SVEUČILIŠTE U SPLITU
KINEZIOLOŠKI FAKULTET

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ANALIZA PERFORMANSI NOGOMETNIH VRATARA ELITNE RAZINE NATJECANJA TIJEKOM TRENINGA I UTAKMICA

DOKTORSKA DISERTACIJA

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Analiza performansi nogometnih vratara elitne razine natjecanja tijekom treninga i utakmica

DOKTORSKA DISERTACIJA

Mentor:
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Performance analysis of elite-level football goalkeepers during training and matches

DOCTORAL THESIS

Supervisor:
Assistant Professor Toni Modrić, PhD

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SUPERVISOR INFORMATION

Toni Modrić; Assistant Professor at the University of Split, Split, Croatia; born 1988 in Split, Croatia. He earned his PhD title in Kinesiology at the University of Split, Split, Croatia in 2022.

His main scientific interest is performance analysis in sport, with main focus in football. Up to date, he has published more than 80 papers in journals indexed in the Web of Science and Scopus, with more than 1.000 citations. He was awarded by several awards for his scientific work, including National Award for Science of the Republic of Croatia in 2023.

At Faculty of Kinesiology, University of Split, he teaches on courses Planning and programming for strength and conditioning, Quantitative methods 1 and 2, and Research methods in kinesiology.

He worked as first-team fitness coach in elite football clubs, including HNK Hajduk Split and RNK Split (Croatia), Galatasaray SK, Besiktas JK, and Kardemir Karabükspor (Turkey), Pafos FC (Cyprus), and Riga FC (Latvia). He also served as a fitness coach with the Croatian youth national team and as Head of Sport Science and Medicine at HNK Hajduk Split, Croatia.

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Commit your work to the LORD, and your plans will be established.

Proverbs 16:3

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LIST OF ABBREVIATIONS

GPS – global positioning system

MP – match performance

xGOT – expected goals on target

CV – contextual variables

UCL – UEFA Champions League

MO – match outcome

ML – match location

OQ – opponent quality

AG – age group

ETL – external training load

MD – match day

MD-1, MD-2, MD-3, MD-4 – days before match day

U17 – under-17 age group

U19 – under-19 age group

SD – standard deviation

ES – effect size

d – Cohen's d

ANOVA – analysis of variance

AIC – Akaike information criterion

CONTENTS

ABSTRACT

This doctoral thesis aimed to provide an integrated understanding of the match and training demands of elite-level goalkeepers. Specifically, Study 1 aimed to examine the effect of match outcome, match location, team and opponent quality on goalkeepers' technical and physical performance during match play; Study 2 aimed to examine the effect of age group on goalkeepers' physical performance during match play; and Study 3 aimed to evaluate goalkeepers' external training load during the weekly training cycle.

Study 1 analysed the match performance of goalkeepers (n = 49) across UEFA Champions League matches (n = 125) during the 2022/23 season. Physical performance was collected using an optical tracking system Player & Ball Tracking System (Hawk-Eye Innovations Limited, Basingstoke, England), while the technical performance was registered using WyScout (Wyscout, Chiavari, Italy). Study 2 analysed differences in the physical performance of goalkeepers (n = 2) between the U17 (10 matches) and U19 (12 matches) age groups during the first half of the 2023/2024 season. Study 3 analysed the external training load of goalkeepers (n = 3) across 67 training sessions during the 2021/2022 half-season. Data in Studies 2 and 3 were collected using a global positioning system, Catapult Vector G7 (Catapult Sports Ltd., Melbourne, Australia).

The results of Study 1 indicated that when winning, goalkeepers faced fewer shots against (Cohen's d = 1.39), conceded fewer goals (d = 2.13), performed more exits (d = 0.37), and made fewer saves (d = 0.52) and reflex saves (d = 0.50) than when losing. At home, goalkeepers conceded fewer goals (d = 0.23) and performed fewer exits (d = 0.25) than away. Compared with low-quality teams, goalkeepers from high-quality teams conceded fewer goals (d = 0.48), completed fewer total (d = 0.35) and accurate passes beyond the defensive third (d = 0.35), and made fewer saves (d = 0.42) and reflex saves (d = 0.33). Against high-quality opponents, goalkeepers conceded more goals (d = 0.48), completed more passes beyond the defensive third (d = 0.28), faced more shots against (d = 0.67), and made more saves (d = 0.55) and reflex saves (d = 0.57) than against low-quality opponents.

The results of Study 2 indicated that total distance covered was significantly greater in the U17 than in the U19 age group (5742 vs. 5290 m, $p = 0.015$), whereas the total number of dives (6.66 vs. 3.75, $p = 0.003$), dive load per minute (0.53 vs. 0.25, $p = 0.001$), and number of high-load dives (1.92 vs. 0.90, $p = 0.027$) were significantly greater in the U19 than in the U17 age group.

The results of Study 3 indicated significant daily differences in total distance ($p = 0.01$), total dives ($p = 0.01$), high-intensity dives ($p = 0.01$), high-intensity accelerations ($p = 0.03$), high-intensity decelerations ($p = 0.02$), and explosive efforts ($p = 0.02$), all of which were greatest three days before the match (MD-3; e.g., total distance: 3629 m on MD-3 vs. 2569–2670 m on other days) and lowest two and one days (MD-2 and MD-1) before the match. Low, medium and high jumps showed no significant daily differences (all $p > 0.05$).

The results of this doctoral thesis showed that (i) technical performance of elite-level goalkeepers was affected by match outcome, team quality, and opponent quality, (ii) physical performance of elite-level goalkeepers differed according to age group, with greater locomotor load in the U17 and greater mechanical load in the U19 age group, and (iii) external training load elite-level goalkeepers was highest three days before the match and progressively decreased as match day approached.

The findings from this research provided new knowledge toward a more comprehensive understanding of the match demands imposed on elite-level goalkeepers and enabled exclusive insights into the training practice of elite goalkeepers during the competitive microcycle. This may give practitioners evidence-based information to improve goalkeeper training design and optimise their long-term development.

Keywords: soccer, external load, training load, mechanical load, contextual variables, match performance, youth development, performance analysis

SAŽETAK

Glavni je cilj ove doktorske disertacije pružiti cjelovito razumijevanje zahtjeva utakmice i treninga s kojima se susreću vratari elitne razine. Konkretno, cilj Studije 1 bio je ispitati utjecaj ishoda utakmice, mjesta odigravanja utakmice te kvalitete momčadi i protivnika na tehničke i fizičke performanse vratara tijekom utakmice; cilj Studije 2 bio je ispitati utjecaj dobne kategorije na fizičke performanse vratara tijekom utakmice; cilj Studije 3 bio je kvantificirati vanjsko trenažno opterećenje vratara tijekom tjednog trenažnog ciklusa.

U Studiji 1 analizirane su performanse vratara (n = 49) na utakmicama UEFA Lige prvaka (n = 125) tijekom sezone 2022./2023. Fizičke performanse prikupljene su optičkim sustavom za praćenje Player & Ball Tracking System (Hawk-Eye Innovations Limited, Basingstoke, Engleska), dok su tehničke performanse praćene korištenjem WyScouta (Wyscout, Chiavari, Italija). U Studiji 2 analizirane su razlike u fizičkim performansama vratara (n = 2) između dobnih kategorija U17 (10 utakmica) i U19 (12 utakmica) tijekom prvog dijela sezone 2023./2024. U Studiji 3 analizirano je vanjsko trenažno opterećenje vratara (n = 3) na 67 treninga tijekom polusezone 2021./2022. Podaci u Studijama 2 i 3 prikupljeni su globalnim sustavom za pozicioniranje Catapult Vector G7 (Catapult Sports Ltd., Melbourne, Australija).

Rezultati Studije 1 pokazali su da su se vratari, kada su pobjeđivali, suočili s manjim brojem udaraca u okvir gola (Cohenov d (d) = 1.39), primili manje golova (d = 2.13), imali više izlazaka (d = 0.37) i imali su manje obrana (d = 0.52) te refleksnih obrana (d = 0.50) nego kada su gubili. Kod kuće su vratari primili manje golova (d = 0.23) i imali manje izlazaka (d = 0.25) nego u gostima. U usporedbi s manje kvalitetnim ekipama, vratari iz više kvalitetnih ekipa primili su manje golova (d = 0.48), izveli manje ukupnih (d = 0.35) i točnih dodavanja izvan obrambene trećine (d = 0.35) i imali su manje obrana (d = 0.42) te refleksnih obrana (d = 0.33). Protiv ekipa više kvalitete vratari su primili više golova (d = 0.48), izveli više dodavanja izvan obrambene trećine (d = 0.28), suočili se s većim brojem udaraca u okvir gola (d = 0.67) i imali su više obrana (d = 0.55) te refleksnih obrana (d = 0.57) nego protiv ekipa niže kvalitete.

Rezultati Studije 2 pokazali su da je ukupna prijeđena udaljenost bila značajno veća u kategoriji U17 nego U19 (5742 u odnosu na 5290 m, p = 0.015), dok su ukupan broj obrana bacanjem (6.66 u odnosu na 3.75, p = 0.003), opterećenje bacanjima po minuti (0.53 u odnosu na 0.25, p = 0.001) i broj bacanja visokog opterećenja (1.92 u odnosu na 0.90, p = 0.027) bili značajno veći u kategoriji U19 nego U17.

Rezultati Studije 3 pokazali su značajne dnevne razlike u ukupnoj prijeđenoj udaljenosti ($p = 0.01$), ukupnom broju bacanja ($p = 0.01$), visoko intenzivnim bacanjima ($p = 0.01$), visoko intenzivnim akceleracijama ($p = 0.03$), visoko intenzivnim deceleracijama ($p = 0.02$) i eksplozivnim naporima ($p = 0.02$), a svi su bili najveći tri dana prije utakmice (MD-3; primjerice, ukupna prijeđena udaljenost iznosila je 3629 m na MD-3 u odnosu na 2569–2670 m ostalih dana), a najmanji dva i jedan dan prije utakmice (MD-2 i MD-1). Niski, srednji i visoki skokovi nisu se značajno razlikovali (svi $p > 0.05$).

Rezultati ove doktorske disertacije pokazuju da (i) na tehničke performanse vratara elitne razine utječu ishod utakmice, kvaliteta momčadi i kvaliteta protivnika, (ii) fizičke performanse vratara elitne razine razlikuju se prema dobnoj kategoriji, uz veće lokomotorno opterećenje u kategoriji U17 i veće mehaničko opterećenje u kategoriji U19, te (iii) vanjsko trenažno opterećenje vratara elitne razine najveće je tri dana prije utakmice i postupno se smanjuje kako se približava dan utakmice.

Nalazi ovog istraživanja pružili su nove spoznaje koje pridonose boljem razumijevanju zahtjeva utakmice s kojima se susreću vratari elitne razine te su omogućili uvid u to kako elitni vratari treniraju tijekom natjecateljskog mikrociklusa. Budući da se temelje na objektivnim podacima, ove spoznaje mogu pomoći stručnjacima da unaprijede planiranje vratarskog treninga i optimiziraju dugoročni razvoj vratara.

Ključne riječi: nogomet, vanjsko opterećenje, trenažno opterećenje, mehaničko opterećenje, kontekstualne varijable, izvedba na utakmici, razvoj mladih igrača, analiza izvedbe

THESIS OUTLINE

This doctoral thesis consists of three published articles:

1. Vladovic, J., Modric, T., Pavlinovic, V., Morgans, R., Majeric, M. (2025) Context is Key: The Effect of Match-Related Variables on Technical and Physical Performance of the UEFA Champions League Goalkeepers. *Montenegrin Journal of Sports Science and Medicine*, *14* (2), 5–12. https://doi.org/10.26773/mjssm.250901
2. Vladovic, J., Morgans, R., Gilic Skugor, B., Pranjic, T., & Modric, T. (2026). Preparing young soccer goalkeepers for the next level: analysis of differences in physical performance between U17 and U19 age groups during match play. *International Journal of Performance Analysis in Sport*, 1–13. https://doi.org/10.1080/24748668.2026.2668233
3. Vladovic, J., Versic, S., Foretic, N., Morgans, R., & Modric, T. (2023). Quantification of External Training Load among Elite-Level Goalkeepers within Competitive Microcycle. *Applied Sciences*, *13*(19), 10880. https://doi.org/10.3390/app131910880

1 INTRODUCTION

1.1 Context

Football is the most widely played team sport in the world, played over two 45-minute periods on a grass pitch approximately 100 × 65 meters in size (Hulteen et al., 2017; MacIntosh, Bravo, & Li, 2019; Plakias, 2025). The game involves two teams composed of ten outfield players and one goalkeeper (Tierney, Young, Clarke, & Duncan, 2016). Outfield players typically operate across larger areas of the pitch and perform a combination of defensive and offensive tasks aimed at maintaining possession, progressing the ball, preventing opposition attacks, and creating goal-scoring opportunities (Yi, Jia, Liu, & Gómez, 2018). In contrast, goalkeepers operate on a smaller area of the pitch and their roles differ substantially from those of outfield players as they are primarily responsible for preventing goals through shot-stopping (Santos, Malico Sousa, Pinheiro, & Jorge Santos, 2022; West, 2018). Modern goalkeepers are also increasingly involved in offensive play by initiating attacking actions and supporting possession through ball distribution (Casal, Stone, Iván-Baragaño, & Losada, 2024; Mikikis, Michailidis, Mandroukas, Mavrommatis, & Metaxas, 2021; Otte, Dittmer, & West, 2023). Therefore, due to their unique role, goalkeepers' match performance substantially differs from that of outfield players (Di Salvo, Benito, Calderón, Di Salvo, & Pigozzi, 2008; White et al., 2018).

Goalkeepers' match performance emerges from the interaction between physical and technical performance (Serrano et al., 2019). However, it is important to note that their success during the match is most often reflected through technical performance (Obetko, Peráček, Mikulič, & Babic, 2022; Tienza-Valverde et al., 2023). Specifically, the outcome of decisive moments, which are critical for the final match result, depends on the goalkeeper's ability to successfully execute position-specific actions, making technical performance a key determinant of competitive success (Lamas, Drezner, Otranto, & Barrera, 2018; White et al., 2020). On the other hand, physical performance also plays an important role for goalkeepers' success during the match, particularly by helping to carry out position-specific tasks in an efficient way (Perez-Arroniz, Calleja-González, Zabala-Lili, & Zubillaga, 2023). Therefore, a comprehensive evaluation of goalkeeper match performance requires a holistic approach that considers both physical and technical performance.

Physical performance is generally defined by the external load demands experienced by players during the match or training (Bourdon et al., 2017). External load can be broadly classified into locomotor and mechanical components (Buchheit, Manouvrier, Cassirame, & Morin, 2015). Locomotor load refers to the external work imposed on an athlete as a function of their displacement without necessarily reflecting internal muscular strain (Vanrenterghem, Nedergaard, Robinson, & Drust, 2017). Typical metrics to quantify locomotor load of goalkeepers are total distance and distance covered at different speed zones (Jara et al., 2019). The classification of speed zones generally varies depending on the monitoring system used (Cummins, Orr, O’Connor, & West, 2013). The most frequently used approach in the literature (Modric, Versic, Sekulic, & Liposek, 2019; Pranjic, Modric, & Uljevic, 2022), and the one adopted in this thesis, is as follows: walking (<7.1 km/h), jogging (7.2–14.3 km/h), running (14.4–19.7 km/h), high-speed running (19.8–25.1 km/h), maximal sprinting (>25.2 km/h), and high-intensity running (>19.8 km/h).

In contrast to locomotor load, the mechanical load reflects the external forces experienced by the musculoskeletal system and is typically driven by discrete, high-force actions that may occur with minimal displacement (Barreira et al., 2017; Harper, Carling, & Kiely, 2019). The most common metrics used to quantify mechanical load in goalkeepers include the number of accelerations, decelerations, dives, and jumps (Abbott, Thomas, & Clifford, 2023; Casamichana et al., 2024), which can be analysed according to their frequency and intensity. Among the various classifications available, the approach most commonly used in the literature (Grimson, Brickley, Smeeton, Brett, & Abbott, 2023; Hernández-Beltrán et al., 2024) and adopted in this thesis is as follows: total accelerations (>0.5 m/s^2), high-intensity accelerations (>3 m/s^2), total decelerations (less than –0.5 m/s^2), high-intensity decelerations (less than –3 m/s^2); total dives and high-intensity dives (intensity greater than 9 arbitrary units); small jumps (< 0.2 m), moderate jumps (0.2 – 0.4m), high jumps (> 0.4 m). Notably, these metrics reflect movements that are more specific to the goalkeeper position and therefore are more useful when assessing goalkeeper physical performance (Sarmento et al., 2024).

Goalkeepers' technical performance consists of the goalkeeper-specific actions carried out during the match, most often evaluated through their frequency and effectiveness (Sainz de Baranda et al., 2019; Tienza-Valverde et al., 2023). Goalkeepers' technical actions are divided into defensive (i.e., goal prevention) and offensive (i.e., ball distribution) actions (Obetko et al., 2022; Szwarc, Chamera, Duda, Memmert, & Radziminski, 2023). Saves represent the most important defensive action and are usually assessed by the number of saves and the save success percentage (Gavião, Gavião, Sant'Anna, Lima, & Garcia, 2021; Gelade, 2014). Regarding offensive actions, ball distribution dominates goalkeepers' total technical activity, quantified by the number, accuracy, and success of their ball distributions (Jamil et al., 2021; Seaton & Campos, 2011). These indicators are specific to the goalkeeper and capture how a strong technical performance contributes to the team's success, which makes them the most appropriate for assessing goalkeeper technical performance (Ruiz-Solano, Gómez-López, Tessitore, García-de-Alcaraz, & Gómez-Ruano, 2022).

The evaluation of physical performance is commonly undertaken using optical systems or radar-based local positioning systems (LPS), and global positioning systems (GPS). Although all these systems allow the collection of highly valid and reliable data on players' external load during match-play (Linke, Link, & Lames, 2018), currently the most popular among professional teams and sports scientists in football is GPS (Akenhead & Nassis, 2016). Compared to the LPS and optical systems, which are fixed, the major advantage of GPS technology is its portability. This allows monitoring matches at different stadiums (especially important when playing away) as well as in training sessions at different training facilities. On the other hand, technical performance is primarily evaluated using event data provided by commercial platforms (e.g., Wyscout, StatsBomb, etc.) or extracted from optical tracking systems (e.g., TRACAB, Hawk-Eye, etc.) (Goes et al., 2021). More recently, advances in computer vision and artificial intelligence have enabled the extraction of both physical and technical performance data directly from broadcast video, eliminating the need for wearable devices or dedicated optical tracking infrastructure (e.g., SkillCorner) (Bassek, Theiner, Ewerth, Memmert, & Raabe, 2025; Crang et al., 2026).

Understanding goalkeepers' match performance has multiple important benefits for practitioners (Perez-Arroniz, Calleja-González, Fernández-Navarro, & Zubillaga-Zubiaga, 2026; West, 2018). Specifically, understanding physical performance helps practitioners identify the physical demands imposed on goalkeepers during match-play and consequently develop training programs that better prepare them for these demands (González-Jarrín, Fernández-Fernández, García-Tormo, & Gutiérrez García, 2025; Moreno-Pérez et al., 2020). Similarly, understanding technical performance provides valuable information regarding a goalkeeper’s effectiveness during competition, supporting evidence-based decision-making related to training design, player development, and match preparation (Kielkopf & Keiner, 2025; Liu, Gómez, & Lago-Peñas, 2015). Therefore, a detailed understanding of goalkeepers’ match performance is essential to maximise their development and competitive performance (Sarmento et al., 2024).

However, match performance in football generally shows high variability (Morgans et al., 2026; Teixeira et al., 2024). For example, goalkeepers may cover ~ 4-6 km in a single match and perform ~ 2-10 saves with ~3–11 dives (Kubayi, 2020; White et al., 2020). Such wide ranges in performance hamper their interpretation and application in practice because, without a stable measurement of performance, it may be difficult to evaluate the effectiveness of a training intervention programme (Carling, Bradley, McCall, & Dupont, 2016). Understanding the factors responsible for these fluctuations is therefore essential for the accurate interpretation of match performance data. For this reason, considerable attention has been devoted to identifying factors associated with variations in goalkeeper match performance (Barrera, Sarmento, Clemente, Field, & Figueiredo, 2021; Ruiz-Solano et al., 2022; Serrano et al., 2019).

Apart from playing position, which is typically considered the primary determinant of match performance in football (Lampre-Ezquerra et al., 2026), contextual factors such as match outcome, match location, team quality, and opponent quality are among the most influential factors affecting match performance (Jerkovic, Modric, & Versic, 2022; Lago, 2009). Theoretically, winning, playing at home or facing a weaker opponent typically results in more attacking playing styles, which may positively influence players’ match performance (Fernandez-Navarro, Fradua, Zubillaga, & McRobert, 2018; Forcher et al., 2023). On the other hand, losing, playing away or against stronger opposition is commonly associated with more defensive playing styles, which may have negative consequences on match performance (Almeida, Ferreira, & Volossovitch, 2014). However, findings across the literature are inconsistent, and no clear consensus exists regarding the influence of contextual factors on match performance (Lago-Peñas, 2012; Trewin, Meylan, Varley, & Cronin, 2017).

It is important to note that most studies investigating the influence of contextual variables on match performance in football have focused exclusively on outfield players (Benéitez-

Andrés et al., 2026; Guimarães et al., 2024; Lago-Peñas & Dellal, 2010; Taylor, Mellalieu, James, & Shearer, 2008). Thus, currently there are only a limited number of studies that have examined goalkeeper match performance in relation to different contextual variables (Liu, Gómez, & Lago-Peñas, 2015; Ruiz-Solano et al., 2022; Serrano et al., 2019). Briefly, Ruiz-Solano et al. (2022) reported that English Premier League goalkeepers from different team quality levels differed in successful passes, goals conceded inside the penalty area, and successful long-ball distribution. Liu, Gómez, and Lago-Peñas (2015) found that saves were the only performance indicator that consistently differed according to team quality in Spanish La Liga goalkeepers. Seaton and Campos (2011) demonstrated that goalkeepers competing at higher levels exhibited superior ball distribution. Kubayi (2020) showed that losing goalkeepers covered greater sprinting distances, whereas goalkeepers from drawing teams completed the highest number of passes during the UEFA Euro 2016 tournament.

Importantly, studies mostly analysed goalkeepers' technical performance in relation to contextual variables, while there is a lack of studies to examine goalkeepers' physical performance in relation to contextual factors (Kubayi, 2020; Serrano et al., 2019). Furthermore, even studies examining technical performance have typically relied on relatively simplistic indicators such as clean sheets, goals conceded, and total saves (Gavião et al., 2021; Liu, Gómez, & Lago-Peñas, 2015), which may not fully capture the complexity of goalkeeper performance during competition (Otte et al., 2023). To address this, advanced metrics such as expected goals on target (xGOT) is needed to better capture a goalkeeper's shot-stopping ability (De-la-Cruz-Torres, Navarro-Castro, & Ruiz-de-Alarcón-Quintero, 2025). Finally, most previous studies investigating goalkeepers' match performance analysed data from teams in national competitions. Therefore, conclusions may have been influenced by geographical, cultural, historical, and social aspects of the observed competition (Sapp, Spangenburg, & Hagberg, 2018). Consequently, current knowledge regarding the influence of contextual factors on goalkeeper match performance remains limited.

Besides contextual factors, differences in goalkeepers' match performance may also arise from individual player characteristics. One of the most frequently discussed factors in this regard is age group (Kilci et al., 2025; Zhou, Lorenzo, Gómez, & Palao, 2020). This is because during growth and maturation, individuals experience substantial improvements in key physical capacities, including speed, endurance, power, and strength (Gundersen et al., 2026). Consequently, advancing in age group is generally accompanied by enhanced physical capacities, which may contribute to improved match performance (González-Jarrín et al., 2025; Hegedüs, Csala, Tóth, & Tóth, 2025). Although previous studies repeatedly coped with this issue, most of the studies investigating age group-related differences among goalkeepers described only technical performance (Kielkopf & Keiner, 2025; Scholefield & Fitzpatrick, 2025). Currently, only a few studies have investigated goalkeepers' physical performance according to the different age groups (Dolański, Rompa, Liu, Wasielewski, & Szwarc, 2018; Hernández-Beltrán et al., 2024).

In brief, Dolański et al. (2018) analysed 48 match observations of U15–U19 goalkeepers and found that physical performance (e.g., total distance, high-intensity running and max speed) showed no age-related differences across different age groups. Hernández-Beltrán et al. (2024) compared youth quality categories and reported that Youth C goalkeepers showed significantly greater high-intensity external load (e.g., high metabolic load distance, high metabolic power efforts) compared to Youth B goalkeepers. However, it is important to note that no study so far has aimed to directly compare goalkeeper-specific physical performance between goalkeepers from different age groups (González-Jarrín et al., 2025). Furthermore, the available studies on youth goalkeepers have generally relied on relatively simple methodological approaches and have not accounted for important contextual factors known to influence match performance (Dolański et al., 2018; Hernández-Beltrán et al., 2024). As a result, it remained unknown how age group influences goalkeepers' physical performance during the match.

In addition to understanding the factors that influence match performance, the appropriate distribution of external training load throughout the weekly training cycle (i.e., the microcycle) is also important for developing effective training programmes (Malone et al., 2015). This is because proper distribution of training load enables the development of physical capacities and skills while simultaneously allowing players to reach their full potential during competition (Castillo, Raya-González, Weston, & Yanci, 2021; Otte, Millar, & Klatt, 2019). The first step in this process is the analysis of training load during individual training sessions within a microcycle. However, previous studies investigating the distribution of training load of football players have mostly involved the outfield players (Martín-García, Gómez Díaz, Bradley, Morera, & Casamichana, 2018; Stevens, de Ruiter, Twisk, Savelsbergh, & Beek, 2017), while studies analysing goalkeepers' training load are scarce.

Specifically, White et al. (2020) and Jara et al. (2019) investigated goalkeepers' external training load across different training types in the English Premier League and the German fifth division, respectively. Grimson et al. (2023) and Malone et al. (2018) explored the relationship between external training load and subjective wellness among goalkeepers competing in the English Premier League and the top Dutch league, respectively. Only Abbott et al. (2023) and Moreno-Pérez et al. (2020) examined weekly external training load among goalkeepers, but in sub-elite goalkeepers from the U23 English Premier League and the Spanish second division, respectively. Evidently, comprehensive knowledge on the distribution of external training load throughout the weekly training cycle among elite-level goalkeepers also remained limited.

Therefore, the main rationale for this doctoral thesis lies in the limited evidence on factors affecting (e.g., contextual – match outcome, match location, team quality, opponent quality, and individual – age group) match performance (e.g., physical and technical) and the weekly distribution of external training load among elite-level goalkeepers. The findings will contribute to a more comprehensive understanding of the physical and technical demands imposed on elite goalkeepers during training and matches. This will provide valuable evidence-based information to support goalkeeper performance monitoring and training design (Moreno-Pérez et al., 2020; White et al., 2018; Ziv & Lidor, 2011). Thus, the application of these findings may facilitate the optimisation of match performance, ultimately contributing to the long-term development of elite goalkeepers and greater success in elite-level football.

1.2 Research aims and hypotheses

The general aim of this doctoral thesis was to provide an integrated understanding of the match and training demands of goalkeepers at elite level. The specific aims of this research were (i) to examine the effect of match outcome, match location, team quality, and opponent quality on goalkeepers' technical and physical performance, (ii) to examine the effect of age group on goalkeepers' physical performance, (iii) to examine goalkeepers' external training load throughout the weekly training cycle.

The hypotheses of this research are as follows: (i) match outcome, match location, team quality, and opponent quality are significantly associated with technical and physical performance, (ii) age group is significantly associated with physical performance, (iii) external training load is unevenly distributed throughout the weekly training cycle.

General aim

Integrated understanding of the match and training demands of goalkeepers at elite level

↓

Study 1 (senior elite, match play)

AIM: The effect of contextual factors on the technical and physical performance of UEFA Champions League goalkeepers

METHODS: 49 goalkeepers, 125 matches (2022/23 season); optical tracking system and event data; one-way ANOVA and Kruskal-Wallis test

MAIN FINDINGS: *Technical performance differed according to match outcome, team quality and opponent quality, whereas physical performance was unaffected.*

→ *contextual factors controlled for*

Study 2 (youth, match play)

AIM: Differences in physical performance between the U17 and U19 age groups during match play

METHODS: 2 goalkeepers, 22 matches (12 U19, 10 U17), one competitive half-season; GPS and accelerometry; generalised linear models

MAIN FINDINGS: *Total distance covered was greater in the U17, whereas the number of total and high-load dives was greater in the U19 age group.*

↓ ↓

Doctoral thesis

Performance analysis of elite-level football goalkeepers during training and matches

↑

Study 3 (senior elite, training)

AIM: External training load throughout the competitive microcycle

METHODS: 3 goalkeepers, 67 training sessions, one competitive half-season; GPS and accelerometry; sessions coded MD-4 to MD-1; one-way ANOVA and cannonical discriminant analysis

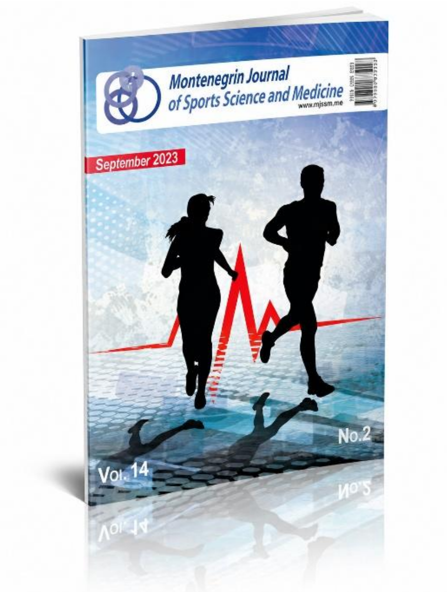
MAIN FINDINGS: *External training load was highest on MD-3 and lowest on MD-2 and MD-1.*

Figure 1. Overview of the three studies included in this doctoral thesis.

2 ORIGINAL STUDIES

2.1 Study 1: Context is Key: The Effect of Match-Related Variables on Technical and Physical Performance of the UEFA Champions League Goalkeepers

Vladovic, J., Modric, T., Pavlinovic, V., Morgans, R., Majeric, M. (2025) Context is Key: The Effect of Match-Related Variables on Technical and Physical Performance of the UEFA Champions League Goalkeepers. Montenegrin Journal of Sports Science and Medicine, 14 (2), 5–12. https://doi.org/10.26773/mjssm.250901



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ORIGINAL SCIENTIFIC PAPER

Context is Key: The Effect of Match-Related Variables on Technical and Physical Performance of the UEFA Champions League Goalkeepers

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Abstract: The majority of studies investigating contextual variables (CV) and match performance (MP) excluded goalkeepers, limiting insights into CV effects on goalkeepers' MP. Therefore, this study aimed to evaluate goalkeepers' MPs according to CV. Data were collected from all UEFA Champions League (UCL) matches during the season 2022/23. MPs, including physical and technical performance, were classified according to the match outcome, match location, team quality, and opponent quality. When winning, goalkeepers faced less shots against (Cohen's d (d) = 1.39), had less conceded goals (d = 2.13) and more exits (d = 0.37), and made less saves (d = 0.52) and reflex saves (d = 0.50) than when losing. When played at home, goalkeepers had less conceded goals (d = 0.23) and exits than when playing away (d = 0.25). When played in high-quality level teams, goalkeepers had less conceded goals (d = 0.48), total (d = 0.35) and accurate passes beyond own third (d = 0.35), saves (d = 0.42) and reflex saves (d = 0.33) than when played in low-quality level teams. When played against high-quality level opponents, goalkeepers had more conceded goals (d=0.48), passes beyond own third (d = 0.28), shots against (d = 0.67), saves (d = 0.55), reflex saves (d = 0.57) than when played against low-quality level opponents. These findings demonstrated that UCL goalkeepers' technical performance was influenced by match outcome, teams' and opponents' quality levels. Therefore, CV should be taken into account in decision-making processes for structuring elements of training and subsequent match preparation.

Keywords: match outcome, match location, opponent quality, team quality, soccer

2.1.1 Introduction

Team sports, such as competitive soccer, require a complex mix of technical, tactical, and physical qualities (França et al., 2023; Modric et al., 2022; Wagner et al., 2023). It is widely recognized that one of the most distinct roles in soccer is the goalkeeper's position (West, 2018). A comprehensive understanding of this role requires evaluation of match performance (MP) through the match analysis, focusing on both physical and technical-tactical demands (White et al., 2018). This evaluation of goalkeepers' MPs is crucial for designing specific training programs that address the physical and technical demands encountered during match-play (Serrano et al., 2019). However, research investigating MPs in soccer shows their high variability, hampering their interpretation and application in practice (Šunjić et al., 2024).

Empirical evidence demonstrated that myriad contextual variables (CV) such as team formation, playing surface, competition type, match location, team quality, opposition quality, and match outcome strongly affect MPs (Freire et al., 2022; Jerkovic et al., 2022; Kutnjak et al., 2025; Liu, Gómez, et al., 2015). However, the majority of studies that analyzed the influence of CV on MPs in soccer excluded goalkeepers. To the best of our knowledge, only a limited number of studies analyzed goalkeepers' MPs according to the CV so far (Liu, Gómez, et al., 2015; Ruiz-Solano et al., 2022).

Briefly, Ruiz-Solano et al. analyzed English Premier League goalkeepers and reported differences among teams' levels in terms of successful passes, goals received inside the box, and successful long ball distribution (Ruiz-Solano et al., 2022). Liu et al. investigated Spanish La Liga goalkeepers and found saves to be the only indicator that differed for goalkeepers of all team levels (Liu, Gómez, et al., 2015). Seaton et al. researched different levels of Spanish goalkeepers and discovered better ball distribution performances as their level of competition increased (Seaton & Campos, 2011). Serrano et al. examined Spanish La Liga goalkeepers' MP and identified a reduction in saves over six seasons (Serrano et al., 2019). Kubayi studied the 2016 European Football Championships and detected losing teams' goalkeepers covered the greatest distance sprinting and drawing teams' goalkeepers with the most passes (Kubayi, 2020).

Although these studies provided valuable information about the influence of CV on goalkeepers' MPs, it should be noted that most of them analyzed data obtained from only one country (Liu, Gómez, et al., 2015; Ruiz-Solano et al., 2022; Serrano et al., 2019).

Therefore, the results were undoubtedly influenced by geographical, cultural, historical, and social aspects of the observed competition (Sapp et al., 2018). In addition, studies mostly studied goalkeepers' technical performance according to the CV (Liu, Gómez, et al., 2015; Ruiz-Solano et al., 2022), while there is a lack of studies to examine goalkeepers' physical performance and CV (Serrano et al., 2019). Consequently, the knowledge about the influence of CV on goalkeepers' physical performance is still limited. Moreover, previous studies investigating MPs according to the CV exclusively evaluated goalkeepers' technical performance through simplistic variables such as clean sheets (Gavião et al., 2021), number of goals conceded (Ruiz-Solano et al., 2022), and total saves (Liu, Gómez, et al., 2015; Serrano et al., 2019). This approach can obscure the true difficulty of a goalkeeper's saves or whether the goals conceded were unstoppable because they don't consider factors like shot distance, angle, speed, and accuracy, and therefore may not be fully suitable for evaluation of goalkeepers' technical performance (Otte et al., 2023). For this reason, a more complex approach when assessing this performance is needed (Baron et al., 2024).

Considering all previous limitations, we believe that new research analyzing complex indicators of technical performance together with physical performance among goalkeepers from multiple teams from different countries is warranted. One of the most elite competitions that includes teams from different countries is the UEFA Champions League (UCL) (Lago-Peñas et al., 2011). Analyzing goalkeepers' complex technical and physical performances according to CV from such competition may provide novel findings enabling a better understanding of natural match-to-match variability in goalkeepers' MPs (Yi et al., 2018). This may be crucial for soccer practitioners to develop specific game strategies and training designs among elite goalkeepers (Serrano et al., 2019). Therefore, this study aimed to evaluate the UCL goalkeepers' MPs according to CV.

2.1.2 Materials and Methods

Participants and Design

In this observational study, the MPs of goalkeepers (n = 49) were obtained from all UCL matches (n = 125) in the 2022/23 season. No matches included extra times. Only the MPs of those goalkeepers who participated in the whole match were analyzed. As a result, the final sample included 242 observations of all 49 goalkeepers. The MPs were classified according to the match outcome (win; n = 96, draw; n = 49, loss; n = 97), match location (home; n = 122, away; n = 119), teams' quality (high-quality level team; n = 158, low-quality level team; n = 84), and opponents' quality (high-quality level opponent; n = 158, low-quality level opponent; n = 84). Players' identities were anonymized following the principles of the Declaration of Helsinki to ensure confidentiality. The investigation was approved by the local university ethics board (approval number: 2181-205-02-05-19-0020).

2.2. Procedures

The MP consisted of physical and technical performance. The physical performance was collected using an optical tracking system Player & Ball Tracking System (Hawk-Eye Innovations Limited, Basingstoke, England). The system's reliability was previously assessed using the official Fédération Internationale de Football Association (FIFA) test protocol for Electronic and Performance Tracking Systems (EPTS). This evaluation involved comparing the data with the Vicon system (Vicon Motion Systems, Oxford Metrics, UK) across five velocity bands (0–7 km/h, 7–15 km/h, 15–20 km/h, 20–25 km/h, and 25+ km/h). The system successfully passed this test protocol (authorization number: 1015068), indicating a high level of reliability (Toni Modric, Versic, Jukic, & Sekulic, 2024). The technical performance data was registered using WyScout® (Wyscout, Chiavari, Italy), a computerized multiple-camera tracking validated analysis tool. The procedure of data collection has been previously described in detail (Pappalardo et al., 2019).

2.3. Variables

The CV variables included match outcome, match location, team quality, and opponent quality. The match outcome was assessed as "win", "draw" or "loss". Match location was recorded as "home" when the team played at home and "away" when the team played away from home. As suggested previously, teams and opponents were classified as "high-quality" or "low-quality" based on UEFA season club coefficients (Liu, Yi, Giménez, Gómez, & Lago-Peñas, 2015). All the physical and technical performance variables with their associated definitions are presented in Table 1.

Table 1. Match performance variables and their definitions

Physical performance-related variables (m)	
Total distance (TD)	Total distance covered in the match.
Low-intensity running (LIR)	Distance covered at speed <14.3 km/h
Moderate-intensity running (MIR)	Distance covered at speed 14.4-19.7 km/h
High-intensity running (HIR)	Distance covered at speed >19.8 km/h
Technical performance-related variables (#)	
Total passes (TP)	Total number of attempts to pass the ball to a teammate
Accurate passes (AP)	Total number of accurate passes
Passes beyond own third (PBOT)	Total number of passes (including goal kicks) that went outside own third
Accurate passes beyond own third (APBOT)	Total number of accurate passes (including goal kicks) that went outside own third
Shots against (SA)	Total number of shots on target faced by the goalkeeper
Conceded goals (CG)	Total number of goals conceded
Saves (S)	A successful attempt from the goalkeeper to prevent a shot from being scored
Reflex saves (RS)	A save from a shot from near distance, where the goalkeeper has to react immediately, using his reflexes to save the ball
Saved penalties (PS)	Total number of penalties saved
Exits (EX)	Total number of goalkeepers exits
Post-Shot expected conceded goals (xCG)	The sum of expected conceded goals (xCG) values of all shots against on target
Post-Shot expected conceded goals – Conceded goals (xCG-CG)	The sum of expected conceded goals (xCG) values of all shots against on target minus the total number of conceded goals

2.4. Variables

The normality of the distributions was tested by the Kolmogorov–Smirnov test and the data are presented as the means ± standard deviations. Homogeneity was checked by Levene's test. Preliminary, k-means cluster analyses were performed to identify a cut-off value of the UEFA season club coefficient and to classify teams and opponents as "high-quality level" or "low-quality level". Later, differences in MP according to the CVs were analyzed by one-way ANOVA or Kruskal-Wallis, depending on the normality of distributions. To assess specific differences in MPs among match outcomes, post-hoc Scheffe's test or comparisons of mean ranks were used based on the normality of distributions. Effect sizes (ES) were evaluated by Cohen's d (>0.20 is small; >0.50 is medium; >0.80 is large ES). For all analyses, Statistica 14.0 (TIBCO Software Inc., Greenwood Village, CO, USA) was used, and $p < 0.05$ was applied.

2.1.3 Results

For team quality, the results identified cluster 1 (high-quality level team) with 102.71 ± 22.26 (range of 77 – 145; n = 158) and cluster 2 (low-quality level team) with 46.75 ±

15.71 (range of 13 – 72; n = 84). For opponent quality, the results identified cluster 1 (high-quality level opponent) with 119.92 ± 16.85 (range of 96 – 145; n = 84) and cluster 2 (low-quality level opponent) with 64.63 ± 21.57 (range of 13 – 91; n = 158).

Table 2 presents differences in goalkeepers' MPs according to the match outcome. With regard to physical performance, goalkeepers covered more MIR in lost compared to won matches (d = 0.20). Concerning technical performance, goalkeepers had fewer SA (d = 0.94 and 1.39, respectively) and CG (d = 1.56 and 2.13, respectively) in drew and won compared to the lost matches. Also, in drew and won matches goalkeepers had lower xCG (d = 1.29 and 1.58, respectively) and greater xCG-CG (d = 0.59 and 0.98, respectively) than in lost matches. In addition, goalkeepers performed more S (d = 0.52) and RS (d = 0.50) in lost compared to the won matches. On the other hand, goalkeepers had more EX in won compared to lost matches (d = 0.37).

Table 2. Differences in match performances of goalkeepers according to match outcome

	LOSS	DRAW	WIN	F/H	p
Total distance	5179.00±586.81	5360.73±520.38	5218.96±574.61	1.70	0.19
Low-intensity running	5025.02±554.64	5229.27±502.26	5090.42±556.97	2.28	0.10
Moderate-intensity running*	131.52±120.13W	110.29±50.74	110.38±93.59L	7.34	0.03
High-intensity running*	22.46±19.00	21.18±20.71	18.17±16.22	3.33	0.19
Total passes	30.45±10.51	30.90±11.31	31.10±9.12	0.10	0.90
Accurate passes	26.26±9.07	26.94±9.65	27.31±8.00	0.35	0.70
Passes beyond own third*	12.85±6.29	13.39±6.70	11.46±5.59	2.38	0.30
Accurate passes beyond own third*	9.37±4.88	10.10±5.16	8.27±4.28	3.45	0.18
Shots against*	6.81±3.00D, W	4.00±2.47L	3.32±1.89L	74.85	0.01
Conceded goals*	2.82±1.41D, W	0.88±0.83L	0.46±0.68L	144.28	0.01
Saves*	3.99±2.45W	3.12±2.20	2.86±1.84L	11.55	0.01
Reflex saves*	2.69±1.94W	2.02±1.82	1.83±1.48L	11.43	0.01
Saved penalties*	0.03±0.17	0.10±0.31	0.04±0.20	3.69	0.16
Exits*	0.93±1.04W	1.47±1.65	1.34±1.20L	7.81	0.02
Post-Shot expected goals against*	2.44±1.18D, W	1.05±0.83L	0.90±0.71L	98.21	0.01
Post-Shot expected goals against – Conceded goals	-0.38±1.00D, W	0.17±0.78L	0.44±0.64L	24.47	0.01

*denotes variables where non-parametric test was used

Table 3 presents differences in goalkeepers' MPs according to match location. Goalkeepers had more CG (d = 0.23) and EX (d= 0.25) when played away compared to at home.

Table 3. Differences in match performances of goalkeepers according to match locations

	Home	Away	F/H	p
Total distance	5225.44±586.04	5239.63±559.34	0.04	0.85
Low-intensity running	5086.50±563.30	5099.82±537.03	0.04	0.85
Moderate-intensity running*	117.24±87.87	120.64±110.15	0.15	0.70
High-intensity running*	21.70±19.78	19.17±16.79	0.21	0.65
Total passes	30.48±9.70	31.13±10.60	0.25	0.61
Accurate passes	26.52±8.26	27.10±9.30	0.27	0.61
Passes beyond own third*	12.18±5.94	12.62±6.38	0.06	0.80
Accurate passes beyond own third*	8.84±4.51	9.31±4.99	0.11	0.74
Shots against*	4.45±2.66	5.27±3.23	3.42	0.06
Conceded goals*	1.32±1.52	1.67±1.52	5.10	0.02
Saves*	3.13±2.03	3.60±2.40	1.69	0.19
Reflex saves*	2.10±1.64	2.33±1.93	0.55	0.46
Saved penalties*	0.06±0.23	0.04±0.20	0.30	0.58
Exits*	1.05±1.16	1.36±1.35	4.18	0.04
Post-Shot expected goals against*	1.38±1.05	1.71±1.32	2.91	0.09
Post-Shot expected goals against – Conceded goals	0.06±0.96	0.04±0.84	0.06	0.81

*denotes variables where non-parametric test was used

Table 4 presents differences in goalkeepers' MPs according to teams' level. Goalkeepers from low-quality level teams had more PBOT (d = 0.35), APBOT (d = 0.35), SA (d = 0.57), S (d = 0.42), and RS (d = 0.33) compared to high-quality level teams. Also, low-quality level teams' goalkeepers had larger xCG (d = 0.38) and more CG (d = 0.48), but lower xCG-CG (d = 0.30) compared to high-quality level teams' goalkeepers.

Table 4. Differences in match performances of goalkeepers according to teams' quality level

	High-quality level team	Low-quality level team	F/H	P
Total distance	5188.51±587.37	5312.80±532.22	2.62	0.11
Low-intensity running	5048.54±566.05	5174.65±506.50	2.92	0.09
Moderate-intensity running*	119.39±116.99	117.79±51.28	2.21	0.14
High-intensity running*	20.58±17.25	20.36±20.37	0.46	0.50
Total passes	31.15±10.56	30.15±9.27	0.52	0.47
Accurate passes	27.37±9.13	25.76±7.98	1.86	0.17
Passes beyond own third*	11.69±5.85	13.75±6.47	5.18	0.02
Accurate passes beyond own third*	8.51±4.49	10.17±5.04	5.94	0.01
Shots against*	4.29±2.76	5.93±3.08	17.68	0.01
Conceded goals*	1.24±1.33	1.96±1.75	10.04	0.01
Saves*	3.05±2.10	3.96±2.35	9.93	0.01
Reflex saves*	2.01±1.62	2.60±2.01	4.69	0.03
Saved penalties*	0.05±0.22	0.05±0.21	0.01	0.92
Exits*	1.16±1.13	1.29±1.49	0.01	0.97
Post-Shot expected goals against*	1.39±1.16	1.84±1.23	8.98	0.01
Post-Shot expected goals against – Conceded goals	0.15±0.76	-0.12±1.11	5.16	0.02

* denotes variables where non-parametric test was used

Table 5 presents differences in goalkeepers' MPs according to opponents' team level. Goalkeepers had more PBOT (d = 0.28), SA (d = 0.67), S (d = 0.55), and RS (d = 0.57) when played against higher-quality level opponents compared to lower-quality level opponents. Also, goalkeepers had larger xCG (d = 0.62) and more CG (d = 0.48) when played against higher-quality teams, compared to lower-quality teams.

Table 5. Differences in match performances of goalkeepers according to opponents' quality level

	High-quality level opponent	Low-quality level opponent	F/H	P
Total distance	5245.38±567.70	5224.22±574.16	0.08	0.78
Low-intensity running	5082.54±541.72	5097.61±553.58	0.04	0.84
Moderate-intensity running*	138.79±154.72	108.03±44.14	0.20	0.65
High-intensity running*	24.05±21.29	18.58±16.29	3.73	0.05
Total passes	32.01±11.25	30.15±9.42	1.88	0.17
Accurate passes	27.56±9.61	26.41±8.27	0.96	0.33
Passes beyond own third*	13.52±6.43	11.80±5.91	4.59	0.03
Accurate passes beyond own third*	9.84±5.14	8.68±4.48	3.70	0.05
Shots against*	6.09±3.19	4.19±2.62	22.35	0.01
Conceded goals*	1.95±1.71	1.24±1.36	11.57	0.01
Saves*	4.14±2.42	2.95±2.00	16.39	0.01
Reflex saves*	2.86±1.87	1.87±1.64	18.85	0.01
Saved penalties*	0.02±0.15	0.06±0.24	1.88	0.17
Exits*	1.21±1.19	1.20±1.31	0.11	0.74
Post-Shot expected goals against*	2.01±1.32	1.30±1.05	19.48	0.01
Post-Shot expected goals against – Conceded goals	0.06±1.04	0.05±0.82	0.01	0.97

*denotes variables where non-parametric test was used

2.1.4 Discussion

This study aimed to evaluate goalkeepers’ MPs according to CV in the UCL. Results indicated that match outcome, teams’ and opponent’s level influenced goalkeepers’ technical performance, while the effect of match location on goalkeepers’ technical performance can be considered trivial. On the other hand, herein analyzed goalkeepers’ physical performance was similar irrespective of the match outcome, location, and the teams’ and opponents’ level. These findings show that CVs influenced goalkeepers’ offensive and defensive technical performance, including effective passing and shot-saving abilities.

When winning, UCL goalkeepers faced less SA (large ES), had less CG (large ES) and made less S (moderate ES), and RS (moderate ES) than when losing. Considering the high standard of the UCL teams (Lago-Peñas et al., 2011) which almost certainly dominate in ball possession when winning (Farias et al., 2020), opponent attackers possibly had fewer opportunities to take shots (Szwarc et al., 2010). Also, goalkeepers' xCG, a metric used to assess the likelihood of scoring for every shot on target made in the game (Barthélémy et al., 2024), was lower when winning compared to losing (large ES), suggesting poor quality of shots by opponent. For this reason, UCL goalkeepers' saving performance were most likely lower when winning compared to losing. Such findings are in the line with study of Liu et al. who reported that La Liga goalkeepers had variables related to goal saving lower when winning (Liu, Gómez, et al., 2015) than when losing. On the other hand, one study revealed that in the European Championship goalkeepers had a similar number of saves irrespective of the match outcome (Kubayi, 2020). These inconsistencies were most likely the consequence of different samples analyzed, suggesting that the association between goalkeepers' technical performance and match outcome may be competition-specific.

Analyzing goalkeepers' goal-preventing performance, our results showed that goalkeepers had more EX (small ES) when winning than when losing. This may suggest that preventing shots by exiting the line of goal may be an efficient strategy for reaching positive match outcome (Mitrotasios et al., 2022), especially as similar findings of preventing shots were noticed by Kubayi where goalkeepers had a greater percentage of aerial duels when winning than losing (Kubayi, 2020). However, due to the small effect size value found in our study, such consideration should be taken with caution. On the other hand, it is more important to emphasize that goalkeepers had higher xCG-CG (large ES) when winning than when losing. The higher value of this metric is typically associated with a greater quality of goalkeeper (Berri et al., 2024), therefore suggesting that UCL goalkeepers helped prevent more goals than expected. All these findings clearly suggest that goalkeepers' technical performance in UCL was highly influenced by match outcome.

Further analysis of goalkeepers' technical performance when playing at home or away showed quite the opposite trend. Specifically, when played at home, UCL goalkeepers had slightly less CG and EX than when playing away (both small ES). However, considering similar values in all other technical performances irrespective of playing home or away, our results suggest that UCL goalkeepers' technical performance was not greatly influenced by match location. Given the consistent findings in previous research, our results may look surprising. For example, Ruiz-Solano et al. analyzed the English

Premier League and found lower values of saves, clearances, total and goals received inside the box at home compared to away matches (Ruiz-Solano et al., 2022). Similar results were also found in the study of Liu et al. who investigated Spanish La Liga goalkeepers and reported differences in their technical performances (i.e., clearances, saves and catches) in home and away matches (Liu, Gómez, et al., 2015). However, we believe that our findings are influenced by the unique characteristics of the observed competition (i.e., the UCL). Specifically, the UCL is a most elite soccer club competition featuring the world's top goalkeepers (Modric et al., 2024). These athletes are highly professional and their performance is likely consistently high, which almost certainly leads to stable technical execution regardless of match location.

Such considerations that better performance can be expected with increased playing standards may be directly supported by further analysis in the current study. Specifically, our results showed that goalkeepers from high-quality level teams had less CG, lower xCG, and higher xCG-CG (all small ES), indicating their increased quality of goalkeeping performance compared to their counterparts from low-quality level teams. It should be also mentioned that goalkeepers from high-quality level teams had less PBOT (small ES), APBOT (small ES), SA (medium ES), S (small ES), and RS (small ES) than goalkeepers from low-quality level teams. Such lower goalkeeping activities when playing in superior teams (i.e., high-quality level teams) are expected (Liu, Gómez, et al., 2015). Although similar trends were observed in previous research which also reported lower goalkeeping activities when playing in higher standard teams (Serrano et al., 2019), it should be considered that small effect size values indicate limited practical relevance.

Analyzing goalkeepers when playing against low and high-level opponents revealed their technical performance to be opponent-dependent. Specifically, goalkeepers had more PBOT (small ES), SA (moderate ES), S (moderate ES) and RS (moderate ES) when played against high-quality level opponents compared to low-quality level opponents. Moderate magnitudes of differences suggest that opponent quality was an important factor distinguishing goalkeepers' saving performance (i.e., SA, S, and RS). As suggested previously, playing against strong opposition typically leads to a loss of ball possession (Lago, 2009). This enables the opponent team more attacking activities (i.e., shots), consequently requiring more saving performance among goalkeepers when playing against higher-quality level opponents. Most likely for the same reason goalkeepers had greater CG (small ES) and xCG (moderate ES) when played against higher-quality opponents compared to lower-quality opponents. These findings are in contrast to the study of Liu et al. who indicated that national-level goalkeepers had more saves against low- compared to high-quality opponents (Liu, Gómez, et al., 2015). Such inconsistencies are most likely a consequence of differences in playing standards of the UCL teams and national-level teams.

In contrast to the goalkeeper's technical performance which can be identified as affected by CV, the physical performance of UCL goalkeepers was poorly influenced by either match outcome, match location, team quality, or opponent quality. Specifically, goalkeepers covered less MIR (small ES) when lost compared to won matches, while all other indicators of physical performances were similar irrespective of winning or losing, playing at home or away, playing in high or low-quality level teams, and playing against higher or lower-quality opponents. This may look controversial as the physical performance of field players is typically highly influenced by CV (Modric et al., 2024). However, the physical performance of goalkeepers does not resemble those of the field players during a competitive match (Di Salvo et al., 2008), and therefore different effects of CV on their physical performance were expected. Interestingly, previous studies have reported that goalkeepers' physical performance could be influenced by CV to some extent. For example, Serrano et al. observed more sprints in La Liga in low- compared to high-quality teams (Serrano et al., 2019), while Kubayi found in the European Championship that losing teams' goalkeepers covered greater sprint distance than winning (Kubayi, 2020). Therefore, it seems that the effect of CV on physical performance is competition-dependent.

Several limitations should be considered when interpreting the findings of this research. Firstly, the current data are reflective of the paradigms and practices of UCL clubs; consequently, the results might only be generalizable to similar cohorts. Secondly, physical performance was assessed only with total distance and distances covered in different speed zones. For in-depth insight into the influence of CV on physical performance, goalkeeping-specific parameters related to physical performance (i.e., number of dives, jumps, and explosive efforts) should be analyzed. Thirdly, due to the limited sample, teams and opponents were classified into only two categories: "high-quality level" and "low-quality level". Therefore, future studies should analyze a larger sample with MP classification in more categories. This will enable a more detailed understanding of the effect of team and opponent quality on MP. Finally, analysis of MPs according to the other match-related variables such as team formation, ball possession percentage, playing style, or effective playing may enable a more comprehensive understanding of the effect of CV on the goalkeepers' MP.

2.1.5 Conclusions

The technical performance of UCL goalkeepers was influenced by match outcome, teams' and opponents' quality level but not by match location. On the other hand, the physical performance of goalkeepers remained similar irrespective of the match outcome and location as well as teams' and opponents' quality level. These findings demonstrated that goalkeepers' technical performance was influenced by CV more than their physical performance. Soccer practitioners should account for CV in decision-making processes for structuring the elements of training and subsequent match preparation. For example, as goalkeepers had more exits in won matches, soccer coaches should incorporate scenarios in training that improve defending crosses by exiting the line. This may encourage players to take exits during the game with more confidence, which can increase the chances of winning. Also, when playing in low-quality level teams or against high-quality level teams, due to their increased match demands (i.e., saves, reflex saves) goalkeepers may require extended periods of recovery or supplementary practices (e.g., ice submersions, massage, etc.).

Conflicts of Interest: The authors declare no conflict of interest.

2.1.6 References

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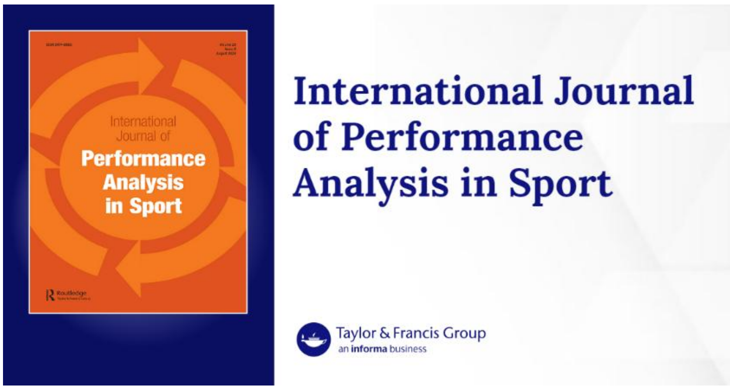
Study 1 analysed how contextual factors influence the technical and physical performance of elite-level senior goalkeepers, thereby providing a reference for goalkeeper match performance at the highest competitive level and establishing which match circumstances need to be accounted for when it is interpreted. Building on this, Study 2 shifted the focus to youth goalkeepers and examined the differences between youth age groups in the match performance of the goalkeepers. Specifically, differences in physical performance between the U17 and U19 age groups were examined while controlling for the contextual factors, so that the observed differences could be attributed to age group rather than to the conditions in which the matches were played.

2.2 Study 2: Preparing young soccer goalkeepers for the next level: analysis of differences in physical performance between U17 and U19 age groups during match play

Vladovic, J., Morgans, R., Gilic Skugor, B., Pranjic, T., & Modric, T. (2026). Preparing young soccer goalkeepers for the next level: analysis of differences in physical performance between U17 and U19 age groups during match play. International Journal of Performance Analysis in Sport, 1–13. https://doi.org/10.1080/24748668.2026.2668233



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Preparing young soccer goalkeepers for the next level: analysis of differences in physical performance between U17 and U19 age groups during match play

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Abstract

This study aimed to examine differences in the physical performance of goalkeepers between the U17 and U19 age groups during official match play while controlling for the contextual factors. Data were collected over a competitive half-season and included 12 matches from the U19 age group and 10 matches from the U17 age group. Physical performance was assessed using Global Positioning System-derived variables, including total and high-intensity running distance covered, number of high-intensity accelerations, number of total and high-intensity dives, dive load per minute, number of jumps, number of explosive efforts, and average time-to-feet. The main findings revealed that the total distance covered was significantly greater (Cohen's d (d) = 1.16) in the U17 than in the U19 age group, indicating greater locomotor load at lower intensities during the match. In contrast, the number of total (d = 1.49) and high-load dives (d = 1.02) was significantly greater in the U19 than in the U17 age group. This indicates that the U19 goalkeepers experienced substantially higher mechanical load, particularly through a greater volume and intensity of diving actions. Training in this age group may benefit from increased emphasis on dive-specific mechanical loading, including progressive exposure to high-load dives and landing mechanics.

Keywords: locomotor load, mechanical load, age-related, goalkeeping-specific, football

2.2.1 Introduction

Advances in monitoring technologies have enabled the accurate quantification of physical performance during soccer match play (Martín-Castellanos et al., 2024; Ponce-Bordón, López-Gajardo, Lobo-Triviño, Pulido, & García-Calvo, 2024). Previous studies have consistently shown that physical performance, defined by the external load demands experienced by players, varies substantially according to playing position (Cotteret et al., 2025). While outfield players typically achieve greater overall and intensive running outputs during match play (Modric et al., 2025), adult goalkeepers cover between 4 and 6 km (Hernández-Beltrán et al., 2024; Vladović, Modric, Pavlinović, Morgans, & Majeric, 2025), with a large proportion of distance accumulated through low-intensity activities, such as walking and jogging (Rocha et al., 2025). However, the physical performance of goalkeepers also encompasses short-duration, high-intensity explosive actions (e.g., jumping, diving, and explosive efforts) that directly contribute to goal prevention (Moreno-Pérez et al., 2020). Although these decisive defensive actions occur relatively infrequently during the match (White et al., 2018), they represent the most critical part of the goalkeeper's role.

Previous studies consistently demonstrated a direct relationship between age and physical performance (Hegedüs, Csala, Tóth, & Tóth, 2025; Kilci et al., 2025; Marcelli, Silvestri, Di Pinto, Gallotta, & Curzi, 2024). In young soccer players, maturation is accompanied by the development of key physical capacities, such as speed, endurance, power, and strength (Gundersen et al., 2026). Consequently, progression from younger to older age may elevate match physical performance. An accurate understanding of these differences in match physical performance across specific age groups is fundamental for informing training periodisation. This is especially important during the late stages of youth development, as this period represents a critical transition phase in which players become progressively closer to adult-level soccer (Morgans et al., 2022).

However, as most studies investigating age-related differences among young goalkeepers described technical and tactical performance (Scholefield & Fitzpatrick, 2025), information on differences in physical performance among young soccer goalkeepers is limited. To the best of our knowledge, only few studies so far have investigated the physical performance of young goalkeepers (Dolański, Rompa, Liu, Wasielewski, & Szwarc, 2018; Hernández-Beltrán et al., 2024). Dolański et al. (2018) analysed position-related differences in physical performance. In addition, the authors examined the differences in physical performance normalised per minute (i.e., relative values) among different age groups and reported similar values for the relative total distance and high-intensity running across all observed age groups. Hernández-Beltrán et al. (2024) compared physical performance between different categories (i.e., quality categories) and reported that Youth B goalkeepers showed significantly higher average time-to-feet, while Youth C goalkeepers demonstrated greater high-metabolic load distance and high-metabolic power efforts.

Nevertheless, none of the previously mentioned studies directly compared differences in physical performance among different age groups (Dolański et al., 2018; Hernández-Beltrán et al., 2024). Moreover, although the authors of both studies described the physical performance of young soccer goalkeepers, a relatively simple methodological approach was employed (Dolański et al., 2018; Hernández-Beltrán et al., 2024). Specifically, contextual factors, such as match location, match outcome, or opponent quality, that influenced physical performance (Kádár et al., 2025; Plakias & Michailidis, 2024; Wang et al., 2026) were not statistically controlled for, raising questions about the relevance of the findings. Therefore, true match demands imposed on young goalkeepers across different age groups are currently unknown, which limits implementing data-driven training periodisation (Hernández-Beltrán et al., 2024).

Therefore, additional research analysing age-related differences in physical performance using a more complex statistical approach is arguably warranted. Such investigations can provide novel insights into how goalkeepers' physical performance evolves across youth age groups. In addition, the findings of such study could help practitioners establish age-specific benchmarks that can be used to design age-appropriate training and load-management strategies for young goalkeepers. Therefore, this study aimed to examine the differences in the physical performance of goalkeepers in the U17 and U19 age groups during official match play. Considering the well-established relationship between age and physical performance (Hegedüs et al., 2025; Kilci et al., 2025; Marcelli et al., 2024), we hypothesised that differences in physical performance would be observed between the U17 and U19 age groups, with greater diving-related actions expected in the older age group.

2.2.2 Methods

Sample and Design

In this observational study, the physical performance of elite young goalkeepers (n = 2; mean ± SD; age: 17.75 ± 1.34; body height: 187.73 ± 3.06 cm; body mass: 78.5 ± 0.7 kg) from different age groups was observed. Goalkeepers were members of the same club that competed in the highest-level U17 and U19 soccer competitions in Croatia in the 2023/2024 season, with a minimum of seven years of structured goalkeeping-specific training experience. In typical microcycles with one match per week, they were included in five field-based and one gym-based training sessions during the week. Data on their physical performance were collected from 12 matches of the U19 age group and 10 matches of the U17 age group over one competitive half-season using the global positioning system (GPS). One observation was made from each match. No matches included extra times or red cards. Only the performance of the goalkeepers who participated in the matches was analysed. Data were collected as part of routine player monitoring during the competitive season; therefore, written informed consent was not required (Winter & Maughan, 2009). Nevertheless, verbal consent was obtained from both the club and the players, and participants' anonymity was guaranteed. Data were anonymised and processed in accordance with the principles of the Declaration of Helsinki to ensure confidentiality. Ethical approval for this study was granted by the Ethics Board of the University of Split, Faculty of Kinesiology (approval number: 2181-205-02-05-19-0020).

Procedures

Physical performance was monitored using a Vector G7 device (Catapult Sports Ltd., Melbourne, Australia) equipped with a 10-Hz global positioning system and a 100-Hz triaxial accelerometer. The validity and reliability of this technology were previously established (J. Castellano et al., 2011). To minimise inter-unit variability, each goalkeeper consistently wore the same device throughout the study period. In line with the manufacturer's guidelines, all the units were activated approximately 30 minutes before the start of each training session to ensure optimal satellite connection. Upon completion of each session, raw data were downloaded using proprietary software (OpenField, Catapult Sports Ltd., Melbourne, Australia). Data files were subsequently processed and trimmed so that only the activity corresponding to the actual match duration was retained for analysis.

Variables

The study variables were divided into dependent and independent variables. The dependent variables (i.e., physical performance) included the total and high-intensity running distance covered (>5.5 m/s), number of high-intensity accelerations (>3 m/s2), number of total and high-intensity dives (i.e., dive load intensity greater than 9 arbitrary units specified by analysing system), dive load per minute, number of jumps, number of explosive efforts (i.e., combined number of high-speed changes in direction (>3 m/s2 or <–3 m/s2, high jumps (>0.4 m), and instances in which a dive was followed by a goalkeeper returning to standing within 1 s), and average time-to-feet. It is worth noting that diving actions and high jumps were identified using distinct accelerometer-based algorithms (impact-centred vs. vertical acceleration patterns) and were, therefore, treated as mutually exclusive events. All selected thresholds were based on criteria commonly used in previous soccer studies (Vladovic, Versic, Foretic, Morgans, & Modric, 2023; White et al., 2020).

The independent variables were as follows: a two-level categorical variable "age group", three-level categorical variable "match outcome", and two-level categorical variables "match location" and "opponent quality". The age group variable was coded with "1" or "2" depending on whether the performance belonged to the U19 or the U17 age group, respectively. Match outcomes were assessed as lost, drew, or won, and match location was assessed as playing home or away. Opponent quality was evaluated based on the opponent's final league position at the end of the half-season. This approach was adopted to provide a more stable and representative classification of team quality across the half-season, avoiding potential fluctuations in ranking during the early stages of competition (i.e., form, injuries, or scheduling differences). Therefore, teams ranked in the upper half of the table were classified as "strong", whereas teams ranked in the lower half were classified as "weak" (Miyazawa, Keika, Sheahan, & Ichikawa, 2017; Modric et al., 2023).

Statistical analysis

Data normality was assessed using the Kolmogorov–Smirnov test, while homogeneity of variances was examined using Levene's test. All the variables met the assumption of normal distribution. Differences in physical performance between the U17 and U19 age groups were examined using generalised linear models. The model-construction process began with the null model, which included only a fixed intercept. A step-up modelling strategy was then applied, whereby fixed effects were sequentially introduced and retained only if they resulted in improved model fit and met the criterion for statistical significance ($p \leq 0.05$) relative to the preceding model. Model comparisons were primarily based on the Akaike information criterion (AIC), with lower values indicating superior fit, alongside chi-square likelihood ratio tests. The likelihood ratio test was conducted by comparing the log-likelihood values of nested models, with degrees of freedom determined by the difference in the number of estimated parameters. The independent variables were selected based on domain expertise, guided by prior research and practical knowledge of the study context. The final models presented in Table 2 were selected based on optimal AIC and log-likelihood values. Model adequacy was additionally assessed through visual inspection of residuals versus fitted values and normal Q–Q plots. Effect sizes were estimated as model-based Cohen's d (d), calculated as standardised differences between estimated marginal means, and interpreted according to established thresholds, with values <0.2 considered trivial, 0.2–0.5 small, 0.5–0.8 moderate, and >0.8 large (Cohen, 2013). All statistical analyses were performed using SPSS (version 25.0; IBM Corp., Armonk, NY, USA), and statistical significance was set at $p < 0.05$.

2.2.3 Results

Descriptive statistics and differences in physical performance between U19 and U17 goalkeepers are presented in Tables 1 and 2. The total distance covered was significantly higher in the U17 than in the U19 age group (5742.27 and 5289.52 m, respectively), with a large effect size ($d = 1.16$). In contrast, in the U19 category, the total number of dives was significantly higher in the U19 than in the U17 age group (6.66 and 3.75, respectively), showing a large effect size ($d = 1.49$). In addition, the dive load per minute was significantly greater in the U19 than in the U17 age group (0.53 and 0.25, respectively), with a large effect size ($d = 1.76$). In addition, the total number of high-load dives differed significantly between age groups, with higher values observed in the U19 than in the U17 age group (1.92 and 0.90, respectively), corresponding to a large effect size ($d = 1.02$). No significant differences were observed between the U19 and U17 age groups in the high-intensity running distance, average time-to-feet, high-intensity accelerations, explosive efforts, or total jumps.

Table 1. Estimated marginal means for U19 and U17 age groups.

	U19		U17			
	Mean	SE	Mean	SE	p	d
Total distance (m)	5289.52	140.19	5742.27	157.67	0.015	1.16
High intensity running (m)	17.78	6.39	30.31	7.18	0.119	NS
High intensity accelerations (#)	18.45	3.91	16.32	4.40	0.655	NS
Total dives (#)	6.66	0.70	3.75	0.79	0.003	1.49
Dive load/min	0.53	0.05	0.25	0.05	0.001	1.76
Total high load dives (#)	1.92	0.29	0.90	0.32	0.027	1.02
Total jumps (#)	13.37	1.69	15.64	1.84	0.268	NS
Average time to feet (s)	1.68	0.26	1.95	0.28	0.479	NS
Explosive efforts (#)	12.06	1.40	14.08	1.52	0.236	NS

SE = standard error, p = p level, d = Cohen's d, NS = non-significant.

Table 2. Differences in physical performance between U19 and U17 goalkeepers.

	Estimate (95%CI)	t (df)	p	Estimate (95%CI)	t (df)	p	Estimate (95%CI)	t (df)	p
	Total distance			High intensity running			High intensity accelerations		
Intercept	5808.60 (5378.99; 6238.21)	28.66 (16)	<0.001	14.75 (−4.82; 34.32)	1.6 (16)	0.130	14.02 (2.03; 26.01)	2.48 (16)	0.025
AG: U19	−452.74 (−806.94; −98.54)	−2.71 (16)	0.015	−12.53 (−28.66; 3.61)	−1.65 (16)	0.119	2.13 (−7.76; 12.01)	0.46 (16)	0.655
MO: Loss	−350.69 (−872.68; 171.29)	−1.42 (16)	0.177	23.28 (−0.5; 47.05)	2.08 (16)	0.054	1.10 (−13.47; 15.66)	0.16 (16)	0.875
MO: Draw	294.56 (−328.93; 918.05)	1 (16)	0.331	3.92 (−24.48; 32.32)	0.29 (16)	0.773	9.71 (−7.68; 27.11)	1.18 (16)	0.254
ML: Home	−92.33 (−471.57; 286.91)	−0.52 (16)	0.613	7.20 (−10.07; 24.48)	0.88 (16)	0.390	2.02 (−8.57; 12.6)	0.4 (16)	0.692
OQ: Weak	−2.91 (−353.41; 347.59)	−0.02 (16)	0.986	5.77 (−10.19; 21.74)	0.77 (16)	0.455	−4.63 (−14.41; 5.15)	−1 (16)	0.331
	Total dives			Dive/min			Total high load dives		
Intercept	3.91 (2.06; 5.76)	4.45 (17)	<0.001	0.25 (0.15; 0.35)	5.05 (20)	<0.001	0.90 (0.24; 1.56)	2.86 (20)	0.010
AG: U19	2.91 (1.15; 4.68)	3.48 (17)	0.003	0.28 (0.13; 0.41)	4.11 (20)	0.001	1.02 (0.13; 1.91)	2.39 (20)	0.027
MO: Loss	0.67 (−1.9; 3.24)	0.55 (17)	0.589	NS		–	NS		–
MO: Draw	1.20 (−1.9; 4.31)	0.82 (17)	0.426	NS		–	NS		–
ML: Home	−1.57 (−3.44; 0.31)	−1.76 (17)	0.096	NS		–	NS		–
OQ: Weak	NS		–	NS		–	NS		–
	Total jumps			Average time to feet			Explosive efforts		
Intercept	15.44 (12.21; 18.67)	10.04 (18)	<0.001	1.95 (1.36; 2.54)	6.92 (20)	<0.001	12.54 (9.87; 15.21)	9.86 (18)	<0.001
AG: U19	−2.27 (−6.45; 1.9)	−1.14 (18)	0.268	−0.28 (−1.07; 0.52)	−0.72 (20)	0.479	−2.02 (−5.47; 1.44)	−1.23 (18)	0.236
MO: Loss	−1.59 (−7.7; 4.52)	−0.55 (18)	0.591	NS		–	−1.86 (−6.91; 3.19)	−0.77 (18)	0.45
MO: Draw	2.20 (−5.06; 9.46)	0.64 (18)	0.533	NS		–	6.47 (0.47; 12.47)	2.26 (18)	0.04
ML: Home	NS		–	NS		–	NS		–
OQ: Weak	NS		–	NS		–	NS		–

AG = age group, MO = match outcome, ML = match location, OQ = opponent quality, NS = non-significant, t = t value, df = degrees of freedom, CI = confidence interval.

2.2.4 Discussion

This study aimed to examine differences in the physical performance of elite-level goalkeepers between the U17 and U19 age groups during official match play while controlling for contextual factors. The main findings indicated that the total distance covered was significantly greater in the U17 than in the U19 group. In contrast, the total and high-load dives and dive load per minute were significantly greater in the U19 than in the U17 age group. No significant differences between age groups were observed in high-intensity running distance, average time-to-feet, high-intensity accelerations, explosive efforts, or total jumps. Our initial hypothesis that age-related differences would be observed between the U17 and U19 age groups, with greater diving-related actions expected in the older age group, can only be partly accepted, as differences were observed only for selected variables.

In soccer, match load (e.g., external load) can be broadly classified into locomotor and mechanical components. Locomotor load refers to the external work imposed on an athlete as a function of their displacement (e.g., distance covered at different intensities) without necessarily reflecting internal muscular strain (Buchheit et al., 2015). Within this framework, the total distance covered is a primary indicator of locomotor load volume (Buchheit & Simpson, 2017). In the present study, the total distance covered was significantly higher in the U17 than in the U19 age group, indicating that goalkeepers in the U17 category were exposed to a greater locomotor load volume during official match play (d = 1.16, large ES). However, this higher locomotor volume was not accompanied by greater locomotor intensity, as no between-group differences were observed in the high-intensity running distance. Such considerations are partly in line with previous research that compared goalkeepers' physical performance normalised per minute across different age groups and reported similar values for the relative total distance and high-intensity running in the U17 and U19 age groups (Dolański et al., 2018). This apparent discrepancy may be the result of methodological differences between studies. Specifically, Dolański et al. (2018) implemented a simple statistical approach to analyse relative values, whereas the present study employed a more complex approach, analysing absolute values while controlling for contextual factors.

Irrespective of causality, our findings, which showed that higher locomotor volume was not accompanied by greater locomotor intensity in the U17 age group, suggest that the increased movement demands in this age group are primarily characterised by a greater amount of low- and moderate-intensity displacement rather than by more demanding high-intensity locomotor actions. A possible explanation for this may lie in age-related differences in tactical behaviour and team coordination. Specifically, previous research demonstrated that collective tactical behaviours tend to be more stable and structured in the U19 than in the U17 cohort (Barnabé et al., 2016), suggesting that younger age groups are characterised by greater variability in team shape and spatial organisation during match play. Consequently, goalkeepers in the U17 age group may be required to engage more frequently in corrective movements, such as continuous repositioning in relation to the defensive line and/or lateral adjustments within the penalty area. These movements are typically performed at low-to-moderate intensities (Bloomfield et al., 2007), and their cumulative occurrence across the match may lead to a greater total distance covered, thereby explaining the higher locomotor volume observed in the U17 category.

In contrast to locomotor load, the mechanical load reflects the external forces experienced by the musculoskeletal system and is typically driven by discrete, high-force actions (e.g., accelerations/decelerations, jumps/landings, and sport-specific explosive movements) that may occur with minimal displacement (Ibrahim, Kingma, de Boode, Faber, & van Dieën, 2019; White et al., 2018). In goalkeepers, mechanical load is strongly influenced by diving actions that involve rapid whole-body acceleration, collisions with the ground, and high eccentric demands during landing and recovery (Ibrahim et al., 2019). In the present study, age-related differences in mechanical load were evident at both the volume and intensity levels but were confined only to goalkeeper-specific actions (e.g., dives).

Thus, regarding mechanical load volume, the total number of dives was significantly higher in the U19 than in the U17 category (d = 1.49, large ES), and this difference persisted when normalised to match exposure, as the dive load per minute was also significantly higher in the U19 category (d = 1.76, large ES). A likely explanation for this finding is the age-related differences in match demands and attacking efficiency, whereby matches of older age groups are typically characterised by faster ball circulation and improved collective organisation, which typically results in higher shot frequency (Moreira Praça et al., 2022; Searston et al., 2025). Consequently, goalkeepers in the U19 age group may be required to intervene more frequently through diving actions in response to a greater number of shots faced (Kielkopf & Keiner, 2025), thereby increasing the cumulative number of dives performed during match play. However, as number of shots could be contextual-depended (Hughes & Franks, 2005), the higher mechanical load identified in the U19 group may partly reflect contextual match demands rather than exclusively age-related differences. Irrespective of causality, it is noteworthy that increase in the mechanical load volume appears to be highly action-specific, as no between-group differences were observed in other mechanical load volume indicators, such as accelerations, explosive efforts, or jumps.

In addition to volume-related differences, mechanical load intensity was also higher in the U19 age group, as evidenced by a significantly greater number of high-load dives compared with the U17 category (d = 1.02, large ES). This suggests that not only U19 goalkeepers perform more diving actions overall, but they are also exposed more frequently to the most mechanically stressful dive events, which likely impose greater landing-related forces on the musculoskeletal system (McNitt-Gray, 2000). Such increased exposure can also be attributed to the characteristics of match play in older age groups, which is typically defined by more efficient attacking structures and higher shot quality (Cláudio Machado et al., 2020; Smith, Callaway, & Broomfield, 2013). Under these conditions, diving actions are more often executed at greater velocities and under increased temporal pressure due to the higher approach speeds of the ball and reduced time available for movement preparation and landing control. This increases the likelihood of dives being classified as high-load events.

Notably, some studies investigating factors affecting the physical match performance of elite adult goalkeepers reported lower locomotor load volume compared to that observed in the U17 age group in the present study (Vladović et al., 2025). On the other hand, other studies demonstrated greater mechanical load in elite adult goalkeepers than that observed in the U19 age group in the present study (White et al., 2020). Therefore, the findings of the present study, showing lower locomotor load volume and greater goalkeeping-specific mechanical load in the U19 than in the U17 age group, are in line with the technical-tactical evolving nature of match play with advancing age (Zhou et al., 2020). In particular, as the level of play increases, goalkeeper involvement becomes less defined by overall locomotor activity but more defined by mechanical load. This is almost certainly a consequence of increased exposure to diving actions in older age groups, which is likely driven by a higher frequency of goal-scoring situations, as the average number of shots typically increases across age groups (Smith et al., 2013). In view of this, the present findings may help to inform long-term goalkeeper development by highlighting the need to progressively align training with the specific physical demands of higher levels of competition, involving gradual transition from general locomotor conditioning towards the more specific, high-intensity, and mechanically demanding goalkeeping actions.

Although the current findings are based on multiple match observations from the same individuals and therefore cannot be generalised to a wider population, they may still offer practically relevant insights for age-specific conditioning and load management of elite young goalkeepers. First, coaches and performance staff should recognise that U19 goalkeepers may experience substantially higher mechanical load, particularly through greater volume and intensity of diving actions. Therefore, training in this age group may benefit from increased emphasis on dive-specific mechanical loading, including progressive exposure to high-load dives and landing mechanics. On the other hand, training the U17 age group may benefit from including drills that promote frequent repositioning and sustained low-to-moderate intensity movement patterns, reflecting the greater overall locomotor demands observed during match play. Importantly, the absence of age-group differences in high-intensity running, high-intensity accelerations, and jumps suggests that conditioning strategies may consider to prioritise action-specific load prescriptions rather than generic drills. From a monitoring perspective, practitioners should differentiate between locomotor and mechanical load indicators when evaluating match demands and training responses. Collectively, the current findings support the implementation of age-tailored training and load-management strategies to optimise performance development during the transition from the U17 to U19 level (McBurnie et al., 2021). Particular attention should be paid to injury prevention strategies, including progressive exposure to high-load diving actions and optimisation of landing mechanics, to mitigate injury risk during this transition period (Vladović et al., 2025, White et al., 2020). In addition, considering that goalkeepers typically perform lower running volumes during training compared to match play (Hayashi et al., 2026), practitioners should deliberately incorporate running-based activities to better replicate match demands. Although the practical relevance of these conclusions is confirmed by the large effect sizes observed in all findings (Modric et al., 2025), the findings should be interpreted as context-specific and applied with caution when extrapolating to other goalkeeping populations.

This study has several limitations. As the relatively small number of goalkeepers were analysed (n = 2), the current findings are reflective of the paradigms and practices of the individuals from the single club. Therefore, the results might only be generalisable to similar cohorts and levels of competition. However, this limitation is inherent in research conducted on goalkeepers, where squad composition typically includes a limited number of specialised players and match exposure is unevenly distributed (Hayashi et al., 2026; Malone et al., 2018; Vladovic et al., 2023). Future research should confirm these findings by analysing a larger sample. In addition, the analysis was limited exclusively to external load indicators, without the inclusion of internal load measures, such as heart rate or subjective indices of perceived exertion. Although external load metrics provide valuable information on match demands (Julen Castellano et al., 2024), the absence of internal load data restricts a more comprehensive interpretation of the underlying physiological stress (Grimson et al., 2023). Therefore, future studies should integrate both external and internal load measures to better characterise the multidimensional demands of match play among young goalkeepers. Finally, given that the number of shots per age group was not available in the present study to support the interpretation of contextual determinants of mechanical load, linking goalkeepers' physical and match performance in future studies may be warranted.

2.2.5 Conclusion

This study is one of the first to directly compare locomotor and mechanical match-load characteristics of elite young goalkeepers between the U17 and U19 age groups, which represent key specialisation stages in goalkeeper development preceding the transition to senior and professional football. As these components capture different aspects of performance, their combined consideration provides a more comprehensive understanding of goalkeeper-specific demands, representing a key contribution of the present study. The results revealed age-related differences in selected locomotor and mechanical indicators. Specifically, a greater locomotor load, as assessed by the total distance covered, was observed in the U17 age group, whereas a substantially higher mechanical load, reflected by both the volume and intensity of diving actions, was observed in the U19 age group. Although, these findings suggest that performance development during the key stages of long-term development of goalkeepers may benefit from age-tailored training, monitoring, and load-management strategies that account for the distinct locomotor and mechanical requirements, they should be interpreted within the context of the observed cases and confirmed in larger samples before broader generalisation.

Disclosure statement

The authors report there are no competing interests to declare.

Data availability statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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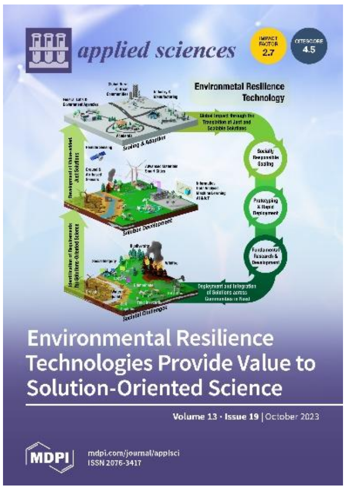
Studies 1 and 2 analysed goalkeepers' match performance while controlling contextual factors, describing the demands imposed on goalkeepers during competition. However, preparing goalkeepers for these demands also requires knowledge of how external training load is distributed across the days of the weekly training cycle, which has rarely been examined at the elite level. Study 3 therefore quantified the external training load of elite-level goalkeepers throughout the competitive microcycle.

2.3 Study 3: Quantification of External Training Load among Elite-Level Goalkeepers within Competitive Microcycle

Vladovic, J., Versic, S., Foretic, N., Morgans, R., & Modric, T. (2023). Quantification of External Training Load among Elite-Level Goalkeepers within Competitive Microcycle. Applied Sciences, 13(19), 10880. https://doi.org/10.3390/app131910880



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Quantification of External Training Load among Elite-Level Goalkeepers within Competitive Microcycle

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Abstract

This study aimed to evaluate the external training load (ETL) of elite-level goalkeepers considering days before match day (MD minus) and playing status in subsequent matches. The ETL of three goalkeepers from the Croatian highest national football competition were analyzed, quantifying goalkeeping-specific physical performance variables (i.e., distances covered, acceleration frequencies, dives, jumps). Data were collected using a 10 Hz global-positioning system and 100 Hz accelerometer technology (Vector G7, Catapult Sports Ltd., Melbourne, Australia) from 67 training sessions. Significant daily differences for almost all physical performance variables were found (all small-to-medium effect sizes (ESs)). Specifically, total distance, total and high-intensity dives, high-intensity accelerations and decelerations, and explosive efforts were greatest on MD-3 and lowest on MD-2 and MD-1. Nonstarters performed more medium jumps on MD-4 (large ES); low jumps on MD-3 (medium ES); total, right-, and left-side dives and low jumps on MD-2 (all small-to-medium ESs); and left-side dives and low and medium jumps on MD-1 (all small-to-medium ESs) compared to the starters. These findings demonstrated that (i) elite-level goalkeepers experienced the greatest ETL on MD-3 and the lowest on MD-2 and MD-1 and that (ii) starters' and nonstarters' ETLs were similar on MD-4 and MD-3, while nonstarters compared to the starters presented slightly greater ETLs on MD-2 and MD-1. This study highlighted the differing daily training demands placed on elite-level goalkeepers, offering valuable insights for their preparation.

Keywords: physical performance; training demands; playing status; soccer

2.3.1 Introduction

Football is a complex and high physically demanding sport [1-3]. Analyses of physical demands in football are usually conducted through the quantification of physical performance, such as total distance, distance covered in different speed zones, and acceleration frequencies [4-6]. Research has shown that outfield players can cover 9–14 km during a match, covering from 5 to 15% of that distance at higher speeds [7-9]. Although physical demands in football have been extensively studied over the last two decades [10,11], the majority of research investigating physical demands in football has not included goalkeepers [12,13].

One of the main reasons for this is the notable differences found in physical demands compared to the other playing positions (i.e., outfield players) [14,15]. Specifically, football goalkeepers on average cover ~ 50% of the total distance and ~ 10% of the high-intensity distance of outfield players [16,17]. Furthermore, the analyses of physical demands for goalkeepers and outfield players differ remarkably [18]. Due to their specific match tasks (i.e., saves, dealing with high crosses, explosive positioning, etc.) [19-21], goalkeepers must perform explosive actions, such as jumping, striking, diving, catching, and/or accelerating and decelerating over short distances [22]. Therefore, analysis of goal-keepers' physical demands usually requires additional quantification of dives, jumps, acceleration frequencies, and explosive efforts [21].

For successful dealing with high physical demands of contemporary football [23], an appropriate distribution of external training load (ETL) is essential [24-27]. Previous research investigating ETLs of football players has mostly involved the outfield players [28,29], while studies analyzing goalkeepers' ETL are scarce. Briefly, White et al. and Jara et al. analyzed the ETL of goalkeepers according to the differing training types without information on daily/weekly demands in the English Premier League and the German fifth league, respectively [21,30]. On the other hand, Abbot et al. and Moreno et al. gave information on weekly demands by comparing ETLs of starter and nonstarter goalkeepers from the U23 English Premier League and the Spanish second division, respectively [22,31]. Furthermore, Grimson et al. and Malone et al. examined the relationship between ETL and subjective wellness in the English Premier League and top Dutch league, respectively [32,33].

Although these studies provide valuable information on goalkeepers' ETL, daily demands of training within a weekly microcycle are rarely presented [22]. Furthermore, studies have mostly investigated subelite goalkeepers and/or have not utilized goalkeeping-specific indicators of ETL [21,22,32] or considered goalkeepers' loads during specific actions. In addition, no studies thus far have investigated differences in goalkeepers' daily demands utilizing multivariate techniques, which can be particularly helpful in the better understanding of ETL [34]. As a consequence, comprehensive knowledge on daily physical demands placed on elite-level goalkeepers is currently limited, and additional research is warranted [22]. The findings from such research could serve football practitioners in goalkeeping-specific training prescription processes. Therefore, this study aimed to evaluate the ETL of elite-level goalkeepers during the competitive microcycle. As empirical evidence suggests that goalkeepers' ETLs may vary considering their playing status in subsequent matches [32], ETL was additionally evaluated for starting and nonstarting goalkeepers (i.e., starters and nonstarters).

2.3.2 Methods

Sample and Design

The participants were three adult male football goalkeepers (mean ± standard deviation, age: 30.33 ± 7.07; body mass: 90.33 ± 7.29 kg; height: 195 ± 4.32 cm) from one team that competed in the highest-level soccer competition in Croatia in the 2021/2022 season. Two of them represented national seniors, while one of them represented the national U-21 team, which characterized them as elite-level goalkeepers. Goalkeepers were observed over training sessions (n = 67) from competitive microcycles, including one match per week during one competitive half season. Only goalkeepers who had the capacity to train without any physical restriction and who were injury-free were eligible.

To evaluate ETL, goalkeepers' physical performances were collected using global-positioning system (GPS) during the in-season training sessions. The final analysis included only weeks that consisted of a minimum of four training days in the week, with six days between the matches and only one match. Based on the amount of days until the game, training sessions were divided into different categories (Toni Modric, Jelicic, & Sekulic, 2021; Stevens et al., 2017). Thus, MD-2 referred to the session that was conducted two days until the match day.

As the data analyzed in this study were derived from routinely measured activities through the in-season, obtaining written informed consent was not required (Rago, Rebelo, Krustrup, & Mohr, 2021). However, verbal consent was obtained from the players if anonymity was ensured. To guarantee player anonymity, all data were deidentified in compliance with the Declaration of Helsinki. The investigation was approved by the Faculty of Kinesiology, University of Split.

Procedures

During each training session, physical performance was measured using a Vector G7 device (Catapult Sports Ltd., Melbourne, Australia) containing a GPS system (10 Hz) and an accelerometer (100 Hz). The validity and reliability of this system were recently described (Castellano, Casamichana, Calleja-González, San Román, & Ostojic, 2011). For each training session, the goalkeepers wore the same device to prevent interunit error. In accordance with the manufacturer's instructions, all devices were consistently activated ~30 minutes before the training sessions to allow the acquisition of satellite signals. Raw data files were exported after the conclusion of each training session using system-specific software (OpenField, Catapult Sports Ltd., Melbourne, Australia). Individual player files were trimmed to ensure that only information relating to the training time was kept for analysis.

Variables

The ETL was evaluated using general and goalkeeping-specific physical performance variables. General physical performance variables included total and high-intensity running distance covered (>5.5 m/s) and the number of high-intensity accelerations (> 3 m/s^2) and high-intensity decelerations (–3 m/s^2) (Bradley et al., 2013; Mallo, Mena, Nevado, & Paredes, 2015).

Goalkeeping-specific physical performance variables included number of explosive efforts (i.e., combined number of high-speed changes in direction, high jumps, and instances in which a dive was followed by a goalkeeper returning to standing within 1 s (Anthony White et al., 2020)); number of total and high-intensity dives (i.e., dive load intensity greater than 9 arbitrary units specified by analyzing system) performed for right side, left side, and to the center (i.e., forward action when the ball is traveling toward the center of the body); number of high (i.e., jump height >0.4 m), medium (i.e., jump height of 0.2-0.4 m), and low (i.e., jump height <0.2 m) jumps (Anthony White et al., 2020).

Statistical Analyses

The Kolmogorov–Smirnov test was used to evaluate the normality of distributions, while homoscedasticity was tested using Levene's test. All variables were normally distributed, so descriptive statistics included means and standard deviations. The univariate differences in physical performance were analyzed via one-way analysis of variance (ANOVA). Scheffe's post hoc analysis was calculated to identify the differences among specific training days. Afterward, effect size (ES) differences were established using ANOVA-derived partial eta-squared (>0.02, small; >0.13, medium; >0.26, large). Multivariate differences in physical performance were analyzed via canonical discriminant analysis. Statistica (version 14; TIBCO Software, Palo Alto, CA, USA) was used for all analyses. The significance level was set at 0.05.

2.3.3 Results

Tables 1 and 2 present descriptive statistics and differences in daily physical performance. Significant daily differences were found for total distance (medium ES), total and high-intensity dives (both medium ES), total and high-intensity left- and right-side dives (all medium ES), high-intensity accelerations and decelerations (both small ES), and explosive efforts (small ES). Specifically, on MD-3, goalkeepers covered the greatest total distance and attempted the highest numbers of total and high-intensity dives (significant post hoc differences when compared to MD-1, MD-2, and MD-4). Also, the greatest numbers of total and high-intensity left-side dives (significant post hoc differences when compared to MD-1 and MD-4) and total and high-intensity right-side dives (significant post hoc differences when compared to MD-1 and MD-2) were noted on MD-3. Additionally, goalkeepers on MD-3 executed the greatest number of high-intensity accelerations and decelerations (significantly different from MD-1), as well as explosive efforts (significantly different from MD-1).

Table 1. Descriptive statistics for daily physical performance (data are given as mean ± SD).

	MD-4	MD-3	MD-2	MD-1
Total distance (m)	2607.1 ± 937.4	3629.4 ± 1524.4	2669.5 ± 761.3	2569.4 ± 486.7
High-intensity running (m)	0.9 ± 2.2	8.5 ± 20.7	4.2 ± 14.7	2.6 ± 4.7
Total dives (N)	26.4 ± 14.9	41.6 ± 20.3	30.2 ± 12.6	25.9 ± 8.4
High-intensity dives (N)	13.5 ± 7.8	21.2 ± 11.5	14.0 ± 7.6	12.7 ± 5.0
Left-side dives (N)	10.9 ± 7.5	18.0 ± 10.2	13.6 ± 6.3	10.9 ± 4.9
High-intensity left-side dives (N)	5.2 ± 4.0	9.9 ± 6.2	6.9 ± 4.0	5.8 ± 3.1
Center dives (N)	6.2 ± 4.3	5.4 ± 4.7	4.4 ± 3.4	4.5 ± 3.4
High-intensity center dives (N)	2.4 ± 2.6	2.3 ± 3.1	1.9 ± 1.8	1.6 ± 1.5
Right-side dives (N)	9.4 ± 6.0	18.2 ± 8.8	12.2 ± 6.5	10.5 ± 4.0
High-intensity right-side dives (N)	5.9 ± 3.3	9.0 ± 4.8	5.2 ± 4.1	5.3 ± 2.8
Low jumps (N)	11.0 ± 7.9	11.6 ± 9.0	10.3 ± 12.7	9.6 ± 6.9
Medium jumps (N)	6.0 ± 4.7	8.5 ± 6.3	8.9 ± 7.3	11.4 ± 6.8
High jumps (N)	1.9 ± 2.1	2.6 ± 3.6	4.9 ± 6.6	5.1 ± 4.2
High-intensity accelerations (N)	4.0 ± 3.6	6.1 ± 5.4	3.3 ± 3.9	3.4 ± 2.7
High-intensity decelerations (N)	2.5 ± 2.1	4.1 ± 3.7	2.5 ± 2.7	2.0 ± 1.9
Explosive efforts (N)	27.9 ± 14.5	44.7 ± 23.3	35.5 ± 27.1	28.9 ± 10.9

Table 2. Differences in daily physical performance.

	ANOVA		Effect Size	MD-4	MD-3	MD-2	MD-1
	f	*p*	μ	Post Hoc			
Total distance	**7.28**	**0.01**	0.17	MD−3	MD−4, MD−2, MD−1	MD−3	MD−3
High-intensity running	1.30	0.28	0.04	-	-	-	-
Total dives	**6.78**	**0.01**	0.16	MD−3	MD−4, MD−2, MD−1	MD−3	MD−3
High-intensity dives	**6.08**	**0.01**	0.15	MD−3	MD−4, MD−2, MD−1	MD−3	MD−3
Left-side dives	**5.35**	**0.01**	0.13	MD−3	MD−4, MD−1	-	MD−3
High-intensity left-side dives	**5.15**	**0.01**	0.13	MD−3	MD−4, MD−1	-	MD−3
Center dives	0.97	0.41	0.03	-	-	-	-
High-intensity center dives	0.74	0.53	0.03	-	-	-	-
Right-side dives	**8.43**	**0.01**	0.19	MD−3	MD−4, MD−2, MD−1	MD−3	MD−3
High-intensity right-side dives	**5.94**	**0.01**	0.14		MD−2, MD−1	MD−3	MD−3
Low jumps	0.22	0.88	0.00	-	-	-	-
Medium jumps	2.48	0.06	0.06	-	-	-	-
High jumps	2.43	0.07	0.06	-	-	-	-
High-intensity accelerations	**3.02**	**0.03**	0.08	-	-	-	-
High-intensity decelerations	**3.32**	**0.02**	0.09	-	MD−1	-	MD−3
Explosive efforts	**3.28**	**0.02**	0.09	-	MD−1	-	MD−3

f = f-test value; p = level of significance. Bold text denotes statistical significance at $p<0.05$. μ – partial eta-squared. Superscripted letters indicate significant post hoc differences when compared to the specific training day.

Table 3 presents a discriminant canonical analysis of multivariate differences in daily physical performance. One discriminant root reached statistical significance (Can R = 0.54, p = 0.01), showing significant differentiation between MD-3 and MD-1. Total distance and total dives (correlations with the discriminant function of r = 0.68 and 0.66, respectively) most greatly contributed to the differentiation, with greater occurrence on MD-3.

Table 3. Multivariate differences in daily physical performance defined by discriminant canonical analysis.

	Root 1	Root 2	Root 3
Total distance	0.68	−0.37	−0.08
High-intensity running	0.26	−0.24	0.16
Total dives	0.66	−0.31	0.22
High-intensity dives	0.63	−0.28	−0.02
High-intensity accelerations	0.12	0.07	−0.01
High-intensity decelerations	−0.23	−0.63	−0.05
Low jumps	−0.31	−0.34	0.40
Medium jumps	0.43	−0.15	−0.25
High jumps	0.48	−0.08	0.01
Explosive efforts	0.43	−0.23	0.35
Can R	0.54	0.33	0.30
Wilks' Lambda	0.58	0.81	0.91
p-value	0.01	0.28	0.32
C: MD-4	0.04	0.80	−0.42
C: MD-3	1.14	−0.22	−0.09
C: MD-2	−0.13	0.13	0.41
C: MD-1	−0.59	−0.27	−0.20

Can R – canonical correlation; root – structure of the discriminant function/root; C – centroid.

Table 4 presents descriptive statistics and differences in daily physical performance between starters and nonstarters. Compared to the starters, nonstarters performed more medium jumps on MD-4 (large ES); more low jumps on MD-3 (medium ES); more total dives (medium ES), left-side dives (medium ES), right-side dives (small ES), and low jumps (medium ES) on MD-2; and more left-side dives (small ES) and low (medium ES) and medium jumps (small ES) on MD-1.

Table 4. Descriptive statistics and differences in daily physical performance between starters and nonstarters.

	MD-4		MD-3		MD-2		MD-1	
	Starters	**Non Starters**	**Starters**	**Non Starters**	**Starters**	**Non Starters**	**Starters**	**Non Starters**
Total distance (m)	2340.6 ± 911.1	3034.7 ± 902.2	3346.5 ± 1312.8	3939.2 ± 1737.3	2437.8 ± 855.2	2854.2 ± 638.6	2555.3 ± 551.5	2586.2 ± 414.1
High-intensity running (m)	1.1 ± 2.8	0.6 ± 0.9	5.1 ± 7.2	12.3 ± 29.2	1.3 ± 3.0	6.5 ± 19.5	2.8 ± 5.0	2.5 ± 4.4
Total dives (N)	22.4 ± 16.4	32.8 ± 10.3	35.2 ± 13.9	48.6 ± 24.2	**24.9 ± 9.9**	**34.4 ± 13.2 ** **	25.3 ± 6.7	26.6 ± 10.1
High-intensity dives (N)	10.6 ± 7.0	18.0 ± 7.4	18.6 ± 8.7	24.1 ± 13.8	11.7 ± 4.8	15.9 ± 9.0	12.3 ± 3.9	13.3 ± 6.2
Left-side dives (N)	9.0 ± 8.4	13.8 ± 5.3	14.5 ± 7.1	21.8 ± 12.0	**10.5 ± 5.1**	**16.1 ± 6.2 ** **	**9.4 ± 3.3**	**12.7 ± 5.8 ***
High-intensity left-side dives (N)	4.0 ± 3.7	7.2 ± 3.8	8.3 ± 3.8	11.7 ± 7.8	5.6 ± 3.1	8.1 ± 4.4	5.0 ± 2.4	6.9 ± 3.6
Center dives (N)	5.3 ± 3.0	7.6 ± 6.0	4.2 ± 2.7	6.8 ± 6.1	4.7 ± 2.9	4.2 ± 3.7	5.5 ± 3.8	3.3 ± 2.4
High-intensity center dives (N)	1.9 ± 1.8	3.2 ± 3.6	1.8 ± 2.1	2.8 ± 3.9	1.9 ± 1.8	1.9 ± 1.8	1.7 ± 1.7	1.4 ± 1.3
Right-side dives (N)	8.1 ± 6.5	11.4 ± 5.0	16.5 ± 6.9	20.0 ± 10.5	**9.8 ± 5.0**	**14.2 ± 7.1 ***	10.5 ± 3.3	10.6 ± 4.8
High-intensity right-side dives (N)	4.8 ± 3.2	7.6 ± 3.0	8.6 ± 4.6	9.5 ± 5.1	4.2 ± 2.1	6.0 ± 5.0	5.6 ± 2.5	5.0 ± 3.2
Low jumps (N)	7.9 ± 7.0	16.0 ± 7.2	**7.8 ± 6.0**	**15.8 ± 10.0 ** **	**5.1 ± 4.2**	**14.6 ± 15.5 ** **	**6.8 ± 4.1**	**12.9 ± 7.9 ** **
Medium jumps (N)	**4.0 ± 3.0**	**9.2 ± 5.5 *****	6.5 ± 3.0	10.7 ± 8.1	6.3 ± 4.6	10.9 ± 8.4	**9.3 ± 4.8**	**13.9 ± 8.0 ***
High jumps (N)	1.1 ± 1.6	3.2 ± 2.3	1.8 ± 3.6	3.5 ± 3.4	3.7 ± 5.0	6.0 ± 7.6	3.9 ± 3.3	6.5 ± 4.9
High-intensity accelerations (N)	4.0 ± 4.1	4.0 ± 3.1	6.1 ± 4.4	6.2 ± 6.4	2.8 ± 3.0	3.8 ± 4.5	4.0 ± 2.8	2.7 ± 2.4
High-intensity decelerations (N)	2.9 ± 2.5	2.0 ± 1.0	4.4 ± 3.6	3.8 ± 3.9	2.1 ± 2.5	2.8 ± 2.8	2.4 ± 2.2	1.5 ± 1.2
Explosive efforts (N)	26.0 ± 17.1	30.8 ± 10.1	44.0 ± 18.7	45.5 ± 28.4	31.0 ± 10.1	39.2 ± 35.2	30.6 ± 8.9	27.0 ± 12.8

Bold text denotes significant differences between starters and nonstarters at $p < 0.05$; * denotes small effect size, ** denotes medium effect size, and *** denotes large effect size.

Table 5 presents a discriminant canonical analysis of multivariate differences in daily physical performance between starters and nonstarters. None of discriminant roots reached statistical significance, showing no significant differentiation between starters and nonstarters in physical performance on MD-4, MD-3, MD-2, and MD-1.

Table 5. Multivariate differences in daily physical performance between starters and nonstarters for different training days defined by discriminant canonical analysis.

	MD-4 Root 1	**MD-3 Root 1**	**MD-2 Root 1**	**MD-1 Root 1**
Total distance	−0.36	−0.22	−0.37	−0.04
High-intensity running	0.11	−0.19	−0.23	0.04
Total dives	−0.34	−0.39	−0.52	−0.11
High-intensity dives	−0.49	−0.27	−0.37	−0.14
High-intensity accelerations	−0.55	−0.56	−0.52	−0.66
High-intensity decelerations	−0.60	−0.39	−0.43	−0.47
Low jumps	−0.53	−0.29	−0.22	−0.44
Medium jumps	−0.15	−0.03	−0.20	0.22
High jumps	−0.36	−0.22	−0.37	−0.04
Explosive efforts	0.11	−0.19	−0.23	0.04
Can R	0.74	0.68	0.62	0.61
Wilks' Lambda	0.45	0.54	0.62	0.62
p-value	0.69	0.22	0.07	0.07
C: Starters	0.81	0.85	0.85	0.69
C: Nonstarters	−1.29	−0.93	−0.68	−0.87

CanR—canonical correlation; root—structure of the discriminant function/root; C—centroid.

2.3.4 Discussion

This is one of the first studies to evaluate the ETL of elite-level goalkeepers during a competitive microcycle quantifying goalkeeping-specific physical performance. The main findings show that (i) goalkeepers experienced the greatest ETL on MD-3 and the lowest on MD-2 and MD-1 and that (ii) starters' and nonstarters' ETLs were similar on MD-4 and MD-3, while nonstarters compared to starters presented a slightly greater ETL on MD-2 and MD-1.

Comprehensive knowledge of daily physical demands placed on elite-level goalkeepers is currently limited [18,32]. To address the relevant literature gaps, this study analyzed the daily physical performance of elite-level football goalkeepers during competitive microcycles (i.e., including one match per week). The results showed significant daily differences for almost all physical performance variables. Specifically, goalkeepers experienced the greatest ETL on MD-3, which was most likely the consequence of implementing high-volume (i.e., defined by total distance and total dives) and high-intensity (i.e., defined by high-intensity dives, high-intensity accelerations and decelerations, and explosive efforts) drills to meet the high physical demands of the game [25,31,33,35]. Considering the current literature, which mostly shows similar results for both goalkeepers and outfield players [12,33], these findings are expected to some extent. However, some studies have shown that both outfield players and goal-keepers experience the greatest ETL on MD-4 [31,36]. These differences in findings are probably caused by the use of different training methods in various countries. [35]. Possibly, some coaches do not prefer the greatest training load for the first training session of the microcycle (i.e., after a 2-day recovery period on MD-4); therefore, they implement high-volume and -intensity drills for the second training session of the microcycle (i.e., MD-3). On the other hand, coaches seeking more time for recovery before a match day most likely implement high-volume and -intensity drills for the first training session of the microcycle (i.e., MD-4).

Evidently, the training methodology can differ in the loading period (i.e., MD-4 and MD-3) [35,36]. However, the majority of the research exploring the training load of both outfield players or goalkeepers has consistently evidenced a decrease in ETL in the final period of the microcycle (i.e., tapering period: MD-2 and MD-1) [12,13,31,33,36]. This strategy enables sufficient recovery from the high physically de-manding sessions during the loading period, which consequently ensures optimal match performance on the match day [31,33,41]. Given the descriptive analysis in the current study indicating the lowest values for almost all physical performance variables on MD-2 and MD-1, our results are fully in the line with these considerations. Collectively, there is no doubt that the elite-level goalkeepers experienced the greatest ETL on MD-3 and the lowest on MD-2 and MD-1. However, it is noteworthy that training volume (i.e., defined by total distance and total dives) most greatly contributed to this differentiation. This is most likely the consequence of the tapering strategy application, which aims to reduce the training volume while maintaining the training intensity prior to the match [28].

The most robust findings of this study are related to goalkeeping-specific physical performance variables, which have been insufficiently investigated so far [21,22]. Firstly, we evidenced greater total and high-intensity dives performed on both left and right sides on MD-3 than on MD-1, while the numbers of center dives, both total and high-intensity, were similar in all training sessions. This suggests that the coaches, when structuring the high-volume and -intensity drills (i.e., on MD-3; please see previous discussion for details), are more focused on saves to the sides, possibly because players during a match typically shoot to the sides of the goal [42]. Further, no significant daily differences for low, medium, and high jumps were found, indicating that goalkeepers performed similar numbers of jumps in all training sessions. Given the tapering theory that underlines decreased ETL toward the end of the week [12,13,28], such a finding may look surprising. However, the descriptive analysis indicated a relatively low jump frequency during a single training day (i.e., ~ 20 to 25 jumps in total). Considering that such frequencies were constant through all training sessions in the week, it seems that elite-level goalkeepers were more oriented toward maintenance rather than toward the development of specific jumping capacities during competitive microcycles.

When analyzing the ETL of goalkeepers who started (i.e., starters) and did not start (i.e., nonstarters) the match, studies have revealed conflicting findings (Abbott et al., 2023; Moreno-Pérez et al., 2020; Anthony White et al., 2020). White el al. and Abbott et al. found greater ETLs for nonstarters compared to starters (Abbott et al., 2023; Anthony White et al., 2020), while Moreno-Pérez et al. indicated that starters completed greater ETLs compared to nonstarters (Moreno-Pérez et al., 2020). In the current study, a similar ETL was found on MD-4 and MD-3 for both starters and nonstarters. Specifically, compared to starters, nonstarters achieved only a greater number of medium jumps on MD-4 and more low jumps on MD-3, while no differences in all other physical performances were found. Additionally, this suggests that a similar training methodology during the loading period was applied for elite-level goalkeepers, irrespective of their playing status in subsequent matches, which is standard procedure, as evidenced in subelite or youth competitions (Abbott et al., 2023; Moreno-Pérez et al., 2020). Interestingly, considering some differences in physical performance between starters and nonstarters found that, on MD-2 and MD-1, it seemed that training methodology in the final part of the microcycle (i.e., tapering period) depended on goalkeepers' playing status. In detail, nonstarters performed more (i) total, right-, and left-side dives and low jumps on MD-2 and more (ii) left-side dives and low and medium jumps on MD-1 compared to the starters. This clearly indicates that nonstarters compared to the starters experienced a slightly greater ETL in the final part of the microcycle. The reason for this may be the fact that starters are often excluded from the shooting practices that occur more often in the final part of the microcycle (Abbott et al., 2023).

Limitations and Strengths

The current study has some limitations that should be taken into account. Firstly, the sample size was limited, including only three observed subjects. However, this is a very common issue in studies involving goalkeepers who compete in elite soccer (Abbott et al., 2023; Malone et al., 2018). Secondly, the study included goalkeepers from one club; therefore, the results can only be applied to similar samples of subjects and levels of competition. Third, as only one-game microcycles were analyzed, the findings are not applicable to elite-level teams playing more than one game per week. However, this study also offers several strengths. Thus, this is one of the first studies to evaluate ETL among elite-level goalkeepers in competitive microcycles using goalkeeper-specific measures. Also, to the best of our knowledge, goalkeepers' loads during the specific actions are described for the first time in the current study. Finally, this study is the first to utilize multivariate techniques to assess differences in goalkeepers' daily demands. Future studies should analyze a larger sample of goalkeepers from multiple elite-level clubs, including microcycles consisting more than one game per week.

Practical Applications

These findings can serve football practitioners in goalkeeping-specific training prescription processes. Specifically, based on the current results, situational drills involving a high number of dives, jumps, and explosive reactions can be implemented up to three days prior to the match. For one and two days prior to the match, involvement of such drills should be reduced to allow goalkeepers to achieve the optimal performance on the match day. Finally, it should be emphasized that increased ETLs of nonstarters before a match may cause their inferior recovery on match day. Therefore, if it is needed for a nonstarter to start or enter a match, football practitioners should be aware of their possible impaired match performance.

2.3.5 Conclusions

The ETL of elite-level football goalkeepers was the greatest on MD-3, most likely due to the implementing of high-volume and -intensity drills to meet the high physical demands of the match. On the other hand, the goalkeepers experienced the lowest ETL on MD-2 and MD-1, which is almost certainly the consequence of tapering strategies aiming to ensure optimal performance on match day. Similar ETLs of the starters and nonstarters on MD-3 and MD-4 indicated that the elite-level goalkeepers' match preparation in the first part of the microcycle was equal, irrespective of their playing status on match day. However, the slightly greater ETL of nonstarters compared to starters on MD-2 and MD-1 suggested that elite-level goalkeepers' match preparation was determined by their playing status in the subsequent match.

Author Contributions:

Conceptualization, S.V.; Methodology, S.V.; Software, N.F.; Validation, N.F.; Formal analysis, J.V.; Investigation, J.V.; Resources, R.M.; Data curation, R.M.; Writing—original draft, J.V.; Writing—review and editing, S.V., R.M., and T.M.; Supervision, N.F. and T.M.; Project administration, T.M. 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 according to the guidelines of the Declaration of Helsinki and was approved by the Ethics Committee of the University of Split, Faculty of Kinesiology (approval number: 2181-205-02-05-19-0020, 1 September 2019).

Informed Consent Statement:

As the data analyzed in this study were derived from routinely measured activities over the course of the competitive season, obtaining written informed consent was not required;

therefore, informed consent was waived by the Ethical Board of the University of Split, Faculty of Kinesiology.

Data Availability Statement:

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Conflicts of Interest:

The authors declare no conflicts of interest.

2.3.6 References

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3 GENERAL CONCLUSION

3.1 Summary of main findings

This research yielded several important conclusions. Firstly, technical performance of elite-level goalkeepers differed according to match outcome, team quality, and opponent quality, whereas physical performance remained unaffected by any of these factors, including match location. Secondly, physical performance of elite-level goalkeepers differed according to age group. Thirdly, external training load was highest three days before the match and progressively decreased as match day approached. These findings provided new knowledge on goalkeepers' match and training demands, supporting their performance monitoring, training design, and long-term development.

The Study 1 examined the effect of contextual factors on match performance of goalkeepers, analysing UEFA Champions League data as the benchmark of the highest level football (Modric et al., 2022). Results demonstrated that technical performance of elite-level goalkeepers was affected by match outcome, team quality, and opponent quality, indicating that football practitioners should account for these factors when structuring the elements of training and subsequent match preparation. Specifically, as winning resulted in more exits compared with losing, coaches may consider incorporating scenarios in training that improve defending crosses by exiting the line, thereby enabling goalkeepers to execute these actions more confidently and effectively during matches. In addition, given that goalkeepers playing for lower-quality teams or against higher-quality opponents performed a greater number of saves, they may require longer post-match recovery periods due to the increased match demands experienced under these circumstances.

On the other hand, the physical performance of elite-level goalkeepers remained relatively similar irrespective of the match outcome, match location, team quality, and opponent quality. However, the findings from Study 2 demonstrated that goalkeepers' physical performance may be affected by age group. In brief, total distance covered was significantly greater in the U17 than in the U19 age group, while the number of total and high-load dives was significantly greater in the U19 than in the U17 age group. This indicates that although contextual factors had a limited effect on goalkeepers' physical performance, individual factors such as age may play a more important role when structuring the elements of training and subsequent match preparation. Specifically, considering higher volume and intensity of diving actions in U19 goalkeepers, training for this age group should place greater emphasis on dive-specific loading and landing mechanics. In contrast, U17 goalkeepers may benefit from drills involving frequent repositioning and sustained low-to-moderate intensity movements, reflecting their greater overall activities during matches.

When structuring the elements of training, the training load must be distributed appropriately across the weekly training cycle in order to maximise match performance and reduce injury risk (Silva, Nakamura, Castellano, & Marcelino, 2023). Therefore, Study 3 quantified the external training load of elite goalkeepers throughout the competitive microcycle. The results showed that external training load was distributed unevenly across the week. Specifically, total distance, total and high-intensity dives, high-intensity accelerations and decelerations, and explosive efforts were greatest on MD-3 and lowest on MD-2 and MD-1. This indicates that situational drills (i.e., involving a high number of dives and explosive efforts) can be implemented up to three days prior to the match. For one and two days prior to the match, involvement of such drills should be reduced to allow goalkeepers to achieve the optimal performance on the match day.

3.2 Strengths and Limitations

The main limitation of this research is sample size in studies 2 and 3, which was limited to the relatively small number of goalkeepers from a single club. Although this is a very common obstacle in studies involving goalkeepers which compete at the elite level of soccer (Hayashi, Rebelo-Gonçalves, Otte, & Nunes, 2026; Malone et al., 2018), the findings from these studies should be generalized only to similar cohorts and competitive levels. Also, in study 1, goalkeepers' match performance was evaluated according to a limited number of contextual factors. Finally, in all studies, goalkeepers' physical performance was evaluated exclusively using external load metrics, without considering internal load measures such as heart rate or rating of perceived exertion. Consequently, the physical demands imposed on goalkeepers was not comprehensively evaluated (Grimson et al., 2023).

On the other hand, this research is among the first to investigate contextual and individual factors affecting match performance of elite level goalkeepers. Moreover, this research enabled exclusive insights into the training practice of elite goalkeepers during the during competitive microcycle by analysing distribution of their external training load which was not presented so far in literature. In addition, this research reinforced importance of evaluating both technical and physical performance when investigating goalkeepers' match performance. Finally, the findings from this research provided new knowledge toward a more comprehensive understanding of the match demands imposed on elite goalkeepers, giving practitioners evidence-based information to improve goalkeeper training design and optimise their long-term development.

3.3 Perspectives for future research

This research confirmed that match performance of goalkeepers is highly variable (Carling et al., 2016; Šunjić, Versic, Modric, Corluka, & Zaletel, 2024; White et al., 2020), which hamper their interpretation and application in practice. For this reason, future studies should continue to investigate determinants of goalkeepers' match performance by analysing factors which were previously shown to influence match performance in soccer such as fixture congestion, playing style or environmental conditions (i.e., temperature, humidity). Also, considering evolving nature of the soccer (Nassis et al., 2020), the physical and technical demands imposed on goalkeepers are expected to change over time. Therefore, it is essential that future studies continue to monitor goalkeeper match and training performance to provide practitioners with up-to-date evidence for optimizing training design and periodization. Importantly, this knowledge should be provided from longitudinal analysis of multiple elite clubs from different countries, which would substantially improve the generalisability of the findings. Finally, for more detailed understanding of demands imposed on goalkeepers during the training and matches, future research should include a more extensive analysis of their technical and physical performance. Specifically, an in-dept analysis of external load metrics (i.e., the values in different periods of matches, relative and peak running outputs, etc.) together with internal load metrics such heart rate or rating of perceived exertion would be worthwhile. Also, evaluation of goalkeepers' technical performance by incorporating tactical performance indicators such as positioning, space control, and involvement in team build-up play would be desirable.

3.4 Final conclusion

Taken together, the three studies presented in this doctoral thesis provide an integrated understanding of the match and training demands imposed on elite-level goalkeepers. By simultaneously analysing match performance with the control of the contextual factors, and the distribution of external training load across the competitive microcycle, this thesis connects what goalkeepers are required to do during matches with the way they are prepared for these demands in training. The findings therefore provide practitioners with evidence-based information for goalkeeper performance monitoring, training design, and match preparation, and establish a foundation for future research aimed at optimising the long-term development of elite-level goalkeepers.

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5 Biography

Jakov Vladović was born on 6 September 1998 in Split, Croatia. He obtained his undergraduate degree in kinesiology, with a specialisation in football, at the Faculty of Kinesiology, University of Split, in 2021. He continued his graduate studies at the same institution and graduated in 2023, receiving a commendation for outstanding academic achievement as one of the three best students in his generation. In 2024, he enrolled in the postgraduate doctoral programme in kinesiology at the same faculty, where he also works as an external associate.

He played football as a goalkeeper throughout all youth age groups of HNK Hajduk Split and continued his senior playing career in clubs competing from the second to the fourth tier of Croatian football. Between 2020 and 2025 he worked as a goalkeeper coach with age groups from U9 to seniors at several clubs, and since 2025 he has worked as a kinesiologist at SportsLab in Split.

His research focuses on performance analysis in football, with a particular emphasis on the physical and technical performance of goalkeepers during training and match play. He received the Best Young Researcher Award at the 21st Annual Scientific Conference of the Montenegrin Sports Academy in Cavtat (2024) and second place in the same category at the 7th International Scientific Conference "Contemporary Kinesiology" in Split (2024). He is the author of four scientific papers published in journals indexed in the Web of Science and Scopus databases, including the three studies that constitute this thesis.

6 Curriculum vitae

Personal information

Croat, born on 6 September 1998, in Split, Croatia

E-mail: j.vladovic@gmail.com

Mother tongue: Croatian. Other languages: English (advanced), Italian (basic)

Education

2024 – today ⇥ PhD student (Faculty of Kinesiology, University of Split, Croatia)

2021 – 2023 ⇥ Master of Kinesiology (Faculty of Kinesiology, University of Split, Croatia)

2017 – 2021 ⇥ Bachelor of Kinesiology, specialization in "Football" (Faculty of Kinesiology, University of Split, Croatia)

Grants and awards

Best Young Researcher Award, 21st Annual Scientific Conference of the Montenegrin Sports Academy (Cavtat, Croatia, 2024)

Second place, Best Young Researcher Award, 7th International Scientific Conference "Contemporary Kinesiology" (Split, Croatia, 2024)

Faculty of Kinesiology commendation for excellent results and grades, among the three best students in the generation

Work experience

06/2025 – today ⇥ Kinesiologist at "SportsLab", Split, Croatia

10/2025 – today ⇥ External associate at Faculty of Kinesiology, University of Split, Croatia

02/2020 – 01/2025 ⇥ Goalkeeper coach (U9 to senior teams) at football clubs "HNK Hajduk Split", "NK Croatia Zmijavci", "NK Sloga Mravince" and "NK Uskok Klis", Croatia

05/2024 – 08/2024 ⇥ Functional fitness and recreation coach at association "Zdravi dan", Solin, Croatia

09/2023 – 12/2023 ⇥ Physical education teacher at Electrical Engineering Secondary School Split and Secondary School "Braće Radić" Nehaj, Croatia

Publications

Vladovic, J., Pehar, M., Morgans, R., Kuko, M., & Modric, T. (2026). More Time in Play, Not More High-Intensity; The Influence of Effective Playing Time on Match Running Performance in Elite Soccer. Sport Mont, 24(2), Ahead of print. https://doi.org/10.26773/smj.260615

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