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ANALYSIS OF FITNESS PERFORMANCE AND THEIR ASSOCIATION WITH THE INCIDENCE AND PREVALENCE OF INJURIES IN YOUNG FOOTBALL PLAYERS; PROSPECTIVE ANALYSIS

DOCTORAL THESIS

Mentor:

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SVEUČILIŠTE U SPLITU

KINEZIOLOŠKI FAKULTET

JAKŠA ŠKOMRLJ

ANALIZA KONDICIJSKIH PERFORMANSI I NJIHOVA POVEZANOST S INCIDENCIJOM I PREVALENCIJOM OZLJEDA KOD MLADIH NOGOMETAŠA; PROSPEKTIVNA ANALIZA

DOKTORSKI RAD

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PODACI O MENTORU

doc.dr.sc. Šime Veršić: prodekan za nastavu i studente

Rođen 1988. godine u Splitu, gdje je završio osnovnu i srednju školu. Diplomirao 2011. godine na Kineziološkom fakultetu Sveučilišta u Splitu, sa završenim doktoratom na Kineziološkom fakultetu u Splitu 2020. godine.

Na mjesto asistenta zaposlen je 2019., a na mjesto docenta 2022. godine.

Nositelj je kolegija Teorija i metodika sportova na vodi 1, Prevencija i kineziterapija u kondicijskoj pripremi sportaša i Conditioning in team sport games na sveučilišnom te Prevencija i rehabilitacija ozljeda i Suvremeni kondicijski programi na stručnom studiju.

Primarni znanstveni fokus su testiranje i analiza kondicijskih performansi te incidencija ozljeda u sportu. Autor je više od 100 znanstvenih članaka indeksiranih u WoS bazi te dobitnik raznih domaćih i međunarodnih priznanja.

Kao pozvani predavač sudjelovao na desetak konferencija i simpozija.

Dosada je kao mentor ispratio preko 90 diplomskih i završnih radova i nadamo se jedan doktorski rad.

ZAHVALE

Svom bivšem treneru, mentoru, kolegi te nakon toliko vremena i prijatelju, doc.dr.sc. Šimi Veršiću, od sveg srca zahvaljujem na poticanju, ustrajnosti i prenesenom znanju tijekom cijelog akademskog školovanja, a posebice tokom doktorskog studija. Bez njegovog vođenja i pomoći, u formalnoj i najčešće neformalnoj komunikaciji, ništa od ostvarenog ne bi bilo moguće.

Profesoru Sekuliću, na neizmjernoj pomoći u svim aspektima ovog rada te na svim dobronamjernim savjetima koji su uvelike olakšali znanstveno djelovanje doktoranda.

Svim kolegama iz HNK Hajduk, djelatnom osoblju i mladim nogometašima – ispitanicima, veliko hvala na sudjelovanju u ovom istraživanju.

Svim profesorima i članovima bivšeg „projektnog ureda“ (prepoznat će se) – neizmjerno hvala na iznimnoj suradnji i prijateljskoj atmosferi koja je uvelike uljepšavala dugi period prikupljanja i obrade podataka.

Na kraju, zahvaljujem svojim najbližima – zaručnici Neri i mojoj obitelji na nesebičnoj podršci i ljubavi koju su pružali i pružaju, tijekom ovog značajnog životnog i akademskog postignuća.

LISTA AKRONIMA

U9 – „under 9“, nogometaši dobne skupine do 9 godina starosti

U11 – „under 11“, nogometaši dobne skupine do 11 godina starosti

U13 – „under 13“, nogometaši dobne skupine do 13 godina starosti

U15 – „under 15“, nogometaši dobne skupine do 15 godina starosti

AAPC – average annual percentage change

IRR – injury incidence rate

95 %CI – 95% confidence intervals

TOR – trauma/overuse ratio

PHV – „peak height velocity“, faza najburnijeg razvoja

DOMS – „delayed onset muscle soreness“, pojava odgođene mišićne bolnosti

OR – odds ratio

SADRŽAJ

SAŽETAK

Glavni cilj ovog rada bio je utvrditi incidenciju, strukturu i ozbiljnost ozljeda u različitim uzrasnim kategorijama elitne nogometne akademije. Područje ozljeda slabije je istraženo kod djece i adolescentnih nogometaša u usporedbi sa odraslim i profesionalnim nogometašima. Problem nedostatka literature očigledan je u kontekstu ozljeda mladih nogometaša iz jugoistočne Europe, a posebice u Hrvatskoj. Budući se radi o populaciji koja je od posebnog društvenog interesa – djeci koja su još u procesu formiranja, tim istraživača/autora smatra nužnim produbiti trenutna saznanja o ozljedama u navedenoj populaciji. Ovaj doktorski rad nastao je na temelju četiri objavljena znanstvena članka.

Cilj prve studije bio je istražiti obrasce ozljeđivanja elitnih mladih nogometaša i utjecaj COVID-19 pandemije na incidenciju ozljeda. Druga studija za cilj je imala utvrditi detalje o tipu, lokaciji, ozbiljnosti i mehanizmu nastanka ozljeda kod mladih nogometaša. Treća studija pokušala je odgovoriti na razlike između pojavnosti traumatskih i ozljeda prenaprezanja u akademskom nogometu kod najmlađih kategorija. Cilj posljednje, četvrte studije bio je proučiti razlike između pojavnosti mišićnih ozljeda kod triju najmlađih dobnih skupina nogometaša.

Uzorak ispitanika sačinjavali su igrači elitne nogometne akademije iz Hrvatske, koji su pripadali kategorijama U9, U11, U13 i U15. Podaci o ozljedama prikupljani su i dokumentirani u klupsku bazu podataka, a ispitanici i njihovi roditelji/skrbnici bili su upoznati sa svrhom istraživanja. Sve informacije o ozljedama su detaljno zabilježene, uključujući datum ozljede i povratka u puni trening, ozlijeđeni dio i stranu tijela, tip, dijagnozu, karakter, nastanak, eventualnu re-ozljedu te kontaktni mehanizam ozljede.

Glavni rezultati prve studije pokazali su da je u promatranom periodu došlo do značajne godišnje redukcije u ozljedama mladih igrača (AAPC = 13.9%, 95 %CI: -23.2 - 3.4). Ipak, pojavom koronavirusa uslijedila je promjena trenda i porast ozljeđivana, izazvana prekidom i ponovnim povratkom u trenažno i natjecateljsko opterećenje. Također, otkriveno je da postoje značajne dobne razlike u ozljeđivanju, gdje se starije uzrasne kategorije ozljeđuju puno češće (IRR; U15 = 7.02/1000h vs U9 = 1.51/1000h).

Rezultati studije 2 sugerirali su stabilan trend ozljeđivanja mišićnih struktura mladih nogometaša (IRR = 1.01, 95%CI: 0.99–1.03), gdje su dvije trećine ozljeda blažeg, funkcionalnih karaktera u odnosu na strukturalne mišićne ozljede, koje se dogode u 33% slučajeva. Također, potvrđeno je da su mišići prednje i stražnje strane natkoljenice najčešće

ozlijeđene strukture te da je prisutan značajno viši rizik za ozljedu tijekom utakmice nego treninga (7.38/1000h (95%CI: 7.29–7.47) vs. 2.25/1000h (95%CI: 2.24–2.26).

Treća studija ukazala je da postoji konzistentan trend ozljeđivanja u mlađim dobnim skupinama, koji ostaje nepromijenjen tijekom rane faze razvoja. Ipak, starije kategorije pretrpe nešto veći broj traumatskih ozljeda, dok kategorije U11 i U13 dožive više ozljeda prenaprezanja (TOR, U15 = 1.18 vs U13 = 0.91 vs U11 = 0.88).

Posljednja, četvrta studija pokazala je najveću incidenciju mišićnih ozljeda kod najstarije U13 grupe u odnosu na U11 i U9 (2.79/1000h vs 1.52/1000h vs 0.22/1000h). Dominantni tip ozljede je funkcionalna ozljeda mišića (64%), gdje se kvadriceps ističe kao najčešće ozlijeđena mišićna struktura u periodu oko ulaska u najburniju fazu somatskog razvoja (54% od svih ozljeda).

Zaključno, rezultati cjelokupnog rada upućuju da (i) postoji generalni/ukupni pad ozljeđivanja mladih nogometaša te da postoje značajne dobne razlike u ozljeđivanju, (ii) postoji relativno stabilan trend pojavnosti mišićnih ozljeda, (iii) starije grupe dožive veći broj traumatskih, a mlađe kategorije veći broj ozljeda prenaprezanja, (iv) nogometaši prilikom ulaska u razdoblje najbržeg tjelesnog rasta značajno više ozljeđuju mišiće prednje strane natkoljenice. Rezultati ovih studija daju uvid u strukturu i incidenciju ozljeđivanja kod najmlađih kategorija elitnih nogometaša, populacije koja je od iznimne društvene važnosti. Otkrivanje epidemioloških zakonitosti u navedenoj skupini prvi je korak ka istovremenom snižavanju stopa ozljeđivanja i optimizacijom trenažnog procesa tijekom faze odrastanja. Prema saznanju autora ovog rada, ovo je prvo istraživanje ovakve vrste u Hrvatskoj, koji će omogućiti detaljan uvid i bolje razumijevanje navedene problematike kod djece pre-pubertetske i pubertetske dobi u Hrvatskoj.

Ključne riječi: nogomet, incidencija ozljeda, mlađe kategorije, elitna akademija, COVID-19

OSNOVNA STRUKTURA RADA

Ovaj doktorski rad se sastoji od četiri objavljene znanstvene studije:

1. Škomrlj, J., Modrić, T., Sekulić, D., Bandalović, A., Turić, A., Bećir, B., & Veršić, Š. (2024). Longitudinal analysis of the incidence rate of injury in elite youth football: Trends over six years including the COVID-19 pandemic period. *Physical therapy in sport*, *66*, 85-92.
2. Skomrlj, J., Modric, T., Sekulic, D., Uljevic, O., Kesic, M. G., Bandalovic, A., Turić, Ante; Bećir, Boris & Versic, S. (2024). Muscle Injuries in Elite Youth Football Academy: A Six-Year Longitudinal Study on the U15 Football Team. *Applied Sciences*, *14*(11), 4422.
3. Škomrlj, J., Versic, S., Kuko, M., Pavlinovic, V., & Sattler, T. (2025). Understanding Injury Dynamics in Youth Soccer: A Six-Season Study of Traumatic and Overuse Injuries. *Sport Mont*, *23*(2), 3-9.
4. Skomrlj, J., Modric, T., Sekulic, D., Kuko, M., Cikojević, L., Bandalovic, A., Turić, Ante; Bećir, Boris & Veršić, Š. (2025). Understanding Longitudinal Muscle Injury Trends in Youth Football: Insights from U9 to U13 Players. *Sports*, *13*(6), 163.

1. UVOD

1.1. Nogomet

Nogomet je kompleksna, aciklična sportska aktivnost karakterizirana mnoštvom isprekidanih visoko-intenzivnih kretnji. Elitni seniorski nogometaši za vrijeme utakmice pretrče između 10 i 13 km, od čega 5% do 15% u visokom intenzitetu (brzine iznad 19,8 km/h) (Modric, Versic, & Sekulic, 2020). Kako bi ostvarili prednost nad protivnikom, igrači tijekom igre upotrebljavaju veliki broj kretnih struktura izvedenih niskim, srednjim ili visokim intenzitetom. Ipak, kratke eksplozivne akcije poput sprinta, promjene smjera, udarca ili duela od najvećeg su značaja za uspjeh u igri (Di Giminiani & Visca, 2017; Sanchez-Sanchez et al., 2021; Stølen, Chamari, Castagna, & Wisløff, 2005). Te visoko intenzivne akcije koje su ovisne o brzinsko-eksplozivnih kapacitetima, manifestiraju se i u utakmicama nogometaša mlađih dobnih kategorija u kojima igrači prevale između 5 i 7 km, pri prosječnoj srčanoj frekvenciji od 85% maksimalne vrijednosti (Rebelo, Brito, Seabra, Oliveira, & Krustrup, 2014). Iako te vrijednosti variraju ovisno o dobnoj kategoriji, navedeni zahtjevi nogometne igre dovode do znatnog opterećenja lokomotornog, kardio-respiratornog i energetskog sustava igrača (Impellizzeri et al., 2006). Kod najmlađih dobnih skupina vidljiva je postupna progresija u fizičkim zahtjevima samog sporta, koja prati zakonitosti procesa odrastanja (Rommers et al., 2020). Primjerice, mlađe kategorije U11 i U9 igraju u formatu 7 protiv 7 i 5 protiv 5, na terenu manjih dimenzija i sa trajanjem utakmica 50 minuta. Nasuprot tome, utakmice U15 i U13 kategorija igraju se na terenu standardnih dimenzija (100 x 65m) sa trajanjem utakmice od 70 minuta.

Povećana izloženost trenažnom i natjecateljskom opterećenju krucijalna je za razvijanje sport-specifičnih vještina i kapaciteta, međutim, usporedno dolazi i do povećanog rizika od ozljeđivanja igrača (S. Jones et al., 2021). Nogometna ozljeda je po definiciji svaka tegoba koju igrač pretrpi, a koja nastane uslijed nogometnog treninga ili utakmice, bez obzira na potrebu za medicinskom intervencijom ili gubitkom vremena zbog nogometnih aktivnosti (Fuller et al., 2006). Osim što predstavljaju zdravstveni problem, među mladim igračima, neuspjesi povezani s ozljedama često dovode do frustracije, smanjene motivacije i u konačnici veće stope odustajanja (eng. „drop-out“) od organiziranih nogometnih programa (Back, Johnson, Svedberg, McCall, & Ivarsson, 2022). Posljedično, odustajanje mladih osoba od bavljenja sportom značajan je socijalni, ekonomski i zdravstveni problem koji pogađa europske zemlje, pogotovo u kontekstu modernog društva ionako smanjene dnevne fizičke aktivnosti (Battaglia, Kerr, & Tamminen, 2024).

1.2. Ozljede u nogometu

U posljednje vrijeme značajan broj istraživanja bavio se pojavnostima ozljeda u profesionalnom i akademskom nogometu te uzrocima istih (Mandorino, Figueiredo, Gjaka, & Tessitore, 2023; Pfirrmann, Herbst, Ingelfinger, Simon, & Tug, 2016; Robles-Palazón et al., 2022). Dosadašnja istraživanja provedena kod mladih nogometaša utvrdila su 2.3 – 4.9 puta veću incidenciju ozljeda na utakmici u odnosu na trening (IRR = 9.5 – 48.7/1000h vs 3.7 – 11.4/1000h), a kao najčešće lokacije ozljeda ističu bedro, koljeno i gležanj (Pfirrmann et al., 2016). Uzrok tome je veći intenzitet, mentalna pobuđenost i razina kompetitivnosti i agresije koja je značajno veća na utakmicama u odnosu na trening (Le Gall et al., 2006). Važno je naglasiti da s porastom dobi raste incidencija ozljeda zadobivenih na utakmici, dok incidencija trenažnih ozljeda pada (Ergun, Denerel, Mehmet, & Ertat, 2013). Generalno, incidencija i ozbiljnost ozljeda raste kako se nogometaši približavaju seniorskom levelu (Price, Hawkins, Hulse, & Hodson, 2004).

Rezultati tih studija sugeriraju slične obrasce ozljeđivanja kod djece i odraslih, a kao najčešće ozlijeđene regije ističu mišiće i zglobove donjih ekstremiteta, na koje utječu određeni unutarnji (intrinzični) i vanjski (ekstrinzični) faktori rizika. Faza razvoja/maturacije, broj prijašnjih ozljeda, neadekvatna rehabilitacija te niska razina razvijenosti motoričkih i funkcionalnih sposobnosti ističu se kao najvažniji intrinzični faktori rizika (Svensson, Alricsson, Olausson, & Werner, 2018). Ekstrinzični faktori poput količine treninga i broja odigranih utakmica, tj. ukupne izloženosti specifičnom nogometnom opterećenju, tipa površine (prirodna i umjetna trava), klimatskih uvjeta te broja i ozbiljnosti prekršaja također utječu na broj i ozbiljnost ozljeda (Dvorak et al., 2000).

1.3. Period najburnijeg rasta

Linearan porast broja i ozbiljnosti ozljeda događa se prije i tijekom puberteta, između 9 i 15 godina, sa povećanom incidencijom ozljeda u periodu najvećeg prirasta u visinu („peak height velocity“ – PHV), sa otprilike 13 godina starosti u muške djece (Read, Oliver, Croix, Myer, & Lloyd, 2015). Materne i sur. (2015) impliciraju/navode značajan skok broja ozljeda kod sportaša u razdoblju koje obuhvaća godinu prije i godinu poslije PHV perioda (Materne, Farooq, Johnson, Greig, & McNaughton, 2015). Tijekom tog perioda djeca doživljavaju rapidne somatske, hormonalne i emocionalne promjene, dobivaju na visini i masi, a njihove sposobnosti i sportska izvedba nerijetko opadaju zahvaljujući fenomenu „adolescentske nespretnosti“ (Bult, Barendrecht, & Tak, 2018). Dodatan faktor koji utječe

na povećanje incidencije ozljeda u periodu oko puberteta je i prije spomenuto povećanje trenažnog i natjecateljskog opterećenja (Hawkins & Metheny, 2001). Zdjelična regija tijela i pripadajući mišićno-tetivni spojevi, apofize, koštane zone rasta i ligamenti trpe znatan stres jer aktivni pokretači (tj. mišići i tetive) moraju proizvoditi otprilike 30% veću silu za pokretanje pasivnog aparata (tj. kostiju) nakon rasta u duljinu tijekom PHV-a (Van Der Sluis et al., 2014).

Pregledom literature ustanovljen je traumatski tip kao najčešća ozljeda, na koji otpada 2/3 svih ozljeda (A. Jones et al., 2019). Ipak, ozljede i sindromi prenaprezanja poput Severove i Osgood – Schlatterove bolesti predstavljaju značajan problem kod mlađih kategorija U11 do U14 (Schultz, Tol, Veltman, & Reurink, 2022). Metodologija rada sa sportašima početnicima iziskuje veći broj ponavljanja nužan za usvajanje osnovnih tehničkih vještina, a u kombinaciji sa nedovoljno usvojenom tehnikom izvedbe dovodi do većeg broja ozljeda prenaprezanja (Zwolski, Quatman-Yates, & Paterno, 2017). Nasuprot tome, stariji igrači doživljavaju veću proporciju traumatskih ozljeda, ponajviše zbog većeg broja fizičkih kontakata između igrača povećane brzine, snage i tjelesnih dimenzija (Serfaty & Palmer, 2025). Zanimljivo, istraživanja pokazuju da se najteže ozljede kod mladih nogometaša događaju u dobi između 14 i 16 godina (Peterson, Junge, Chomiak, Graf-Baumann, & Dvorak, 2000). Stariji adolescenti bilježe najveći broj fraktura zbog visokih sila koje ispoljavaju, rigoroznog sustava treninga i utakmica koji nalikuje seniorskom režimu te povećanoj ukupnoj nogometnoj izloženosti, uz još nepotpuno/nedovoljno formiran lokomotorni sustav (Le Gall, Carling, & Reilly, 2008).

1.4. Mišićne ozljede

Unatoč napretku u sportskoj znanosti, nogometne ozljede, posebice one mišićne, i dalje su veliki izazov, s trendovima koji pokazuju mali ili nikakav pad u njihovoj pojavnosti. Glavni čimbenik stabilnom trendu mišićnih ozljeda su sve veći intenzitet i učestalost natjecanja (Ekstrand, Spreco, Bengtsson, & Bahr, 2021). Problematika mišićnih ozljeda donjih ekstremiteta prisutna je i u akademskom nogometu, sa udjelom od 37% svih ozljeda te sa relativno visokom incidencijom od 2 mišićne ozljede na 1000 sati nogometne izloženosti (Ekstrand, Hägglund, & Waldén, 2011; Robles-Palazón et al., 2022). Mišići prednje i stražnje strane natkoljenice ističu se kao najčešće ozlijeđene mišićne strukture u nogometu, sa nešto većom dominacijom ozljeda mišića kvadricepsa kod mladih nogometaša u odnosu na seniore, gdje su mišići stražnje lože označeni kao najranjivija mišićna skupina (A. Jones et al., 2019; Price et al., 2004). Zajedno sa spomenutim mišićima, skupina primicača

natkoljenice (adduktorna skupina) te mišići stražnje strane natkoljenice (m. gastrocnemius i m. soleus) čine 87% i 92% svih mišićnih ozljeda kod mladih, odnosno, kod odraslih nogometaša (Ekstrand et al., 2011; A. Jones et al., 2019).

Mišićno-tetivne strukture zdjelične i preponske regije posebno su ranjive kod dječaka pubertetske dobi, kada uslijed morfoloških promjena dolazi do smanjivanja kontraktilnih kapaciteta navedenih struktura (Tak et al., 2015). Najčešći je beskontaktni tip mišićnih ozljeda (<66%), ponajviše uslijed visoko-intenzivnih kretnji poput sprinta, kočenja i promjena smjera koje stavljaju povećano opterećenje na mišiće stražnje lože, ponajviše dugu glavu m. biceps femorisa (Huygaerts et al., 2020). Nadalje, uočen je relativno nizak broj re-ozljeda kod mladih nogometaša (svega 3-15%), ponajviše zbog prisutnosti medicinskog osoblja te manjeg pritiska ka bržem povratku u puni trenažni režim (Mandorino et al., 2023). Kao dodatan razlog ističe se činjenica da zbog manje trenažne dobi, mlađi igrači imaju manji broj prijašnjih ozljeda koje su označene kao najznačajniji prediktor buduće ozljede (Kucera, Marshall, Kirkendall, Marchak, & Garrett, 2005). Upravo zato, važno je utjecati na kontrolabilne faktore koji smanjuju rizik od doživljavanja prve mišićne ozljede, a posljedično i ponovljenih ozljeda (npr. kontrola opterećenja, mišićna jakost, fleksibilnost, tehnika kretanja, nutritivne strategije) (Arnason et al., 2004). U dostupnoj literaturi postoji manjak informacija o mišićnim ozljedama kod najmlađih dobnih skupina U9, U11 i U13. Očekivano, starije grupe bilježe veću incidenciju mišićnih ozljeda, primarno zbog ubrzanog razvoja igrača koji se bliže PHV-u te nesrazmjera koštanih i mišićnih struktura povezanog s pubertetskim razdobljem (Bult et al., 2018). Prevalencija mišićnih ozljeda kod U9 grupe je zanemariva, dok U11 i U13 kategorije bilježe postupan porast mišićnih ozljeda sa primarno blažim tipom ozljede (DOMS vs ruptura mišićnih vlakana) (McNaughton et al., 2020).

Zaključno, s obzirom na očigledan manjak istraživanja koja se bave pitanjem pojavnosti te karakteristikama ozljeda nogometaša iz najmlađih kategorija, pogotovo u ovom /jugo-istočnom dijelu Europe, nužno je postaviti epidemiološki okvir ozljeđivanja u navedenoj populaciji. Prema saznanjima autora, ovo je prva studija ovakve vrste koja je pružila detaljan uvid u strukturu i incidenciju ozljeda kod mladih nogometaša iz elitne hrvatske nogometne akademije.

1.5. Ciljevi istraživanja

Glavni cilj ovog rada bio je (i) analizirati trendove ozljeđivanja te mogući utjecaj COVID-19 pandemije na incidenciju ozljeda kod elitnih mladih nogometaša U8 do U15 kategorije, (ii) utvrditi detalje o tipu, lokaciji, ozbiljnosti i kontaktnoj prirodi mišićnih ozljeda u U15 kategoriji nogometaša, (iii) utvrditi distribuciju ozljeda kod U8 do U15 elitnih mladih nogometaša te (iv) istražiti pojavnost ozljeda mišićnog sustava kod najmlađih dobnih kategorija U8 do U13. U projektnom prijedlogu ovog rada navedeni su i drugi ciljevi istraživanja (v) analiziranje utjecaja pojedinih antropometrijskih varijabli, kapaciteta mišićne snage, jakosti i fleksibilnosti, stanja umora te trkačke izvedbe i njihovu možebitnu povezanost s ozljedama te (vi) kreiranje prediktivnog modela procjene rizika od zadobivanja ozljede temeljenom na analizi podataka, strojnome učenju i statističkom modeliranju. Navedeni ciljevi predstavljaju sljedeću fazu ovog sveobuhvatnog znanstvenog istraživanja te će omogućiti dublje razumijevanje ovog multifaktorijalnog problema.

2. ORIGINALNE STUDIJE

2.1 Studija 1: Longitudinal analysis of the incidence rate of injury in elite youth football: Trends over six years including the COVID-19 pandemic period

Škomrlj, J., Modrić, T., Sekulić, D., Bandalović, A., Turić, A., Bećir, B., & Veršić, Š. (2024). Longitudinal analysis of the incidence rate of injury in elite youth football: Trends over six years including the COVID-19 pandemic period. *Physical therapy in sport*, *66*, 85-92., https://doi.org/10.1016/j.ptsp.2024.01.006

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Longitudinal analysis of the incidence rate of injury in elite youth football: Trends over six years including the COVID-19 pandemic period

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Abstract

Objectives: We aimed to analyze injury trends and the possible effects of the coronavirus disease (COVID-19) pandemic on the incidence rates of injury in young elite football players. Design: A prospective cohort study design was adopted. Participants: Our study included 832 male football players who suffered an injury during any of the six competitive seasons. Setting: An elite youth football academy. Main outcome measure: Descriptive data and the incidence of injury were calculated. A generalized linear mixed model was used to assess differences in the occurrence of injury among the various age groups. Joinpoint regression was used to analyze injury trends. Results: Joinpoint regression models showed a statistically significant decrease in the incidence of injury in all age groups with an average annual percent change (AAPC) of 13.9 (95%Confidence Interval [CI]:-23.2 - 3.4) and -13.5 (95%CI:-24.5– -0.9) for models with zero and one joinpoint, respectively. Football players in older age groups sustain a higher number of injuries, probably due to a higher number of matches and greater training intensity. Conclusion: This study showed a downward trend in injuries in the participants prior to the pandemic, with an evident increase in the incidence rate of injury during the COVID-19 pandemic.

Keywords: youth, football, training, injury incidence, COVID-19

2.1.1 Introduction

Players perform a variety of movements during football matches at an intensity approaching the lactate threshold with a mean heart rate that is 85% of the maximum value (Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2012). Previous studies have confirmed that the demand for youth (e.g., under 18 years of age) sports and training increase with age that increases the risk of injury in cases of insufficient maturation status (Buchheit & Mendez-Villanueva, 2014; Harley et al., 2010; Price, Hawkins, Hulse, & Hodson, 2004; Renshaw & Goodwin, 2016). Not surprisingly, the problem of injury occurrence is extensively investigated in youth football (Jones et al., 2019; Pfirrmann, Herbst, Ingelfinger, Simon, & Tug, 2016; Robles-Palazón et al., 2022).

The mean injury rate in the under-12 years (U12) up to the under-19 years (U19) age categories is reported to be 5.7/1000h, with a much higher risk of injury occurrence in the match (14.4/1000h) compared to during training (2.8/1000h) (Robles-Palazón et al., 2022). Meanwhile, a study conducted on players younger than 13 years of age revealed much lower injury incidence rates of 0.61/1000h and 4.57/1000h during training and match, respectively, with at least 1 injury per season in 5.7% of players (Rössler, Junge, Chomiak, Dvorak, & Faude, 2016). Generally, the most frequent injuries are soft tissue strains caused by sprinting, kicking the ball, and tackling an opponent (Jones et al., 2019). Midfielders and defenders are the most frequently injured players, and goalkeepers sustain the fewest injuries (Jones et al., 2019).

It is generally accepted that the best approach to minimizing the impact of injury in young football players is to introduce a continuous screening of the players, along with the implementation of training programs that target modifiable and controllable risk factors (Kempe, Rasmussen-Barr, & von Rosen, 2023; Read, Jimenez, Oliver, & Lloyd, 2018). Consequently, various injury prevention programs have been developed worldwide to reduce number and harmful effects of injuries (Olsen et al., 2004). These multifaceted programs combine components of neuromuscular, strength, balance, and agility training and have been proven to have protective effects by reducing the number of injuries (C. Emery & Meeuwisse, 2010). One of the most popular structured programs used for injury reduction in youth football is FIFA 11+, a comprehensive warm-up protocol used to improve muscle strength, kinesthetic awareness, and neuromuscular control (Bizzini, Junge, & Dvorak, 2013). The program has been shown to be effective in both professional as well as young male and female football players (Owoeye, Akinbo, Tella, & Olawale, 2014; Sadigursky et al., 2017; Steffen et al.,

2013). Studies have also confirmed that strength, balance, and coordination training employed as a primary intervention strategy, significantly reduces the risk of knee and ankle sprains in high school football players (Read, Oliver, De Ste Croix, Myer, & Lloyd, 2016). Finally, the use of objective load monitoring devices, such as global positioning systems and heart rate monitors, allows optimal planning and periodization of the load and help minimize the risk of overtraining and injuries (Bourdon et al., 2017; Teixeira et al., 2021).

The start of the coronavirus disease (COVID-19) pandemic at the end of 2019 imposed measures of social distancing and lockdown, interrupted and altered the sports world in general, and had the highest impact on youth sports (Drezner, Drezner, Magner, & Ayala, 2021; Sanderson & Brown, 2020; Wolf et al., 2021). An interruption of training is known to cause a decline in the relevant physical capacities and skills after only 4 weeks (for example, power, strength, agility, and sport-specific contact skills) (Latella & Haff, 2020), and so it was not surprising that studies indicated higher injury rates upon return to full training after a COVID-19-induced break, especially in the first few weeks of retraining (Sarto et al., 2020). More precisely, a restart of training and official matches caused a rise in musculoskeletal injuries to players, presumably because of prior physical deconditioning and an increase in volume and intensity needed to endure congested national and international competition schedules (Vincent, Patel, & Zaremski, 2022). In support of this hypothesis, investigators found a 300% increase in injury rates of professional German Bundesliga players after the COVID-19 lockdown (Seshadri, Thom, Harlow, Drummond, & Voos, 2021). In addition, an initial decrease at the onset of the pandemic and a subsequent two-fold increase in injury incidence following the return to sports was observed in the pediatric clinic population (Johnson et al., 2021).

Overall, it is known that football training and matches impose high psychological and physiological demands even on young players, leading to a significant number of injuries (Jones et al., 2019; Pfirrmann et al., 2016; Renshaw & Goodwin, 2016). Moreover, recent reports have suggested that the COVID-19 lockdown resulted in an increased injury rate owing to a lack of systematic training and medical management of athletes (Sarto et al., 2020; Seshadri et al., 2021). However, there is a lack of data on the mediating effect of the COVID-19 pandemic on injury occurrence in football, and this problem is particularly understudied in youth football. Moreover, to our knowledge, no study has prospectively investigated this problem by observing injury incidence in young athletes several years before and during the pandemic period.

Therefore, the main aim of this study was to analyze injury trends in six competitive seasons and the effect of the COVID-19 pandemic on the incidence of injuries in a sample of young elite football players in the Under-9 years (U9) through Under-15 years (U15) age categories. Additionally, this study aimed to determine the possible differences in injury incidence among different age groups. Initially, we hypothesized that (i) injury incidence would be higher in older age categories, and that (ii) the pandemic period would change the trends in injury incidence observed during the pre-pandemic period.

2.1.2 Methods

Study design

This prospective cohort study conducted injury surveillance during six competitive seasons, from the beginning of the 2016/2017 season to the end of the 2021/2022 season. Injury data were extracted from the U9 to U15 category of football club (see below for details). Written informed consent was obtained from the parents or legal guardians of all participants, considering that they were underaged. This study was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Kinesiology, *** (Ethical Approval Number: 2181-205-02-05-23-0007).

Participants

A total of 832 young male football players (age range 6.5-15.6 years) were included in the study. All were registered as players of the *** football academy. The participants in this study were elite youth players, since *** football academy is considered one of the best and most productive football academies in Europe (CIES, 2022). Players were included in the study from the moment they were registered and were excluded immediately upon their release from the academy. For the purpose of this study, and according to their chronological age, the players were divided into four age groups as follows: U9 (N=120), Under-11 (U11) (N=188), Under-13 (U13) (N=246), and U15 (N=278). To preserve the confidentiality of the obtained data, all the participants were assigned a code number known only to the investigators. For the purpose of the study, it is important to note the differences in game demands between age categories. The U15 and U13 category games are played 11 versus 11 players on a full-sized pitch length, with matches lasting 70 minutes. Conversely, younger age groups (U11 and U9) play their

games in a 7 versus 7 players and 5 versus 5 players game formats, respectively, on a smaller pitch and with a 50-minute game duration.

Variables/Data collection

Injuries were recorded daily by the medical professionals of the football academy before or after the training sessions. All injuries were classified according to the consensus statement of the FIFA Medical Assessment and Research Centre (Fuller et al., 2006). An injury was defined as "any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time-loss from football activities." Injuries were classified by their cause as overuse (chronic) or acute (traumatic). Any illness, disease, or mental complaints were not included in the analysis. Football exposure was calculated/estimated as the number of training and match hours per age category. Also, training and match exposure for all groups were adjusted for the pandemic 2019/2020 season, due to the complete absence of training from March until June 2020. Injury incidence was expressed as the mean number of injuries sustained per 1000 hours of exposure to football training or competition.

Statistics

Descriptive data for all age groups are presented as percentages and absolute numbers, including means and standard deviations. The injury incidence was calculated as the number of injuries sustained per 1000h of exposure. The injury incidence rate ratios were calculated between year-1 and year-6, by usage of MedCalc software. A generalized linear mixed model (binary logistic regression) analysis was used to determine differences in injury occurrence between different age-categories. To analyze the injury trend over the observed period, Joinpoint Regression Program 4.9.1.0 (Statistical Research and Applications Branch, National Cancer Institute) was used with models with zero and one joinpoint. This trend analysis method has been used in epidemiology studies where time trends of some specific health issues were analysed (Coronado et al., 2015; Fares, Stewart, McBride, & Maclean, 2023). Statistica 13.0 (TIBCO Software Inc, USA), Microsoft Excel 2019 (Microsoft, USA) and SPSS software (IBM, SPSS, version 25.0) packages were also used for calculations, with a P-value of 0.05 considered statistically significant.

2.1.3 Results

The findings of this study suggest that the overall injury incidence increased with age, with the lowest rates in the U9 group (1.51/1000h), and the highest in the U15 group (7.02/1000h). Accordingly, the U13 group had a higher injury rate than the U11 group (6.33/1000h vs 4.16/1000h, respectively).

Injury rates generally declined between the years 2016 and 2020 (U9= 1.74/1000h vs 1.44/1000h, U11= 5.88/1000h vs 0.87/1000h, U13= 7.39/1000h vs 3.12/1000h, U15= 11.92/1000h vs 5.31/1000h). The most evident decline in injury incidence was observed in the oldest category (U15), where the number of injuries sustained per 1000h of exposure dropped from 11.92 in the first season to 6.65 in the last observed season. Likewise, the injury rates of all other age groups declined during the 6-year study period (U9= 1.74/1000h vs 0.69/1000h, U11=5.88/1000h vs 2.80/1000h, and U13=7.39/1000h vs 5.23/1000h, for the 2016/17 and 2021/22 seasons, respectively) (Table 1).

Table 1. Injury incidence on 1000 hours of exposure for all, trauma and overuse injuries during 6 seasons

		16/17	17/18	18/19	19/20	20/21	21/22	Mean±SD
U9	ALL	1.74 (1.69-1.76)	1.45 (1.41-1.49)	2.07 (2.02-2.13)	1.66 (1.61-1.72)	1.44 (1.39-1.48)	0.69 (0.66-0.72)	1.51±0.46
	T	0.87 (0.84-0.9)	0 (0-0)	1.38 (1.34-1.43)	0.42 (0.39-0.44)	1.08 (1.04-1.12)	0.35 (0.32-0.37)	0.68±0.52
	O	0.87 (0.84-0.9)	1.45 (1.41-1.49)	0.69 (0.66-0.72)	1.25 (1.2-1.29)	0.36 (0.34-0.38)	0.35 (0.32-0.37)	0.83±0.46
U11	ALL	5.88 (5.81-5.96)	5.06 (4.99-5.14)	6.62 (6.54-6.7)	2.85 (2.8-2.91)	1.74 (1.7-1.77)	2.8 (2.75-2.84)	4.16±1.96
	T	1.72 (1.68-1.76)	3.04 (2.98-3.09)	4.17 (4.1-4.23)	1.04 (1.01-1.07)	0.87 (0.84-0.9)	1.6 (1.56-1.63)	2.07±1.28
	O	4.17 (4.1-4.23)	2.03 (1.98-2.07)	2.45 (2.4-2.5)	1.82 (1.77-1.86)	0.87 (0.84-0.9)	1.2 (1.17-1.23)	2.09±1.17
U13	ALL	7.39 (7.33-7.46)	8.39 (8.32-8.47)	6.84 (6.78-6.91)	6.98 (6.91-7.05)	3.12 (3.08-3.16)	5.23 (5.18-5.28)	6.33±1.88
	T	3.27 (3.23-3.31)	4.66 (4.61-4.72)	3.66 (3.61-3.71)	3.02 (2.97-3.07)	1.34 (1.31-1.36)	2.91 (2.87-2.95)	3.14±1.09
	O	4.12 (4.08-4.17)	3.73 (3.68-3.78)	3.18 (3.14-3.23)	3.96 (3.91-4.02)	1.78 (1.75-1.81)	2.32 (2.29-2.36)	3.18±0.95

U15	ALL	11.92 (11.84-11.99)	6.33 (6.27-6.38)	6.83 (6.78-6.89)	5.06 (5.01-5.11)	5.31 (5.26-5.36)	6.65 (6.59-6.71)	7.02±2.51
	T	6.98 (6.92-7.04)	3.22 (3.19-3.26)	3.35 (3.31-3.4)	2.39 (2.35-2.43)	2.41 (2.38-2.45)	3.86 (3.81-3.9)	3.7±1.7
	O	4.93 (4.89-4.93)	3.1 (3.07-3.14)	3.48 (3.44-3.52)	2.67 (2.63-2.71)	2.9 (2.86-2.93)	2.79 (2.76-2.83)	3.31±0.84

Legend: ALL – all injuries, T – training injuries, O – overuse injuries

When comparing among age categories, the highest injury risk was observed for the U15 group. Specifically, the U15 category experienced the highest injury occurrence in three out of six seasons (seasons 2016/17, 2020/21, and 2021/22, respectively). In seasons 2017/18 and 2018/19, the U13 group sustained the highest number of injuries (Figure 1). Injury incidence in the 2018/19 season was almost the same between the U13 and U15 groups (6.84/1000h vs 6.83/1000h, respectively).

Figure 1. Match and training injury incidence on 1000 hours of exposure for each category (U9-U15), and for total sample (ALL)

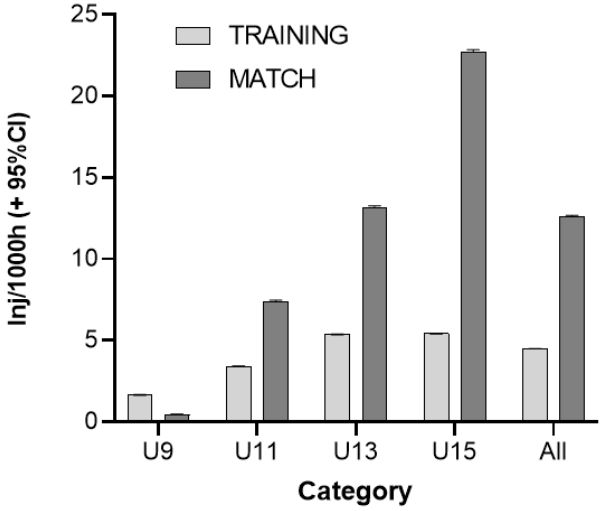


Figure 1 provides information regarding the match and training injury incidence for each of four age groups separately, and for all players. The match injury incidence was higher than the training injury incidence in U15 (OR=5.43, 95%CI:5.4-5.45 vs 22.69, 22.54-22.85), U13 (OR= 5.37, 95%CI: 5.35-5.4 vs 13.15, 13.03-13.27), and U11 (OR = 3.42, 95%CI: 3.39-3.44 vs 7.36, 7.25-7.47), as well as when observed for all age groups combined (OR= 4.51, 95%CI: 4.50-4.52 vs 12.62, 12.56-12.69). Only the U9 category suffered more training-related than match-related injuries on 1000 hours of exposure (OR = 1.66, 95%CI: 1.64-1.68 vs 0.46,0.43-0.49).

Figure 2 shows trends of traumatic and overuse injuries during the observed period, separately for each age-category. There is an evident decrease in overuse injuries over the course of six seasons in all age groups. Although not as obvious, the decrease is present for traumatic injuries, also. The difference in injury rates is apparent between the age groups, where the older categories suffered more injuries, both in the traumatic and overuse categories.

Figure 2. The trend of traumatic (A) and overuse (B) injuries through the years (presented as injuries/1000h of exposure).

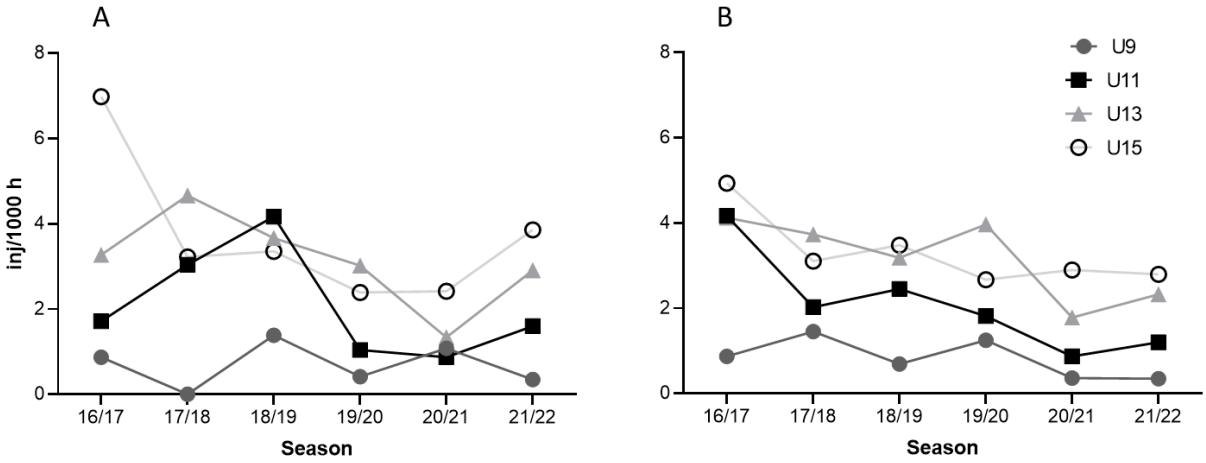


Table 2. Injury incidence differences among age categories (Generalized mixed model)

SEASON 2016/2017			
	Coefficient (Std.Error)	t (Sig.)	Exp (Coefficient) (95%CI)
Intercept	*-2.374 (0.43)*	*-5.519 (0.001)*	*0.093 (0.040-0.217)*
U15	2.983 (0.804)	3.7008 (0.001)	19.47 (4.045-96.323)
U13	1.836 (0.622)	2.95 (0.004)	6.72 (1.840-21.371)
U11	1.238 (0.567)	2.183 (0.03)	3.447 (1.128-10.540)
U9	0*		
SEASON 2017/2018			
	Coefficient (Std.Error)	t (Sig.)	Exp (Coefficient) (95%CI)
Intercept	*-0.936 (0.331)*	*-2.826 (0.005)*	*0.392 (0.204-0.754)*
U15	2.156 (0.784)	2.748 (0.007)	8.633 (1.837-40.577)
U13	0.824 (0.549)	1.502 (0.135)	2.279 (0.772-6.725)
U11	-0.511 (0.519)	-0.985 (0.326)	0.6 (0.216-1.669)
U9	0*		
SEASON 2018/2019			
	Coefficient (Std.Error)	t (Sig.)	Exp (Coefficient) (95%CI)

Intercept	*-0.869 (0.342)*	*-2.540 (0.012)*	*0.420 (0.214-0.823)*
U15	1.973 (0.658)	3 (0.003)	7.195 (1.966-26.323)
U13	0.627 (0.542)	1.156 (0.249)	1.871 (0.643-5.448)
U11	0.006 (0.504)	0.013 (0.990)	1.006 (0.373-2.716)
U9	0*		
SEASON 2019/2020			
	Coefficient (Std.Error)	t (Sig.)	Exp (Coefficient) (95%CI)
Intercept	*-0.313 (0.332)*	*-0.945 (0.346)*	*0.731 (0.380-1.406)*
U15	2.134 (0.707)	3.016 (0.003)	8.446 (2.091-34.122)
U13	1.398 (0.546)	2.562 (0.011)	4.047 (1.379-11.880)
U11	-0.342 (0.491)	-0.696 (0.488)	0.270-1.873)
U9	0*		
SEASON 2020/2021			
	Coefficient (Std.Error)	t (Sig.)	Exp (Coefficient) (95%CI)
Intercept	*-0.805 (0.334)*	*-2.413 (0.017)*	*0.447 (0.231-0.864)*
U15	2.352 (0.692)	3.399 (0.001)	10.503 (2.579-41.187)
U13	2.069 (0.566)	3.656 (0.001)	7.913 (2.589-24.186)
U11	1.078 (0.484)	2.227 (0.027)	2.938 (.130-7.643)
U9	0*		
SEASON 2021/2022			
	Coefficient (Std.Error)	t (Sig.)	Exp (Coefficient) (95%CI)
Intercept	*-0.926 (0.342)*	*-2.706 (0.007)*	*0.396 (0.202-0.778)*
U15	3.279 (0.861)	3.809 (0.001)	26.547 (4.857-145.111)
U13	1.583 (0.529)	2.993 (0.003	4.868 (1.715-13.821)
U11	0.379 (0.485)	0.782 (0.435)	1.461 (0.561-3.802)
U9	0*		

Calculation of the injury odds was done for all age-categories for 6 years. In the 2016/17 season, the odds of suffering an injury for the U15 group were estimated to be 19.47 times the corresponding odds for the U9 group ($p<0.01$). In the next two seasons, comparing the oldest and the youngest group (i.e., U15, and U9, respectively) the likelihood of sustaining an injury decreased significantly (2017/18 = 8.63 [$p<0.01$], and 2018/19 = 7.19 [$p<0.01$], respectively). Finally, in the last observed season (i.e., 2021/22), the odds for injury occurrence have risen again, when the U15 group odds were estimated to be 26.57 times the corresponding odds for the U9 group ($p<0.01$).

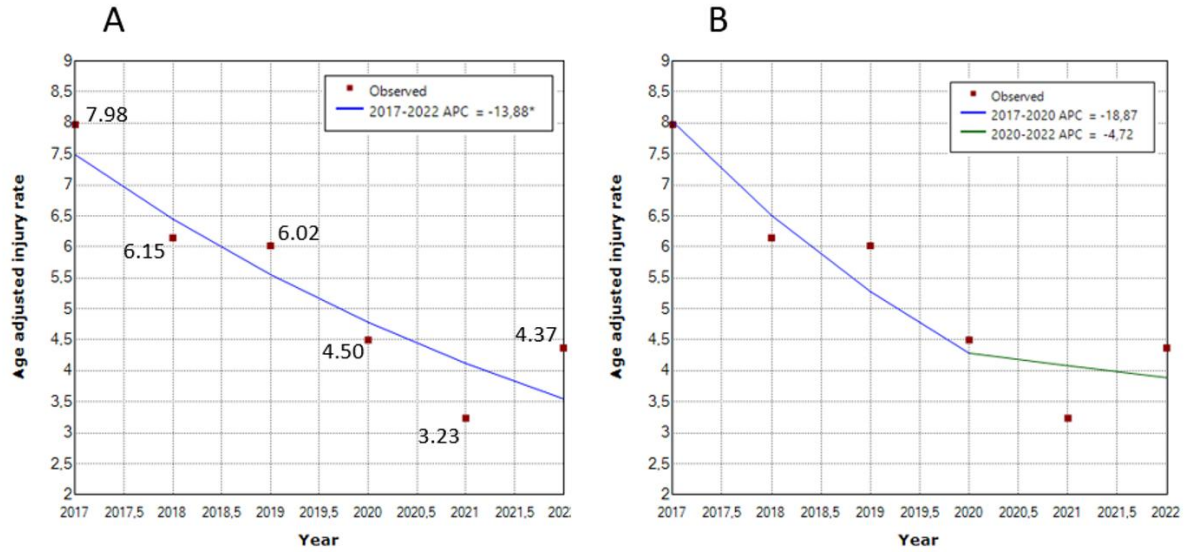
The injury incidence rate ratios (IRR) (Table 3) were calculated for the overall sample and separately for age categories between year-1 (2016/17) and year-6 (2021/22). Results suggest a general decrease in injury incidence for all categories with an IRR value of 1.73 (95%CI:1.35-2.22). The most evident decrease in injury incidence was observed for the youngest U9 category that had an IRR value of 2.25 (95%CI:0.92-5.49).

Table 3. Injury incidence rate ratio, comparison between year-1 and year-6

CATEGORY	IRR 1-6 years (95%CI)
U9	2.2508 (0.9244-5.4923)
U11	2.102 (1.34-3.13)
U13	1.413 (1.054-1.855)
U15	1.79 (1.454-2.183)
ALL	1.73 (1.3502-2.228)

The Joinpoint regression models with age-adjusted rates are presented in Figure 3 (models with 0 and 1 joinpoint). The first model shows a significant annual decrease in injuries with an Annual Percent Change (APC) value of -13.9 (95%CI:-23.2 - 3.4) implying that in the observed 6-year period, the injury rate decreased by 13.9% per year.

Figure 3. Joinpoint regression model with zero joinpoints (A) and one joinpoint (B) (* indicates that the Annual Percentage change is significantly different from zero at $p < 0.05$)



In the model with one joinpoint, two segments can be observed, with one referring to the pre-COVID period between 2017 and 2020, and the other to the post-COVID period between 2020 and 2022. In the first segment, the APC value is -18.9 (95%CI:-66.4-95.6), while in the second segment the APC value is -4.7 (95%CI:-83.6-454.1). Given that a smaller sample of time points was present in each segment, the wide range of confidence intervals suggests some uncertainty in the annual decline in the number of injuries. However, the Average Annual Percent Change (AAPC) was -13.5 (95%CI:-24.5– -0.9), indicating a statistically significant downward trend during the 6 years, with 13.5% fewer injuries on average per year.

2.1.4 Discussion

This study aimed to analyze the injury trends of players from the U9 through U15 age categories in six competitive seasons, including the COVID-19 pandemic period, and to determine possible age-related differences in injury incidence. This study had three important findings. First, a clear downward trend in the incidence of injuries was observed in the pre-pandemic period. Second, the results suggest a halt to that trend in the COVID season, with the overall injury incidence increasing in the last season. Finally, there was a statistically significant difference in injury incidence between the age categories, with the number of injuries increasing with the age of the player. Therefore, our initial study hypothesis can be accepted.

Decrease in the incidence of injuries in the pre-pandemic period

A significant decrease in the overall injury incidence and number of injured players was evident for all observed age categories during the 6-season period selected for this study, starting from the 2016/17 season. To provide a perspective for these results, we speculate that these findings can be explained by the following two factors: (i) applied preventive strategies and (ii) change in turf.

The first explanation of the evident decrease in injury incidence over the observed pre-pandemic period is related to the specifics of the applied preventive strategy that can be divided into five sub-strategies: (i) strength and power training, (ii) balance and coordination training, (iii) warm-up strategies, (iv) continuous screening of the players, and (v) objective evaluation of workload. It is documented that strength and power training elicits physiological changes

responsible for mitigating injury risk, such as elevated neuromuscular function, improved inter- and intra-muscular coordination, and strengthening of the adjacent tissues and joints (Beato, Maroto-Izquierdo, Turner, & Bishop, 2021; Lauersen, Andersen, & Andersen, 2018). This type of conditioning was specifically implemented during the training week at the youth academy and was carried out regularly, regardless of the season. Second, while balance and coordination are essential for optimal performance and prevention of injuries, various exercises aimed at improving dynamic balance and postural stability are incorporated into the training program as well (Hammami, Granacher, Makhlouf, Behm, & Chaouachi, 2016). Further, following the football authorities' opinion that one of the most effective ways to prevent injuries in young soccer players is to have a proper warm-up routine that will not increase the overall load (Daneshjoo, Mokhtar, Rahnama, & Yusof, 2012), the warm-up protocols (e.g. "Raise – Activate – Mobilize - Potentiate") employed at the academy regularly included segments such as neuromuscular control, activation and tonization of the muscles, balance, innervation, etc. (Bizzini et al., 2013; Impellizzeri et al., 2013; Jeffreys, 2006). In addition, the authors indicated that young male elite football players could improve dysfunctional movement patterns with corrective exercise programs (Campa, Spiga, & Toselli, 2019). Therefore, we continuously screened players and identified potential risk factors to enable coaches to create individualized corrective programs (Rogers et al., 2019). Finally, we continuously used heart rate monitors and GPS devices throughout the study period to objectively quantify internal and external player load (Colby, Dawson, Heasman, Rogalski, & Gabbett, 2014; Owen et al., 2015). Although the impact of the aforementioned preventive strategies on the reduction of injuries was not directly measured, the authors of this study are practitioners actively involved in the training process of the youths observed herein and are familiar with the training methodology of the academy. Therefore, we can assume that these implemented strategies, with their well-known and previously proven mediating effects on injury occurrence, are one of the main reasons for the general decrease in injury incidence among the players studied here.

Although not directly related to the preventive strategies applied, we must highlight one organization-specific factor that significantly contributed to the decrease in injury occurrence in the pre-pandemic period. With respect to the football academy used in this study, we would like to highlight the constant cooperation between the various staff members (coaches, strength and conditioning professionals, physiotherapists, and medical doctors). Although seemingly anecdotal, it is important to note that studies have already confirmed a decrease in the injury rate of youth categories, attributing this to increased contributions from sports and medical

professionals (C. Emery & Meeuwisse, 2010; Tears, Chesterton, & Wijnbergen, 2018). This multidisciplinary team attenuates the influence of extrinsic (e.g. pitch, rules, equipment) and modifiable intrinsic (e.g. strength, endurance, balance) injury risk factors with the purpose of improving the overall health status of athletes (C. A. Emery & Pasanen, 2019; Raya-Castellano & Uriondo, 2015). The cooperation of all involved is required, as a lack of communication between the medical and the coaching staff may be the critical factor impacting risk of injury (Ekstrand et al., 2023).

Finally, in addition to all the aspects discussed above, we have to highlight the possibility that changes in the playing surface and footwear may have had an impact on injury-occurrence trends in our study. For example, knee and ankle sprains are cited as significant risk factors for athletes competing on artificial turf because of changes in shoe-playing surface interactions (Balazs et al., 2015). Back pain, a common complaint in young footballers, appears to be aggravated after training on artificial turf (Haag et al., 2016). Engineering efforts have recently resulted in a new generation of softer synthetic surfaces (Lanzetti et al., 2017), that may have diminished surface-related problems. Hence, one of the reasons for the initial decrease in the number of injuries (i.e., over the first two to three observed seasons) could be the installation of a new artificial turf in the Spring of 2017. Therefore, knowing that pitch stiffness and friction are key factors involved in surface-related injuries, (Skovron, Levy, & Agel, 1990; Steffen, Andersen, & Bahr, 2007; Woods, Hawkins, Hulse, & Hodson, 2002) we can assume that the new and softer playing surface was at least partially a factor that contributed to the reduction in the overall injury rate in our study as well.

Changes in the injury incidence rate with the onset of the COVID-19 pandemic

The downward trend of injuries that was evident in the period of 2016-2019, stopped during the 2019/2020 season (onset of the COVID-19 pandemic). Although the APC for the post-COVID-19 period does not show a significant annual change, in comparison to the pre-pandemic period, a slightly different trend in injury occurrence is clear (-18.9 and -4.7, in the pre-pandemic and post-pandemic periods, respectively). Additionally, injury incidence rates showed higher numbers of injuries per 1000 hours of exposure overall and for three of the four observed categories (see Table 4 for details). Since this is one of the first studies to examine this issue, comparisons with previous reports are limited. However, in explaining the mechanisms of the observed changes in trends, we will try to include our professional

experience from the field and known issues related to the problem of COVID-19 illness and the COVID-19 pandemic-period.

In the period of the emergence of the COVID-19 virus, as a means of fighting against the pandemic, measures such as lockdowns, home isolation of the population, and interruption of numerous activities, including sports training and competitions, were used to fight the pandemic. The period of interrupted or reduced training load (detraining) affects various physiological systems and all related physical capacities, and this leads to a reduction in the work capacity of the athlete (Jukic et al., 2020; Kalinowski, Myszkowski, & Marynowicz, 2021). For example, research on trained athletes indicated a substantial reduction in type II fibers after 2 weeks of detraining and a deterioration of speed capacities after 5 weeks of detraining (Kovacs, Pritchett, Wickwire, Green, & Bishop, 2007). In addition, Cohen et al. suggested that the absence of high-speed running and sports-specific reactive movements during the lockdown could be the missing cognitive and specific mechanical stimuli for elite football players (Cohen et al., 2021). Indeed, the training maladaptation that occurred due to a forced break from training had left these athletes underprepared and had predisposed them to an increased risk of injury (Annino et al., 2022; Córdova-Martínez, Caballero-García, Roche, Pérez-Valdecantos, & Noriega, 2022; Kremen Jr et al., 2023).

In support of our findings, the increased incidence of injuries upon return to training after the lockdown was reported in studies on the Premier League and Bundesliga (Mannino et al., 2023; Marotta et al., 2021; Seshadri et al., 2021). Prolonged periods of rest, home confinement, shortened retraining periods, condensed competition schedules and the unavailability of exercise-based injury prevention programs led to the observed increases in musculoskeletal injury rates (Martens et al., 2021). However, not all studies confirmed a higher risk of injury during the pandemic period. For example, the incidence of muscle injuries among Italian professional football players did not significantly rise compared to the period before the COVID-19 lockdown (Marotta et al., 2021). However, it seems that the majority of reports indicated negative trends in injury occurrence as a result of the pandemic period.

Apart from this, it is reasonable to suppose that the COVID-19 infection itself could be the reason for an increase in injury prevalence in the season 2021/22. Specifically, recent medical records from our professional team indicated that more than half of the players suffered from COVID-19 illness during the pandemic season (Nincevic et al., 2023). Although football players are extremely fit and conditioned, they were not spared by the disease and can display,

in some cases, extreme cardiovascular and respiratory complications (Fabre et al., 2020). It is important to note that the COVID-19 virus causes muscle damage, inflammation, and loss of muscle tissue due to excessive production of cytokines that leads to oxidative stress and consequent myocyte damage (Annino et al., 2022; Córdova-Martínez et al., 2022). We can assume that these factors created unfavorable conditions for athletes upon returning to regular training regimens after being infected, and this may have influenced the injury occurrence rates in the pandemic- and post-pandemic period in our participants as well.

Age-related differences in injury incidence

Finally, our results suggest a higher injury-risk in older age categories and a progressive increase in injuries across the various age groups. This finding can be explained primarily by the higher training and match intensity as the players advance in age (Teixeira et al., 2021; Wrigley, Drust, Stratton, Scott, & Gregson, 2012). Importantly, a substantial leap in training and match load occurs in the U12 and U13 categories, respectively, when the game evolves from small-sized teams to adult football standards, and the number, complexity, and intensity of the training sessions increases (Rommers et al., 2020). Simultaneously, the players enter a specific period of development (i.e. peak height velocity), when they start to grow rapidly (Kemper et al., 2015; Van Der Sluis et al., 2013), and this results in a higher injury-risk in the older age-categories.

In general, our findings are in agreement with other studies where the incidence rate of injury for pubertal players tends to increase consistently, with chronological age, maturity, and quality level being identified as the risk factors (Inklaar, 1994; Le Gall et al., 2006; Price, Hawkins, Hulse, & Hodson, 2004; Robles-Palazón et al., 2022). However, it must not be ignored that there is some evidence that more mature players (i.e. older, taller and heavier) are at a greater risk of sustaining injury as a result of greater competitiveness, risk-taking, and a more aggressive style of play (Le Gall, Carling, & Reilly, 2008; Le Gall et al., 2006; Stuart, Morrey, Smith, Meis, & Ortiguera, 2002).

Strengths and limitations

The main limitation of this study is that we analyzed the injury rate within only one football academy. Thus, conclusions drawn from this study should be taken with caution and applied to

a population of similar levels and characteristics. Therefore, a broader sample including injury data from multiple elite-level academies would be of interest to practitioners working with players of high quality. Also, players released from the Academy were not followed up, thus their impact on the findings remains unclear. Finally, we were not able to clearly distinguish the influence of COVID-19 illness itself, from the possible negative connotations of the lack of training during the pandemic period and lockdown, on changes in injury incidence.

The main strength of our study is the longitudinal design that enabled the detection of the changes in injury rates during the 6-year observed period. This is especially important knowing that the observed period included the COVID-19 pandemic, as there is a significant lack of studies exploring its effects and consequences in the youth sports population. The sample of participants in this study was large as we included players from U9 to U15 age categories. As for the knowledge of the authors, this is the first study involving young age footballers that has systematically analyzed injury trends during a longer period. Finally, a significant strength is the sample of young elite football players involved in the investigation, as *** academy was rated as one of the most productive football academies in Europe in 2022 (CIES, 2022). *** academy is widely considered to be one of the best, with a large number of players originating from the Academy playing at an elite senior level across Europe.

2.1.5 Conclusion

This study demonstrated an overall decrease in the injury rates of young elite Croatian football players during six competitive seasons. More precisely, a reduction in the number of injuries in all age categories observed during the pre-pandemic period changed to an elevation of the injury rate during the pandemic period. The COVID-19-related interruption in training (resulting from illness and unavailability of training) resulted in a heightened risk of sustaining injury following the resumption of training and competition.

Future studies addressing injuries in youth football should include more variables such as injured body parts, character, type, and mechanism of injury to gain more detailed insights into injury occurrence. This would help create preventive measures for these specific younger age categories.

Clinical recommendations

The findings of this study suggest that the implementation of preventive strategies reduces the incidence of injuries in young football players. These data confirm yet again that consistent investment in the financial and human resources of football academies is necessary, as it seems to have a positive effect on youth development through a reduction in exposure-related negative outcomes such as injuries. Continuous education of football academy personnel as well as the upgradation and improvement of sports equipment used in youth clubs is of utmost importance.

Sports management staff should be extremely cautious when reincorporating young athletes into training regimens after a prolonged absence from regular exercise, especially due to viral infections. Careful, gradual, and progressive inclusion into the training process and, ultimately, competition is advised. In future studies, it is necessary to further investigate the impact of the COVID-19 infection itself on the incidence of injuries, in order to clearly determine how much training, or its absence, affects injuries, and the magnitude of the physiological changes caused by the infection.

Ethical approval

This study was done according to the Declaration of Helsinki and was approved by the ethical committee of the Faculty of Kinesiology, University of Split, with the approval number 2181-205-02-05-23-0007.

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CRediT authorship contribution statement

Jakša Škomrlj: Investigation, Project administration, Writing – original draft. **Toni Modrić:** Conceptualization, Software. **Damir Sekulić:** Conceptualization, Supervision, Writing – review & editing. **Ante Bandalović:** Data curation, Resources. **Ante Turić:** Data curation, Resources. **Boris Bećir:** Data curation, Resources. **Šime Veršić:** Conceptualization, Software, Validation, Visualization, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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2.2 Studija 2: Muscle injuries in elite youth football academy: a six-year longitudinal study on U15 football team

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Muscle injuries in elite youth football academy: a six-year longitudinal study on U15 football team

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Abstract

To develop specific preventive strategies, it is necessary to investigate in detail the occurrence of injuries in young football players. This study aimed to provide details about the type, location, severity, and contact nature of muscle injuries in elite U15 Croatian football players. A total number of 130 muscle injuries occurred during the six competitive seasons, of which 88 were DOMS injuries and 42 were rupture injuries. Specifically, 87% of all muscle injuries were to the four major groups: hamstrings (43), quadriceps (41), adductors (25), calves (6), and with only 15 injuries to the other muscle groups. The muscle injury incidence was stable during the observed period as the injury incidence rate ratio (IRR) was 1.01 (95%CI: 0.99-1.03) with 3.13 (95%CI:3.09-3.17) muscle injuries per 1000 hours of exposure in the first season and 3.06 (95%CI:3.02-3.1) in the sixth season. A significantly higher risk for muscle injuries was discovered in the competition as the incidence for the whole observed period was 7.38 (95%CI:7.29-7.47) compared to 2.25 (95%CI:2.24-2.26) in the training. Despite the relatively stable number of sustained muscle injuries, the relative proportion of muscular injuries increased over the years due to a severe decrease in total number of injuries. Regarding the proportion of the players that had sustained a muscle injury, our results suggest that approximately two out of five players can expect a muscular injury over the one-season period. Relatively high injury expectance rates, as well as reinjury rates, require specific preventive

interventions that will reduce the number and severity of new and recurred injuries. Future studies should include a wide set of predictor variables in order to establish the most important injury risk factors.

Keywords: academy, football, elite, muscle, injury

2.2.1 Introduction

Football is one of the most demanding sports in terms of injuries (Robles-Palazón et al., 2022). Highly intensive and repetitive changes of directions, accelerations, decelerations, jumps, kicks, and tackles represent a significant risk of sustaining injury. This is also present in youth football as young players train intensively while going through different phases of growth and development (Read, Oliver, De Ste Croix, Myer, & Lloyd, 2018). Clubs all around the world have organized football academies where children from the age of 8 to 19 are training and are being prepared for the demands of senior-level football. For young players to develop properly and progress in all aspects of football, regular exposure to training and match loads is essential. The occurrence of an injury sidelines the player from training for a specific amount of time, which leads to a decline in his fitness abilities and disrupts the process of the player's football development (Barguerias-Martínez et al., 2023). This can also affect young player's well-being and mental health as their ambitions and sports goals are being interrupted (S. Jones et al., 2019). For this reason, it is necessary to investigate in detail the occurrence of injuries in young football players in order to develop specific preventive strategies. The first step in that process is to determine the characteristics of youth football injuries by type, location, mechanism, and severity (Robles-Palazón et al., 2022).

While among senior football players, this topic is well covered, it is not the case in the population of young players, where there is a lack of systematic prospective studies on individual age categories (Robles-Palazón et al., 2022). This is particularly important to identify for players in the pubertal phase, between 13 and 16 years of age. This period corresponds with the highest annual gains in body height and body mass or the appearance of the peak high velocity (PHV) (Kyprianou et al., 2022; A Van der Sluis, Elferink-Gemser, Brink, & Visscher, 2015). Adolescent awkwardness is a known phenomenon used to describe this period when the muscles are not still fully developed in terms of size and strength, while the trunk and extremities already increased significantly (Alien Van Der Sluis et al., 2013). This disproportion can potentially cause an imbalance in strength and flexibility features and can

lead to bad movement mechanics, compensations, and even a decline in motor performance (Beunen & Malina, 1988; Alien Van Der Sluis et al., 2013). Finally, this drop in motor abilities and skills, and the inability to withstand the high intensity to which the tissues of young soccer players are exposed, represent a significant risk factor for injury (Alien Van Der Sluis et al., 2013). This is supported by recent studies, for example, the one on young Dutch football players showed that athletes had significantly more traumatic and overuse injuries in the year of PHV than in the year before PHV (Alien Van Der Sluis et al., 2013). Studies showed that youth football players of pubertal age have 5.3 injuries/1000 h of football exposure which is significantly higher than players of prepubertal age (1.6 injuries/1000 h) (Robles-Palazón et al., 2022). Also, a study on six English professional football academies indicated that the highest rate of severe injuries among young players occurs in the U15 categories (Read et al., 2018). This increased likelihood of injuries is explained by maturation effects and increasing demands of training and competition (Robles-Palazón et al., 2022).

In general, studies reported muscle strains, along with sprains as the most common injury type, while the thigh was the most frequently injured anatomical body part in youth football (Read et al., 2018; Robles-Palazón et al., 2022). In particular, hamstring and quadriceps muscle injuries have been regularly reported as the most common (Price, Hawkins, Hulse, & Hodson, 2004; Raya-González, Suarez-Arrones, Larruskain, & de Villarreal, 2018). Muscle injuries represent one of the major problems in both senior and youth football, with a proportion of up to 37% of all injuries (Ekstrand, Hägglund, & Waldén, 2011). Recent studies reported that the number of muscle injuries is not declining, despite advances in diagnostics, therapies and training methodology, and has even increased in the last 20 years (Ekstrand et al., 2023). Muscle injuries are usually classified as either functional or structural, with functional being classified as fatigue-induced neurogenic injuries and structural being muscle tears of fibers or bundles (Ekstrand et al., 2011). Muscle injuries are mostly non-contact and are the focus of sports scientists and practitioners as they are caused by several controllable factors and can therefore be prevented in some amount (Almeida, Maher, & Saragiotto, 2018; Sintes & Caparrós, 2019; van der Horst, 2018). Although this is a multifactorial health problem in which risk factors are often in cause-and-effect relationships, studies have highlighted several clear risk factors (Arnason et al., 2004; Hägglund, Waldén, & Ekstrand, 2013). Some of these factors such as age, previous injuries and surface conditions cannot be controlled (Cardoso-Marinho et al., 2022; Svensson, Alricsson, Olausson, & Werner, 2018). On the other side player's range of motion, muscle strength and flexibility, physical fitness and mechanical load imposed on

players are something that coaches can and must take care of (Arnason et al., 2004; Hägglund et al., 2013).

Given that studies have shown that systematic strength and conditioning training, proper warm-up and workload monitoring can reduce their incidence, it is necessary to determine in detail the profile of muscle injuries in young soccer players and to monitor their occurrence over a longer period (Cardoso-Marinho et al., 2022). Considering the limited body of knowledge in terms of muscle injury classification among elite young pubertal football players, and particularly the absence of this kind of study on the sample of Croatian youth players, the main aim of this study was to identify the incidence of muscle injuries among U15 football players over a six-year period. The authors aimed to provide details about the type, location, severity, and contact nature of muscle injuries in order to give guidelines for the creation of specific preventive programs.

2.2.2 Methods

Study design

This longitudinal study observed injury occurrence and characteristics in the U15 category of an elite Croatian football academy. The studied period included six competitive seasons, starting from the season 2016/2017 and lasting until the 2021/2022 season. The injury data was extracted from the academy database. All the players were notified about the purpose of the study. Written informed consent was obtained from the parents or legal guardians of all participants, considering they were underage. This study was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Kinesiology (Ethical Approval Number: 2181-205-02-05-23-0007).

Participants

The sample of participants comprised 278 young male football players (age range = 13.6-15.6). The sample is considered elite as the players were part of football academy competing at the highest level of the domestic championship. All playing positions, including goalkeepers, were analysed in this study. In the observed period, this age category averaged 5.5 training sessions (e.g., team training, strength training and individual training) and 1 match per week throughout

the season, respectively, with at least one day during the week without organized football exposure. The warm-up strategies used in the academy are provided in the Supplementary file. The exposure accounted for the preparatory and competitive period, excluding the transition period without team training. Due to a regular fluctuation of the roster during winter break (e.g., dissatisfied players changing between the teams), and to avoid potential bias of the results, only the players that completed the full competitive season were included in the final sample. Confidentiality of the extracted injury data was preserved, as all the participants were given a code number known only to the authors.

Variables

Medical professionals recorded muscle injuries during the regular daily medical check-ups, occurring right before or after the training session or match. All injuries were reported to the internal database and were immediately shared among the different compartments of the club. Muscle injuries were recorded and classified either as (i) functional muscle injuries represented as Delayed Onset Muscle Soreness (DOMS) or (ii) structural injuries i.e. ruptures (a partial, or complete tear of muscle fibers). The accuracy and the consistency of the clinical diagnosis were obtained with the use of ultrasound imaging. Permission for return to play was granted by the medical doctor once the ultrasound imaging showed a total healing of the tissue, with pain-free contraction of the muscle and an appropriate overall fitness status evaluated by the whole medical and coaching staff. A reinjury was defined as an injury to the same location and categorized as the same type after the player had returned to full participation following the initial injury. Injury severity, expressed as a total number of days in absence from training, was presented separately for DOMS and rupture injuries, respectively. Football exposure was calculated for all the observed seasons and was reported as the number of training and match hours. The total player-match exposure time in hours for a team was given by (N_m * P_m * D_m /60) where N_m is the number of team-matches played, P_m is the number of players in the team, and D_m is the duration of the match in minutes. Similarly, the total training exposure time in hours is given by (P_t * D_t /60), where P_t is the number of players attending a training session and D_t is the duration of the training session in minutes. Exposure time was adjusted for the 2019/2020 season, where there was a complete cessation of training due to the COVID-19 lockdown. Specifically, muscle injury incidence was calculated as the number of muscle injuries sustained per 1000h of the training and match exposure, respectively. Also, injuries

were classified as new one or a reinjury, according to the affected body region, contact nature of injuries, and training/game occurrence.

Statistics

Descriptive data was presented, including arithmetic means and standard deviations. The muscle injury incidence was calculated as the number of injuries sustained per 1000h of exposure. The injury incidence rate ratio, along with the 95% confidence intervals, were calculated between the first and the last observed season.

MedCalc Statistical Software (version 19.2.6), Microsoft Excel 2019 (Microsoft, USA) and SPSS software (IBM, SPSS, version 25.0) were used for the analysis. The level of statistical significance was set at $p < 0.05$.

2.2.3 Results

A total of 130 muscle injuries were recorded during the six-year period with 42 of them defined as ruptures and 88 as DOMS (Table 1). Structural muscle injuries (i.e. ruptures) sidelined players from team training and competition for 25.8 days on average, while DOMS resulted in 7.5 days of average absence. Approximately every fifth muscle injury was re-injury and the vast majority were described as non-contact.

Table 1. Descriptive data.

	No. of injuries	Days out	Re-injury	Training	Match	Unknown	Contact	Non-contact	IRR 1-6 years (95%CI)
Rupture	42	25.8	9	28	11	3	6	36	1.01 (0.99-1.03)
DOMS	88	7.5	20	71	16	1	7	81	
Total	130	13.5	29	99	27	4	13	117	

Injury incidence was stable during the observed period as the injury incidence rate ratio (IRR) was 1.01 (95%CI: 0.99-1.03), with 3.13 (95%CI:3.09-3.17) muscle injuries per 1000 hours of

exposure in the first season and 3.06 (95%CI:3.02-3.1) in the sixth season (Table 1 and 2, and Figure 1). A significantly higher risk for muscle injuries was present in the games as the incidence for the whole observed period was 7.38 (95%CI:7.29-7.47) compared to 2.25 (95%CI:2.24-2.26) in the training.

Table 2. Muscle injuries/1000 h of exposure

Season	Overall	Muscle injuries Training	Match	All injuries
2016/2017	3.13 (3.09-3.17)	2.73 (2.69-2.77)	6.56 (6.34-6.76)	11.92 (11.84-11.99)
2017/2018	2.51 (2.47-2.54)	1.93 (1.9-1.96)	9.84 (9.59-10.1)	6.33 (6.27-6.38)
2018/2019	2.86 (2.82-2.89)	2.15 (2.12-2.18)	8.20 (7.97-8.43)	6.83 (6.78-6.89)
2019/2020	2.11 (2.07-2.14)	1.69 (1.66-1.72)	6.90 (6.68-7.11)	5.06 (5.01-5.11)
2020/2021	2.66 (2.62-2.69)	2.22 (2.18-2.25)	6.45 (6.25-6.65)	5.31 (5.26-5.36)
2021/2022	3.06 (3.02-3.1)	2.90 (2.86-2.94)	4.92 (4.74-5.09)	6.65 (6.59-6.71)
All	2.73 (2.71-2.74)	2.25 (2.24-2.26)	7.38 (7.29-7.47)	7.02 (6.96-7.08)

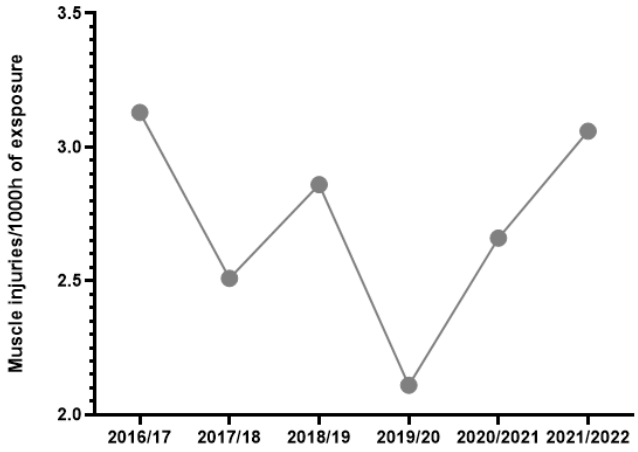

Figure 1. Muscle injuries/1000 hours of exposure

The majority of the injuries occurred to the lower body, with hamstrings (N=43) and quadriceps (N=41) being injured most frequently. Besides these two groups, U15 players suffered significant amounts of adductor injuries (N=25), while only six calf injuries were reported in the observed period.

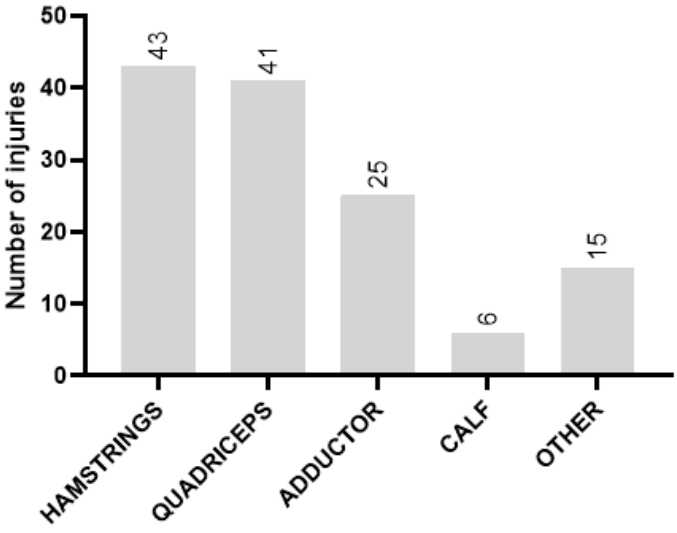

Figure 2. Muscle injuries by injured region

Table 3. Number of players, total and muscle injuries and incidence rate

Season	Registered players	Players with muscle injuries	Incidence rate	Total injuries	Total muscle injuries
2016/2017	45	21	0.47	99	26

2017/2018	52	19	0.37	53	21
2018/2019	47	16	0.34	55	23
2019/2020	46	13	0.28	36	15
2020/2021	45	14	0.31	44	22
2021/2022	43	18	0.42	50	23

The proportion of muscle injuries had an increased trend during the six-year period, with 26% and 46% of all injuries classified as muscle ones in the first and the last season respectively (Table 3 and Figure 3). However, the absolute number of muscle injuries remained relatively stable.

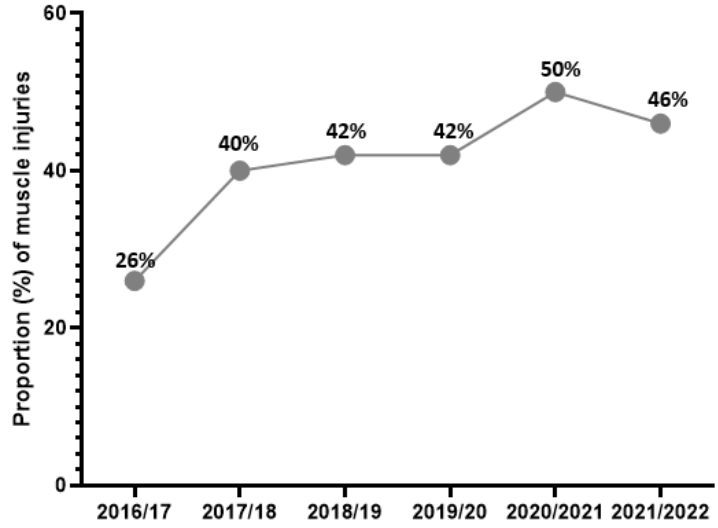

Figure 3. Proportion of muscle injuries

Figure 4 shows that the incidence rate of players suffering a muscle injury had a downward trend until the 2019/2020 season (i.e. from 46.7% to 28.3% of players with muscle injuries), with that trend being altered and rising up to 41.9% in the last season. This implies that in the U15 team of 20 players, approximately eight of them can expect muscle injury over the one-season period.

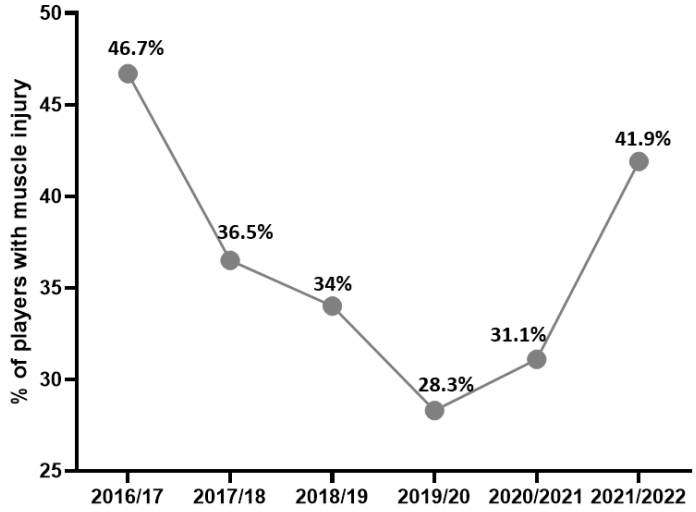

Figure 4. Proportion of players with muscle injuries

2.2.4 Discussion

There are several important findings of the study. First, the results suggest a relatively stable muscle injury incidence throughout the study period. Second, the hamstrings and quadriceps muscles are the most injured body parts. Lastly, the evidence indicates that 40% of players in this category are expected to sustain a muscle injury during the season.

Injury incidence

The results of this study have shown a slightly higher overall injury incidence compared to the recent meta-analysis on a similar sample (i.e. U13-U16 players) (7.02/1000h vs 5.3/1000h, respectively) (Robles-Palazón et al., 2022). However, when compared to the Swedish players of the same age, our players displayed almost the same injury rates (7.02/1000h vs 6.8/1000h) (Timpka, Risto, & Björmsjö, 2008). More specifically, the mean muscle injury incidence in our study is found to be 2.73/1000h. Similarly, investigators reported a muscle injury rate of 3.2/1000h in a group of U13-U18 Middle Eastern football players (Wik et al., 2021). Interestingly, the number of muscle injuries remains quite stable throughout the six competitive seasons, as there is no significant difference between the years, which is reflected in the IRR of 1.01 between year one and year six. Regarding the injury time trends, a major 18-year prospective cohort study revealed a gradual decrease in training and match injury rates of professional football players (Ekstrand, Spreco, Bengtsson, & Bahr, 2021). However, as far as

muscle injury trends are concerned, the situation is quite the opposite. For example, the number and severity of hamstring injuries doubled in the last 21 seasons, with muscle injuries increasing by 6.7% annually over the last 8 seasons (Ekstrand et al., 2023). This increment is explained through a continuous increase in both intensity (i.e., higher volume of running at higher velocities) and total amount of international team travel and matches.

Although minimal, an evident annual decrease in injuries was present up until the season 2019/20, from which the number of injuries rose again. This trend change coincides with the emergence of the COVID-19 pandemic. The pre-pandemic injury drop can be explained by the current use of scientifically proven training methodologies that have been shown to reduce the risk of injury (Le Gall, Carling, & Reilly, 2008). These include better preventive measures, more developed training methods and player and coach education, all of which were being applied in the here-stated academy. Since the start of the global pandemic, there has been a lack of studies as there are only a few of them that have examined the effect of the COVID-19 disease on injury occurrence in football, and especially in youth players (Mannino et al., 2023; Martens et al., 2021). The interruption-related training maladaptation, lack of medical evaluation, inadequate re-training period, congested competition schedule and the negative effect of the disease itself are all associated with the rise in injuries following the comeback to sport (Škomrlj et al., 2024).

In line with the existing data, a much higher match than training incidence was observed in this study (7.38/1000h vs 2.25/1000h, respectively). For example, a 10-year study on the elite French U13-U16 football players revealed an injury incidence of 11.2/1000h and 3.8/1000h, for match and training, respectively (Le Gall et al., 2006). Among other factors, underlying explanations include greater playing demands and intensities in competition, number of contacts and collisions, and fatigue accumulation during the match (Bangsbo, Mohr, & Krustrup, 2006; Price et al., 2004; Wik et al., 2021). Also, match-induced psychological arousal, observed mainly through higher competitiveness and more aggressive play, results in elevated injury risk (Le Gall et al., 2008).

Location and type of injuries

The results suggest the thigh as the most commonly injured body area, with hamstrings being slightly more injured than the quadriceps muscle. In accordance with our results, the upper leg (i.e., anterior and posterior thigh) has been considered to be the most common injury location

in youth football players (Bourogiannis, Hatzimanouil, Semanltianou, Georgiadis, & Sykaras, 2023; Ergun, Denerel, Mehmet, & Ertat, 2013; Price et al., 2004). Generally, previous epidemiologic studies in adult football players have shown that the hamstring group is the single most injured muscle (Ekstrand et al., 2023; A. Jones et al., 2019). It is important to highlight the architectural specifics of the muscle, as the hamstrings are a multi-joint muscle group with dual innervation and a great proportion of fast-twitch fibers (Raya-González, de Ste Croix, Read, & Castillo, 2020). These anatomic characteristics can, in some cases, result in a disruption of running coordination patterns and increase injury risk, as it is known that hamstring injuries mostly occur during running, especially at higher velocities (Huygaerts et al., 2020; Schache, Dorn, Blanch, Brown, & Pandy, 2012). The injury to the hamstrings typically happens during the active lengthening of the muscle (i.e., eccentric muscle contraction), with the late swing phase of the running gate cycle responsible for 81% of strains (Danielsson et al., 2020). With almost the same injury occurrence as hamstrings, the quadriceps muscle also seems to be a vulnerable area and is sometimes regarded as the most injured muscle in the youth population (Cloke et al., 2012). For example, Pietsch et al. recently reported that previous quadriceps injury, recent hamstring injury, the dominant kicking leg and competitive match play were all strongly associated with quadriceps injury (Pietsch & Pizzari, 2022). Regarding the quadriceps injury mechanism, the kicking action is identified as the most common, due to a high volume of passing and shooting, with quadriceps being the main agonist in these movements (Hägglund et al., 2013). Further, adductor muscles are also common injury sites in football, with highly intense and repetitive movements such as kicking, change of direction and inside passing (Markovic, Šarabon, Pausic, & Hadžić, 2020). The hip-groin-pelvis region is highly affected in the PHV period when muscles and tendons adapt slowly to changes in limb length and body mass and are thereof reduced capacity for producing and sustaining force (Dupré & Potthast, 2020; Monasterio et al., 2021). It is interesting to note that 87% of all muscle injuries included four big muscle groups in the lower limb. Comparably, Ekstrand et al. reported that 92% of all muscle injuries affect the hamstrings, quadriceps, adductors and calves in professional footballers (Ekstrand et al., 2011).

A considerably higher amount of DOMS injuries was noticed, in contrast to muscle ruptures (88 vs 42, respectively). Moderate severity (i.e., injury lasting shorter than 28 days) was observed for both types of injuries, with DOMS resulting in 7.5 days lost from training, compared to 25.8 days of time loss due to muscle rupture. As previously mentioned, this result is not surprising because, unlike ruptures, DOMS is not characterized by structural fiber

damage. Similarly, a 4-year prospective study revealed a median of 4.2 and 22.5 days of time-loss, for DOMS and muscle tears, respectively (MCNAUGHTON et al., 2020). The re-injury rate was the same for DOMS and muscle ruptures, with every fifth injury being a re-injury. The same is reported in a study by Hawkins et al., where 22% of injuries are relapses of a previous injury (Hawkins & Fuller, 1999). Such a high re-injury rate may be explained by a premature attempt to return to unrestricted activity, with the injured tissue not being fully reorganized and healed (Cloke et al., 2012).

Proportion of muscle injuries

In general, there is an evident increase in the proportion of muscle injuries throughout the 6-year period. As the total number of other injuries (e.g., bone and joint injuries) decreased over the years, a relative increase in muscle injury incidence occurred due to a relatively stable absolute number of muscle injuries. On average, 41% of all injuries incurred are related to the muscular system. This is in agreement with previous studies, where 37% and 45% of injuries at elite senior and youth levels were observed, respectively (Ekstrand et al., 2011; Renshaw & Goodwin, 2016).

The proportion of players that had sustained a muscle injury gradually decreased until the 2019/20 season, when this trend was altered, assumingly because of the negative effects caused by the COVID-19 pandemic mentioned earlier. Since the authors of the study are coaches at here observed football academy, we assume that preventive measures, including regular and supervised strength, balance and coordination training, combined with a regular medical examination, may be the crucial factor responsible for the reduction in the number of injured players. However, results suggest that approximately two out of five players in the U15 sustained an injury, regardless of the advanced training methodology employed. As discussed above, the circa-PHV players, especially those in the U15 age category, are predisposed to higher muscular injury risk due to disruption in motor control and anthropometric discrepancies (Bult, Barendrecht, & Tak, 2018; Alien Van Der Sluis et al., 2013).

Strengths and limitations

This study has some limitations that need to be considered. First, the sample included only the players from one category of one football academy. However, as there is an evident lack of data

on the specific age groups, this study may enable comparisons with football academies from other geographic regions. Further, it is possible that for various reasons (e.g. players refusing to report musculoskeletal problems, coaches forcing players to train), some injuries were not reported, thereby biasing the data set. Nevertheless, medical staff meticulously gathered and classified all the injuries according to consensus statements, therefore validating all the reported data in terms of injury surveillance in football (Fuller et al., 2006). Also, a lack of the follow up for the released players is one of the study limitations, as these players could have possibly been the ones that were injured the most, thereby biasing the dataset. Regarding the main strengths of the study, the elite sample of players analysed over the course of six years are two of the most significant. Additionally, detailed and specified information about muscle injuries, based on the mentioned consensus statement, is provided.

2.2.5 Conclusions

A total number of 130 muscle injuries was reported during the six seasons, with a much higher number of DOMS injuries compared to rupture injuries (88 vs 42, respectively) in the elite U15 Croatian football players. The occurrence of muscle injuries decreased during pre-pandemic, with a slight change in injury trend observed at the start of the COVID-19 pandemic. The hamstrings, quadriceps, adductors and calves are the most injured muscles, contributing to 87% of all muscle injuries. Finally, muscle injuries account for approximately 40% of all injuries, with two out of five players expected to sustain a muscle injury during the competitive season.

Detailed injury information provided in this study may enable the creation of specific training interventions aimed at reducing the number of muscle injuries. Specifically, preventive measures targeting the most affected lower body regions should be carried out regularly in this age category, focusing on muscle strength, endurance, flexibility and balance between the dominant and non-dominant side. Moreover, with the reinjury expectance being approximately 20%, special attention to the previously injured players is needed to reduce this relatively high reinjury rate.

Guidelines for future studies include incorporation of the broad set of predictor variables and investigation of their influence on muscle injury occurrence.

Author Contributions

Conceptualization, A.B. and B.B.; Methodology, T.M.; Investigation, O.U.; Data curation, M.G.K.; Writing—original draft, J.S. and A.T.; Writing—review & editing, S.V.; Supervision, D.S. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of the University of Split, Faculty of Kinesiology (Ethical Approval Number: 2181-205-02-05-23-0007).

Informed Consent Statement

Written informed consent was obtained from the parents or legal guardians of all participants.

Data Availability Statement

The data presented in this study is available on request from the

corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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2.3 Studija 3: Understanding Injury Dynamics in Youth Soccer: A Six-Season Study of Traumatic and Overuse Injuries

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ORIGINAL SCIENTIFIC PAPER

Understanding Injury Dynamics In Youth Soccer: A Six-Season Study Of Acute And Overuse Injuries

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Abstract

Despite extensive research on adolescent and late-pubertal soccer players, there is limited longitudinal data on injury incidence in prepubertal and early pubertal soccer players. This study aimed to analyze the incidence and distribution of traumatic and overuse injuries in youth soccer players aged 8 to 15 years over six competitive seasons. A prospective cohort study was conducted on 811 youth soccer players from a professional soccer academy, tracking injuries across six seasons (2016/17–2021/22). Injury data were extracted from medical records and classified based on the FIFA consensus statement. Injuries were categorized as traumatic or overuse, with incidence expressed per 1000 hours of exposure. While the distribution of traumatic and overuse injuries remained consistent across age categories, younger players exhibited a higher proportion of overuse injuries, whereas older players sustained more traumatic injuries. Additionally, injury incidence increased with age, with the highest number recorded in U15 players. The overall traumatic-to-overuse injury ratio was approximately 50:50, differing from patterns seen in senior-level players. Injury incidence in youth soccer players follows an age-related trend, with overuse injuries being more prevalent in younger players and traumatic injuries increasing with age. These findings highlight the need for age-specific injury prevention programs, emphasizing proper workload management for younger players and injury mitigation strategies for older athletes. Future research should investigate long-term injury trends and predictors across multiple clubs to optimize player development and safety.

Keywords: youth soccer, injury incidence, traumatic injuries, overuse injuries, player development, injury prevention

2.3.1 Introduction

Youth football participation expands worldwide, with more and more children being registered in domestic clubs and associations every year. Due to the growing interest and related intensified competition, the training and selection process in youth football has gotten more challenging, with stronger, faster, and more agile children being selected (Fortin-Guichard et al., 2022; Mikić, Marasović, Rađa, Erceg, & Sivrić, 2024). Studies have shown that the intensity of play in youth football, primarily observed through an increase in the number of explosive actions, progressively increases with the age of the players (Di Giminiani & Visca, 2017; Ergun, Denerel, Mehmet, & Ertat, 2013; Sermaxhaj et al., 2024; Wagner et al., 2023). Related to this, an increased load is necessary for the development of players' skills and capacities, as well as for their preparation and adaptation to the demands of the senior level (Rabbani, Wong, Clemente, & Kargarfard, 2021). Due to this increased training and game load, injuries are an inevitable part of the overall process (Bourogiannis, Hatzimanouil, Semanltianou, Georgiadis, & Sykaras, 2023; Eckard, Padua, Hearn, Pexa, & Frank, 2018). Despite advancements in knowledge, technology, and the growing number of professionals involved in training, the continuous rise in injury rates remains a serious issue in this population of athletes (Bourdon et al., 2017; Price, Hawkins, Hulse, & Hodson, 2004). Injuries disrupt the development of young athletes by negatively affecting their future performances and keeping them away from sports training for a period of time, thereby slowing down the development of relevant abilities (Jones et al., 2019). Given the growing interest in football, a comprehensive investigation into injury occurrence in this vulnerable population is essential to create a safer environment for young participants.

Due to the importance of this topic and the sensitivity of the observed population, the issue of injuries in young football players have been extensively studied (Jones et al., 2019; Nilsson, Östenberg, & Alricsson, 2016; Read, Oliver, Croix, Myer, & Lloyd, 2015; Rössler, Junge, Chomiak, Dvorak, & Faude, 2016). Studies conducted on football players from the U9 to U21 categories indicate an injury rate ranging from 1.3 to 21.1 per 1000 hours of exposure, with a mean of 5.8 injuries per 1000 hours of exposure (Weishorn et al., 2023). Notably, as players age, both the absolute number of injuries and the proportion of injured players within a team increase (e.g. 22% in older players (U18 to U21) versus 10% in younger players (U9 to U16) (Jones et al., 2019). The injury rate is higher in older players (U17 to U21), reaching 7.9 injuries per 1000 hours, compared to younger categories (U9 to U16), which record 3.7 injuries per 1000 hours (Jones et al., 2019). Interestingly, authors suggest that footballers over the age of

14 exhibit injury characteristics similar to adult players in terms of injury type, location, mechanism, and even frequency (Hägglund, Waldén, & Ekstrand, 2009; Junge & Dvorak, 2004). Chronologically older and more physically developed players tend to play more aggressively, take greater risks, and engage in a significantly higher number of physical duels, much like senior players, which directly correlates with an increased risk of injury (Le Gall et al., 2006). While numerous studies focus on footballers in late puberty and adolescence, there is a significant lack of research on prepubertal children (Faude, Rößler, & Junge, 2013). The available data indicate an overall injury incidence of 0.1 to 1.6 injuries per 1000 hours for children under 12 years old (Faude et al., 2013; Rinaldo, Gualdi-Russo, & Zaccagni, 2021). The lower number of injuries in this age group can be attributed to several factors, including the lower intensity of play and generally fewer training hours (Rinaldo et al., 2021; Rommers et al., 2020). Due to inter-individual differences in the growth and maturation process, it is crucial to examine injury characteristics in the youngest age categories, as their physical development presents unique challenges. Between the ages of 11 and 13 in female children and 13 and 15 in male children, rapid skeletal growth occurs—a phase known as peak height velocity (PHV). Research suggests that during this period, as well as one year before and after PHV, young athletes are at an increased risk of both traumatic and overuse injuries. This heightened susceptibility is likely due to increased physical load, reduced load resistance caused by adolescent "clumsiness," and pre-existing growth-related pain syndromes (Bult, Barendrecht, & Tak, 2018; Materne, Farooq, Johnson, Greig, & McNaughton, 2016; Van der Sluis, Elferink-Gemser, Brink, & Visscher, 2015).

Among the youngest football players, the most common traumatic injuries are bone fractures, particularly of the tibia and forearm bones. These injuries are often attributed to the immaturity of the skeletal system and insufficiently developed falling techniques. Since training intensity increases with age, excessively intense training sessions introduced too early can lead to overuse injuries and even burnout syndrome, especially when combined with inadequate rest and recovery protocols (Brenner, Medicine, & Fitness, 2007; Brink et al., 2010). Additionally, growth-related injuries, such as Osgood-Schlatter disease (which peaks in the U14 category) and Sever's disease (which peaks in the U11 category), are common issues in youth football and affect approximately 17% of pre-adolescent players (Schultz, 2022). Due to their more developed bodies and higher levels of strength and power, older players are more prone to traumatic injuries, which predominantly include knee and ankle sprains, muscle lesions, and contusions (Wik et al., 2021).

A review of the literature highlights a lack of systematic longitudinal studies examining injury frequencies by type in prepubertal and early pubertal youth football players. Tracking the distribution of injuries over the years of growth and development is essential for assessing the adaptation of young athletes to football-specific training. Therefore, the present study aims to determine the frequency of both traumatic and overuse injuries in soccer players aged 8 to 15 years. By identifying injury patterns in this population, these findings can contribute to developing appropriate training strategies and optimizing training loads, ensuring that young football players are trained safely and effectively. A deeper understanding of injury risks in younger athletes is crucial for fostering long-term athletic development while minimizing injury-related setbacks.

2.3.2 Methods

Study design

This prospective cohort study examined the frequency and characteristics of traumatic and overuse injuries in youth soccer players aged 8 to 15 years. The study was conducted over a multi-season period, tracking injury incidence and distribution across different age categories. Injury data were extracted from the internal medical database of a professional football academy. Before participation, all players and their legal guardians were informed about the purpose and methodology of the study, and written informed consent was obtained. The study was conducted in accordance with the Declaration of Helsinki and received approval from the Ethics Committee of the Faculty of Kinesiology (Ethical Approval Number: 2181-205-02-05-23-0007).

Participants

A total of 811 youth soccer players (age range 8–15 years) were included in this study. All participants were registered players of a professional youth football academy, competing in their respective age categories (U9, U11, U13, U15). Players were included from the moment of their registration and were excluded immediately upon leaving the academy. In order to ensure data consistency, only players who completed a full competitive season were included in the final analysis. Confidentiality of the extracted injury data was maintained by assigning anonymous identification codes to each participant, known only to the research team.

Figure 1. Time line of the study protocol with number of subjects tested in each competitive season

Variables and data collection

All injuries were systematically recorded and classified by medical professionals of the academy during daily medical check-ups before or after training sessions and matches. Injury classification was based on the consensus statement of the FIFA Medical Assessment and Research Centre (Fuller et al., 2006). Injuries were classified as either acute (traumatic) injuries or overuse injuries based on their mechanism of occurrence. Acute injuries were defined as those resulting from a specific, identifiable event, such as fractures, sprains, or contusions, whereas overuse injuries were attributed to repetitive microtrauma without a clear incident, including conditions like tendinopathies, Osgood-Schlatter disease, and Sever's disease. Injury severity was assessed based on time lost from training and competition, and football exposure was calculated for each season by summing the total training and match hours per player. Adjustments were made for the 2019/2020 season to account for training interruptions caused by the COVID-19 pandemic. Injury incidence was expressed as the number of injuries per 1000 hours of exposure, with injuries further categorized by type, anatomical location, and severity. Additionally, the proportion of traumatic vs. overuse injuries was analyzed across age groups, while reinjury was defined as an injury occurring at the same location and of the same type after the player had returned to full participation.

Statistics

Descriptive data were presented as arithmetic means and standard deviations. The muscle injury incidence was calculated as the number of injuries sustained per 1000 hours of exposure, while the injury incidence rate ratio (IRR) and 95% confidence intervals were computed to

compare injury rates between the first and last observed seasons. To examine differences between acute and overuse injuries, a chi-square test was performed using an online statistical calculator. The level of statistical significance was set at $p < 0.05$. Statistical analyses were conducted using MedCalc Statistical Software (version 19.2.6), Microsoft Excel 2019 (Microsoft, Redmond, WA, USA), and SPSS (IBM, Armonk, NY, USA, version 25.0).

2.3.3 Results

Injury incidence for all age categories, expressed as the number of injuries per 1000 hours of exsposure is presented in Table 1, separately for traumatic, overuse and overall injuries. Additionally, the ratio between traumatic and overuse injuries is presented with values above 1 indicating more traumatic injuries for specific categories and seasons, and vice versa.

Table 1. Injury incidence /1000 h of exsposure

Season	Category	Trauma	Overuse	Overall	Trauma/overuse ratio
16/17	U9	0.87	0.87	1.74	1.00
	U11	1.72	4.17	5.88	0.41
	U13	3.27	4.12	7.39	0.79
	U15	6.98	4.93	11.92	1.41
17/18	U9	0.00	1.45	1.45	0.00
	U11	3.04	2.03	5.06	1.50
	U13	4.66	3.73	8.39	1.25
	U15	3.22	3.10	6.33	1.04
18/19	U9	1.38	0.69	2.07	2.00
	U11	4.17	2.45	6.62	1.70
	U13	3.66	3.18	6.84	1.15
	U15	3.35	3.48	6.83	0.96
19/20	U9	0.42	1.25	1.66	0.33
	U11	1.04	1.82	2.85	0.57
	U13	3.02	3.96	6.98	0.76
	U15	2.39	2.67	5.06	0.89
20/21	U9	1.08	0.36	1.44	3.00
	U11	0.87	0.87	1.74	1.00

	U13	1.34	1.78	3.12	0.75
	U15	2.41	2.90	5.31	0.83
21/22	U9	0.35	0.35	0.69	1.00
	U11	1.60	1.20	2.80	1.33
	U13	2.91	2.32	5.23	1.25
	U15	3.86	2.79	6.65	1.38

The injury incidence rate ratios (IRR) (Table 2) were calculated for the overall sample and individual age categories between 2016/17 and 2021/22, showing a general decrease in injury incidence across all groups (IRR = 1.73, 95% CI: 1.35–2.22). The most significant decline was observed in the U9 category (IRR = 2.25, 95% CI: 0.92–5.49).

Table 2. Injury incidence rate ratio, comparison between year 1 and year 6 with 95% condifence intervals

	IRR 1-6	95% CI	
ALL	1,73	1,35	2,23
U9	2,25	0,92	5,49
U11	2,10	1,34	3,13
U13	1,41	1,05	1,86
U15	1,79	1,45	2,18

Figure 1 presents the total number of both traumatic and overuse injuries for each category in the observed period. Results suggest a higher number of overuse injuries in all categories except the oldest, U15 (126 traumatic vs 106 overuse).

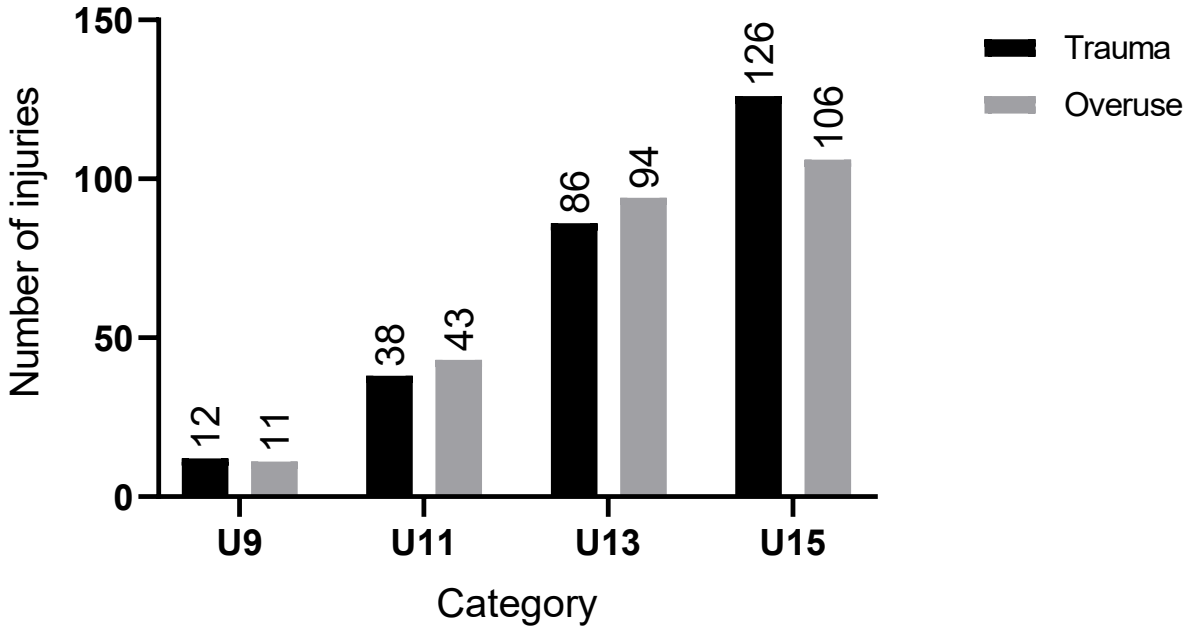

Figure 1. Total number of traumatic and overuse injuries per category

The results of the chi-square test are presented in Table 3 and show no significant differences between the number of players suffering traumatic compared to players with overuse injuries. For the U9 category in the second season, no traumatic injuries were recorded so the calculations were conducted for the remaining three categories.

Table 3. Differences between the number of players with traumatic and overuse injuries (Chi-square test - $\chi 2$)

Season	Category	Trauma		Overuse		$\chi 2$ (p)
		N	%	N	%	
16/17	U9	3	20%	2	13.3%	6.47
	U11	5	17.9%	14	50.0%	(0.09)
	U13	14	32.6%	22	51.2%	
	U15	31	68.9%	24	53.3%	
17/18	U9	0	0%	3	21.4%	0.22
	U11	8	29.6%	7	25.9%	(0.89)
	U13	21	52.6%	16	42.1%	
	U15	19	42.3%	18	38.5%	
18/19	U9	4	17.4%	2	8.7%	

	U11	10	36.7%	7	26.7%	0.97
	U13	14	35.7%	15	40.5%	(0.81)
	U15	17	40.4%	16	38.3%	
19/20	U9	1	4.2%	2	8.3%	1.05
	U11	4	11.4%	5	14.3%	(0.79)
	U13	12	30.0%	15	37.5%	
	U15	15	32.6%	12	26.1%	
20/21	U9	3	13.6%	1	4.5%	1.35
	U11	3	9.1%	4	12.1%	(0.72)
	U13	8	19.5%	10	24.4%	
	U15	17	37.8%	17	37.8%	
21/22	U9	1	4.5%	1	4.5%	0.13
	U11	7	20.0%	5	14.3%	(0.98)
	U13	16	38.6%	13	31.8%	
	U15	20	51.2%	14	34.9%	
OVERAL	U9	12	9.9%	11	9.1%	2.26
L	U11	37	20.1%	42	22.9%	(0.52)
	U13	84	34.7%	92	37.9%	
	U15	120	45.4%	101	38.1%	

2.3.4 Discussion

This study aimed to analyze the incidence of traumatic and overuse injuries in soccer players aged 8 to 15 years, revealing several key findings. The most notable result is that there were no significant differences in the types of injuries across individual age categories, indicating a consistent injury distribution throughout development. However, younger players exhibited a slightly higher incidence of overuse injuries, whereas older players sustained more traumatic injuries. Moreover, the findings confirm that injury incidence increases with age, as older players experienced a greater total number of injuries compared to younger age groups. Finally, the overall number of acute and overuse injuries was similar across all age groups, suggesting a balanced occurrence of both injury types.

The absence of significant differences in the distribution of traumatic and overuse injuries across individual age categories suggests a consistent injury pattern throughout player development. This finding indicates that, despite physiological and biomechanical changes associated with growth, young soccer players experience similar proportions of acute and overuse injuries at different stages of development. Such results align with previous research emphasizing that both traumatic and overuse injuries remain prevalent across youth age groups (Pulici, 2024). A similar distribution of injury types may reflect the structured training methodologies and injury prevention programs implemented at the academy, ensuring balanced workloads across different age categories. Additionally, the lack of significant variation in injury type suggests that injury mechanisms remain relatively unchanged during early football development, reinforcing the need for generalized prevention strategies applicable to all age groups.

However, results suggest a slightly higher incidence of overuse injuries in younger players and a greater incidence of traumatic injuries in older players with also general increase in injury incidence in older age. The observed differences in injury patterns across age groups can be explained by the changing demands of training and competition as players develop. Younger players tend to sustain more overuse injuries, likely due to repetitive movements involved in learning new techniques, a high volume of training repetitions, and insufficient mastery of movement patterns (Zwolski, Quatman-Yates, & Paterno, 2017). While increased training loads generally have a protective effect by enhancing strength and neuromuscular control, excessive training exposure can lead to overuse injuries, overtraining, and even illness (Serfaty & Palmer, 2025). Conversely, older players experience a higher proportion of traumatic injuries, reflecting the increased physical intensity of matches, greater competitiveness, and more aggressive style of play. With stronger, faster, and larger players engaging in frequent duels and physical contact, the likelihood of trauma-induced injuries such as sprains, contusions, and fractures increases. The overall rise in injury incidence with age is consistent with previous studies, which attribute this trend to greater training and match exposure, as well as the higher physical and tactical demands of the game (Karabin, Pupiš, & Švantner, 2024; Rabie, Arafa, Bahloul, & Abdelbadie, 2025; Serfaty & Palmer, 2025).

Our study found that the total traumatic-to-overuse injury ratio over six seasons was approximately 50:50, which is in line with previous studies on youth soccer (Błażkiewicz, Grygorowicz, Białostocki, & Czaprowski, 2018; Rommers et al., 2020). However, this distribution differs from patterns seen in senior players, where traumatic injuries tend to be

more prevalent (Leppänen et al., 2019; Rommers et al., 2020). The shift toward more acute injuries in older players is likely due to increased match intensity, greater physical contact, higher training loads, and more competitive play at the senior level. Additionally, mature athletes may have better neuromuscular control and movement efficiency, reducing the likelihood of overuse injuries while being more exposed to high-impact trauma (Mandorino, Figueiredo, Gjaka, & Tessitore, 2023). These findings emphasize the importance of tailoring injury prevention strategies to different age groups, considering the evolving injury risks as players transition from youth to senior-level competition.

2.3.5 Conclusion

This study examined the incidence and distribution of traumatic and overuse injuries in youth soccer players aged 8 to 15 years over a six-season period, revealing several key findings. The results showed that injury types were consistently distributed across all age categories, with younger players experiencing slightly more overuse injuries, while older players sustained more traumatic injuries and more injuries overall. The number of traumatic and overuse injuries was unexpectedly equal, suggesting that training methodologies and injury prevention strategies may influence injury patterns.

From a practical perspective, these findings highlight the importance of age-specific injury prevention programs that account for the unique physiological and biomechanical demands of young athletes. Coaches and medical staff should closely monitor training loads, ensuring a gradual progression in intensity to minimize overuse injuries in younger players while implementing techniques to reduce the risk of traumatic injuries in older age groups. Future research should focus on longitudinal studies with larger number of clubs to examine the long-term effects of injury trends on player development and to identify age-specific injury predictors.

Acknowledgments

There are no acknowledgments.

Conflict of interest

The authors declare that there is no conflict of interest.

2.3.6 References

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2.4 Studija 4: Understanding Longitudinal Muscle Injury Trends in Youth Football: Insights from U9 to U13 Players

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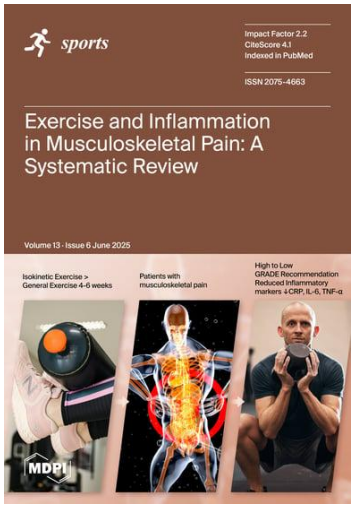

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Understanding Longitudinal Muscle Injury Trends in Youth Football: Insights from U9 to U13 Players

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Abstract

This longitudinal study investigated the incidence and characteristics of injuries among U9, U11, and U13 football players in an academy setting over a six-season period, from 2016/17 to 2021/22. A total of 374 injuries were analyzed, with a particular focus on muscle injuries, including Delayed Onset Muscle Soreness (DOMS), muscle ruptures, and contusions. The study revealed that the highest injury incidence occurred in the U13 group, with quadriceps injuries being most prevalent in both the U13 and U11 groups. The study found that muscle injuries accounted for a significant proportion of all injuries, particularly in the U13 group, where muscle injuries increased over time. Intrinsic factors such as physical development during puberty and extrinsic factors like training intensity and psychological pressures, may contribute to the higher injury rates in older age groups. Additionally, seasonal fluctuations in injury rates were observed, with a notable decline during the COVID-19 lockdowns in 2019/20 and 2020/21, followed by an increase post-lockdown due to deconditioning. The study highlights the vulnerability of young athletes to muscle injuries, particularly during growth spurts, and calls for further research into training methods and injury prevention strategies to mitigate these risks.

Keywords: injury incidence, academy, elite players, muscle injuries

2.4.1 Introduction

Youth football is experiencing a shift toward early specialization, with children engaging in structured training from a younger age (Clarke, Cushion, & Harwood, 2018; Wrona et al., 2023). While team sports like football have traditionally followed a later specialization model, modern training within structured academy environments emphasizes football-specific activities at an early stage, leading to higher training frequencies and longer cumulative training exposure (Haugaasen, Toering, & Jordet, 2014; Teixeira, Silva, Romero, Miguel, & Vicente, 2025). Although accumulating sport-specific practice hours is beneficial for skill acquisition and cognitive development, excessive training loads have been linked to an increased risk of overuse injuries and early dropout (Moseid, Myklebust, Fagerland, & Bahr, 2019; Sweeney, Horan, & MacNamara, 2021).

The Long-Term Athlete Development (LTAD) model suggests that training volume, intensity, and complexity should progress gradually as athletes mature (Balyi & Hamilton, 2004). At the youngest levels (U9–U10), training primarily focuses on fundamental football techniques through play-based learning (Bate, 1996). However, as players approach U12–U13, training becomes more structured, transitioning to senior-sized pitches (100–105 m × 64–68 m) with 11 vs. 11 matches of standard 60-minute duration. This shift, combined with physical maturation, leads to increased physiological demands and greater injury susceptibility (Rinaldo, Gualdi-Russo, & Zaccagni, 2021).

A critical factor influencing injury risk in youth football is Peak Height Velocity (PHV), a phase of rapid somatic growth typically occurring earlier in female (between ages 11-13) than in male children (between ages 13–15)(Shanmugam & Maffulli, 2008). During this period, accelerated musculoskeletal development—characterized by sudden increases in bone length, muscle-tendon imbalances, and altered neuromuscular control—can predispose athletes to injuries (Shanmugam & Maffulli, 2008). Previous studies indicate that PHV coincides with a higher incidence of injuries, particularly in the lower back, pelvis, knees, and Achilles tendon (Materne et al., 2021). Additionally, increased training and match intensity during this phase further exacerbate injury risk (Price, Hawkins, Hulse, & Hodson, 2004). This aligns with findings by Materne et al., who reported significant variation in injury incidence across youth age groups (Materne et al., 2021).

Injury characteristics vary significantly across age groups. Young footballers (U9–U10) primarily suffer minor contusions and ankle sprains, with relatively low muscle injury

prevalence (Materne et al., 2021). However, from U10 onwards, there is a notable rise in growth-related injuries, likely due to biomechanical imbalances, such as altered neuromuscular control, muscle-tendon unit asymmetries, and poor coordination during growth spurts (Bult, Barendrecht, & Tak, 2018). By U12 and U13, muscle injuries become more frequent, often resulting from increased training loads, weakened muscle structures, and growth-related changes in muscle-tendon dynamics (Price et al., 2004).

Despite the growing body of research on youth football injuries, studies focusing specifically on muscle injury trends in pre-adolescent players remain scarce. Understanding how muscle injury incidence differs across age groups is crucial for optimizing training loads, reducing injury risk, and ensuring long-term player development. The aim of the study was to analyze muscle injury occurrence in U9–U13 players over six seasons, providing insights that can help coaches and medical staff refine training methodologies to enhance performance while minimizing injury risk. Unlike previous cross-sectional studies, the research team employed a longitudinal approach, allowing for the identification of seasonal patterns and developmental trends in muscle injuries across early age groups.

2.4.2 Methods

Study design

This study investigated injury incidence in the U9, U11, and U13 groups, the three youngest age groups in the academic setting. Injury surveillance was carried out in the period from the season 2016/17 until the season 2021/22. The players who reported an injury were immediately examined by the medical specialist, and the injury data were gathered systematically across the study period. Written informed consent was obtained from the parents or legal guardians of all participants, considering that all the players in the study were minors. This study was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Kinesiology.

Participants

A total of 374 injuries among male U13, U11, and U9 players were analysed in the study. Of the overall number of injuries, 151 injuries were to the muscles. The players in the study gradually progressed through the categories as they grew in age. In the studied academy, each

generation had its age group, but for the needs of our study and the overall similarities among the groups, we merged/tied two generations into one age group (e.g., U8 and U9 all considered U9 group, U10 and U11 all considered U11, etc.). The sample included players from all playing positions, regardless of the obvious positional differences and their respective playing demands. It is important to note that training and competition differ among the studied groups, with league formats varying slightly across age groups. For example, the U9 group averaged four 75-minute training sessions with a 40-minute match per week, during 44 weeks of the season. The same applies to the U11 category, except for the training duration, which lasted for 90 minutes. As stated before, the most significant difference occurs in the U12 and U13 groups, with 60 minutes of gameplay on the full-size pitch. All players progressed chronologically through the groups, with position and playing time not being exclusion criteria. During the study, all the players were assigned a code to preserve the identity of the athletes.

Variables

The medical specialist was at their disposal for a daily check-up. In this study, an injury was defined as any musculoskeletal complaint resulting from football training or match play that required medical attention and/or led to a restriction in participation, in line with the consensus definitions for injury surveillance in football (Bult et al., 2018). Both traumatic and overuse injuries were included. DOMS (Delayed Onset Muscle Soreness) was classified as an injury only if it led to at least one missed training session or required medical treatment, following similar classification approaches used in other longitudinal injury surveillance studies. Although DOMS is a common adaptation to exercise, its inclusion reflects practical relevance in our academic setting, where significant soreness is documented and managed medically due to its impact on participation. Each injury was evaluated for severity (days absent), recurrence, contact nature, and activity type (training/match).

Immediately following the physical check-up, the injury data was available to all involved in the process (e.g., coaching staff and academy managers) through the club database. All injuries were recorded, with muscle injuries specifically classified as either (i) functional muscle injuries, represented by Delayed Onset Muscle Soreness (DOMS) and contusions, or (ii) structural injuries, i.e., ruptures (partial or complete tears of muscle fibers) (Ekstrand, Hägglund, & Waldén, 2011). Injury severity was calculated for all muscle injuries (i.e., DOMS, ruptures, and contusion injuries) in all age groups, respectively. Football exposure

was calculated separately for all the observed seasons and age groups, and was reported as the number of training and match hours. Exposure time was adjusted for the 2019/2020 season, when a complete ban from all activities followed the COVID-19 lockdown (from March 2020 to July 2020). Muscle injury incidence was expressed as the number of muscle injuries sustained per 1000h of training and match exposure, respectively. All muscle injuries were classified either as new or recurring injuries, according to the body part, the contact nature of injuries, and the training or match occurrence. Regarding the injured body sites, muscle injuries were divided into the four most affected groups: hamstrings, quadriceps, adductors, psoas muscle and all other injured muscles.

Statistics

Descriptive data included arithmetic means and standard deviations. The muscle injury incidence for all age groups was presented as the number of injuries sustained per 1000h of exposure, along with the incidence rate ratio that compared the absolute change in injuries across the seasons.

MedCalc Statistical Software (version 19.2.6), Microsoft Excel 2019 (Microsoft, USA), and Chi-square calculator (https://www.socscistatistics.com/tests/chisquare2/default2.aspx) were used for the analysis. The statistical significance was set at $p < 0.05$ for all calculations.

2.4.3 Results

A total of 151 muscle injuries (U13 = 108, U11 = 39, U9 = 4) were analyzed in the study. The results revealed the highest number of muscle injuries in the oldest U13 category (n=108), along with 39 muscle injuries in the U11 age category. The youngest U9 age category suffered only 4 injuries to the muscular system.

Table 1 presents the descriptive data for all age groups. The majority of muscular injuries (64%) are characterized as DOMS injuries. Rupture injuries were the most serious, resulting in 25 days of absence on average for the U13 and U11 categories. No rupture was suffered in the U9 age group during the observed period. On average, players in the U11 category remained out of the training process slightly more than the U13 category (13.5 and 12.8 days average, respectively), with the U9 category losing one week of training per muscle injury. A higher

number of training injuries was noticed in the U13 and U11 groups, in contrast to the U9 category, where 75% of muscle injuries occurred during the match. Approximately 21% of injuries happened after direct contact, either with the opponent or with the ball.

Table 1. Descriptive data for muscle injuries across age categories.

		# Injuries	Days out	Reinjury	Occurrence		Contact
					Training	Match	
U13	Rupture	27	24.5	14	18	9	5
	Doms	68	8.4	3	54	14	5
	Contusion	13	5.4	4	8	5	13
	Total	108	12.8	21	80	28	23
U11	Rupture	12	25.5	2	8	4	4
	Doms	26	8.9	4	20	6	2
	Contusion	2	6	0	2	0	2
	Total	39	13.5	6	30	10	8
U9	Rupture	/	/	/	/	/	/
	Doms	4	7.3	0	1	3	0
	Contusion	/	/	/	/	/	/
	Total	4	7.3	0	1	3	0

Legend: # Injuries – number of injuries

The results suggest the highest muscle injury incidence in the U13 group (=2.79/1000h), with much higher match injury incidence than training injury incidence (=8.73/1000h vs =2.26/1000h, respectively). Similarly, the match incidence is higher than training incidence in the U11 and U9 groups as well (=4.72/1000h vs =1.31/1000h, and =1.50/1000h vs =0.06/1000h, respectively). Ultimately, the overall injury incidence follows the same pattern as above, with numbers increasing with age (Figure 1).

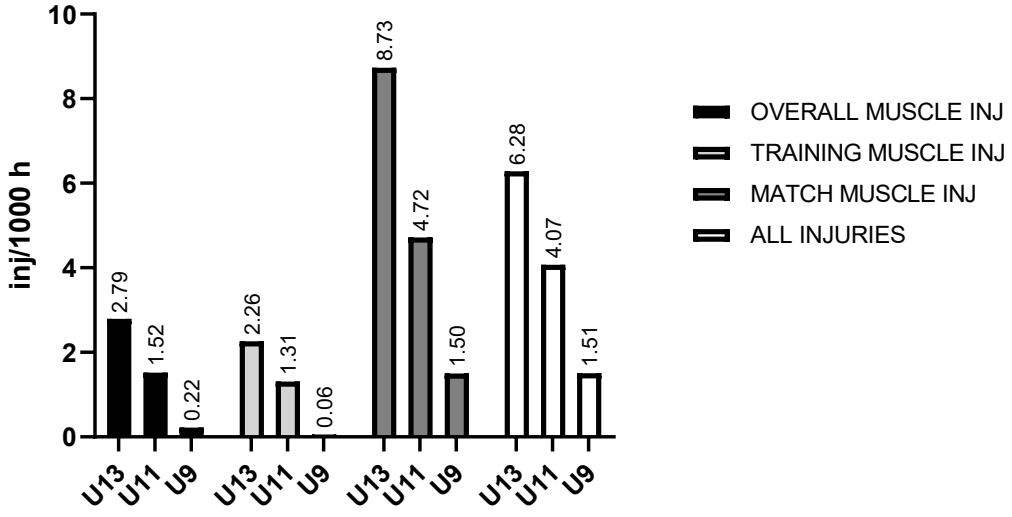

Figure 1. Muscle and total injury incidence per 1000 hours across different age categories (inj/1000h – injuries per 1000h of exposure, U13 – under 13, U11 – under 11, U9 – under 9.)

There is no difference in the muscle injury occurrence between the U13 and U11 across the seasons (Chi-square ($\chi 2$) = 0.56; p = 0.99). A slight drop in injury incidence in both groups was found in the 2019/20 and 2020/21 seasons, respectively (Figure 2).

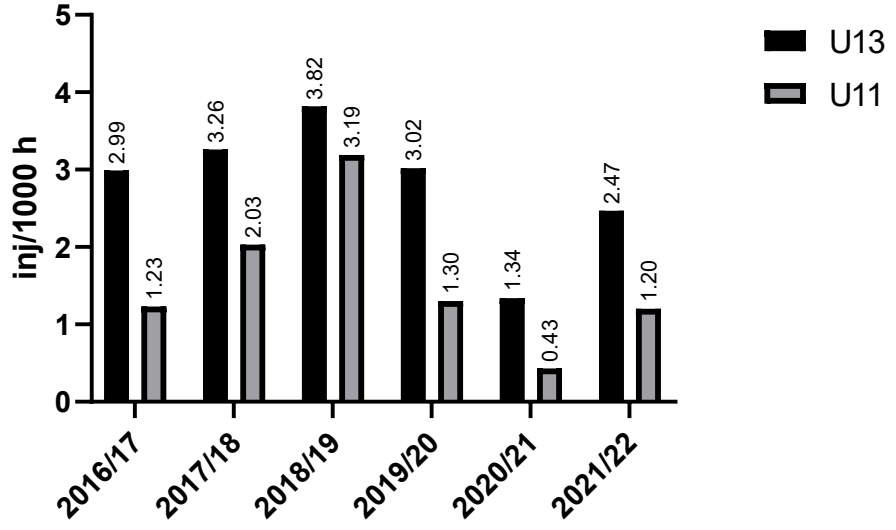

Figure 2. Injury incidence trends across seasons for U13 and U11 players (inj/1000h – injuries per 1000h of exposure, U13 – under 13, U11 – under 11.)

The U13 group suffered more muscle injuries compared to the U11 group. However, when comparing between the categories, no difference was found in the injury rates of different muscle groups. Regarding major muscle groups, the quadriceps were injured most frequently in both groups (Figure 3). Hamstring injuries were the second most common injury site in the U13 category, as opposed to adductors in the U11 group.

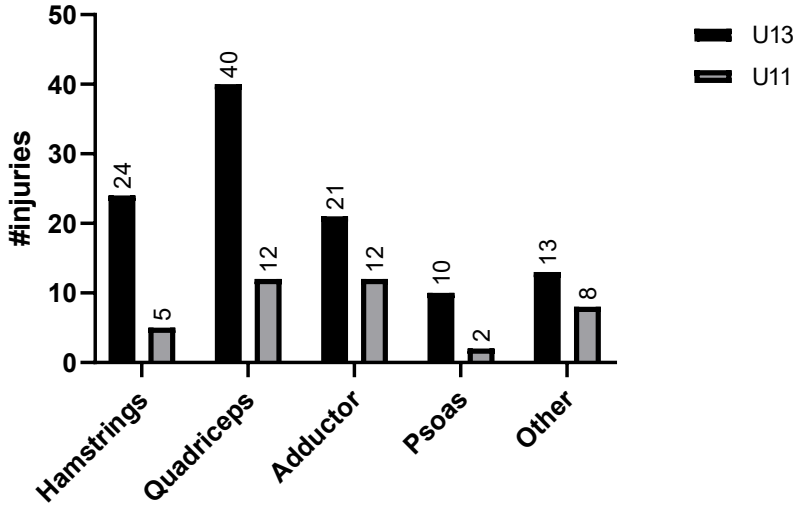

Figure 3. Distribution of muscle injuries by muscle group in U13 and U11 players (#injuries – number of injuries, U13 – under 13, U11 – under 11.)

The proportion of muscle injuries in total injury incidence follows a similar trend in the U13 and U11 age categories (Figure 4). Namely, there has been a rise in muscle injury proportion from the 2016/17 season until the 2018/19 season, followed by a drop in the next two seasons (i.e., seasons 2019/20 and 2020/21, respectively) and a final increase in the last investigated season. Not a single muscle injury was recorded in two out of six observed seasons in the U9 category.

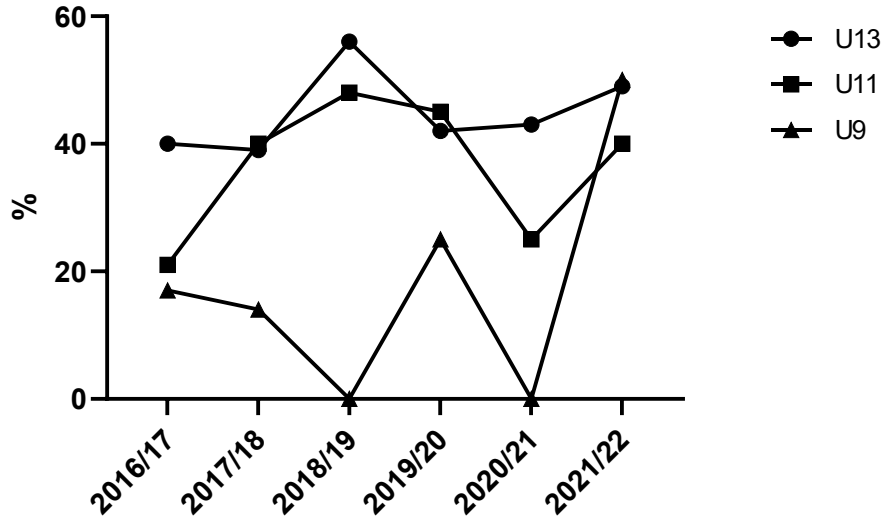

Figure 4. Percentage of injuries over time across age categories (% - percentage of muscle injuries in the total sample of injuries)

2.4.4 Discussion

This study aimed to investigate the overall and muscle injury characteristics among the three youngest academy age groups. According to the results, the most important finding is the highest injury incidence in the oldest U13 age category. Further, the results suggest that the quadriceps were the most injured muscle in the U13 and U11 age groups. Finally, the proportion of muscle injuries was nearly the same in both age groups across the observed period.

Injury incidence

The higher injury incidence observed in the U13 age group, particularly muscle injuries, may be partly explained by multiple intrinsic and extrinsic factors that have been highlighted in previous studies (Bult et al., 2018; Faude, Rößler, & Junge, 2013; Price et al., 2004). One of the primary contributors is the accelerated physical growth during puberty, which has been previously suggested to contribute to disproportionate development between bones, tendons, and muscles, increasing susceptibility to injury (Bult et al., 2018). Additionally, the increased intensity of training and competition (i.e., transition to full pitch 11v11), coupled with greater psychological pressure, may further contribute to the higher risk of injury (Faude et al., 2013). Moreover, as injuries are shown to increase with age, older athletes might have suffered a

previous injury that predisposed them to a higher injury risk (Arnason et al., 2004). Although muscle injuries increased significantly in the U11 group (IRR 1.25) compared to U13 (IRR 1.15), the overall muscle injury incidence between these groups remained similar. This aligns with previous studies in English youth academies, where injury risk was found to double between U12 and U13 and increase significantly from U10 to U12. (Deehan, Bell, & McCaskie, 2007). The relatively low injury rates in our study suggest that extreme deviations, such as injury spikes, are unlikely in this population.

Fluctuations in injury rates across seasons were influenced by several factors, including training intensity, competition load, playing surfaces, weather conditions, and player maturation stages (Costa e Silva, Silva, Teles, & Fragoso, 2024; Jespersen, Holst, Franz, Rexen, & Wedderkopp, 2014). Although not measured directly in this study, coaching changes have been linked to variations in muscular injury incidence, as different training methodologies, such as altered strength conditioning programs or biomechanical cueing, can impact injury rates (Dönmez et al., 2020).

Results indicated an increase in muscle injuries in the first half of the study period, both in the U13 and U11 age groups. Despite advancements in training technology, injury prevention strategies, and increased involvement of medical professionals, injury rates in our academy increased slightly until the 2019/20 season (Emery, Roy, Whittaker, Nettel-Aguirre, & Van Mechelen, 2015). This may be due to the reduction in muscle flexibility and strength during rapid skeletal elongation, a well-documented risk factor for muscle injuries (Materne et al., 2021).

The COVID-19 pandemic caused an unprecedented disruption in training, with lockdown measures leading to prolonged inactivity and detraining effects (Keemss, Sieland, Pfab, & Banzer, 2022). The lockdown measures were mandated in Croatia on two occasions during 2020/2021 as well, from December to January and from March to May. As a result, injury incidence dropped during the 2019/20 and 2020/21 seasons due to reduced training and match exposure. Similarly, studies investigating the pediatric population have shown a significant (i.e., up to 15%) reduction in injuries compared to the pre-pandemic season (Vincent, Patel, & Zaremski, 2022). However, upon resumption of regular activities, a sharp increase in injuries was observed, likely due to deconditioning and loss of neuromuscular control (Stokes et al., 2020). This reinforces the importance of progressive return-to-play protocols following periods of inactivity to reduce injury risk (Geldenhuys, Burgess, Roche,

& Hendricks, 2022). Moreover, given that we are discussing children in their formative years, where they should be consistently involved in vigorous physical activity, the evident risk posed to their development by multiple breaks in activity is clear.

Location and type of injuries

In youth football players, DOMS injuries are generally more common than ruptures, with muscle strains being more prevalent than ligament or tendon injuries (Bult et al., 2018). Hence, emphasis should be placed upon a gradual progression of training load to prevent excessive muscle fatigue (Balyi & Hamilton, 2004). Among the U11 age group, injuries tend to result in longer absences, possibly due to these being the athletes' first encounters with injuries and time away from training. This requires a more cautious and conservative approach to rehabilitation to ensure proper recovery and return to the field. In addition, a recent study by Light and colleagues suggested an increase in total football exposure from 10.000 hours to 22.000 hours when moving from the U10 to U11 age group (Light et al., 2021). Approximately 17% of injuries were recurrent, aligning with 22-25% of reinjury rates reported in previous studies (Ergun, Denerel, Mehmet, & Ertat, 2013). Further efforts should focus on addressing biomechanical deficits to reduce the risk of subsequent reinjury (Emery et al., 2015). Training-related injuries were more common due to the significantly higher volume of training exposure, although the relative incidence is much higher during the matches (Wik et al., 2021). Approximately 20% of injuries were contact-related, much lower than reported in older age groups (U15–U19: 40–60%) (Faude et al., 2013). This suggests that non-contact injuries play a more prominent role in younger players, highlighting the need for improved movement efficiency, neuromuscular control, and flexibility training. The injury locations across different age groups (U9, U11, and U13) showed no significant differences, with similar body regions and muscle groups being affected, as the same movement patterns (kicking, running, turning) are used across these age categories. The pattern of injuries remains largely constant, suggesting that movement-specific injuries are not significantly influenced by age (Pfirrmann, Herbst, Ingelfinger, Simon, & Tug, 2016). In the U13 group, the quadriceps were most commonly injured, followed by the hamstrings, while U11 players experienced a similar number of quadriceps and adductor injuries. Consistent with existing literature, the hamstrings, quadriceps, and hip region are particularly vulnerable to injury due to the high volume of multidirectional, high-speed movements in football (Medeiros, Marchiori, & Baroni, 2020).

Additionally, during the circa-PHV period, rapid growth and development place significant demands on the hip muscles, increasing their susceptibility to strain (Dupré & Potthast, 2020). As young athletes are still developing strength and coordination, they may struggle with proper movement mechanics, which can put extra strain on these muscle groups (Bult et al., 2018). Therefore, structured eccentric strength training should be introduced to circa-PHV athletes to enhance muscle resilience at key sites (Moseid et al., 2019).

Proportion of muscle injuries

A similar trend in muscle injuries was observed across the two older age groups, with nearly identical injury incidences in three out of six seasons. The proportion of muscle injuries rose consistently (in the U11 and U13 age groups, respectively) until the 2019/20 season, when COVID-related disruptions impacted the data. A similar pattern is observed throughout the period, with both the overall injury incidence and the proportion of muscle injuries increasing. In the context of analyzing the relative proportions in the overall injury dataset, this suggests that muscle injuries increased at a faster rate than total injuries, leading to a larger share of muscle injuries within the overall injury pool. On average, the proportion of muscle injuries was 45% for the U13 group and 37% for the U11 group, which aligns with previous findings in elite youth footballers, where muscle injuries accounted for 45% of the total (Renshaw & Goodwin, 2016). Although training technology has advanced and conditioning coaches have been added to support these age groups, muscle injuries have continued to rise. Therefore, it is crucial to further investigate the appearance and mechanisms of injuries, as well as the risk factors in this young and vulnerable population. A potential solution could lie in the use of objective measures such as GPS and RPE to track and monitor workload (Materne et al., 2021). This could offer insights into whether training loads are appropriate and highlight periods of excessive strain that may predispose these players to injury. Interestingly, no muscle injuries were recorded in the U9 group during two out of the six seasons, highlighting the already low injury incidence in this age group (Light et al., 2021).

Strengths and limitations

One of the key limitations of this study is the inability to control for other potential influencing factors, such as maturity status or bio-motor abilities, which could significantly impact the incidence of muscle injuries. These factors, while not addressed in the current study, are crucial in understanding the complex relationship between physical development and injury risk. Additionally, the study's focus on a single football academy limits its generalizability, as the results may not apply to other contexts or regions. Despite these limitations, the study's longitudinal design, spanning six years and involving a large sample size in the elite youth academy, provides a clear insight into muscle injury occurrence in the U9 to U13 age groups. The emphasis on the youngest age groups is a major strength, as it identifies the most vulnerable regions of the body that are prone to injury during this critical developmental phase. By identifying these early risks, the study provides a foundation for proactive measures to safeguard young athletes' long-term health and development.

2.4.5 Conclusion

This study highlights the higher injury incidence in the U13 age group, likely due to increased training intensity, rapid physical development, and higher psychological pressure. Muscle injuries, particularly in the quadriceps, were most prevalent in the U13 and U11 groups, with the proportion of muscle injuries rising steadily over the study period. Although training methods have advanced and conditioning coaches have been introduced, muscle injury rates remain high, particularly among the U13 and U11 groups, indicating that the rapid maturation process during these years increases susceptibility to injury. The findings emphasize the importance of age-specific injury prevention strategies, particularly during periods of significant physical development. For younger athletes (U9-U11), emphasis should be placed on developing fundamental movement skills, balance, and coordination through neuromuscular training. As athletes progress (U13-U15), injury prevention should include progressive strength training targeting key muscle groups, alongside refining movement mechanics such as landing and cutting techniques. In older youth athletes (U16+), sport-specific conditioning and individualized load management become essential to prevent overuse injuries. Overall, improving movement competency, running mechanics, and structured strength training can significantly reduce injury risk in young athletes. Future research should aim to control these confounding variables and explore other significant predictors of injury more thoroughly.

Author Contributions

Conceptualization, J.S., and S.V.; Methodology, T.M., D.S., and S.V.; Software, L.C.; Validation, T.M. and M.K.; Formal analysis, J.S., and S.V.; Investigation, J.S. and S.V.; Resources, M.K. and L.C.; Data curation, A.B., A.T., and B.B.; Writing—original draft, J.S.; Writing—review and editing, S.V.; Visualization, D.S.; Supervision, T.M., D.S., and S.V.; Project administration, S.V. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of the University of Split, Faculty of Kinesiology (Ethical Approval Number: 2181-205-02-05-23-0007).

Informed Consent Statement

Written informed consent was obtained from the parents or legal guardians of all participants.

Data Availability Statement

The data is available upon reasonable request.

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Conflicts of Interest

The authors declare no conflict of interest.

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3. GENERALNI ZAKLJUČAK

Sukladno postavljenim ciljevima, nekoliko je ključnih nalaza ovog rada: (i) uočen je generalan pad incidencije ozljeda mladih nogometaša koji se mijenja pojavom pandemije, (ii) mladi nogometaši najčešće dožive blaže mišićne ozljede natkoljenice, sa značajno većim rizikom tijekom natjecanja, (iii) starije kategorije pretrpe više traumatskih, a mlađe kategorije više ozljeda prenaprezanja, (iv) mladi nogometaši prilikom ulaska u period puberteta značajno više ozljeđuju mišiće prednje strane natkoljenice. Zaključci ovih radova jasno odgovaraju na pitanja koliko, kako i gdje se događaju najveći rizici za nastanak ozljeda kod elitnih nogometaša mlađih dobnih kategorija.

Prva studija sugerira ukupni pad stope ozljeđivanja kod mladih hrvatskih nogometaša. Točnije, negativan trend ozljeđivanja svih kategorija zaustavljen je pojavom koronavirusa, kada uslijed naglog prekida i nastavka aktivnosti dolazi do povećanja rizika zadobivanja ozljede. Primjena aktualnih prevencijskih strategija kod mladih sportaša (nedvojbeno je) jedan od mehanizama odgovornih za smanjivanje pojavnosti ozljeda.

Druga studija ukazala je da nogometaši U15 kategorije dominantno pretrpe/trpe blaže mišićne ozljede, uz dva od pet nogometaša tog uzrasta koji će doživjeti mišićnu ozljedu tijekom jedne natjecateljske sezone. Slično kao i u prvoj studiji, pojava COVID-19 pandemije uzrokovala je porast mišićnih ozljeda povratkom u trenažni i natjecateljski režim. Ova studija još je jednom potvrdila da su četiri glavne mišićne skupine donjih ekstremiteta, mišić kvadriceps, mišići stražnje lože, mišići primicači natkoljenice te lisni mišić, strukture koje su najviše podložne ozljedama u nogometu mlađih dobnih skupina.

Treća studija pokazala je konzistentnu distribuciju prema tipu ozljede u svim kategorijama od U8 do U15 mladih nogometaša. Ipak, uočene su blage razlike koje ukazuju da najmlađe kategorije doživljavaju više ozljeda prenaprezanja od starijih igrača, koji pak pretrpe nešto veći broj traumatskih ozljeda.

Posljednja, četvrta studija potvrdila je veću incidenciju ozljeda kod U13 nogometaša, ponajviše zbog specifičnosti razvojnog perioda u kojem se nalaze te zbog povećanja trenažnog i natjecateljskog intenziteta. Mišićne ozljede, posebice mišića kvadricepsa, najčešće su kod U13 i U11 grupa, a udio mišićnih ozljeda u ukupnoj incidenciji raste stabilno kroz godine.

3.1 Ograničenja i prednosti

Glavna limitacija ovog istraživanja jest činjenica da su istraživani trendovi ozljeđivanja samo jedne nogometne akademije, što naravno smanjuje mogućnost generalizacije na populacije slične kvalitete i karakteristika. Nadalje, postoji mogućnost da neke ozljede nisu bile prijavljene od strane igrača, dokumentirane u klupskoj bazi podataka te posljedično ni analizirane, čime je moguće poremećena kvaliteta analiziranih podataka. Ipak, igrači koji su prijavili tegobe pažljivo su pregledani od strane medicinskog tima, a ozljede su klasificirane prema konsenzusu o prikupljanju podataka nogometnih ozljeda (Fuller et al., 2006). Nemogućnost kontrole ostalih faktora koji su potencijalno utjecali na pojavnost ozljeda, primjerice biološke dobi te razine motoričkih i funkcionalnih sposobnosti, također je jedno od ograničenja ovog rada.

Longitudinalni dizajn ove studije koji je omogućio detekciju promjena u pojavnosti ozljeda tijekom šest natjecateljskih sezona najznačajnija je snaga ovog rada, posebice uzimajući u obzir činjenicu da je promatrani period obuhvatio COVID-19 pandemiju.

Dalje, uzorak mladih igrača iz elitne nogometne akademije koja je, prema dostupnim podacima, jedna od najproduktivnijih nogometnih škola sa velikim brojem igrača koji trenutno nastupaju u najboljim europskim ligama, također doprinosi kvaliteti/relevantnosti donesenih zaključaka (Top training clubs for European-based players, 2022). Na kraju, potrebno je naglasiti da je ovo, prema saznanjima autora, prva studija koja je analizirala ozljede najmlađih hrvatskih nogometaša kroz duži vremenski period.

Otkrivanjem broja, strukture i ozbiljnosti, te identificiranjem kritičnih regija, a posebice mišićnih ozljeda, ova studija pruža osnovu za kreiranje i implementaciju dobno-specifičnih prevencijskih strategija koje će pomoći očuvanju zdravlja najmlađih sportaša te optimizaciji sportskog treninga od najranije dobi.

3.2 Smjernice za buduća istraživanja

Epidemiologija ozljeda i dalje ostaje nedovoljno istraženo područje, poglavito u kontekstu djece nogometaša kao društveno osjetljive populacije. Buduća istraživanja trebala bi biti usmjerena na otkrivanje prediktorskih varijabli i faktora rizika, kontrolom kojih će se pravovremeno moći provesti primarna prevencija, tj. izbjegavanje zadobivanja prve ozljede. Glavni cilj grupe autora radova prezentiranih u ovom radu, u sljedećoj fazi istraživanja jest otkrivanje povezanosti između određenih razvojnih (biološka dob), antropometrijskih (npr. tjelesna visina, masa, količina potkožnog masnog tkiva), funkcionalnih (aerobni i anaerobni kapaciteti) te motoričkih varijabli (maksimalna jakost, snaga, brzina, agilnost) i incidencije ozljeda u mlađim dobnim skupinama. Nadalje, potrebno je istražiti utjecaj natjecateljskih trkačkih parametara (ukupna prijeđena udaljenost, udaljenost prijeđena u pojedinim zonama, ubrzanja, kočenja) na pojavnost ozljeda, poglavito beskontaktnih mišićnih ozljeda. Finalno, sljedeće studije trebale bi proširiti populaciju ispitanika na ostale elitne hrvatske akademije te tako dobiti uvid u dugotrajne ishode stope ozljeda na razvoj mladih igrača.

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BIOGRAFIJA

Jakša Škomrlj rođen je 2. kolovoza 1998. u Splitu, Hrvatskoj. Diplomu magistra kineziologije stekao je 2022. godine, na Kineziološkom fakultetu Sveučilišta u Splitu, sa usmjerenjem Kondicijske pripreme sportaša.

Interes prema fizičkoj pripremi pojavio se još tijekom aktivne igračke karijere, koja je zbog ozljeda, nažalost ili nasreću, prekinuta tijekom prve godine studija. Odustanak od aktivnog bavljenja sportom omogućio je potpuni fokus na akademsko i praktično obrazovanje, pa se tako tijekom druge godine studija otvara prilika za rad u jednom splitskom fitness centru.

Nešto kasnije postaje članom Akademije HNK Hajduk, prvo volonterski zatim profesionalno, gdje sljedećih 5 godina sudjeluje u radu svih uzrasnih kategorija te tako dobiva najbolji uvid u specifičnosti razvoja nogometaša od najmlađe do seniorske dobi.

Trenutno je zaposlen kao kondicijski trener veoma uspješne seniorske ekipe FC Noah Erevan.

Uz podršku mentora (i još nekoliko profesora), 2023. godine odlučuje se za upis na poslijediplomski doktorski studij na Kineziološkom fakultetu Sveučilišta u Splitu, gdje paralelno radi kao vanjski suradnik – predavač na redovnom i stručnom studijskom programu.

Primarni znanstveni fokus ovog istraživača je analiza performansi i incidencije ozljeda u nogometu, sa 7 članaka indeksiranih u WoS bazi.