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Original Article

Comparison of pitch sizes and floater numbers on internal and external load in small-sided soccer games

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Abstract:
The study examined the impact of pitch size and the number of floaters on internal and external load in small-sided soccer games (SSGs). Twenty male professional soccer players from Thai League 3 (age: 21.4 ± 1.82 years; height: 175 ± 5.41 cm; weight: 64.7 ± 3.87 kg; body fat: 9.54 ± 3.30%; VO_2max: 57.7 ± 4.43 ml/kg/min) participated. The research analyzed four SSG formats: 4v4 and 4v4+2 (with two floaters) on both small (32 × 25 m) and large (40 × 30 m) pitches. Each session comprised four sets of 4-min games, separated by 4-min passive rest intervals. Internal load was assessed using heart rate (HR) monitors, tracking maximum HR, mean HR, and time spent in HR zones. External load was evaluated using Global Positioning System (GPS) devices, measuring total distance (TD), high-intensity running, sprint distance, accelerations, and decelerations. The results indicated that the 4v4 format on the large pitch elicited the highest physiological responses (HRmax: 182.15 ± 8.27 beats/min; HRmean: 171.80 ± 9.12 beats/min) and the greatest time spent in Zone 5 (29.15 ± 27.71%). The 4v4+2 format on the large pitch resulted in the highest TD covered (2797.50 ± 146.51 m). High-intensity running was most prevalent in the 4v4 format on small pitches (238.60 ± 82.72 m). No significant differences were observed in sprint distances or acceleration and deceleration frequencies across conditions. These findings indicate that coaches should use the 4v4 format on large pitches to enhance high-intensity conditioning, whereas the 4v4+2 format on small pitches is better suited for technical development. This study offers evidence-based recommendations to help coaches optimize SSG configurations according to specific training goals.
Keywords: soccer**, small-sided games, high intensity, physiological response, locomotor activities**.

Introduction

Small-sided games (SSGs) have gained popularity in soccer training owing to their ability to simultaneously enhance technical skills, tactical awareness, and physical fitness while closely replicating match conditions (Fernández-Espínola et al., 2020; Clemente et al., 2021). These training formats provide considerable flexibility in adjusting key variables such as player numbers, pitch size, rules, and game duration (Iacono et al., 2021; Riboli et al., 2020), with each modification influencing both internal and external training loads (Clemente et al., 2023). The use of floaters (neutral players) is a common strategy in SSGs, where they support the team in possession, creating a constant numerical advantage to improve ball retention and goal-scoring opportunities (Praça et al., 2020; Moniz et al., 2020). Research has shown that incorporating floaters influences players' tactical behavior (Carvalho et al., 2021; Clemente, 2022) and affects both physiological and physical demands during training (Asian-Clemente et al., 2021; Lozano et al., 2020). Nagy et al. (2020) examined heart rate (HR) responses in SSGs with different player numbers, including different configurations of additional neutral attacking players. The study examined nine professional soccer players, measuring their HR periodically during SSG training, including maximum HR. The results revealed that the 3v3 SSG format without additional neutral attacking players produced the highest HR values. In contrast, the 3v3+3 format led to lower HR responses compared to other formats. The presence of neutral attacking players introduced a numerical imbalance, changing the game's physiological demands.

Pitch size is a key factor influencing training load in SSGs, particularly in relation to the area per player, which is determined by dividing the total pitch area by the number of players (Santos et al., 2021; Riboli et al., 2022). Research has demonstrated that pitch dimensions significantly affect players' physiological responses and movement patterns (Castillo et al., 2021; Lemes et al., 2020). Larger pitches generally elicit higher-speed running and greater total distances (TDs), whereas smaller pitches emphasize short-distance movements and frequent directional changes (Dalen et al., 2021; Clemente et al., 2023). Nunes et al. (2021) highlighted that adjusting pitch size and player formations could be an effective strategy for increasing exercise intensity and improving passing tactics. Furthermore, these variations can enhance both offensive and defensive transitions by improving the speed of ball possession. While previous studies have primarily explored the effects of floaters and pitch dimensions separately (Praça et al., 2020; Castillo et al., 2021), the interaction between these two factors and their combined impact on training load remains insufficiently understood. Gaining deeper insight into

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the relationship between floater numbers and pitch size would allow coaches to better regulate training intensity and tailor sessions to specific objectives, ultimately enhancing the effectiveness of training programs (Iacono et al., 2021; Riboli et al., 2022).

Internal and external loads are essential for monitoring and managing training sessions. Internal load reflects physiological responses such as HR and perceived exertion, while external load quantifies the physical work performed, including distance covered, speed, and acceleration (Riboli et al., 2020; Lozano et al., 2020; Santos et al., 2021). Assessing both parameters offers a comprehensive understanding of the training workload (Clemente et al., 2021). Clemente et al. (2022) analyzed the workload of both regular players and floaters in a specific SSG format. Twenty semi-professional soccer players participated in a 4v4+2 SSG, with variations in floater positioning (internal floater, external floater, and no floater). The analyzed variables included TD covered, distance at speeds of 7–13.9 km/h, 14–17.9 km/h, and ≥18 km/h, as well as acceleration, deceleration, peak and average HR, and rating of perceived exertion (RPE). The results revealed that internal floaters covered more TD, performed more accelerations, and had higher RPE than players in other positions. Furthermore, both internal and external floaters covered greater distances at 7–13.9 km/h, 14–17.9 km/h, and >18 km/h.

Although previous research has established that both the number of floaters and pitch size independently influence training load (Asian-Clemente et al., 2021; Castillo et al., 2021), there is no clear consensus on their combined effects, especially concerning the training intensity of internal and external loads when using two floaters or varying pitch sizes during training (Clemente et al., 2021; Riboli et al., 2022). Additionally, the impact of floaters on different pitch sizes may vary based on players' skill levels and performance, underscoring the need for further investigation (Lemes et al., 2020; Santos et al., 2021).

This study examines the impact of pitch dimensions (32 × 25 m and 40 × 30 m) and the number of floaters (4v4 and 4v4+2) on both internal and external loads in soccer SSGs. Specifically, it focuses on exploring the interaction between these factors. By understanding how varying the number of floaters across different pitch sizes influences training loads, the study offers valuable insights for coaches when designing effective training programs. This knowledge will help practitioners better manage training intensity based on specific objectives, ultimately optimizing athletes' performance development through more targeted training prescriptions.

Materials and methods

Participants

The study involved 20 male professional soccer players from Thai League 3 (mean ± SD; age: 21.4 ± 1.82 years, height: 175 ± 5.41 cm, weight: 64.7 ± 3.87 kg, body fat percentage: 9.54 ± 3.30%, VO_2max: 57.7 ± 4.43 ml/kg/min). All participants completed the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) to assess their maximal oxygen consumption. VO_2max was calculated using the formula: VO_2max (ml/kg/min) = IR1 distance (m) × 0.0084 + 36.4 (Karakoc et al., 2012). Participants were then randomly assigned to groups, with no significant differences in mean VO_2max values between them.

The inclusion criteria required participants to be free from any muscle or joint injuries and to engage in regular training sessions for at least five days per week. Exclusion criteria involved participants with injuries that hindered their ability to participate in the experimental procedures, as well as those who failed to comply with the research protocols. All participants were informed about the research procedures, potential benefits, and associated risks. Written informed consent was obtained from each participant. This study was approved by the Human Research Ethics Committee of Kasem Bundit University, Bangkok, Thailand, in line with the Declaration of Helsinki (approval number: KBU-HREC 034/67).

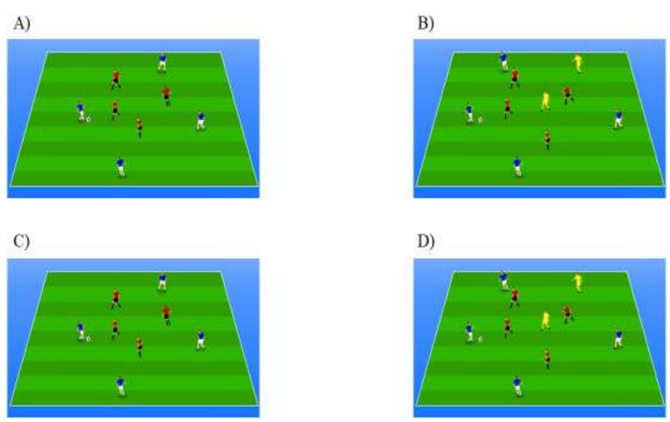

Figure 1. Four SSG methods: (A) Ball possession without floater players on a small pitch (32 × 25 m); (B) Ball possession with two floater players on a small pitch (32 × 25 m); (C) Ball possession without floater players on a large pitch (40 × 30 m); and (D) Ball possession with two floater players on a large pitch (40 × 30 m)

Design

This study analyzed the internal and external loads during SSGs with varying numbers of floating players. The games were played on an outdoor natural grass surface. Two pitch sizes were used: a small pitch measuring 32 × 25 m (1 player per 100 m^2) and a large pitch measuring 40 × 30 m (1 player per 150 m^2) (Michailidis, 2024). The study examined three SSG formats: 4v4 without floating players and 4v4 with two floating players (Figure 1). Floating players were limited to playing only with the team in possession of the ball (attacking team). Before each training session, participants' resting HRs were measured, and the SSG format for that day was randomly selected. A standardized 15-min warm-up protocol was followed before each session, which included 5 min of jogging, 8 min of dynamic stretching, and 3 sets of 10-m maximum speed sprints for muscle activation (Eniseler et al., 2017)

The SSG sessions were held from 4:00 to 6:00 PM on Mondays and Thursdays. Each session consisted of 4 sets of 4-min games, with 4-min passive rest intervals between sets (Riboli et al., 2023; Eniseler et al., 2017). A minimum recovery period of 72 h was required between sessions with different SSG formats (Silva et al., 2018; Goulart et al., 2022).

Procedure

The Polar Pro system (Polar Electro, Kempele, Finland) was used to measure both internal and external loads for each player. Participants wore identical Polar Team Pro chest straps (Polar Electro, Kempele, Finland) positioned at the center of the chest and secured at the lower sternum with an elastic band. Data were recorded on the devices and subsequently downloaded via the manufacturer's software (POLAR Team Pro, version 1.3.1; POLAR, Polar Electro Oy, Kempele, Finland). HR measurements were used to evaluate internal load during matches, excluding rest periods. Continuous HR measurements were recorded from all participants at 1-s intervals during the gameplay. The maximum HR (HRmax) and absolute mean HR (beats/min) were determined, while the relative mean HR (%HRmax) was calculated using the following formula: %HRmax = Exercise HR / [220 − age] × 100%.

Each participant's mean HRs were categorized based on the proportion of playing time (%) using predefined intensity zones: Zone 3 (70%–79% HRmax), Zone 4 (80%–89% HRmax), and Zone 5 (90%–100% HRmax). Maximum and average HR responses were recorded for each individual, following the methodology outlined by Nagy et al. (2020). Players' movements during SSGs, representing the external load, were recorded using portable Global Positioning System (GPS) devices (Polar Electro, Kempele, Finland). The Polar Team Pro devices were placed in straps attached to specially designed chest bands, worn at mid-chest according to the manufacturer's guidelines. All data were downloaded through the Team Pro webpage (teampro.polar.com). During each SSG, the following parameters were measured: TD, high-intensity runs (15–23.9 km/h), sprints (>24 km/h), number of accelerations (>2 m/s), and number of decelerations (>2 m/s), as described by Riboli et al. (2020). Ten minutes before each match, selected players were equipped with HR monitors, vests, and devices. After equipment setup and the collection of preliminary situation data and individual player information, the exact start time of the SSG training was recorded. All SSG training sessions were recorded to validate the collected data. Equipment was removed after each game. Each session was analyzed individually, considering the entire game duration, excluding recovery periods, as outlined by Tatakasem et al. (2024).

Statistical analysis

The results are presented as mean ± standard deviation (SD). The normality of the data distribution was evaluated using the Kolmogorov–Smirnov test, and parametric statistical methods were applied. A repeated-measures analysis of variance (ANOVA), followed by Bonferroni post-hoc tests, was used to compare internal load (HR) and external load (locomotor activities) across different SSG formats, as well as to examine differences in each SSG bout. Additionally, paired t-tests for dependent samples were performed to compare performance indicators in each SSG. Statistical significance was set at $p < .05$, and all analyses were performed using SPSS version 26 (SPSS Inc., Chicago, IL, USA).

Results

The study analyzed internal and external loads in small-sided soccer games (SSGs) with varying pitch sizes and floater numbers.

Table 1 Internal load between pitch sizes and number of floaters in small-sided games

Internal load variables	Small-sided game formats			
	Small (32 × 25 m)		**Large (40 × 30 m)**	
	4v4	**4v4+2**	**4v4**	**4v4+2**
HR max (beats/min)	181.55 ± 8.75	169.55 ± 8.85 $^{*,\#}$	182.15 ± 8.27	177.44 ± 9.40
HR max (%)	90.70 ± 4.11	85.00 ± 4.47 $^{*,\#}$	91.50 ± 4.07	88.90 ± 4.62
HR mean (beats/min)	168.15 ± 10.09	156.15 ± 11.73 $^{*,\#}$	171.80 ± 9.12	164.10 ± 8.45
HR mean (%)	84.25 ± 5.13	78.40 ± 5.72 $^{*,\#}$	86.20 ± 4.51	82.30 ± 4.28
Zone 3	22.75 ± 13.10	11.27 ± 5.43 *	10.85 ± 10.74 *	17.55 ± 20.53
Zone 4	39.62 ± 11.77	49.00 ± 8.69 *	48.20 ± 23.94	34.35 ± 24.32
Zone 5	15.98 ± 12.12	7.16 ± 10.23	29.15 ± 27.71 *,**	18.60 ± 24.86

* Significant differences ($p < 0.05$) with 4v4 small, ** Significant differences ($p < 0.05$) with 4v4+2 small, $^{\#}$ Significant differences ($p < 0.05$) with 4v4 large, $^{\#\#}$ Significant differences ($p < 0.05$) with 4v4+2 large

Table 1 presents the comparative analysis of internal load variables, including HRmax, HRmean, and time spent in predefined HR zones (Zones 3–5). HRmax: The 4v4+2 small-pitch format exhibited significantly lower values than both the 4v4 small-pitch and 4v4 large-pitch formats ($p < 0.05$) in HRmax (HRmax: 169.55 ± 8.85 vs. 181.55 ± 8.75 and 182.15 ± 8.27 beats/min) and percentage of maximum HR (HRmax %: 85.00 ± 4.47 vs. 90.70 ± 4.11 and 91.50 ± 4.07%). Additionally, the mean HR (HRmean: 156.15 ± 11.73 vs. 168.15 ± 10.09 and 171.80 ± 9.12 beats/min) and percentage of mean HR (HRmean %: 78.40 ± 5.72 vs. 84.25 ± 5.13 and 86.20 ± 4.51%) were also lower in the 4v4+2 small-pitch format ($p < 0.05$).

Time in HR zones: The 4v4+2 small-pitch and 4v4 large-pitch formats had significantly lower values than the 4v4+2 small-pitch format ($p < 0.05$) in Zone 3 (11.27% ± 5.43% and 10.85% ± 10.74% vs. 22.75% ± 13.10%). However, the 4v4+2 small-pitch format showed significantly higher values than the 4v4 small-pitch format ($p < 0.05$) in Zone 4 (49.00% ± 8.69% vs. 39.62% ± 11.77%). In contrast, the 4v4 large-pitch format exhibited significantly higher values than both the 4v4 small-pitch and 4v4+2 small-pitch formats ($p < 0.05$) in Zone 5 (29.15% ± 27.71% vs. 15.98% ± 12.12% and 7.16% ± 10.23%).

Table 2 External load between pitch sizes and number of floaters in small-sided games

External load Variables	**Small-sided game formats**			
	Small (32 × 25 m)		**Large (40 × 30 m)**	
	4v4	**4v4+2**	**4v4**	**4v4+2**
Total distance (m)	2596.25 ± 117.33	2475.25 ± 121.98	2669.85 ± 182.33 $^{**,\#\#}$	2797.50 ± 146.51 $^{*,**,\#}$
High-intensity runs (m)	238.60 ± 82.72	91.35 ± 35.91	211.20 ± 45.58 *,**	138.60 ± 86.47 *,**
Sprints (m)	4.90 ± 4.21	3.60 ± 8.79	6.65 ± 5.10	2.10 ± 5.12
Accelerations (n)	22.70 ± 12.29	28.35 ± 6.17	21.00 ± 7.12 **	23.90 ± 9.17
Decelerations (n)	25.10 ± 5.59	27.40 ± 11.38	27.80 ± 8.09	27.60 ± 14.21

* Significant differences ($p < 0.05$) with 4v4 small, ** Significant differences ($p < 0.05$) with 4v4+2 small,
$^{\#}$ Significant differences ($p < 0.05$) with 4v4 large, $^{\#\#}$ Significant differences ($p < 0.05$) with 4v4+2 large

Table 2 summarizes the external load variables, including TD, high-intensity running distance, sprint distance, and the frequency of accelerations and decelerations. TD: The 4v4+2 large-pitch format showed higher values compared to the 4v4 small-pitch, 4v4 large-pitch, and 4v4+2 small-pitch formats ($p < 0.05$). Furthermore, the 4v4 large-pitch format covered more TD than the 4v4+2 small-pitch format (2797.50 ± 146.51 m vs. 2596.25 ± 117.33 m, 2669.85 ± 182.33 m, and 2475.25 ± 121.98 m; $p < 0.05$). High-intensity running distance: The 4v4 and 4v4+2 large-pitch formats had lower values compared to the 4v4 small-pitch format (211.20 ± 45.58 m and 138.60 ± 86.47 m vs. 238.60 ± 82.72 m; $p < 0.05$). However, the 4v4 and 4v4+2 large-pitch formats exhibited higher values than the 4v4+2 small-pitch format in high-intensity running (211.20 ± 45.58 m and 138.60 ± 86.47 m vs. 91.35 ± 35.91 m; $p < 0.05$). Accelerations: The 4v4 large-pitch format displayed lower values than the 4v4+2 small-pitch format in acceleration (21.00 ± 7.12 vs. 28.35 ± 6.17; $p < 0.05$).

Discussion

The aim of this study was to examine the effects of pitch dimensions and the number of floating players on both internal and external loads during SSGs. The results highlight significant relationships between these factors and their influence on training intensity, offering valuable insights into soccer training methodologies.

Internal Load Responses

The analysis of physiological responses showed that the 4v4 format on a larger pitch (40 × 30 m) produced the highest HRmax and HRmean compared to other formats, with values of 182.15 ± 8.27 and 91.50 ± 4.07, respectively. The time spent in Zone 5 was 29.15% ± 27.71%. This finding is consistent with the study by Gantois et al. (2023), which reported a higher HRmean in SSGs played on larger pitches compared to smaller ones, with HRmean values of 173.42 ± 3.60 and 169.17 ± 8.10 and maximum HR values of 89.20% ± 3.63% and 87.20% ± 2.11%, respectively. The cardiovascular demands observed in this study, reaching approximately 90% of HRmax across all pitch sizes (ranging from 85% to 89% of HRmax), are consistent with previous research on SSGs in soccer players. This suggests that such game formats may offer an effective stimulus for enhancing endurance performance in soccer players (Gregory & Travis, 2016). All training formats in this study were classified as high-intensity aerobic or interval training, in line with Hov et al. (2023), who stated that maximal aerobic training could be achieved through high-intensity interval training (HIIT) at 90%–95% of HRmax for 4-min intervals. This approach has been shown to improve maximal oxygen uptake (VO_2max) and lactate threshold. Additionally, this type of training enhances lactate tolerance, maximal oxygen uptake, and the number of high-speed running efforts. MacInnis & Gibala (2017) also observed that during high-intensity interval aerobic exercise, cardiac activity increased, leading to improved blood circulation to large muscle groups. The immediate effect of exercise triggers increased vasodilation in the muscles, thereby improving oxygen delivery to both the body and muscles.

Additionally, Castillo-Rodríguez et al. (2023) supported these findings, noting that larger pitch sizes in SSGs enable players to achieve physiological responses similar to those in actual match conditions. The 4v4 format on a larger pitch offers more playing space for soccer players, further reinforcing the conclusions of

Farhani et al. (2021), who suggested that reducing the number of players while increasing pitch size enhanced physiological intensity. In contrast, the 4v4+2 format on a smaller pitch led to more time spent in Zone 3 (70%–79% HRmax), indicating that floating players help reduce training intensity. Furthermore, the inclusion of two floating players (4v4+2) significantly lowered both HRmax and HRmean, especially on the small pitch (32 × 25 m). This reduction in physiological load is consistent with the findings of Nunes et al. (2021), which showed that floating players reduced possession pressure, enabling teams to retain the ball more effectively while reducing the need for rapid movements. Expanding the playing area and using different player formations can further increase exercise intensity and improve tactical actions, such as passing. Moreover, these adjustments can be leveraged to improve both offensive and defensive transitions by increasing the speed of ball possession.

External Load Responses

This study examined the external load intensity in SSGs and found that the TD covered in the 4v4 and 4v4+2 formats on larger pitches was significantly higher than in other formats, with distances of 2669.85 ± 182.33 m and 2797.50 ± 146.51 m, respectively. High-intensity running distances were also recorded in both 4v4 formats across different pitch sizes, measuring 238.60 ± 82.72 m and 211.20 ± 45.58 m. Beato et al. (2023) further demonstrated that SSGs played on larger pitches led to greater total running distances and higher-intensity running compared to smaller pitch formats. Coaches should prioritize large-pitch SSGs for high-intensity training because they allow for greater TD per minute and higher-intensity running, making them more reflective of actual match demands. In this study, small-pitch SSGs had a player-to-area ratio of one player per 100 m^2, while large-pitch SSGs had a ratio of one player per 150 m^2. The larger pitch size facilitated more efficient movement compared to smaller pitches. Riboli et al. (2022) recommended using a larger area per player to better match competitive demands, especially for developing technical skills and enhancing possession-based training. This finding is consistent with Faga et al. (2023), who suggested that pitch sizes smaller than 75 m^2 per player could impair aerobic performance. For optimal aerobic fitness development in athletes, SSG pitch sizes ranging from 76 to 300 m^2 per player are ideal.

Similarly, de Dios-Álvarez et al. (2024) observed that SSGs with less than 100 m^2 per player affected acceleration patterns because the limited space forced more frequent movements to receive passes. In contrast, pitch sizes ranging from 101 to 350 m^2 per player promote greater total movement and high-intensity running because the increased space allows for the creation of support angles. Clemente et al. (2023) also showed that larger pitch sizes significantly impacted the TD covered by players. Additionally, De Dios-Álvarez et al. (2024) found that larger player-to-area ratios enhanced movement opportunities, particularly when floating players generated extra passing options. Hargreaves and Spriet (2020) highlighted that high-intensity activities, such as sprinting or quick directional changes, surpassed match-play speeds, leading to increased ATP and muscle glycogen consumption, while oxygen availability became insufficient. This results in an increased demand for maximal oxygen consumption (75%–100%) during recovery. Athletes with higher VO_2max values recover more quickly. Consequently, using SSGs in soccer training is an effective way to develop sport-specific aerobic capacity by reducing player numbers, which enhances physiological responses, technical skills, and tactical awareness. Several factors, including player numbers, pitch dimensions, game rules, and coaching interventions, influence SSG training (Sarmento et al., 2018). This approach is further supported by Ueda et al. (2023), who indicated that floating players encouraged creative movement patterns and technical skill development.

Conclusions

This study shows that changing pitch dimensions and the number of floating players significantly affects both internal and external loads in SSGs in soccer. The results indicate that the 4v4 format on large pitches effectively enhances physiological responses and movement activity, making it an ideal training method for developing sport-specific endurance in soccer players or maintaining cardiovascular fitness during the competitive season. Additionally, the 4v4+2 format on large pitches influences both internal and external loads. The larger pitch size creates more space per player, requiring increased movement. Defensive players, in particular, may need to cover more distance to regain possession of the ball. These findings highlight the importance of carefully considering spatial constraints and player numbers when designing SSG-based training programs. Coaches can use this information to develop more effective training sessions that balance physiological demands with technical and tactical development.

Future research should focus on technical skills in SSGs to explore the relationship between skill execution and physiological responses. Additionally, investigating how varying numbers of floating players and positional roles affect both internal and external loads across different player populations may offer valuable insights for optimizing training methodologies in soccer.

Conflicts of interest

The authors declare no conflict of interest.

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