doi: 10.4085/1062-6050-0507.24

Title: Return on investment of anterior cruciate ligament injury prevention programs in the United States

Authors: Collin Peterson, PhD, MAT, ATC; Tao Li, MD, PhD *; Marc Norcross, PhD, ATC

Corresponding Author:
Tao Li, M.D., Ph.D.
Associate Professor
Health Policy
College of Health
Oregon State University
Email: Tao.Li2@oregonstate.edu
Address: 458 Waldo Hall
2250 SW Jefferson Way
Corvallis, Oregon 97331-8660

Co-Author:
Collin Peterson, PhD, MAT, ATC
Health Policy, College of Health, Oregon State University, Corvallis, OR
petersc9@oregonstate.edu

Marc Norcross, PhD, ATC
Kinesiology & Athletic Training, College of Health, Oregon State University, Corvallis, OR
marc.norcross@oregonstate.edu

Acknowledgement: This work was supported by the National Athletic Trainers' Association Research and Education Foundation Doctoral Grant #2122DGP01 (student awardee: Collin Peterson; faculty mentor: Tao Li). The conclusions and opinions expressed in this article are the authors' alone.

Title: Return on investment of anterior cruciate ligament injury prevention programs in the United States

Abstract

Context

Anterior cruciate ligament (ACL) tears represent a significant health and economic burden in high school athletes. Despite evidence showing lower extremity injury prevention programs (IPPs) are effective at preventing ACL injury, IPPs lack widespread adoption.

Objective

Compare the cost-benefit of implementation of an injury prevention program versus standard warm-up in a national high school soccer population using a health system perspective.

Design

Cost Benefit Analysis.

Setting

Simulation of nationwide implementation of an IPP for United States high school soccer players.

Patients or Other Participants

Data for high school soccer players from the 2018-2019 season.

Main Outcome Measure

Return on investment was calculated using the cost of ACL treatment prevented with IPP use and the cost of IPP implementation.

Results

IPP implementation was the preferred strategy with a return on investment of $7.51 saved in ACL treatment costs prevented for every dollar spent on IPP implementation in our full model. When separating analysis by insurance type, private payors continued to show profitability while public payors failed to break even. The total net monetary benefit was over $60 million when simulating national-level IPP implementation.

Conclusions

IPP implementation has the potential to generate significant medical cost savings in short-term ACL treatment costs, especially for private payors, when implemented in a national high school soccer population. The expected cost-benefit of IPPs should encourage broader implementation efforts and the inclusion of economically relevant stakeholders.

Key Words

Economic evaluation; cost benefit analysis; return on investment; anterior cruciate ligament injury; injury prevention program

Key Points

- Nationwide IPP implementation had a profitable return on investment in our full model and model that accounted for only private payors.
- The net monetary benefit of nationwide IPP implementation was over $60 million.

Introduction

Anterior cruciate ligament (ACL) tears are a major health burden as incident rates continue to increase with high school-age athletes being at increased risk[1]. ACL tears result in costly surgical reconstruction and rehabilitation treatment[2] and estimates of ACL tear lifetime burden in the United States range from $7.6 billion to $17.7 billion[3].

Evidence suggests lower extremity injury prevention programs (IPPs) could help mitigate the burden of ACL injuries[4]. IPPs are multicomponent training programs often used in place of a warm-up that utilize a combination of strength, plyometrics, agility, and flexibility exercises along with feedback on movement technique to decrease the risk of injury[5]. Studies have found that IPPs reduce risk of ACL tears in athletes by 51-85%[6-9]. Despite overwhelming evidence that IPPs can significantly reduce ACL tears in adolescent athletes, widespread adoption of IPPs has not occurred[10]. Coaches play a key role in IPP implementation and efforts have focused on addressing their perception of IPPs [10]. Coaches have cited a lack of organizational and administrative support and education as barriers to implementing IPPs and recommended policy changes to incorporate IPP instruction into coaching education and licensure[11]. Despite these recommendations, little research exists predicated towards organizational and policy stakeholders who could make these changes. There have been recent efforts to unify different stakeholders in supporting systems-level change in IPP implementation[1], but the alignment of financial incentives to support implementation efforts still remain unclear.

Economic evaluations quantify the costs and consequences of specific interventions to provide payors, policymakers, and providers the necessary information to adopt implementation strategies[12]. Economic evaluation analyses of IPPs have been conducted in other countries[13] and found nationwide IPP campaigns can have positive economic impacts[14]. Given the significant differences in healthcare systems between the United States and other countries, economic evaluation specific to a United States context is necessary to understand the cost-benefit of IPPs. According to our search only a single cost-effectiveness analysis for an ACL IPP has been conducted in the United States[4]. **The aim of this study is to compare the cost-benefit of implementation of an IPP versus standard warm-up at a national level using a health system perspective in a high school soccer population.** We hypothesize that national-level implementation of IPPs will be the favored strategy. We expect this current study can inform resource allocation and incentive structure for policymakers and stakeholders to advance IPP implementation.

Methods

Study Design

The study design is a cost-benefit analysis of national level implementation of a lower extremity IPP versus standard warm-up on ACL treatment costs. Because implementation is being simulated at a national-level and there are many external factors that cannot be accounted for, a conservative approach was taken in both the selection of study perspective, parameters, model restrictions, and use of robust sensitivity analysis. Analysis was restricted to ACL-related treatment costs from a health system perspective over a time horizon of a single high school soccer season. To better inform what stakeholders may be involved in implementation based on the alignment of financial incentives, analysis was restricted to public and private payors in addition to performing full model analysis including both payor types. The figure in the appendix depicts the decision tree model used to evaluate IPP implementation versus standard warm-up. Because we are evaluating the prevention of costs related to adverse health events, effectiveness measures were inverted when assessing cost-benefit in the model (lower treatment costs are preferred).

Study Population and Model Design

Our reference case uses United States high school soccer athletes from the 2018-2019 season. This population was selected for several reasons. The 2018-2019 season is the latest year where estimates of both national levels of high school soccer participation and estimates of national high school soccer ACL injuries could be identified to calculate season annual incident rates of ACL injury. Using a specific season also allows for analysis at an average per athlete level and perform microsimulation of a single season to simulate annual total cost-benefit. While IPPs are effective at reducing lower extremity injuries in a variety of different cutting sports, the most robust evidence exists for soccer athletes. Male and female athletes were included because IPPs have been effective in both populations [6] and the values used for our IPP effectiveness measures were taken from studies of both male and female athletes.

Model Parameters

Probabilities

Table 1 lists the parameters and values used in our models and sensitivity analyses. To get the probability of an ACL injury occurring, season annual ACL injury incidence rates were calculated using literature values that estimated total national soccer ACL injuries from a national high school sports-related injury surveillance system for the 2018-2019 season[23]. The number of ACL injuries for the 2018-2019 season was compared to the 10-year average using a paired t-test and was less but not significantly different (P=0.8433). Soccer participation statistics for the 2018-2019 from the National Federation of State High School Associations (NFHS) were used to calculate the season annual incidence rate of ACL injury in high school soccer athletes. Sensitivity analysis values for ACL incidence rate were calculated using the years with the least and most amount of estimated total national ACL injuries in the last 10 years[23] and applied to the 2018-2019 soccer participation statistics[24].

[Insert Table 1 here]

Because not all ACL injuries result in surgery despite this often being the preferred treatment option in a young, active population[3], values from the literature for the proportion of ACL injuries that result in ACL surgery for high school soccer athletes were used for the probability of an ACL injury resulting in surgery. While some studies have found ACL injuries in adolescent soccer athletes are treated surgically upwards of 80% of the time[23,25,26], a conservative estimate of 75% was used as our base value.

Given our health system perspective and the wide range of reported ACL surgical costs[19], we stratified ACL treatment costs by payor type. 2019 census data for children (ages 6-18) was used to estimate the proportion of athletes that would be privately and publicly insured[27]. Because the uninsured made up such a small proportion of children (1.68%) and because insurance coverage typically is a requirement for high school sports participation, uninsured children were excluded. Public insurance and private insurance covered 36.91% and 62.09% of children respectively[27]. Insurance type likely impacts the probability of receiving ACL surgery. In order to get a more conservative estimate of ACL surgeries, the risk ratio of undergoing ACL surgery was calculated using values from the literature comparing rates of ACL reconstruction between privately insured and publicly insured individuals ages 6-17 over a two-year span. A risk ratio of 0.46 (54% reduction in the chance of getting surgery) was used to reduce the probability of receiving ACL reconstruction in individuals with public insurance[15]. For sensitivity analysis, risk ratio values of 0 and 1 were used to simulate changes in public insurance coverage where 0 would be no surgical treatment and 1 would be the same probability of ACL surgery as private insurance.

The values for the probability of an IPP preventing an ACL injury were taken from several systematic reviews on the efficacy of IPPs in similar populations to our study population. A conservative estimate of a 50% reduction in ACL injury incidence was used as the base model value despite systematic review estimates between 51-85%[6-9].

Costs

The main costs in our model are the cost of IPP implementation and the cost of ACL surgical and conservative treatment. IPP implementation costs per athlete were taken from previous economic evaluations of IPPs that accounted for teaching materials, cost of training coaches, and cost of teaching athletes[4,13,22]. For the base model value, Rössler et al., 2019's methods for calculating costs for country wide implementation in Switzerland were adapted for a United States high school soccer population (calculations included in the appendix). The base model value was $11.81 per player. For sensitivity analysis, an unadapted version of Rössler et al., 2019's[13] IPP costs per palyer and a value from Swart et al., 2014[4] that is almost three times our base value that was calculated only using trained athletic trainers for teaching the IPP were used.

Separate values for public and private insurance were used for the cost of ACL reconstruction. A base value of $4,342.38 was used for public insurance based on using 80% of the average cost for ACL reconstruction from the Centers for Medicare & Medicaid Services (CMS) payment rates for outpatient hospitals and ambulatory surgical centers[20]. While there is variation in Medicaid payment rates by state, studies have reported using an 80% Medicare payment rate to estimate Medicaid rates[3,21]. While the cost of ACL reconstruction has been reported as high as $52,000[19], a base value of $15,046 was used for private insurance based on the average cost of ACL reconstruction from a study of a private insurance claims dataset[2]. For sensitivity analysis, a low value equal to public insurance was used.

For the cost of ACL rehabilitation, data from the American Physical Therapy Association on Medicaid reimbursement was used to get the average cost of $88 for an hour session of therapeutic exercise treatment[18]. While an average of 25 visits for ACL rehabilitation has been reported[17], we used a conservative estimate of 20 visits for publicly insured patients to get a base value of $1,760. For private insurance, a base value of $2,549.96 was taken from the literature for 6 months of ACL rehabilitation post-

ACL reconstruction[16]. This is likely a conservative estimate as previous studies have reported rehabilitation costs over $5,000[2,3]. The costs of ACL rehabilitation were used for calculating conservative treatment costs for athletes that do not undergo ACL reconstruction after ACL injury and added to the costs for patients that underwent ACL reconstruction as rehabilitation is expected as part of surgical treatment. For the low value of sensitivity analysis for both public and private insurance, a value of $0 was used to simulate a patient not seeking out rehabilitation services.

All costs were adjusted to 2023 US dollars using the All Urban Consumer Price Index[28]. For IPP costs that were originally reported in Swiss Francs, a currency converter was used to report 2023 US dollars[29].

Analysis

Cost-benefit was assessed through the calculation of return on investment (ROI) with IPP use accounting for all medical treatment costs (surgical treatment and conservative treatment costs) prevented and a more conservative model that only accounted for medical costs from surgical treatment that were prevented. The following equations were used to calculate ROI:

$$Return\ on\ investment_{total\ medical\ costs} = \frac{medical\ costs\ prevented_{conservative\ treatment} +\ medical\ costs\ prevented_{surgical\ treatment}}{IPP\ implementation\ costs}$$

$$Return\ on\ investment_{surgical\ treatment\ costs} = \frac{medical\ costs\ prevented_{surgical\ treatment}}{IPP\ implementation\ costs}$$

ROIs were calculated accounting for all payors, public payors only, and private payors only. When calculating ROIs separately by payor type, ROIs only account for medical costs prevented for that payor type and simulate if IPP implementation costs were fully funded by the specified payor type. IPP implementation costs were not proportioned by payor type because this is not realistic to an implementation scenario where teams receiving IPP implementation likely have a mix of soccer athletes of both payor types that cannot be separated. One-way and two-way sensitivity analyses were used to assess model uncertainty using incremental cost effectiveness ratios (ICERs) for key parameters like the risk ratio of ACL injury with IPP use, risk ratio of surgery with public insurance, cost of IPP implementation, and cost of ACL surgery for private payors. An ICER is equal to the change in cost with IPP implementation divided by the change in medical costs saved from IPP implementation compared to standard warm-up use. Because medical costs saved is the effectiveness measure, the willingness to pay is $1 and an ICER of 1 represents a breakeven point where medical costs saved and IPP implementation costs are equal.

In addition to ROI, need to treat values for preventing a single ACL injury for each payor type and all payors were calculated using the following equation adjusted for the payor type proportions:

$$need\ to\ treat_{ACL\ injury} = \frac{1}{incidence\ rate_{standard\ warm-up} - incidence\ rate_{IPP\ use}}$$

The upper and lower values for IPP risk ratios used in the sensitivity analysis were used to get confidence intervals. Per athlete costs were used to get the cost of preventing a single ACL injury. Calculations and decision tree analysis were conducted using TreeAge Pro Healthcare Version 2024 (TreeAge Software, Williamstown, Massachusetts).

Results

IPP implementation had a ROI of $7.51 in medical costs prevented per dollar spent on IPP implementation in our all-payor model of all medical treatment costs (surgical and conservative treatment). For surgical treatment only in the all-payor model, $6.90 in medical costs were saved per dollar spent on IPP implementation. When running analysis for only private payors funding IPP implementation, both the overall model and conservative surgical treatment only model had profitable ROIs for private payors (see table 2 for results). However, when analyzing IPP implementation funded by public payors only, both the full model and conservative treatment model were below a breakeven point of a dollar saved in public payor medical costs for every public payor dollar spent on IPP implementation.

[Insert Table 2 here]

Our microsimulation of national IPP implementation for the 2018-2019 soccer season involved 853,182 players randomly completing our model. Total IPP implementation costs were $10,076,079.42 for national-level implementation. Medical costs prevented were $9,383,381.42 for public payors and $67,212,334.02 for private payors. The total net monetary benefit was $66,519,636.02. For medical costs related to only ACL injuries that received surgical treatment, the net monetary benefit was $60,240,609.64.

Because national implementation strategies are not likely to result in 100% successful adoption of IPPs, assessing uncertainty surrounding the reduction in relative risk with IPP use is critical. Figure 1 depicts the ICER for different risk ratio values with IPP use where the ICER is equal to the change in cost with IPP implementation divided by the change in medical costs saved from IPP implementation compared to standard warm-up use. An ICER of 1 represents a breakeven point where medical costs saved and IPP implementation costs are equal. A risk ratio of 0.93 or a 7% reduction in risk of ACL injury with IPP implementation is needed to breakeven. This is within even the highest confidence intervals calculated in systematic reviews of IPP effectiveness[6-9,30].

[Insert Figure 1 here]

The two-way sensitivity analysis in figure 2 was used to evaluate risk ratios with IPP use and IPP implementation costs simultaneously. IPP implementation was the dominant strategy for all risk ratios below 0.80 (20% reduction in risk) even when IPP costs were set to an upper bound of almost 3 times our base value.

[Insert Figure 2 here]

IPP implementation remained the dominant strategy at all values across both one-way and two-way sensitivity analyses of ACL reconstruction and rehabilitation costs when set equal to public payors in both the full model and assessing private payors only.

The risk ratio for public payors receiving surgical treatment was evaluated using one-way sensitivity analysis to assess how increased access to surgical treatment may impact IPP effectiveness if funded by public payors only. A risk ratio of 0.55 (45% less chance of surgical treatment compared to private payors) was needed for public insurers alone to break even and is 0.09 greater than our base risk ratio value of 0.46.

Table 3 contains the results of calculating need to treat statistics for our own model as well as comparison values from the literature. Successful implementation of an IPP would be needed for 111 athletes to prevent a single ACL injury. The need to treat value from our model was similar to need to treat values that were adapted from existing literature that ranged from 70-133 treated athletes to prevent an ACL injury[6,31,32]. Using a value of $11.81 as the cost of IPP implementation per athlete, it would cost $1,312.22 to prevent an ACL injury when including all-payors. When assessing private payor type alone, the cost of treating enough athletes to prevent an ACL injury in a privately insured athlete was lower than the price of surgical and conservative treatment for private payors. For public payors, the cost of treating enough athletes to prevent an ACL injury in a publicly insured athlete was above conservative treatment costs but below surgical treatment costs.

[Insert Table 3 here]

Discussion

Our study compared the cost-benefit of national-level IPP implementation versus standard warm-up in preventing ACL injury-related medical costs from a health system perspective in high school soccer athletes. IPP implementation was consistently the preferred strategy in both full and more conservative surgical treatment only models as well as across several sensitivity analyses. However, when separated by payor type, IPP implementation was not profitable if only funded by public payors alone while it was profitable if only funded by private payors. The lower reimbursement rates of Medicaid, the smaller proportion of athletes with public insurance, and the reduced rate of surgical treatment for publicly insured athletes all contribute to a lower ROI for public payors. Sensitivity analysis of the risk ratio of publicly insured athletes receiving surgical treatment showed that an increase from a base value of 0.46 to 0.55 was enough for public payors to break even. Even with this increase in our risk ratio adjustment, publicly insured athletes are only receiving ACL surgery 41% of the time when suffering an ACL injury in our model. A limitation of this study is the lack of specific data on insurance type for high school soccer athletes and ACL reconstruction rates for high school soccer athletes by insurance type. The lack of accurate measures for this population may limit some interpretation by payor type especially for public payor results. For both the proportion of athletes by insurance type and the risk ratio of receiving surgical treatment based on insurance type were only available for the general population ages 6-17. Athletes are more likely to receive ACL reconstruction[33], so the risk ratio measures of receiving surgical treatment may underestimate surgery rates in high school soccer athletes with public insurance. The consistent success of the all-payor models highlights opportunities for public-private partnership that could benefit both parties as well as decrease the burden of ACL injury in high school soccer athletes.

Significant opportunity exists for healthcare cost savings and improved patient health using IPPs even when using conservative estimates. In a microsimulation of the 2018-2019 high school soccer season, we found net monetary benefits of over $60 million dollars with national-level IPP implementation. The focus on a narrow set of short-term costs, limited study population, and use of conservative estimates for a single type of injury all contribute to what is likely an underestimate of potential medical cost savings. IPPs have proven to be effective in other cutting sports besides soccer[6]. IPPs have also been effective in younger populations and varying skill levels[30]. Expanding IPP implementation to other sports participants can result in additional medical cost savings and may also result in reduced marginal implementation costs as coaches across different sports from the same school could be trained simultaneously.

Our study likely underestimates the potential medical cost savings of using IPPs. The long-term burden of ACL injury and other lower extremity injuries prevented by IPPs were not accounted for. Future medical spending related to osteoarthritis[3] and increased risk of additional ACL injury[34] were also not included in our models. IPPs have been effective in preventing other lower extremity injuries[11] and often are most effective at preventing the most severe injuries[22]. Adjusting for not all athletes receiving surgical treatment as well as using conservative base values for ACL injury incidence rate and reduced risk with IPP use also contribute to a more conservative approach compared to other US-based IPP models[4]. While our models do not account for high school soccer athletes that already use an IPP and therefore may overestimate the potential benefits of IPP implementation, this is not likely to have a significant impact on results. Coaches have reported IPP use rates as low as 4.4%[35] that would result in little change to estimates of medical cost savings.

Sensitivity analysis highlights that IPPs can generate cost savings even when IPP implementation efforts are not fully successful. IPP compliance is a noted concern with IPP implementation and previous literature has highlighted barriers to implementation that exist at the implementor level[10]. In sensitivity analysis of the risk ratio of ACL injury with IPP use, only a 7% decrease in risk of ACL injury was needed for IPP implementation to break even. While there are limitations to accurately predicting implementation costs at a national level, two-way sensitivity analysis of IPP costs and risk ratios found that IPP implementation was still profitable with only a 20% decrease in risk of ACL injury and implementation costs almost 3 times as high as our base value. Given the relatively low risk ratio needed to break even and the much higher risk ratios reported in multiple systematic reviews[6,7,9], there is good reason to believe scaling up IPP implementation can still be successful in generating medical cost savings without perfect compliance.

Need to treat values show that medical cost savings can also be achieved at smaller scales. Using our model values, 111 athletes need to be treated to prevent an ACL injury. When accounting for the cost of IPP implementation, these values are below the cost of ACL surgical and conservative treatment for public and private payors. If the average soccer team has 20 players per team and both a men’s and women’s soccer team at a high school, medical cost savings could be achieved treating 6 teams or 3 high schools. If a more conservative 20% reduction in ACL injury risk was used, about

14 teams or 7 schools would need to perform IPPs to prevent an ACL injury at a cost of $3,280.56. Given the patchwork of state and national sports and high school organizations, implementation efforts at the school district, county, and regional levels are likely more feasible while still capable of success based on our results. Smaller scale efforts may also be better suited for fostering co-creation and self-ownership of IPPs with coaches that can improve implementation[36]. Future studies should account for additional costs related to ACL and other injuries in the context of real-world application.

We expect this study would inform IPP implementation efforts at organizational and policy levels that have previously been overlooked. The significant amount of medical cost savings available with IPP implementation in our conservative and constrained models illustrate an opportunity that demands real-world attempts at implementation. The inaugural meeting of the National ACL Injury Coalition recognized that a strategic priority in addressing the complexity of IPP implementation is uniting the variety of stakeholders involved (e.g. schools, sports clubs, parents, and coaches)[1]. Accounting for both public and private payors in our overall model and in separate models makes it apparent that third party payors especially have financial incentive to be involved and should be included as a stakeholder. Private insurance companies may be a viable route for accessing funding to expand implementation efforts. Recent actions by the National ACL Injury Coalition in developing goals for widespread IPP adoption[1] and the United States Soccer Federation dedicating a webpage to ACL injury prevention[37] are signs of progress. Efforts should continue to put in place policies that make IPP education a part of coaching licensure and to engage other relevant national stakeholders like the National Federation of State High School Associations and

National Athletic Trainers' Association that can play a role in increasing implementation within their constituencies. Ultimately, efforts and application of knowledge from different stakeholders at various social-ecological levels are needed if widespread IPP adoption is going to be achieved.

Conclusion

There is significant opportunity for medical cost savings when implementing IPPs at a national level in a high school soccer population with private payors having the most to gain. Implementation on a smaller scale is also likely to have a positive expected value when accounting for ACL treatment costs prevented and the cost of IPP implementation. Efforts should focus on increasing IPP adoption through more localized efforts as well as engaging organizational and policy stakeholders at higher levels.

References

1. Robbins L, Farrey T, Janosky J, Minjares V, Mandelbaum BR, Pearle A. Preventing Anterior Cruciate Ligament (ACL) Injuries in High School Sports Participants: An Executive Summary of the Inaugural Meeting of the National ACL Injury Coalition. *HSS Journal®*. 2023;0(0):15563316231211320. doi:10.1177/15563316231211320

2. Herzog MM, Marshall SW, Lund JL, Pate V, Spang JT. Cost of Outpatient Arthroscopic Anterior Cruciate Ligament Reconstruction Among Commercially Insured Patients in the United States, 2005-2013. *Orthop J Sports Med*. Jan 2017;5(1):2325967116684776. doi:10.1177/2325967116684776

3. Mather RC, 3rd, Koenig L, Kocher MS, et al. Societal and economic impact of anterior cruciate ligament tears. *J Bone Joint Surg*. Oct 2 2013;95(19):1751-9. doi:10.2106/jbjs.L.01705

4. Swart E, Redler L, Fabricant PD, Mandelbaum BR, Ahmad CS, Wang YC. Prevention and screening programs for anterior cruciate ligament injuries in young athletes: a cost-effectiveness analysis. *J Bone Joint Surg*. May 7 2014;96(9):705-11. doi:10.2106/JBJS.M.00560

5. Padua DA, DiStefano LJ, Hewett TE, et al. National Athletic Trainers' Association Position Statement: Prevention of Anterior Cruciate Ligament Injury. *J Athl Train*. Jan 2018;53(1):5-19. doi:10.4085/1062-6050-99-16

6. Sadoghi P, von Keudell A, Vavken P. Effectiveness of Anterior Cruciate Ligament Injury Prevention Training Programs. *J Bone Joint Surg*. 2012;94(9):769-776. doi:10.2106/jbjs.K.00467

7. Donnell-Fink LA, Klara K, Collins JE, et al. Effectiveness of Knee Injury and Anterior Cruciate Ligament Tear Prevention Programs: A Meta-Analysis. *PLoS One*. 2015;10(12):e0144063. doi:10.1371/journal.pone.0144063

8. Gagnier JJ, Morgenstern H, Chess L. Interventions Designed to Prevent Anterior Cruciate Ligament Injuries in Adolescents and Adults:A Systematic Review and Meta-analysis. *Am J Sports Med*. 2013;41(8):1952-1962. doi:10.1177/0363546512458227

9. Huang YL, Jung J, Mulligan CMS, Oh J, Norcross MF. A Majority of Anterior Cruciate Ligament Injuries Can Be Prevented by Injury Prevention Programs: A Systematic Review of Randomized Controlled Trials and Cluster-Randomized Controlled Trials With Meta-analysis. *Am J Sports Med*. May 2020;48(6):1505-1515. doi:10.1177/0363546519870175

10. Norcross MF, Johnson ST, Bovbjerg VE, Koester MC, Hoffman MA. Factors influencing high school coaches' adoption of injury prevention programs. *J Sci Med Sport*. 2016/04/01/ 2016;19(4):299-304. doi:https://doi.org/10.1016/j.jsams.2015.03.009

11. Mawson R, Creech MJ, Peterson DC, Farrokhyar F, Ayeni OR. Lower limb injury prevention programs in youth soccer: a survey of coach knowledge, usage, and barriers. *Journal of Experimental Orthopaedics*. 2018/10/11 2018;5(1):43. doi:10.1186/s40634-018-0160-6

12. Eisman AB, Kilbourne AM, Dopp AR, Saldana L, Eisenberg D. Economic evaluation in implementation science: Making the business case for implementation strategies. *Psychiatry Res*. 2020/01/01/ 2020;283:112433. doi:https://doi.org/10.1016/j.psychres.2019.06.008

13. Rössler R, Verhagen E, Rommers N, et al. Comparison of the '11+ Kids' injury prevention programme and a regular warmup in children's football (soccer): a cost

effectiveness analysis. *Br J Sports Med*. 2019;53(5):309-314. doi:10.1136/bjsports-2018-099395

14. Junge A, Lamprecht M, Stamm H, et al. Countrywide campaign to prevent soccer injuries in Swiss amateur players. *Am J Sports Med*. Jan 2011;39(1):57-63. doi:10.1177/0363546510377424

15. Solarczyk JK, Roberts HJ, Wong SE, Ward DT. Healthcare Disparities in Orthopaedic Surgery: A Comparison of Anterior Cruciate Ligament Reconstruction Incidence Proportions With US Census-Derived Demographics. *J Am Acad Orthop Surg Glob Res Rev*. Jul 1 2023;7(7)doi:10.5435/JAAOSGlobal-D-22-00271

16. Zhang JY, Cohen JR, Yeranosian MG, et al. Rehabilitation Charges Associated With Anterior Cruciate Ligament Reconstruction. *Sports Health*. Nov-Dec 2015;7(6):538-41. doi:10.1177/1941738115606878

17. Chava NS, Fortier LM, Verma N, et al. Patients With Medicaid Insurance Undergoing Anterior Cruciate Ligament Reconstruction have Lower Postoperative International Knee Documentation Committee Scores and are Less Likely to Return to Sport Than Privately Insured Patients. *Arthrosc Sports Med Rehabil*. Aug 2022;4(4):e1457-e1464. doi:10.1016/j.asmr.2022.05.005

18. American Physical Therapy Association. APTA State Medicaid Payment Rate Guide. https://www.apta.org/your-practice/payment/medicaid/state-medicaid-payment-rate-guide

19. Lee J, Guzek RH, Shah NS, Lawrence JTR, Ganley TJ, Shah AS. How Much Will My Child's ACL Reconstruction Cost? Availability and Variability of Price Estimates for Anterior Cruciate Ligament Reconstruction in the United States. *J Pediatr Orthop*. Nov-Dec 01 2022;42(10):614-620. doi:10.1097/BPO.0000000000002254

20. Centers for Mediciare & Medicaid Services. *2023 Procedure Price Lookup Comparison File*. 2023. https://www.cms.gov/medicare/medicare-fee-service-payment/hospitaloutpatientpps/annual-policy-files/2023

21. Casper DS, Schroeder GD, Zmistowski B, et al. Medicaid Reimbursement for Common Orthopedic Procedures Is Not Consistent. *Orthopedics (Online)*. Mar 2019 2023-12-01 2019;42(2):193-196. doi:10.3928/01477447-20181227-06

22. Krist MR, van Beijsterveldt AMC, Backx FJG, Ardine de Wit G. Preventive exercises reduced injury-related costs among adult male amateur soccer players: a cluster-randomised trial. *J Physiother*. 2013/03/01/ 2013;59(1):15-23. doi:https://doi.org/10.1016/S1836-9553(13)70142-5

23. Ngatuvai MS, Yang J, Kistamgari S, Collins CL, Smith GA. Epidemiological Comparison of ACL Injuries on Different Playing Surfaces in High School Football and Soccer. *Orthop J Sports Med*. May 2022;10(5):23259671221092321. doi:10.1177/23259671221092321

24. National Federation of State High School Associations. *High School Participation Survey Archive*. 2023. https://www.nfhs.org/

25. Joseph AM, Collins CL, Henke NM, Yard EE, Fields SK, Comstock RD. A multisport epidemiologic comparison of anterior cruciate ligament injuries in high school athletics. *J Athl Train*. Nov-Dec 2013;48(6):810-7. doi:10.4085/1062-6050-48.6.03

26. Gupta A, Pierpoint L, Comstock D, Saper M. Sex differences in anterior cruciate ligament injuries among US high school soccer players: an epidemiologic study. *Orthop*

J Sports Med. 2019/03/01 2019;7(3_suppl):2325967119S00157. doi:10.1177/2325967119S00157

27. US Census Bureau. Data from: ACS 5-Year Estimates Detailed Tables. 2019.

28. Bureau of Labor Statistics. Consumer Price Index. Bureau of Labor Statistics, U.S. Department of Labor. https://www.bls.gov/cpi/

29. Exchangerates.org.uk. Swiss Franc to US Dollar Spot Exchange Rates for 2015. https://www.exchangerates.org.uk/CHF-USD-spot-exchange-rates-history-2015.html

30. Al Attar WSA, Bakhsh JM, Khaledi EH, Ghulam H, Sanders RH. Injury prevention programs that include plyometric exercises reduce the incidence of anterior cruciate ligament injury: a systematic review of cluster randomised trials. *J Physiother*. Oct 2022;68(4):255-261. doi:10.1016/j.jphys.2022.09.001

31. Sugimoto D, Myer GD, Bush HM, Klugman MF, Medina McKeon JM, Hewett TE. Compliance with neuromuscular training and anterior cruciate ligament injury risk reduction in female athletes: a meta-analysis. *J Athl Train*. Nov-Dec 2012;47(6):714-23. doi:10.4085/1062-6050-47.6.10

32. Pfile KR, Curioz B. Coach-led prevention programs are effective in reducing anterior cruciate ligament injury risk in female athletes: A number-needed-to-treat analysis. *Scand J Med Sci Sports*. Dec 2017;27(12):1950-1958. doi:10.1111/sms.12828

33. Joshi A, Basukala B, Singh N, Panta S, Sharma R, Pradhan I. Variations in common operations in athletes and non-Athletes. *J Orthop*. Jul-Aug 2022;32:160-165. doi:10.1016/j.jor.2022.06.006

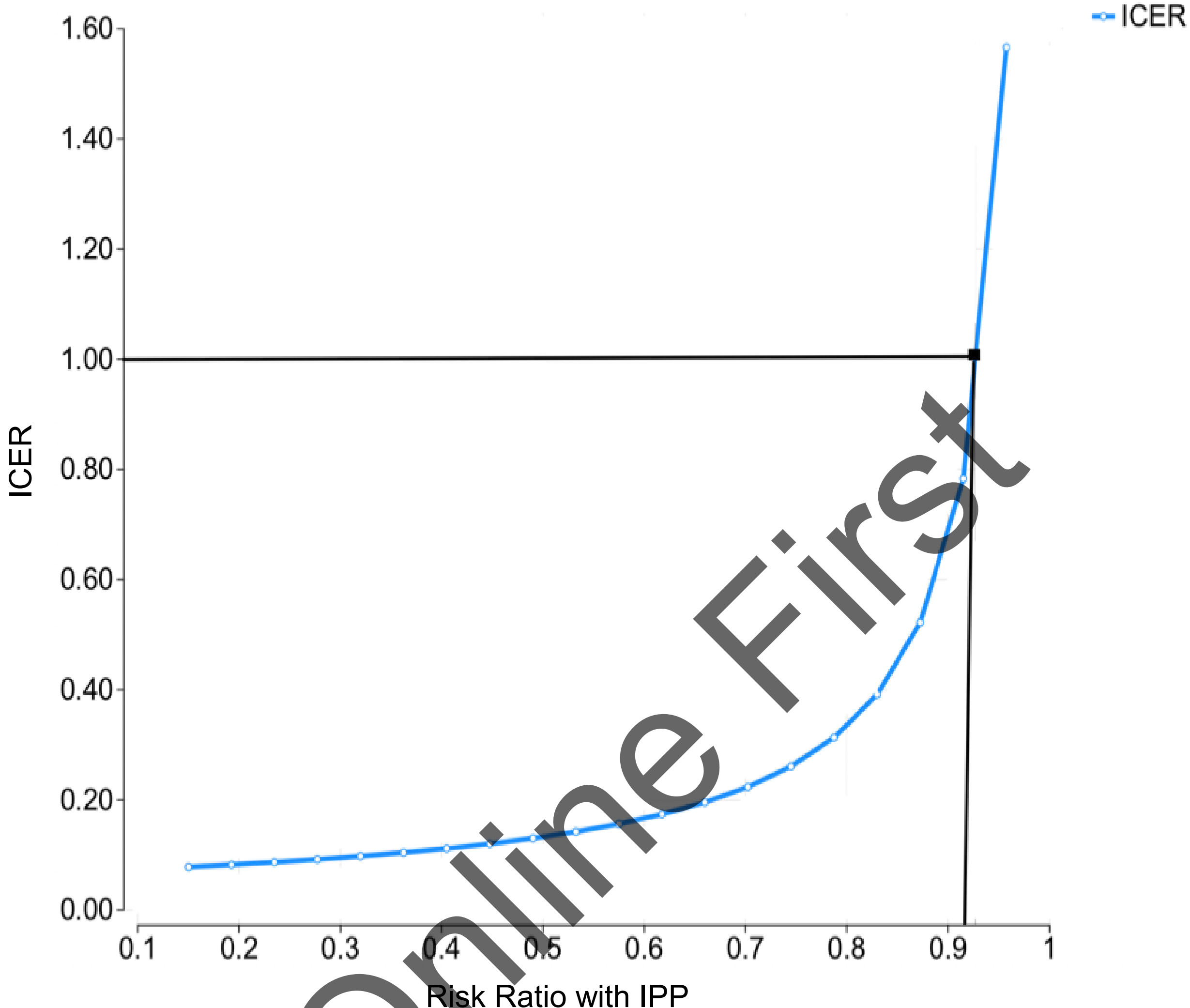
34. Hewett TE, Di Stasi SL, Myer GD. Current concepts for injury prevention in athletes after anterior cruciate ligament reconstruction. *Am J Sports Med*. Jan 2013;41(1):216-24. doi:10.1177/0363546512459638

35. Janosky JJ, Russomano J, Duscha C, et al. ACL Injury Prevention Education Improves Implementation of Neuromuscular Training Among High School Sports Coaches: A Cross-Sectional Survey Study. *HSS Journal*®. 2024;0(0):15563316241236194. doi:10.1177/15563316241236194

36. Benjaminse A, Verhagen E. Implementing ACL Injury Prevention in Daily Sports Practice—It's Not Just the Program: Let's Build Together, Involve the Context, and Improve the Content. *Sports Med*. 2021/12/01 2021;51(12):2461-2467. doi:10.1007/s40279-021-01560-4

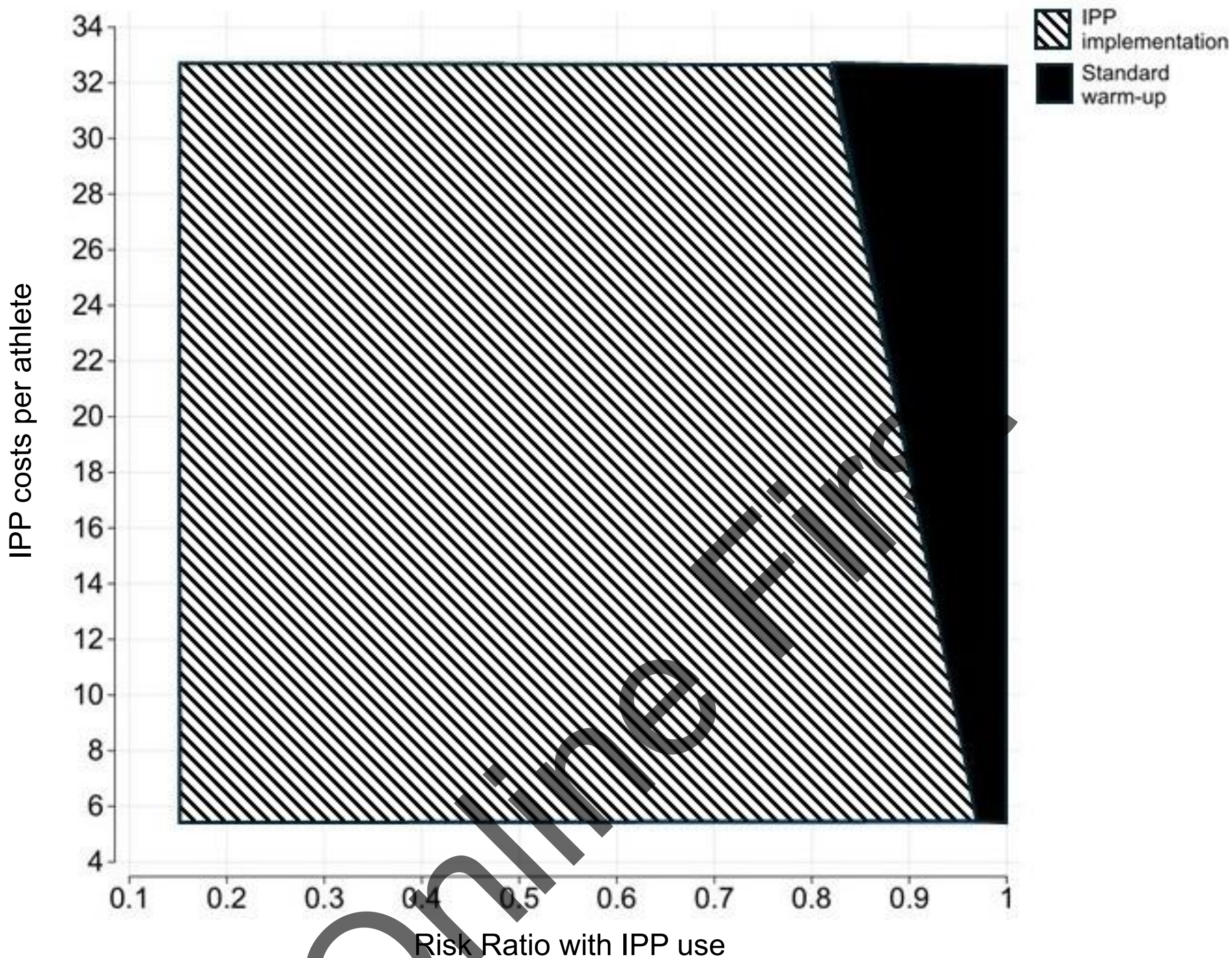
37. US Soccer Federation. Recognize to Recover: Injury Prevention. http://www.recognizetorecover.org/injury#sleep-strategy

Figure 1: One-way Sensitivity Analysis of Injury Prevention Program Risk Ratio Values



[a] IPP= injury prevention program; ICER= incremental cost effectiveness ratio.
[b] ICER below 1 is profitable.

Figure 2: Two-way Sensitivity Analysis of Injury Prevention Program Risk Ratio and Implementation Cost Values



[a] IPP= injury prevention program.
[b] Shaded regions signify the dominant strategy at intersection point of risk ratios with IPP use and IPP costs per athlete values

Table 1. Parameter Values and Sources for Economic Evaluation Models and Sensitivity Analysis

Parameter	Research model	Sensitivity analysis		Sources
	Base value	Low value	High value	
Probabilities, proportions, and risk ratios				
ACL injury incidence rate per annual season	0.018	0.013	0.020	Swart et al., 2014; Ngatuvai et al., 2022; Gupta et al., 2019;
Probability of ACL reconstruction	75%	75%	80%	Joseph et al. 2013; Ngatuvai et al., 2022; Gupta et al., 2019
Proportions of payor type	36.91% public insurance 62.09% private insurance	0% public insurance 0% private insurance	100% public insurance 100% private insurance	US Census Bureau, 2019
Risk ratio of IPP program	0.50	0.15	1	Donnell-Fink et al., 2015; Gagnier et al., 2013; Huang et al., 2020; Sadoghi et al., 2012; Al Attar et al., 2022
Risk ratio of public insurance receiving ACL reconstruction	0.46	0	1	Solarczyk et al., 2023
Costs[b]				
Cost of ACL reconstruction Private insurance: Public insurance:	 $15,046.57 $4,342.38	 $4,342.38 $3,393.04	 $34,846.53 $5,291.70	Herzog et al., 2017; Lee et al., 2022; Center for Medicaid & Medicare Services, 2023; Mather et al., 2013; Casper et al., 2019
Cost of ACL rehabilitation Private insurance: Public insurance:	 $2,432.96 $1,760.00	 $0 $0	 $5,298.47 $2,200.00	Herzog et al., 2017; Zhang et al., 2015; Mather et al., 2013; Chava et al., 2022;

				American Physical Therapy Association, 2023;
IPP Costs per player	$11.81	$5.42	$32.66	Rössler et al., 2019; Swart et al., 2014; Krist et al., 2013

[a] ACL= anterior cruciate ligament; IPP= injury prevention program.
[b] Costs reported in 2023 US dollars.

Table 2. Return on Investment for Injury Prevention Program Implementation and Total Net Monetary Benefit for 2018-2019 High School Soccer Microsimulation by Payor Type

		Public payor funded only	Private payor funded only	All payors
ACL surgical and conservative treatment costs[b]				
Per player Model	ROI calculation	(all medical costs prevented insured by public payors)/ cost of IPP implementation	(all medical costs prevented insured by private payors)/cost of IPP implementation	(all medical costs prevented)/cost of IPP implementation
	ROI value	$0.92	$6.60	$7.51
2018-2019 Microsimulation (853,182 high school soccer athletes)	Treatment costs prevented	$9,383,381.42	$67,212,334.02	$76,595,715.44
	Total IPP implementation costs	$10,076,079.42	$10,076,079.42	$10,076,079.42
	Net monetary benefit	-$692,698.00	$57,136,254.60	$66,519,636.02
ACL surgical treatment costs only[b]				
Per player model	ROI calculation	(value of ACL surgeries prevented insured by public payors)/total cost of IPP implementation	(value of ACL surgeries prevented insured by private payors)/total cost of IPP implementation	(value of ACL surgeries prevented)/total cost of IPP implementation
	ROI value	$0.59	$6.30	$6.90
2018-2019 Microsimulation (853,182 high school soccer athletes)	Treatment costs prevented	$5,852,182.42	$64,464,506.64	$70,316,689.06
	Total IPP implementation costs	$10,076,079.42	$10,076,079.42	$10,076,079.42
	Net monetary benefit	-$4,223,897.00	$54,388,427.22	$60,240,609.64

[a] ACL= anterior cruciate ligament; ROI= return on investment; IPP= Injury prevention program.
[b] Reported in 2023 US dollars.

Table 3: Need to Treat and Associated Costs From 2018-2019 National Model and Literature Values

	Number of athletes needed to treat to prevent an ACL injury	IPP implementation costs to prevent an ACL injury[b]
2018/2019 national model: all payor[c]	111 (65,278)	$1312.22 (771.90,3280.56)
2018/2019 national model: public insurance[c]	301 (177,753)	$3555.19 (2091.29,8887.99)
2018/2019 national model: private insurance[c]	176 (104,440)	$2079.92 (1223.48,5199.80)
Sadoghi et al., 2012	70 (38,187)	$826.70 (448.78,2208.47)
Sugimoto et al., 2012[d]	120 (74,316)	$1417.20 (873.94,3731.96)
Pfile & Curioz, 2017[d]	133 (96,217)	$1570.73 (1133.76,2562.77)

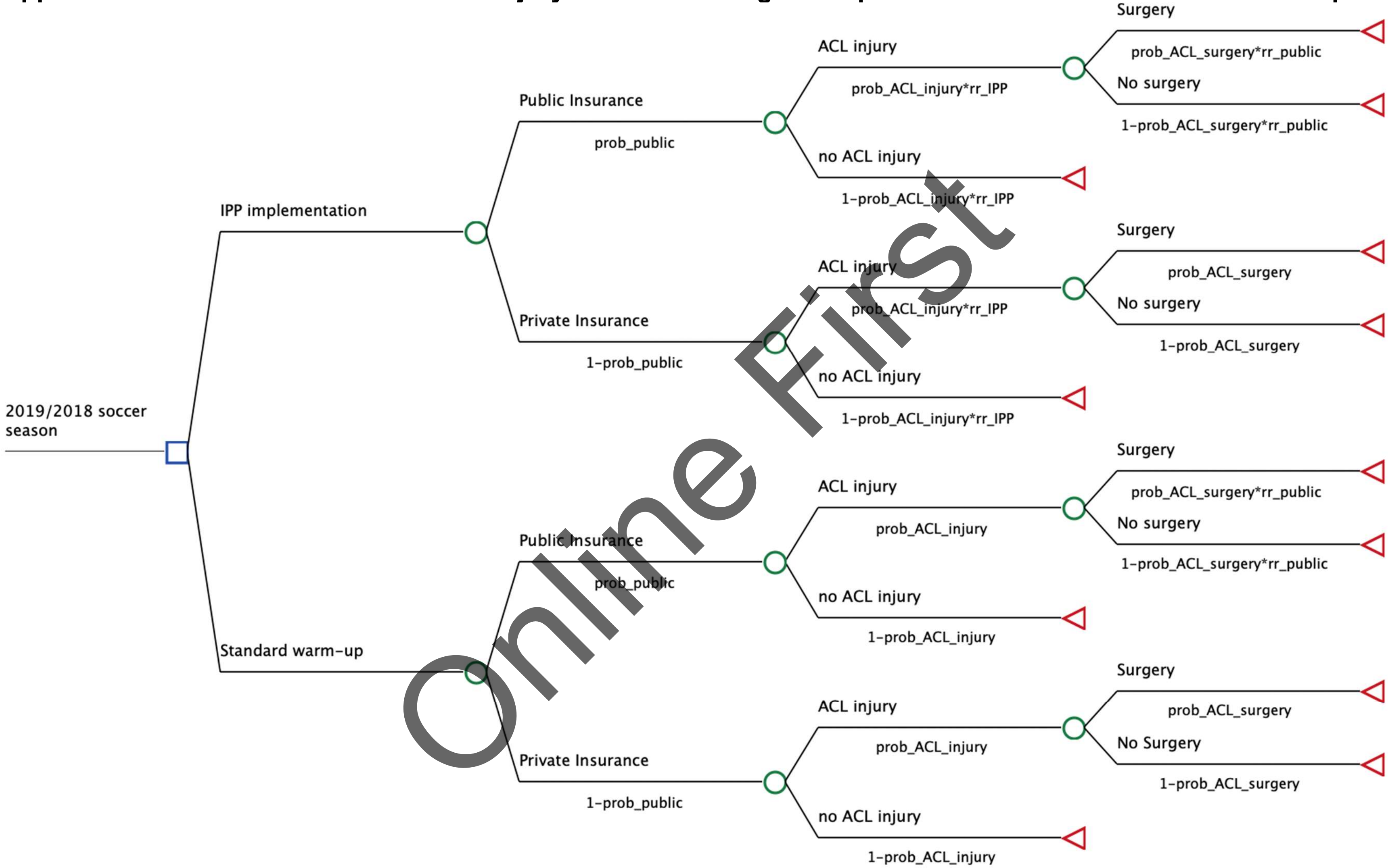
[a] ACL= anterior cruciate ligament; IPP= injury prevention program.

[b] Reported 2023 US dollars.

[c] Confidence intervals produced using sensitivity analysis values for IPP risk ratios, lower bound= 0.15, upper bound=0.80.

[d] Need to treat numbers come from studies that only include female participants.

Appendix: Decision Tree Used to Model Injury Prevention Program Implementation Versus Standard Warm-up



[a] IPP= injury prevention program; ACL= anterior cruciate ligament; prob_public= probability of having public insurance; prob_ACL_injury= incidence rate of ACL injury; rr_IPP= risk ratio for ACL injury with IPP use; prob_ACL_surgery= the probability of an ACL injury undergoing surgical treatment; rr_public= risk ratio for receiving ACL surgery for someone who

has public insurance; IPP_cost= cost of national IPP implementation per athlete; cost_ACL_surgery_private= cost of ACL reconstruction for private payors; cost_ACL_surgery_public= cost of ACL reconstruction for public payors; cost_rehab_private= cost of ACL rehabilitation for private payors; cost_rehab_public= cost of ACL rehabilitation for public payors; athlete_surgery= athlete who sustains an ACL injury and receives surgical treatment; athlete_no_surgery= athlete who sustains an ACL injury and receives conservative treatment; athlete_no_injury= athlete who does not sustain an ACL injury

[b] Because the effectiveness outcome is dollars spent on ACL treatment, effectiveness measures were inverted to reflect increased medical spending on ACL treatment as a negative outcome.

Adaptation of Rössler et al., 2019's Methods for Countrywide Injury Prevention Program Implementation in the United States for the 2018-2019 High School Soccer Season

Items	Per unit cost (unit)	Total cost per year	Total cost per player-year
Materials/delivery (2 for each coach)	$10.92 (school)	$269,276.28	$0.32
Website (development and maintenance per year)	$21,580 (3 websites for relevant stakeholders: NFHS, US soccer, NATA)	$64,740.00	$0.07
Opportunity costs (3.5 hours for instruction and travel X $15 minimum wage X 2 for each coach)	$105 (school)	$2,589,195.00	$3.03
Salary for course instructors ($30 salary x 3.5 hours x number of schools X 2 instructors)	$210 (school)	$5,178,390.00	$6.07
Food and drink for a course (4 people X $20 X number of schools)	$80 (school)	$1,972,720.00	$2.31
			$11.81

[a] Costs reported in 2023 US dollars

[b] 853,182 high school soccer player; 24,659 high schools with soccer teams (NFHS, 2023).