

# Effects of playing surface on physiological, technical, and mood parameters in 5v5 small-sided soccer games in youth players

Galip Torbalı , Umut Gök , Yağmur Gök , Abdullah Canikli 

*Faculty of Sports Sciences, University of Tokat Gaziosmanpaşa, Tokat, Türkiye.*

## Abstract

**Received:**  
October 19, 2025

**Accepted:**  
January 03, 2026

**Online Published:**  
January 18, 2026

**Keywords:**  
Playing surface,  
psychophysiological  
responses, small-sided  
games, technical  
performance.

**Aim:** This study aimed to compare the psychophysiological, kinematic, and technical responses of young soccer players during 5v5 small-sided games (SSGs) performed on artificial turf and natural grass surfaces. **Method:** Twenty male soccer players (age:  $12.2 \pm 0.41$  years) participated in two experimental sessions conducted under standardized environmental conditions (29 °C, 40% humidity). Each player completed four 5-minute SSG bouts with 2-minute recovery intervals on both surface types, separated by 48 hours of rest. Total distance, mean heart rate ( $HR_{mean}$ ), peak heart rate ( $HR_{peak}$ ), percentage of maximum heart rate ( $\%HR_{max}$ ), rating of perceived exertion (RPE), and physical enjoyment scale (PES) as well as technical actions and mood responses (Brunel Mood Scale; BRUMS) were recorded. Paired-sample t-tests were applied, and significance was set at  $p < 0.05$ . **Results:** No significant differences were observed between surfaces in  $HR_{mean}$ ,  $HR_{peak}$ ,  $\%HR_{max}$ , RPE, PES, or total distance covered ( $p > 0.05$ ). However, players performed significantly more successful passes, successful shots, interceptions, and ball losses on artificial turf than on natural grass ( $p < 0.05$ ). Mood responses were largely independent of surface type, although minor effects were noted, including tension and vigour ( $p > 0.05$ ). **Conclusion:** While the psychophysiological load of 5v5 SSGs was similar on both surfaces, technical performance was superior on artificial turf. These findings suggest that surface type has a greater impact on technical execution than on physiological or psychological responses during SSGs in young soccer players.

## Introduction

In soccer training, incorporating practices that closely resemble the nature of the game is of great importance for the physical and mental development of players (Owen et al., 2012; Arslan et al., 2021). Moreover, the manifestation of performance in soccer is shaped by the interaction among tactical, technical, physical, and psychological components (Stølen et al., 2005). Small-sided games (SSGs) have emerged as one of the most effective training methods that enhance soccer performance by improving players' technical skills, developing tactical awareness, and increasing physical conditioning (Sarmiento et al., 2018). In soccer, psychophysiological factors such as perceived exertion, enjoyment level, and emotional state can play a decisive role in players' performance outcomes (Soylu et al., 2025). The variation in physiological, physical, technical, or tactical responses during games is generally influenced by

factors such as the number of players (formats), pitch dimensions, and game rules (Clemente et al., 2020). Furthermore, research on playing surfaces has suggested that variations in surface type are likely to influence the characteristics, style, and tempo of the game (Dragoo & Braun, 2010). Considering that soccer players are required to move in multiple planes and directions, the way the foot interacts with the ground directly affects the athlete's physical movements (Little & Williams, 2005).

Soccer has traditionally been played on natural grass; however, advancements in artificial turf systems have led to a growing acceptance of third-generation artificial surfaces among soccer clubs (Soligard et al., 2012; Fuller et al., 2007). Consequently, the impact of playing surfaces on the technical and physical components of soccer performance has been increasingly investigated in recent years (Kanaras et al., 2014). Modric et al. (2023) reported that playing on artificial turf is

✉ U. Gök, e-mail: gokumut80@gmail.com

physically more demanding than playing on natural grass, particularly for defenders and midfielders. Similarly, Brito et al. (2017) found that total distance covered and the volume of very high-intensity running were significantly greater on artificial turf compared to natural grass, whereas Andersson et al. (2008) observed no significant differences between the two surfaces in total distance covered or high-intensity running. Regarding technical actions, performances on artificial and natural turf surfaces were reported to be similar (Andersson et al., 2008). These differences arise from the influence of surface stiffness and friction on the transmission of ground reaction forces, which affects metabolic power production during acceleration, deceleration, and changes of direction (Luo & Stefanyshyn, 2011; Ponce-Bordón et al., 2024). However, the existing literature has predominantly focused on physiological and technical parameters, with limited attention given to psychophysiological factors within the context of SSGs.

Several researchers have compared different soccer surfaces in terms of performance (López-Fernández et al., 2019; Ponce-Bordón et al., 2024; Kutnjak et al., 2024), injury risk (Fuller et al., 2007; Meyers, 2017), and technical performance (Andersson et al., 2009; Brito et al., 2017; O’Meagher et al., 2022). However, only a limited number of studies have examined the potential influence of surface type within the context of SSGs. Although young soccer players present a distinct profile from adults in terms of technical efficiency, decision-making speed, and motor control, the existing literature has addressed this age group only to a limited extent. Santos et al. (2013) reported that pitch surface did not influence tactical performance in U13 players. Conversely, Folgado et al. (2007) demonstrated that U10 players executed a higher number of successful passes on natural grass compared with sand surfaces. Brito et al. (2012) evaluated the effects of playing surface—artificial turf, sand, and asphalt—on soccer SSGs, reporting that total distance covered was greater on asphalt and artificial turf compared to soil surfaces. In contrast, average heart rate values were lower on asphalt than on artificial turf and soil surfaces. In a study comparing recovery kinetics of physical performance following soccer-specific exercise on natural and artificial turf, Nédélec et al. (2013) demonstrated that a single training session on artificial turf did not induce greater fatigue or delay

recovery compared to natural grass among players regularly exposed to artificial surfaces. Taken together with studies emphasizing the role of SSGs as effective training methods that enhance technical skills, tactical awareness, and physical conditioning (Sarmiento et al., 2018), these findings highlight the need for further research on how playing surfaces influence players’ physiological responses during both SSGs and match situations (Andersson et al., 2008). Therefore, the aim of the present study was to compare the psychophysiological, kinematic, and technical responses of young soccer players during 5v5 SSGs performed on natural and artificial grass surfaces. Accordingly, the study hypothesized that, due to its structural characteristics, artificial turf would elicit greater technical, psychophysiological, and kinematic demands during SSGs compared with natural grass.

## Methods

### Study Design

In the present study, a repeated-measures design was employed, involving 20 soccer players who participated in a SSGs format on two different surface types: natural grass and artificial turf. The study was conducted during the pre-season period between 17:00 and 19:00 under environmental conditions of approximately 29°C temperature and 40% relative humidity. A 48-hour recovery period was provided between the two experimental sessions. Prior to participation, detailed information about the study was provided to the players and their parents, and written informed consent was obtained from both. Additionally, ethical approval for the study was granted by the Tokat Gaziosmanpasa University Social and Human Sciences Research Ethics Committee (Graduate Education Institute Directorate) under the decision dated October 20, 2023, and numbered 01-30.

### Participants

A total of 20 young male soccer players (age:  $12.2 \pm 0.41$  years; height:  $160.9 \pm 8.78$  cm; body mass:  $50.0 \pm 9.72$  kg; body mass index:  $19.2 \pm 2.70$  kg/m<sup>2</sup>), all of whom were licensed and actively competing in U-12 and U-13 teams, voluntarily participated in the study. To ensure the reliability of the collected data, specific inclusion criteria were established: (i) having at least one year of active playing experience with a valid soccer license, (ii) no injury within the

previous month, (iii) absence of illness or injury symptoms on the testing days, (iv) full participation in all experimental sessions, and (v) no use of performance-enhancing drugs or stimulants.

### Data Collection Tools

Players' body mass and height were assessed using a digital scale integrated with a stadiometer (Seca, Germany). All measurements were performed by the same evaluator while participants were barefoot and wearing light clothing. Body mass index (BMI) was calculated using the following formula:  $BMI = \text{body mass (kg)} / \text{height (m}^2\text{)}$ . Anthropometric assessments were conducted in the morning, with players in an anatomical standing position, barefoot, and wearing only shorts after an overnight fast. Prior to and following the SSG sessions, players completed several psychophysiological assessments: the Rating of Perceived Exertion (RPE) scale, the Physical Enjoyment Scale (PES) (Soylu et al., 2023) to evaluate exercise enjoyment, and the Brunel Mood Scale (BRUMS), which consists of 24 items assessing mood states such as depression, tension, confusion, anger, fatigue, and vigour (Soylu et al., 2022). During the games, players' heart rate and distance covered were continuously recorded at 1-second intervals using Polar V800 heart rate monitors (Polar Electro Oy, Kempele, Finland). All sessions were video recorded using a Canon HF R806 camera (Canon Inc., Tokyo, Japan) with 1080p resolution, and subsequent notational analysis was conducted by qualified analysts to evaluate technical performance parameters, including successful passes, unsuccessful passes, ball losses, interception, successful shots, and unsuccessful shots.

### Procedure

The first day of the study was designated as an adaptation session, during which players were informed about the procedures and anthropometric measurements were taken. On the second day, the SSGs were conducted on a artificial turf field, whereas on the third day, the SSGs were performed on a natural grass field. Each SSG session commenced following a 15-minute standardized warm-up. The SSGs were organized in a 5v5 format on a  $30 \times 35 \text{ m}^2$  pitch ( $105 \text{ m}^2$  per player), consisting of four 5-minute sets with 2-minute passive recovery periods between sets. Small goals measuring  $3 \times 2 \text{ m}$  were used along with goalkeepers; however, goalkeepers' data were excluded from the analyses. No specific rules or tactical constraints were

imposed on the players, and they received continuous positive coach feedback throughout all sessions. The players completed the BRUMS immediately before and after the games, and they additionally filled out the RPE and PES scales immediately upon completion of each game. During the games, players' heart rates and distance covered were continuously recorded using heart rate monitors and Polar V800 devices. All sessions were video-recorded using high-resolution cameras. The recorded video footage was analyzed using the eAnalyze Soccer software to enable an in-depth assessment of the players' technical performance. To maintain the continuity of play, additional balls were provided by spectators positioned at the sidelines whenever the ball went out of bounds, and no special rules were applied during the SSGs.

### Data Analyses

In the analysis of the present study, descriptive statistics were expressed as mean  $\pm$  standard deviation. Differences in technical and psychophysiological responses during the small-sided games were assessed using paired-sample t-tests, and effect sizes were also calculated to determine the magnitude of the differences. Post-hoc effect sizes (ES) were calculated using Cohen's d. ES values were defined as small ( $\geq 0.01$ ), medium ( $\geq 0.06$ ), or large ( $\geq 0.14$ ) (Cohen, 1988). Statistical significance was set at  $p < 0.05$ , and all analyses were performed using SPSS software (version 24.0).

## Results

This section of the study presents the statistical results for psychophysiological, kinematic, technical, and Brunel Mood responses during 5v5 small-sided games performed on artificial and natural grass surfaces.

Table 1 presents the statistical results of the psychophysiological responses during the 5v5 SSGs. Accordingly, no statistically significant differences were observed between the groups in total distance covered, HRmean, HRpeak, %HRmax, RPE, and PES ( $p > 0.05$ ).

Table 2 presents the statistical results of technical activity responses during the 5v5 SSGs. The analysis revealed statistically significant differences between the groups in successful passes, successful shots, interception, and ball losses ( $p < 0.05$ ). Specifically, the SSGs conducted on the artificial turf

demonstrated higher frequencies of successful passes, successful shots, interception, and ball losses compared to those performed on natural grass. No

statistically significant differences were observed between the groups for unsuccessful passes and unsuccessful shots ( $p > 0.05$ ).

**Table 1**

Psychophysiological responses to the 5v5 ssgs played on artificial turf and natural grass (Mean  $\pm$  SD).

	Artificial Turf	Natural Grass	t	p
Total Distance	1.50 $\pm$ 0.18	1.48 $\pm$ 0.15	.500	0.588
HR <sub>mean</sub>	186.32 $\pm$ 9.33	182.99 $\pm$ 7.03	1.197	0.246
HR <sub>peak</sub>	199.06 $\pm$ 7.52	197.15 $\pm$ 5.74	.872	0.394
%HR <sub>max</sub>	93.54 $\pm$ 1.54	92.79 $\pm$ 1.62	1.519	0.145
RPE	10.81 $\pm$ 1.77	10.86 $\pm$ 1.56	-.112	0.912
PES	46.78 $\pm$ 9.27	49.11 $\pm$ 7.76	-1.150	0.264

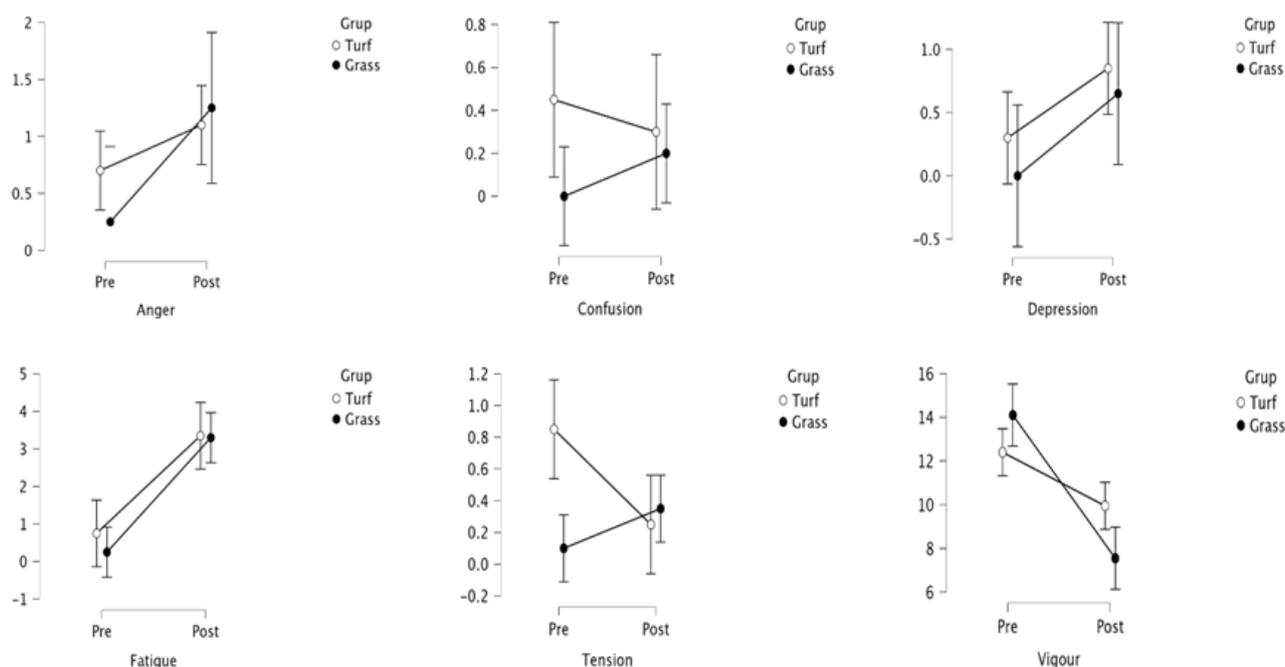
HR<sub>mean</sub>: Mean Heart Rate; HR<sub>peak</sub>: Peak Heart Rate; %HR<sub>max</sub>: Percentage of Maximum Heart Rate; RPE = Rating of Perceived Exertion; PES: Physical enjoyment scale; Mean = arithmetic mean; SD: Standard Deviation; p = significance value; p < 0.05

**Table 2**

Technical activity responses to the 5v5 ssgs played on artificial turf and natural grass (Mean  $\pm$  SD).

	Artificial Turf	Natural Grass	t	p	ES
SP	15.05 $\pm$ 2.74	11.40 $\pm$ 2.98	3.950	0.001*	1.28
USP	4.20 $\pm$ 0.62	4.10 $\pm$ 0.97	.567	0.577	-
SS	2.75 $\pm$ 1.12	2.05 $\pm$ 1.10	4.765	0.001*	0.63
USS	1.50 $\pm$ 1.54	1.70 $\pm$ 1.17	-.847	0.408	-
LB	3.50 $\pm$ 1.00	2.15 $\pm$ 1.18	6.469	0.001*	1.23
INT	3.45 $\pm$ 1.00	2.15 $\pm$ 1.04	5.940	0.001*	1.27

SP: Successful pass; USP: unsuccessful pass; SS: Successful shot; USS: unsuccessful shot; LB: lost ball; INT: Interception; Mean = arithmetic mean; SD: Standard Deviation; p = significance value; p < 0.05; ES: Effect Size.



**Figure 1.** Brunel mood states responses of different pitch dimension.

Figure 1 shows that the results of the two-way repeated measures ANOVA indicate a statistically significant interaction effect between Group and Time for Tension and Vigour, while no significant interaction was found for Anger  $F(1, 38) = 1.41, p = .242, \eta^2p = .005$ , Confusion  $F(1, 38) = 1.47, p = .233, \eta^2p = .014$ , Depression  $F(1, 38) = 0.05, p = .826, \eta^2p < .001$ , and Fatigue  $F(1, 38) = 0.36, p = .552, \eta^2p = .002$ . For Tension, the interaction was significant,  $F(1, 38) = 11.18, p = .002, \eta^2p = .084$ . Post-hoc tests revealed that this was driven by a significant decrease in tension from pre-test to post-test specifically in the Turf group ( $p = .002$ ), with no significant change observed in the Grass group ( $p = .172$ ). Furthermore, at pre-test, the Turf group had significantly higher tension than the Grass group ( $p = .004$ ), a difference that disappeared post-test. For vigour, the interaction was also significant,  $F(1, 38) = 11.57, p = .002, \eta^2p = .055$ . Although vigour decreased significantly in both groups from pre-test to post-test (both  $p \leq .007$ ), the post-hoc analysis confirmed that the magnitude of this decrease was significantly greater in the Grass group ( $p < .001$ ) compared to the Turf group ( $p = .007$ ), leading to the significant interaction.

## Discussion

In the present study, no significant differences were observed in HRmean, HRpeak, %HRmax, RPE, PES, or total distance covered among young soccer players during 5v5 SSGs performed on different surfaces. Hughes et al. (2013) reported similar HRmean values and comparable fatigue responses in match simulations conducted on high-quality natural and artificial turf, indicating that surface type did not influence physiological responses. Similarly, Wundersitz et al. (2021) found no differences in physiological responses across natural grass, artificial turf, and concrete surfaces. In another study with elite soccer players, Andersson et al. (2009) highlighted that total distance covered was comparable between natural and artificial turf surfaces. Furthermore, Wundersitz et al. (2021) reported that RPE did not differ significantly between artificial and natural turf, suggesting that players perceived similar subjective exertion across different playing surfaces. Additionally, Manca Kutnjak et al. (2024) observed in female soccer players that total running distance was not influenced by surface type for wide defenders and

forwards, whereas central defenders and midfielders covered slightly greater distances on artificial turf. Overall, these studies indicate that when surface conditions are standardized above a certain threshold, physiological and kinematic responses do not differ substantially. These findings align with the results of the present study, suggesting that players experience similar levels of physiological load across different playing surfaces.

Contradictory findings have also been reported in the literature. Brito et al. (2012) observed that during games on soil, asphalt, sand, and artificial turf, mean and peak HR values were lowest on asphalt, moderate on sand, and highest on artificial turf. Di Michele et al. (2009) reported higher heart rate on artificial turf compared to natural grass in young soccer players, whereas Jorge Lopes Fernandes (2018) found that mean heart rate was higher on natural grass than on artificial turf in elite U-16 female players. Similarly, Ponce-Bordón et al. (2024) reported lower total distance covered on artificial turf and higher perceived exertion on high-quality natural grass in professional soccer players. Rago et al. (2016), comparing sand and artificial turf in eight adult players, found that total distance covered was substantially greater on artificial turf, while perceived exertion was significantly higher on sand. Another study (López-Fernández et al., 2019) indicated that total distance covered was greater in all games played on natural grass compared to artificial turf. In contrast, Brito et al. (2017) reported higher total distance on artificial turf than on natural grass in young soccer players. These conflicting results may be attributed to variations in surface quality, pitch dimensions, player level, and game format. Additionally, because mechanical loading on the musculoskeletal system is greater on natural grass, perceived exertion may increase while high-intensity running may decrease (Bradley et al., 2009). Therefore, the absence of significant surface-related differences in the present study can be explained by the high quality of the playing surfaces, standardized game format, and comparable fitness levels of the participants. In addition, the game format used in the study appears to directly influence players' kinematic and physiological loads by increasing ball-possession duration, fluctuations in game tempo, and on-field intensity.

Regarding technical performance, the findings of the present study indicate that the number of successful passes, successful shots, interception, and

ball losses was higher on artificial turf compared to natural grass. These results largely align with previous literature reported by Andersson et al. (2009) and Brito et al. (2017). Andersson et al. (2009) noted that more short passes and midfield combinations occurred on artificial turf. Similarly, Brito et al. (2017) reported higher numbers of successful passes and interception on artificial turf compared to soil and natural grass, whereas unsuccessful passes were more frequent on soil surfaces. These findings suggest that artificial turf may provide players with an advantage in technical actions due to more predictable ball bounce, surface uniformity, and greater stability during ball control. On the other hand, O'Meagher et al. (2022) reported no significant differences in soccer skill performance between natural and artificial turf. This discrepancy may be attributed to the fact that their study assessed passing test performance rather than technical actions during actual gameplay. Therefore, the surface-related differences observed in the present study favoring artificial turf are largely consistent with the literature and may, in some cases, be influenced by specific field characteristics and player attributes.

Although previous studies have reported that players tend to prefer natural grass due to surface feel and game comfort, and artificial turf for factors such as the clarity of line markings (Burillo et al., 2014; Sassi et al., 2011), no significant differences in enjoyment were observed between natural and artificial turf in the present study. This may be attributed to the young age of the players and their limited ability to perceive differences in surface quality. When examining mood responses, SSGs played on different surfaces induced minor changes in tension and vigour, but these changes did not result in significant differences between groups. At the pre-test, the Artificial Turf group exhibited significantly higher tension scores compared to the Grass group; however, this difference was no longer observed at the post-test. Additionally, although vigour levels significantly decreased from pre-test to post-test in both groups, post-hoc analysis revealed that the reduction was markedly greater in the Grass group than in the Artificial Turf group, resulting in a significant interaction effect. These findings suggest that while surface type may initially influence players' psychological states, such effects tend to diminish with repeated exposure and adaptation to training conditions. This may be explained by the

players' young age and their limited perceptual sensitivity to subtle differences in surface quality.

## Conclusion

In conclusion, no significant differences were observed between surfaces in terms of mean and peak HR, %HRmax, RPE, enjoyment, or total distance covered. However, technical performance was superior on artificial turf, with higher numbers of successful passes, shots, interception, and ball losses compared to natural grass. Mood responses were largely independent of surface type, although minor effects were noted, including tension and vigour. This study has several limitations. First, the small sample size restricts the generalizability of the findings. Moreover, the fact that the research was conducted exclusively with young male soccer players limits the applicability of the results to different age groups and female athletes. Focusing on a single age category also prevented the assessment of how developmental differences may influence physiological and technical responses to various surface types. In addition, using only the 5v5 SSG format did not allow for the examination of the variable loading profiles that may emerge from different game designs (e.g., pitch size, number of players, rules, and tactical constraints). The natural and artificial turf pitches utilized in this study met specific quality standards, which constrained the ability to observe potential mechanical and technical responses that might occur on surfaces with different levels of hardness, maintenance conditions, or structural properties. Although psychological responses were assessed, the direct effects of surface characteristics on emotional state, motivation, and cognitive processes were not examined in detail. Finally, the absence of analyses on running-speed zones as well as acceleration and deceleration variables made it difficult to fully explain the impact of different surfaces on kinematic and mechanical loading profiles. Future research is recommended to investigate different age groups, genders, various game formats, and a wider range of pitch qualities, as well as to directly examine the psychological effects of playing surface differences.

## Authors' Contribution

Study Design: GT, AC, UG; Data Collection: GT, AC; Statistical Analysis: AC, YG; Manuscript Preparation: UG, YG; Funds Collection: UG, YG.

## Ethical Approval

The study was approved by the Tokat Gaziosmanpaşa University of Social and Human Sciences Research Ethical Committee (2023/01-30) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

## Funding

The authors declare that the study received no funding.

## Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

## References

- Andersson, H., Ekblom, B., & Krstrup, P. (2008). Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. *J Sport Sci*, 26(2), 113-122. <https://doi.org/10.1080/02640410701422076>
- Arslan, E., Kilit, B., Clemente, F. M., Soylu, Y., Sögüt, M., Badicu, G., Akca, F., Gokkaya, M., & Murawska-Ciałowicz, E. (2021). The effects of exercise order on the psychophysiological responses, physical and technical performances of young soccer players: combined small-sided games and high-intensity interval training. *Biology (Basel)*, 10(11), 1180. <https://doi.org/10.3390/biology10111180>
- Bradley, P. S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krstrup, P. (2009). High-intensity running in English FA Premier League soccer matches. *J Sport Sci*, 27(2), 159-168. <https://doi.org/10.1080/02640410802512775>
- Brito, Â., Roriz, P., Silva, P., Duarte, R., & Garganta, J. (2017). Effects of pitch surface and playing position on external load activity profiles and technical demands of young soccer players in match play. *Int J Perf Anal Spor*, 17(6), 902-918. <https://doi.org/10.1080/24748668.2017.1407207>
- Brito, J., Krstrup, P., & Rebelo, A. (2012). The influence of the playing surface on the exercise intensity of small-sided recreational soccer games. *Hum Mov Sci*, 31(4), 946-956. <https://doi.org/10.1016/j.humov.2011.08.011>
- Burillo, P., Gallardo, L., Felipe, J. L., & Gallardo, A. M. (2014). Artificial turf surfaces: perception of safety, sporting feature, satisfaction and preference of football users. *Eur J Sport Sci*, 14 Suppl 1, S437-S447. <https://doi.org/10.1080/17461391.2012.713005>
- Clemente, F.M., Afonso, J., Castillo, D., Los Arcos, A., Silva, A., & Sarmiento, H. (2020). The effects of small-sided soccer games on tactical behavior and collective dynamics: a systematic review. *Chaos Soliton Fract*, 134, 109710. <https://doi.org/10.1016/j.chaos.2020.109710>
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. 2nd edn Lawrence Erlbaum: Hillsdale.
- Di Michele, R., Di Renzo, A. M., Ammazalorso, S., & Merni, F. (2009). Comparison of physiological responses to an incremental running test on treadmill, natural grass, and artificial turf in young soccer players. *J Strength Cond Res*, 23(3), 939-945. <https://doi.org/10.1519/JSC.0b013e3181a07b6e>
- Dragoo, J. L., & Braun, H. J. (2010). The effect of playing surface on injury rate: a review of the current literature. *Sports Med*, 40(11), 981-990. <https://doi.org/10.2165/11535910-000000000-00000>
- Folgado, H., Duarte, R., Laranjo, L., Sampaio, J., & Fernandes, O. (2007). *Heart rate and technical responses to variation in pitch dimension and surface in "three-a-side" youth soccer drills*. Retrieved 20 January, 2013, from <http://hdl.handle.net/10174/2086>
- Fuller, C. W., Dick, R. W., Corlette, J., & Schmalz, R. (2007). Comparison of the incidence, nature and cause of injuries sustained on grass and new generation artificial turf by male and female football players. Part 1: match injuries. *Br J Sports Med*, 41 Suppl 1(Suppl 1), i20-i26. <https://doi.org/10.1136/bjism.2007.037267>
- Hughes, M. G., Birdsey, L., Meyers, R., Newcombe, D., Oliver, J. L., Smith, P. M., Stembridge, M., Stone, K., & Kerwin, D. G. (2013). Effects of playing surface on physiological responses and performance variables in a controlled football simulation. *J Sports Sci*, 31(8), 878-886. <https://doi.org/10.1080/02640414.2012.757340>
- Kanaras, V., Metaxas, T. I., Mandroukas, A., Gissis, I., Zafeiridis, A., Riganas, C. S., ... & Vrabas, I. S. (2014). The effect of natural and artificial grass on sprinting performance in young soccer players. *Am J Sports Sci*, 2(1), 1-4. <https://doi.org/10.11648/j.ajss.20140201.11>
- Kutnjak, M., Pavlinovic, V., & Modric, T. (2024). The effect of pitch surface on match running performance in women's soccer. *Appl Sci*, 15(1), 40. <https://doi.org/10.3390/app15010040>
- Little, T., & Williams, A. G. (2005). Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res*, 19(1), 76-78. <https://doi.org/10.1519/14253.1>
- Luo, G., & Stefanyshyn, D. (2011). Identification of critical traction values for maximum athletic performance. *Footwear Sci*, 3(3), 127-138. <https://doi.org/10.1080/19424280.2011.639807>
- López-Fernández, J., Gallardo, L., Fernández-Luna, Á., Villacañas, V., García-Unanue, J., & Sánchez-Sánchez, J. (2019). Pitch size and game surface in different small-sided games. Global indicators, activity profile,

- and acceleration of female soccer players. *J Strength Cond Res*, 33(3), 831-838. <https://doi.org/10.1519/JSC.0000000000002090>
- López-Fernández, J., Sánchez-Sánchez, J., Rodríguez-Cañamero, S., Ubago-Guisado, E., Colino, E., & Gallardo, L. (2018). Physiological responses, fatigue and perception of female soccer players in small-sided games with different pitch size and sport surfaces. *Biol Sport*, 35(3), 291-299. <https://doi.org/10.5114/biol.sport.2018.77829>
- Meyers, M. C. (2017). Incidence, mechanisms, and severity of match-related collegiate men's soccer injuries on FieldTurf and natural grass surfaces: a 6-year prospective study. *Am J Sports Med*, 45(3), 708-718. <https://doi.org/10.1177/0363546516671715>
- Modric, T., Esco, M., Perkovic, S., Basic, Z., Versic, S., Morgans, R., & Sekulic, D. (2023). Artificial turf increases the physical demand of soccer by heightening match running performance compared with natural grass. *J Strength Cond Res*, 37(11), 2222-2228. <https://doi.org/10.1519/JSC.0000000000004539>
- Nédélec, M., McCall, A., Carling, C., Le Gall, F., Berthoin, S., & Dupont, G. (2013). Physical performance and subjective ratings after a soccer-specific exercise simulation: comparison of natural grass versus artificial turf. *J Sports Sci*, 31(5), 529-536. <https://doi.org/10.1080/02640414.2012.738923>
- O'Meagher, R., O'Reilly, J., & Ali, A. (2022). The effect of different playing surfaces on soccer skill performance. *Int J Sports Sci Coach*, 17(6), 1378-1384. <https://doi.org/10.1177/1747954121110663>
- Owen, A. L., Wong, D. P., Paul, D., & Dellal, A. (2012). Effects of a periodized small-sided game training intervention on physical performance in elite professional soccer. *J Strength Cond Res*, 26(10), 2748-2754. <https://doi.org/10.1519/JSC.0b013e318242d2d1>
- Ponce-Bordón, J. C., Polo-Tejada, J., Sanabria-Pino, B., Rubio-Morales, A., García-Calvo, T., & Lobo-Triviño, D. (2024). The influence of the playing surface on workload response in Spanish professional male soccer players. *Sensors (Basel)*, 24(14), 4506. <https://doi.org/10.3390/s24144506>
- Rago, V., Rebelo, A. N., Pizzuto, F., & Barreira, D. (2016). Small-sided soccer games on sand are more physically demanding but less technically specific compared to games on artificial turf. *J Sports Med Phys Fitness*, 58(4), 385-391. <https://doi.org/10.23736/S0022-4707.16.06708-6>
- Santos, R., Dias, C., Garganta, J., & Costa, I. (2013). Does playing surface influence the tactical performance of soccer players? *Rev Educ Fis UEM*, 24(2), 247-252. <https://doi.org/10.4025/reveducfis.v24.2.17965>
- Sarmiento, H., Clemente, F. M., Harper, L. D., Costa, I. T. da, Owen, A., & Figueiredo, A. J. (2018). Small sided games in soccer – a systematic review. *Int J Perf Anal Spor*, 18(5), 693-749. <https://doi.org/10.1080/24748668.2018.1517288>
- Sassi A, Stefanescu A, Bosio A, Riggio M, Rampinini E, 2011. The cost of running on natural grass and artificial turf surfaces. *J Strength Cond Res*, 25, 3, 606-611. <https://doi.org/10.1519/JSC.0b013e3181c7baf9>
- Soligard, T., Bahr, R., & Andersen, T. E. (2012). Injury risk on artificial turf and grass in youth tournament football. *Scand J Med Sci Sports*, 22(3), 356-361. <https://doi.org/10.1111/j.1600-0838.2010.01174.x>
- Soylu, Y., Arslan, E., & Kilit, B. (2022). Psychometric properties of the Brunel mood scale in Turkish adults and adolescents athletes. *Sportmetre Journal of Physical Education and Sport Sciences*, 20(2), 56-67. <https://doi.org/10.33689/spormetre.1060329>
- Soylu, Y., Arslan, E., & Kilit, B. (2023). Exercise and enjoyment: a scale adaptation study for adolescents and adults athletes. *Sportmetre Journal of Physical Education and Sport Sciences*, 21(1), 93-104. <https://doi.org/10.33689/spormetre.1183236>
- Soylu, Y., Chmura, P., Arslan, E., & Kilit, B. (2025). Intra- and inter-format variability of psychophysiological and technical responses in different small-sided soccer game formats: A repeated measures study. *Int J Sports Sci Coach*, 20(5), 1987-1996. <https://doi.org/10.1177/17479541251341391>
- Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. *Sports Med*, 35(6), 501-536. <https://doi.org/10.2165/00007256-200535060-00004>
- Wundersitz, D. W., Staunton, C. A., Gordon, B. A., & Kingsley, M. I. (2021). The influence of playing surface on external demands and physiological responses during a soccer match simulation. *J Sports Sci*, 39(24), 2869-2877. <https://doi.org/10.1080/02640414.2021.1976472>