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