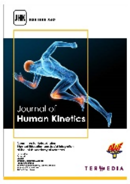

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Section IV – Psychological and Sociological Aspects of Sport and Exercise

Oculometric Variables of Young Soccer Players during Dribbling: A Dual-Task Study

by
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Eye movements are reliable indicators of cognitive workload associated with the visual demands of tasks. This study investigated oculometric variables (pupil diameter, fixation count, and saccades) in soccer players with different experience levels during dual-task (motor-cognitive) performances. Twenty-eight male youth soccer players were included: an elite group (n = 13) and an amateur group (n = 15). A within-subject design was used, and players completed four test protocols (P1–P4) involving dribbling with or without concurrent visual stimuli. Performance times, error counts, and oculometric data were recorded. Both groups required more time to complete protocols when visual stimuli were added (p < 0.001). The elite group completed tasks faster and with fewer mistakes than the amateur group (p < 0.05). Pupil dilation was observed across all protocols, with the largest dilation occurring in P1 (p < 0.001), although no group differences were found in pupil size changes (p > 0.05). The elite group demonstrated fewer fixations and more saccades compared to the amateur group. Fewer fixations and saccades were observed in P1 than in the other protocols (p < 0.05). Experienced players displayed more saccadic movements, possibly reflecting more efficient visual scanning strategies under cognitive load. No evidence of peripheral vision usage was found. These findings suggest experience-related differences in oculomotor behavior during complex dual-task scenarios, yet further studies are needed before practical training implications can be drawn.

Keywords: *soccer; dual-task performance; pupil diameter; saccadic eye movements*

Introduction

Soccer is a highly competitive sport that depends on the integration of advanced motor abilities and sophisticated cognitive processes. Technical skills, such as passing sequences, maintaining ball possession, and dribbling, are fundamental determinants of performance (Forsman et al., 2016). To attain optimal outcomes, athletes must execute technical-tactical and psychological actions under conditions that are both information-rich and time-pressured (Zurutuza et al., 2017). Successful performance hinges on the capacity to sustain efficient visuomotor processing while undertaking diverse perceptual and motor tasks at a high tempo. Accordingly, players must distribute their attention across multiple objects in real time (e.g., the ball, teammates, opponents) and generate rapid responses to complex and dynamically evolving situations (Luis-del Campo et al., 2024).

Consider a dribbling scenario: while controlling the ball, a player may hear a teammate calling for a pass, feel an opponent closing in, register the coach's urgent instructions, and experience the crowd's heightened noise level. In such moments, athletes must concurrently manage visual and auditory stimuli and cope with internal distractions (Vítor de Assis et al., 2021). Optimal dribbling demands keeping the ball close to the desired trajectory at speed; inadequate control increases the likelihood of losing possession (Russell and Kingsley, 2011). Effective dribbling and ball advancement afford substantial tactical advantages, and elite dribblers consistently

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display swift reactions and decision-making (Zago et al., 2016).

The quality of a player's technical response is governed by the seamless coupling of perceptual-cognitive and motor skills within continuously changing environments (Russell and Kingsley, 2011). Extracting and updating information from such contexts impose substantial demands on anticipation, rapid decision-making, and visual efficiency; players must constantly evaluate ball position, teammate and opponent movements, tactical instructions, and their own physical capabilities (Williams et al., 2011). Consequently, high-level soccer performance requires the coordinated deployment of cognitive, perceptual, sensorimotor, and visual faculties to maximise effectiveness and adapt swiftly to situational exigencies (Trecroci et al., 2016).

Eye movements are widely regarded as precise indicators of the cognitive effort imposed by the task's visual demands (Tao et al., 2019). Among the most informative oculometric indices there are saccadic behaviour and the pupil diameter, which together yield valuable insight into underlying processes such as mental workload and visual attention (Mahanama et al., 2022). In particular, larger pupil diameters reliably reflect greater mental effort (Alnæs et al., 2014). Within sport-science research, pupillary responses have been employed to quantify athletes' attentional investment (Campbell et al., 2019; Moran et al., 2016); a recent study in soccer has even shown an inverse association between cognitive effort and tactical efficiency, whereby players who expend less cognitive effort during a task exhibit more effective tactical behaviour on the field (Cardoso et al., 2021).

Saccadic eye movements are likewise tied to executive functions such as inhibitory control, processing speed, and attentional allocation (Hutton, 2008), and saccadic metrics are frequently used as proxies for cognitive workload (Keskin et al., 2020). Micro-saccades, in particular, appear to aid the extraction of salient cues from both foveal and parafoveal regions (Piras et al., 2021). Converging evidence further suggests that highly skilled athletes adopt more efficient gaze strategies (Piras et al., 2021)—either by producing fewer but longer fixations on task-relevant locations (Piras et al., 2014) or, conversely, by acquiring the requisite information through a greater number of shorter fixations (Vítor de Assis et al., 2021).

In open-skill sports such as soccer and basketball, athletes must distribute their attention across multiple environmental cues, including the ball, teammates, and opponents (Williams et al., 1999), while simultaneously executing complex motor actions such as running, passing, and dribbling. This situation creates an inherent dual-task demand (Casanova et al., 2009). Dual-process theory explains the successful management of concurrent cognitive and motor tasks (Evans and Stanovich, 2013). The effects of dual-task paradigms on performance may be explained by Cognitive Load Theory (CLT). CLT further posits that working memory has limited capacity—when this capacity is split among several tasks, performance can decline (Sweller, 1994). In this context, dual-task conditions impair performance because attentional resources are divided between tasks (Asadi et al., 2022). A review of dual-task research showed that acute exposure to dual-task conditions can impair both motor and cognitive performance, whereas long-term dual-task training tends to improve performance in both domains (Moreira et al., 2021). Such training appears to cultivate novel perceptual strategies that optimise attentional focus on task-relevant cues, thereby enhancing decision-making efficiency (Fleddermann et al., 2019). Complementary computerised cognitive interventions, such as choice-reaction drills and multiple-object tracking, also strengthen key cognitive functions (decision-making, working memory, attention, peripheral vision) that underpin elite soccer performance (Scharfen and Memmert, 2021).

A review of the literature indicates that while dribbling skills in soccer players with varying levels of experience have been assessed using visual cues during dribbling drills, there is a notable absence of studies evaluating visual-cognitive load within a true motor-cognitive dual-task paradigm. Addressing this gap, the present study employed a dual-task design that integrated dribbling with visual stimuli to examine how players' skill levels would influence oculometric variables such as the pupil diameter, fixation frequency, and saccadic eye movements during a representative soccer task. Based on this aim, several hypotheses were formulated. First, it was hypothesized that the introduction of additional visual signals would impair motor performance—reflected in longer completion times and increased error rates—in both elite and amateur groups, which is consistent with findings by Bekris et al. (2018). Second, elite players were expected to perform the dribbling task more quickly and with fewer errors than the amateur group, again reflecting previous evidence of skill-based advantages (Bekris et al., 2018). Third, it was predicted that elite players would exhibit oculometric efficiency, demonstrated by smaller pupil dilation (Cardoso et al., 2021), fewer fixations (Piras et al., 2014), and a greater number of saccadic eye movements (Piras et al., 2021) compared to the amateur players. More specifically, it was expected that the increased cognitive demands of the dual-task condition would elevate mental workload relative to the motor task alone, resulting in larger pupil diameters, a higher number of saccades, and fewer fixations across participants.

Methods

Participants

An a priori power analysis using G*Power version 3.1.9.4 was conducted to determine the required sample size. Setting an alpha level of 0.05, statistical power of 0.95, a large effect size of $f = 0.4$ (Vater et al., 2017), with two groups (skill levels), four repeated measurements (protocols), and a correlation of $r = 0.5$ among repeated measures, the analysis indicated a minimum sample size of 16 participants. Accordingly, a total of 28 male youth soccer players were recruited from U14 teams in Turkey, including 13 players competing at the national level from an elite soccer academy and 15 players competing at the regional level from a non-elite soccer academy. Following previous classifications (Bekris et al., 2018), national-level players were designated as the elite group, while regional-level players comprised the amateur group. All participants reported no cardiovascular, chronic, or neurological disorders and possessed normal or corrected-to-normal vision. Prior to participation, both players and their parents or legal guardians were fully informed of the study's risks, benefits, requirements, and procedures, and written informed consent was obtained. The study protocol was approved by the Ethics Committee of the Eskisehir Technical University, Eskisehir, Turkey (approval code: 7705; approval date: 15 March 2019) and conducted in accordance with the Declaration of Helsinki. The descriptive data of the participants are presented in Table 1.

Apparatus

Eye-tracking data were collected using Tobii Pro Glasses 2 (Stockholm, Sweden), a binocular, head-mounted device with infrared corneal reflection pupil detection. Recordings were transferred from the device's SD card to Tobii Pro Lab Software (version 1.102) for analysis. The system operated at a sampling rate of 100 Hz, providing gaze accuracy of 0.62° and spatial precision of 0.34° under optimal conditions, according to the manufacturer. Calibration was performed using the manufacturer's one-point procedure.

Visual stimuli were delivered via the FitLight Trainer™ system (FitLight Sports Corp., Canada), comprising eight LED lights with programmable colors and flashing intervals. Players' completion times for each protocol were recorded using the Electronic Timing System (Smart Speed Fusion Sport Pty Ltd., Brisbane, Queensland, Australia).

Tasks and Procedure

The test protocol was divided into four subcategories (Protocols 1–4) (Wallman et al., 2005). The applied test, recommended by the Football Association of Finland, had been previously used in a similar study (Forsman et al., 2016) (Figure 1).

Protocol 1 (P1) consisted of a motor test to examine the players' specific technical skills without visual cues. Protocols 2–4 included a motor-cognitive dual-task test of increasing difficulty (Bekris et al., 2018). While running with the ball, players had to simultaneously and continuously name randomly ordered colours (red, blue, or yellow) as fast as possible at either end of the trial.

Visual signals were provided using two LED lights with randomly changing colours, placed at the players' eye level. These targets were arranged to be readily visible to soccer players and sufficiently large to be detected by them. In the protocols, both the duration of visual stimuli and the inter-stimulus intervals between them progressively increased. In Protocol 2 (P2), visual cues were displayed for 0.5 s with 1-s inter-stimulus intervals; in Protocol 3 (P3), cues were presented for 0.5 s with 0.5-s intervals; and in Protocol 4 (P4), the stimuli were shown for 0.3 s with 0.5-s intervals.

Before starting the study, the participants were informed about the measurements and asked to complete a standard dynamic warm-up protocol to minimise the risk of musculoskeletal injury during testing. All tests were performed at the same location, under similar environmental conditions and in the same order (Protocols 1–4), which prevented a learning effect (Bekris et al., 2018). Each soccer player performed the dribbling test on a different day but at the same time, between 05.30 and 07.00 pm. After participants completed their warm-up, the eye tracker was positioned, and calibration was completed. After calibration, participants were asked to practice the experimental session once for a trial. Next, measurements were started, and each of the four protocols was recorded separately. Each player was measured in individual sessions lasting approximately 15 min.

Oculometric Measures

Eye-tracking recordings were transferred from the device's SD card to Tobii Pro Lab Software for analysis. To assess attentional effort, the pupil diameter was measured during a 5-s baseline period at the start of each protocol (P1–P4) and throughout the entire trial. During data processing, a moving average filter in Tobii Pro Lab was applied to reduce noise and artifacts in the pupil data. This filter averaged consecutive data points to minimize sudden fluctuations and transient distortions caused by eye blinks. Values from both eyes were averaged for analysis (Ballet et al., 2023). Each athlete completed four trials, yielding a total of 112 recordings for subsequent analysis.

Fixations were identified using the Tobii Pro Lab's I-VT (Velocity-Threshold Identification) algorithm. This algorithm classified periods with gaze velocity below 30°/s as fixations, and periods exceeding this threshold as saccades. Additionally, a fixation was required to last at least 100 ms and occur within a 3° visual angle (Carl and Gellman, 1987). Saccades were characterized as rapid, voluntary eye movements redirecting the gaze over 15°–20° with peak velocities up to 900°/s (Liversedge et al., 2011).

For handling missing data, gaps shorter than 100 ms were filled using linear interpolation, while gaps longer than 100 ms were excluded from analysis. Pupil diameter data were only analyzed when binocular recordings were available; for single-eye data, Tobii Pro Lab's automatic binocular averaging function was applied.

To control for potential confounding effects of luminance changes and individual differences across trials, all testing sessions were conducted in a well-lit indoor environment with consistent ambient lighting. Pupil diameter values were baseline-corrected using the initial 5-s measurement for each trial, accounting for individual differences in baseline pupil size and transient light adaptation. These procedures ensured that variations in the pupil diameter primarily reflected attentional effort rather than environmental lighting or inter-individual variability.

The total number of fixations and saccades was calculated for each protocol. These procedures were systematically implemented to ensure the validity, reliability, and reproducibility of the data.

Measures of Protocols

The research team recorded the time taken by athletes to complete all protocols (i.e., performance duration), the total number of lights on during P2, P3, and P4, and the number of correct and incorrect answers made by the players from these lights.

Statistical Analysis

Data were described as mean (M) and standard deviation (SD). Before statistical analyses, the normality of the variables was tested using the Shapiro-Wilk test. A mixed-model analysis of variance (ANOVA) was used to analyse differences among protocols and groups. The participants' experience level was the between-subject factor, and the protocols were the within-subject factors. For repeated measures ANOVA, violations of the sphericity assumption were corrected using Greenhouse-Geisser procedures. Effect sizes were reported as partial eta squared ($\eta p2$). Significant main and interaction effects were followed up using Bonferroni-corrected pairwise comparisons. IBM SPSS Statistics software (version 26.0, IBM Corp., Armonk, NY, USA) was used for mathematical computations. The significance level was set at $p < 0.05$.

Results

Performance Duration

Descriptive statistics for the groups are presented in Table 2. Analysis of variance revealed significant main effects for both 'protocol' (F(3,78) = 9.925, $p < 0.001$, $\eta_p^2 = 0.276$) and 'group' (F(1,26) = 6.709, $p = 0.016$, $\eta_p^2 = 0.205$) on performance duration. However, the interaction effect between 'protocol' and 'group' was not significant (F(3,78) = 1.566, $p = 0.204$). The elite group demonstrated shorter performance duration compared to the amateur group ($p < 0.05$). Post-hoc analyses indicated that the duration of P1 was significantly shorter than that of P2, P3, and P4 ($p < 0.001$). Descriptive characteristics of the groups and the experimental protocol duration are illustrated in Figure 2.

Oculometric Variables

Analysis of variance for pupil size change revealed a significant main effect of the protocol (F(4,104) = 30.760, $p < 0.001$, $\eta_p^2 = 0.541$), but no significant main effect of the group (F(1,26) = 0.013, $p = 0.912$) or the protocol × group interaction (F(4,104) = 1.639, $p = 0.170$). Post-hoc analyses indicated significant pupil dilation across all protocols ($p < 0.001$), with dilation during P1 being greater than during P2, P3 and P4 ($p < 0.001$). Descriptive data on pupil size changes are presented in Figure 3.

For the number of fixations, significant main effects were found for the protocol (F(3,78) = 14.140, $p < 0.001$, $\eta_p^2 = 0.352$), the group (F(1,26) = 4.255, $p = 0.049$, $\eta_p^2 = 0.141$), and their interaction (F(3,78) = 3.693, $p = 0.015$, $\eta_p^2 = 0.124$). The elite group exhibited fewer fixations than the amateur group ($p < 0.05$). Post-hoc tests showed that the number of fixations in P1 was lower compared to P2, P3, and P4 ($p = 0.001$ for P2; $p < 0.001$ for P3 and P4). A univariate test identified P3 as the primary source of this difference (F(1,26) = 5.285, $p = 0.030$, $\eta_p^2 = 0.169$).

Regarding the number of saccades, ANOVA revealed significant main effects for the protocol (F(3,78) = 10.440, $p = 0.001$, $\eta_p^2 = 0.286$) and the group (F(1,26) = 15.899, $p < 0.001$, $\eta_p^2 = 0.379$), but no significant protocol × group interaction (F(3,78) = 1.860, $p = 0.178$). The elite group produced more saccades than the amateur group ($p < 0.05$). Post-hoc comparisons indicated that the number of saccades during P1 was fewer than in P2, P3, and P4 ($p = 0.002$ for P2; $p = 0.017$ for P3 and P4).

Number of Mistakes across Protocols and Groups

ANOVA for the number of mistakes revealed significant main effects of the protocol (F(2,52) = 336.478, $p < 0.001$, $\eta_p^2 = 0.928$) and the group (F(1,26) = 11.735, $p = 0.002$, $\eta_p^2 = 0.311$). The protocol × group interaction was not significant (F(2,52) = 0.244, $p = 0.726$). Post-hoc analyses indicated that the number of mistakes in P2 was lower than in P3 and P4, and the number of mistakes in P3 was lower than in P4 ($p < 0.001$). Additionally, the elite group made significantly fewer mistakes than the amateur group ($p < 0.05$). The mean number of mistakes for each group and protocol is illustrated in Figure 4.

Table 1. Demographic and anthropometric characteristics of elite and amateur soccer players included in the study.

Variable	Elite Group (Mean ± SD)	Amateur Group (Mean ± SD)
Age (years)	14.00 ± 0.00	14.00 ± 0.00
Body Height (cm)	165.31 ± 0.02	165.67 ± 0.08
Body Mass (kg)	48.30 ± 2.02	50.73 ± 6.61
Years of Experience	6.92 ± 0.75	4.10 ± 0.63

Table 2. Descriptive statistics for the groups.

Variables	P1		P2		P3		P4	
	AG	EG	AG	EG	AG	EG	AG	EG
Duration (sn)	27.38 ± 0.29	26.84± .38	29.06 ± 0.27	27.50 ± .34	28.63 ± 0.34	27.71 ± 0.43	28.54 ± 0.29	27.76 ± 0.35
Pupil dilation (%)	15.75 ± 3.08	19.99 ± 2.36	10.32 ± 1.94	6.75 ± 1.97	6.25 ± 2.24	6.75 ± 2.66	6.89 ± 2.34	4.54 ± 1.63
Count of mistake	-	-	25.13 ± 0.63	21.69 ± 0.43	35.87 ± 1.00	32.69 ± 0.84	47.13 ± 1.42	42.85 ± 1.28
Number of fixations	16.00 ± 5.66	17.31 ± 6.25	111.66 ± 25.91	49.69 ± 13.10	102.07 ± 22.07	41.77 ± 11.96	92.73 ± 23.07	45.15 ± 9.76
Number of saccades	1164.67 ± 147.88	1756.62 ± 111.23	1557.40 ± 71.51	1989.85 ± 67.76	1501.73 ± 112.21	2019.92 ± 60.25	1618.53 ± 106.48	1909.92 ± 58.67

Note: Values are given as M = Mean ± SEM = Standard error of the mean. P1 = Protocol 1, P2 = Protocol 2, P3 = Protocol 3, P4 = Protocol 4, AG = Amateur group, EG = Elite group

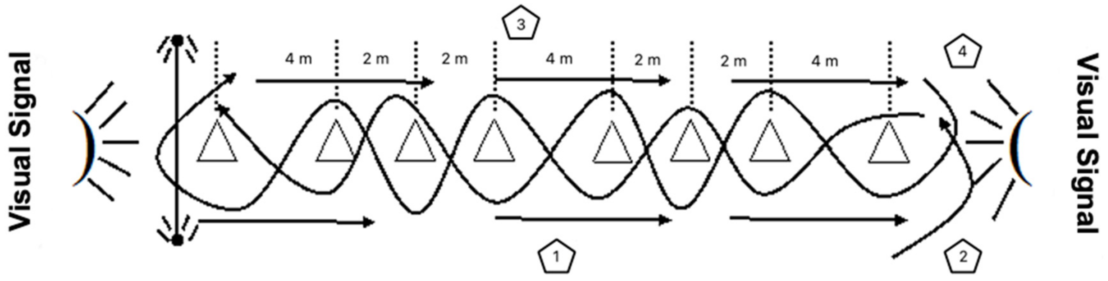

Figure 1. Schematic representation of the testing protocol. (1) Straight running with the ball (the player must touch the ball at least three times before returning), (2) dribbling and returning among the cones, (3) straight running with the ball (the player must touch the ball at least three times before returning), and (4) finishing by dribbling between the cones (Bekris et al., 2018).

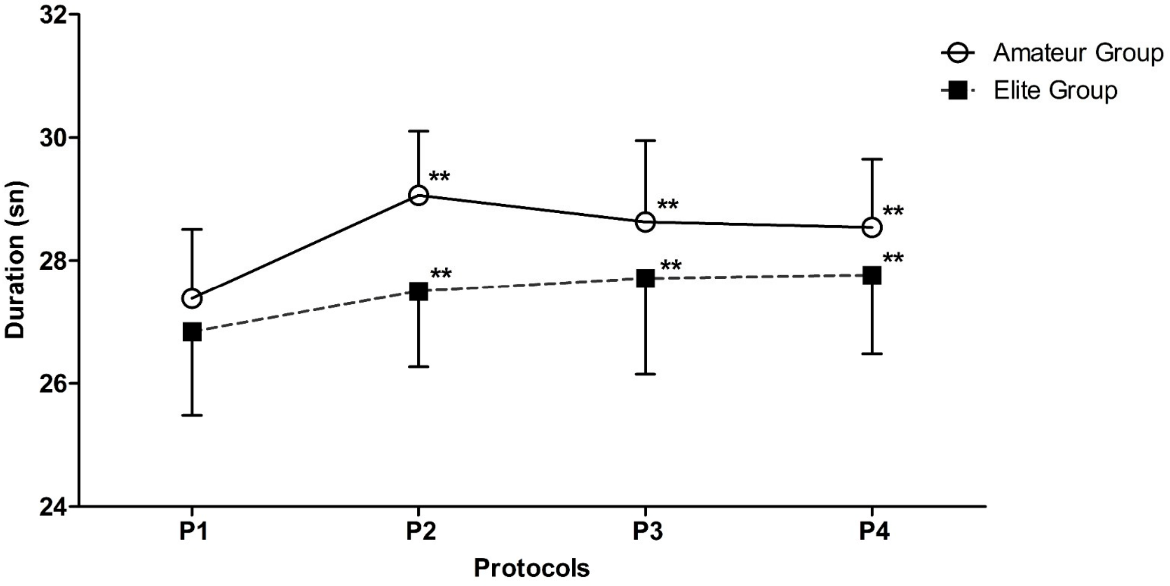

Figure 2. Descriptive statistics of groups and experimental protocol duration.

*Note: Values are given as M = Mean ± SEM = Standard error of the mean; P1 = Protocol 1, P2 = Protocol 2, P3 = Protocol 3, P4 = Protocol 4; ** shows differences from P1 (p < 0.001)*

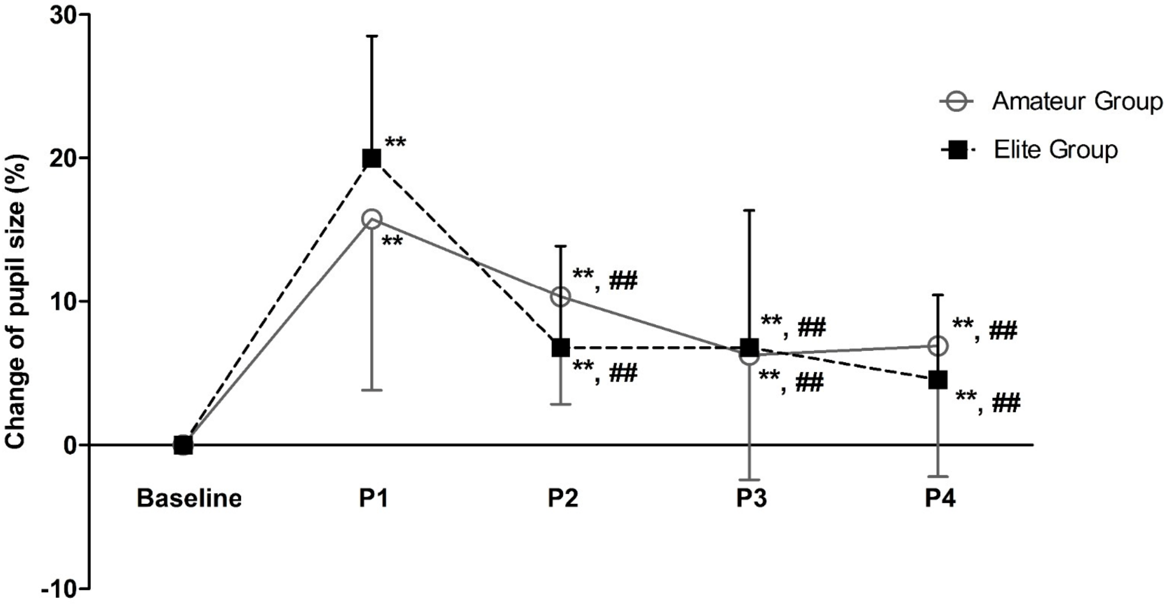

Figure 3. Descriptive statistics of the pupil diameter across experimental conditions.

*Note: Values are given as M = Mean ± SEM = Standard error of the mean. P1 = Protocol 1, P2 = Protocol 2, P3 = Protocol 3, P4 = Protocol 4. ** shows differences from baseline, ## shows differences from P1 (p < 0.001)*

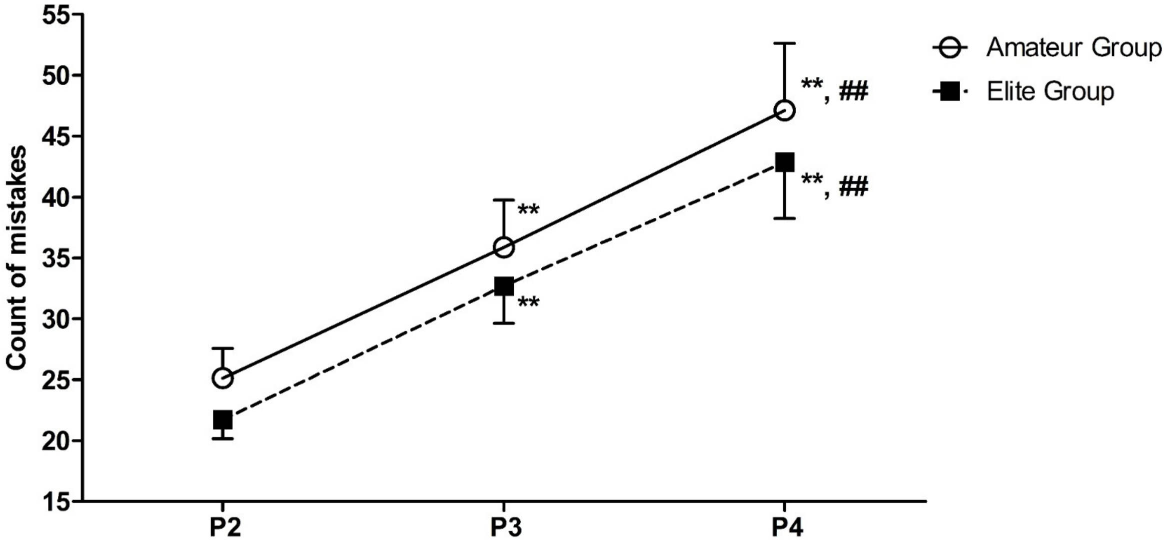

Figure 4. Mean number of mistakes across protocols and groups.
*Note: Values are given as M = Mean ± SEM = Standard error of the mean. P2 = Protocol 2, P3 = Protocol 3, P4 = Protocol 4; ** shows differences from P2, ## shows differences from P3 (p < 0.001)*

Discussion

The present study aimed to examine both technical-motor performance (e.g., performance duration, the number of mistakes) and oculometric variables (e.g., the pupil diameter, counts of fixations and saccades) during dual-task (motor-cognitive) performances of soccer players with different levels of experience. The main findings of the study show that both the elite and amateur groups' performances deteriorated with the addition of visual signals. Moreover, the elite group outperformed the amateur group in technical-motor task/performance duration, the number of protocol mistakes, and visual search behaviour.

As expected, the addition of visual cues decreased the performance of both groups under the dual-task condition. Similarly to previous studies, increased task difficulty was associated with greater cognitive demands, which in turn appeared to impair performance (Asadi et al., 2022; Bekris et al., 2018; Büchel et al., 2022). This aligns with recent findings suggesting that secondary tasks, particularly those with high motor or cognitive complexity, can significantly impair tactical and technical performance in soccer players (Moreira et al., 2025).

The findings indicate that in sports such as soccer, where rapid decision-making and environmental awareness are critical, technical skills are closely related not only to motor proficiency, but also to cognitive and visual-perceptual processes. Therefore, incorporating visual recognition elements into training and assessment procedures may contribute to the development of players' in-game decision-making and ball control skills in a more realistic context. As noted by Bekris et al. (2018), presenting technical-motor tasks alongside visual requirements can be an effective approach for both evaluating and enhancing dribbling performance. Furthermore, implementing complex visuomotor training protocols has been shown to produce a crossover effect, enhancing reactive agility across different levels of task complexity (Zhang et al., 2026).

The findings of this study reveal that the relationship between the pupil diameter and task difficulty is not always linear. Luis-del Campo et al. (2024) expected larger pupil sizes in time-limited tasks due to increased mental load; however, they observed the opposite—smaller pupil sizes under time-limited conditions. Similarly, the current study's hypothesis, which predicted a gradual increase in the pupil diameter based on task complexity (Alnæs et al., 2014), was not supported by the data. In the present study, the largest pupil dilation was observed in P1. It is considered that in the remaining protocols (P2, P3, P4), players may have exhibited more peripheral gaze behavior due to the increased number of visual stimuli. This shift may have led to a redistribution of visual attention from central to peripheral regions. Indeed, the literature highlights that peripheral vision is a critical component of perceptual-cognitive ability in soccer. Vater et al. (2019) noted that peripheral viewing enabled athletes to shift their attention quickly and covertly from the foveal (central) to peripheral areas while maintaining a stable gaze, allowing for accurate processing of foveal cues and effective perception of game patterns via peripheral vision. Therefore, the findings of this study suggest that increasing visual complexity alters athletes' attentional strategies and that pupillometric responses are influenced not only by cognitive load, but also by the distribution of visual attention. This underlines the importance of assessing both central and peripheral visual processing abilities, particularly in dynamic sports such as soccer.

These results further suggest that participants may have lacked sufficient attentional resources to process the secondary visual task effectively. Gabbett and Abernethy (2012) showed that, in dual-task paradigms of varying difficulty, primary-task performance could remain unchanged because athletes consciously prioritized attentional resources toward the primary task. Consistently with that interpretation, the present study detected no significant differences in the pupil diameter or completion time across Protocols 2, 3, and 4, even though error rates increased with task difficulty. The absence of additional pupil dilation—despite a growing number of errors—implies that attention allocated to the secondary visual stimuli did not increase proportionally.

The pupillometry literature is, however, far from unanimous. Several studies have reported no change in pupil size across skill levels or task demands (Campbell et al., 2019; Moran et al., 2016), whereas others have observed a reduction in the pupil diameter as task requirements intensified (Carnegie et al., 2020; Fletcher et al., 2017). Taken together, these mixed findings highlight that pupillary responses depend on a complex interplay of cognitive load, visual-attentional strategy, and the task context. Consequently, future research should employ more nuanced experimental designs, e.g., combining central and peripheral eye-movement metrics with pupillometry, to clarify how attentional resources are allocated under varying dual-task conditions in sport.

The present findings also reveal that the number of saccades increased as light-presentation time decreased, and that elite players executed more saccadic eye movements—yet committed fewer errors—than amateur players. We interpret this as evidence that the time-constrained training protocol enhanced the participants' attentional systems, enabling faster orienting to environmental cues during the visual task. Rapid reactions to complex, time-pressured game situations require soccer players to shift attention efficiently among multiple objects (e.g., opponents, teammates, the ball). Executing quick saccades allows them to locate the most relevant target as soon as possible (Luis-del Campo et al., 2024).

Our data align with earlier research showing that expert players are more willing to avert their gaze from the ball and display superior visual proficiency (Paillard and Noé, 2006). In the current study, elite players completed all protocols in less time and with fewer errors, while demonstrating more saccades and fewer fixations than amateur players, which is consistent with evidence that tactical performers gather essential information in shorter duration and with fewer fixations (Vítor de Assis et al., 2021). Bekris et al. (2018) likewise reported that skilled players employed more efficient visual-search strategies than novices. Furthermore, motor execution and performance efficiency in team sports are significantly influenced by the choice of oculomotor scanning strategies (Popowczak and Zwierko, 2025). Collectively, these results suggest that the optimal perceptual-cognitive skills shown by experienced players during dribbling underpin their superior technical performance.

The findings of the present study support the growing body of evidence suggesting that cognitive load plays a critical role in the development of technical and tactical skills in soccer. Previous research has shown that lower cognitive effort is associated with more effective tactical behavior and decision-making (Cardoso et al., 2021). Accordingly, it has been emphasized that incorporating high cognitive demands into technical training can enhance players' ability to manage mentally demanding situations during competition. This is particularly relevant in dual-task contexts, where athletes are required to perform both motor and cognitive tasks simultaneously.

Dual-task training has been shown to improve not only motor performance but also cognitive functioning (Moreira et al., 2021), and our findings are in line with this perspective. In order to facilitate the transfer of training gains to match-relevant performance, it has been recommended that coaches integrate cognitively demanding elements into motor training routines (Friebe et al., 2024). Such an approach may help athletes maintain their technical and tactical proficiency even under pressure, reducing performance deterioration in cognitively demanding scenarios.

In this context, the current study highlights the potential benefits of training that simultaneously targets both cognitive and motor domains. Through structured exposure to cognitive challenges during motor execution, players may develop more robust perceptual-cognitive mechanisms that support effective decision-making and skill execution under game-like conditions.

Limitations and Directions for Future Research

Although the present study advances understanding of the perceptual-cognitive factors underlying anticipation and decision making in soccer, several limitations should be noted. First, visual stimuli were presented from fixed positions; future protocols incorporating a wider range of cue locations and motion trajectories would better approximate the dynamic visual environment of match play. Second, players' roles (e.g., winger, forward, defender) were not differentiated, and positional demands likely influenced gaze strategies; position-specific samples could clarify role-dependent adaptations.

Methodologically, only simple visual cues were used. Integrating eye-tracking feedback and 3D immersive displays could (1) enable precise monitoring of gaze control and attentional allocation alongside motor performance, (2) identify players who struggle to stabilize gaze during dribbling, and (3) allow athletes to refine visual attentional skills through progressive, ecologically valid drills. Measuring pupil size during dynamic tasks such as dribbling presents additional challenges: head and body movements, rapid gaze shifts, and small luminance variations can introduce artifacts, potentially reducing the reliability of the pupil diameter as an indicator for attentional effort. Despite applying noise-reduction filters, baseline correction, and controlled lighting, some variability in pupil measurements may reflect these task-related constraints rather than true attentional fluctuations.

Finally, longitudinal studies are needed to determine whether improvements in gaze control and attentional allocation translate into sustained gains in technical and tactical performance under competitive conditions.

Conclusions

This dual task investigation of youth soccer players demonstrates that successful execution of technically demanding dribbling under cognitive load hinges on efficient visual attentional strategies—specifically, a higher frequency of saccadic eye movements and effective use of peripheral vision. These oculometric patterns enable players to acquire critical environmental information rapidly while maintaining motor accuracy.

The findings underscore three practical implications: (1) Training Design: integrating cognitively challenging elements (e.g., time pressured visual cues) into technical drills can foster the perceptual cognitive adaptations required for match situations. (2) Performance Monitoring: eye tracking metrics provide objective markers, such as the saccade rate and fixation distribution, that coaches can use to diagnose visual search efficiency and tailor feedback. (3) Skill Assessment: the present protocol offers a continuous, game relevant test of speed, accuracy, and decision making, providing athletes and practitioners with a reliable tool for benchmarking technical progression. In conclusion, these insights highlight the value of coupling motor and cognitive demands in training to cultivate the perceptual cognitive skills that underpin elite soccer performance.

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References

Alnæs, D., Sneve, M. H., Espeseth, T., Endestad, T., van de Pavert, S. H. P., & Laeng, B. (2014). Pupil size signals mental effort deployed during multiple object tracking and predicts brain activity in the dorsal attention network and the locus coeruleus. *Journal of Vision, 14*(4), 1. https://doi.org/10.1167/14.4.1

Asadi, A., Saeedpour-Parizi, M. R., Aiken, C. A., Jahanbani, Z., Abadi, D. H. S., Simpson, T., & Marchant, D. (2022). Effects of attentional focus and cognitive load on novice dart throwing: Evidence from quiet eye duration and pupillary responses. *Human Movement Science, 86,* 103015. https://doi.org/10.1016/j.humov.2022.103015

Ballet, C., Barreto, J., Hope, E., & Casanova, F. (2023). What is the visual behaviour and attentional effort of football players in different positions during a real 11v11 game? A pilot study. *F1000Research*, *12*, 679. https://doi.org/10.12688/f1000research.134231.4

Bekris, E., Gissis, I., Ispyrlidis, I., Mylonis, E., & Axeti, G. (2018). Combined visual and dribbling performance in young soccer players of different expertise. *Research in Sports Medicine, 26*(1), 43–50. https://doi.org/10.1080/15438627.2017.1393751

Büchel, D., Gokeler, A., Heuvelmans, P., & Baumeister, J. (2022). Increased cognitive demands affect agility performance in female athletes-implications for testing and training of agility in team ball sports. *Perceptual and Motor Skills*, *129*(4), 1074–1088. https://doi.org/10.1177/00315125221108698

Campbell, M. J., Moran, A. P., Bargary, N., Surmon, S., Bressan, L., & Kenny, I. C. (2019). Pupillometry during golf putting: A new window on the cognitive mechanisms underlying quiet eye. *Sport, Exercise, and Performance Psychology*, *8*(1), 53–62. https://doi.org/10.1037/spy0000148

Cardoso, F. da S. L., García-Calvo, T., Patrick, T., Afonso, J., & Teoldo, I. (2021). How does cognitive effort influence the tactical behavior of soccer players? *Perceptual and Motor Skills*, *128*(2), 851–864. https://doi.org/10.1177/0031512521991405

Carl, J. R., & Gellman, R. S. (1987). Human Smooth Pursuit: Stimulus-Dependent Responses. *Journal of Neurophysiology*, *57*(5), 1446–1463. https://doi.org/10.1152/jn.1987.57.5.1446

Carnegie, E., Marchant, D., Towers, S., & Ellison, P. (2020). Beyond visual fixations and gaze behaviour. Using pupillometry to examine the mechanisms in the planning and motor performance of a golf putt. *Human Movement Science*, *71*, 102622. https://doi.org/10.1016/j.humov.2020.102622

Casanova, F., Oliveira, J., Williams, M., & Garganta, J. (2009). Expertise and perceptual-cognitive performance in soccer: a review. *Revista Portuguesa de Ciencias Do Desporto*, *9*(1), 115–122. https://doi.org/10.5628/rpcd.09.01.115

Evans, J. S. B. T., & Stanovich, K. E. (2013). Dual-process theories of higher cognition: Advancing the debate. *Perspectives on Psychological Science*, *8*(3), 223–241. https://doi.org/10.1177/1745691612460685

Fleddermann, M.-T., Heppe, H., & Zentgraf, K. (2019). Off-court generic perceptual-cognitive training in elite volleyball athletes: task-specific effects and levels of transfer. *Frontiers in Psychology*, *10*, 1–12. https://doi.org/10.3389/fpsyg.2019.01599

Fletcher, K., Neal, A., & Yeo, G. (2017). The effect of motor task precision on pupil diameter. *Applied Ergonomics*, *65*, 309–315. https://doi.org/10.1016/j.apergo.2017.07.010

Forsman, H., Gråstén, A., Blomqvist, M., Davids, K., Liukkonen, J., & Konttinen, N. (2016). Development of perceived competence, tactical skills, motivation, technical skills, and speed and agility in young soccer players. *Journal of Sports Sciences*, *34*(14), 1311–1318. https://doi.org/10.1080/02640414.2015.1127401

Friebe, D., Banzer, W., Giesche, F., Haser, C., Hülsdünker, T., Pfab, F., Rußmann, F., Sieland, J., Spataro, F., & Vogt, L. (2024). Effects of 6-week motor-cognitive agility training on football test performance in adult amateur players–a three-armed randomized controlled trial. *Journal of Sports Science & Medicine*, *23*(2), 276–288. https://doi.org/10.52082/jssm.2024.276

Gabbett, T. J., & Abernethy, B. (2012). Dual-task assessment of a sporting skill: influence of task complexity and relationship with competitive performances. *Journal of Sports Sciences*, *30*(16), 1735–1745. https://doi.org/10.1080/02640414.2012.713979

Hutton, S. B. (2008). Cognitive control of saccadic eye movements. *Brain and Cognition*, *68*(3), 327–340. https://doi.org/10.1016/j.bandc.2008.08.021

Keskin, M., Ooms, K., Dogru, A. O., & De Maeyer, P. (2020). Exploring the cognitive load of expert and novice map users using EEG and eye tracking. *ISPRS International Journal of Geo-Information*, *9*(7), 429. https://doi.org/10.3390/ijgi9070429

Liversedge, S., Gilchrist, I., & Everling, S. (2011). *The Oxford handbook of eye movements*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199539789.001.0001

Luis-del Campo, V., Morenas Martín, J., León Llamas, J. L., Ortega Morán, J. F., Díaz-García, J., & García-Calvo, T. (2024). Influence of the time-task constraint on ocular metrics of semi-elite soccer players. *Science and Medicine in Football*, *8*(2), 179–186. https://doi.org/10.1080/24733938.2023.2172203

Mahanama, B., Jayawardana, Y., Rengarajan, S., Jayawardena, G., Chukoskie, L., Snider, J., & Jayarathna, S. (2022). Eye movement and pupil measures: A review. *Frontiers in Computer Science*, *3*, 733531. https://doi.org/10.3389/fcomp.2021.733531

Moran, A., Quinn, A., Campbell, M., Rooney, B., Brady, N., & Burke, C. (2016). Using pupillometry to evaluate attentional effort in quiet eye: A preliminary investigation. *Sport, Exercise, and Performance Psychology*, *5*(4), 365-376. https://doi.org/10.1037/spy0000066

Moreira, P. E. D., Albuquerque, M. R., Fortes, L. D. S., & Praça, G. M. (2025). How Do Cognitive and Motor Dual-Tasks during Small-Sided Games Impact the Tactical Performance of Youth Soccer Players?. *Journal of Human Kinetics*, *97*, 249–261. https://doi.org/10.5114/jhk/192202

Moreira, P. E. D., Dieguez, G. T. de O., Bredt, S. da G. T., & Praça, G. M. (2021). The acute and chronic effects of dual-task on the motor and cognitive performances in athletes: a systematic review. *International Journal of Environmental Research and Public Health*, *18*(4), 1–13. https://doi.org/10.3390/ijerph18041732

Paillard, T. H., & Noé, F. (2006). Effect of expertise and visual contribution on postural control in soccer. *Scandinavian Journal of Medicine & Science in Sports*, *16*(5), 345–348. https://doi.org/10.1111/j.1600-0838.2005.00502.x

Piras, A., Pierantozzi, E., & Squatrito, S. (2014). Visual search strategy in judo fighters during the execution of the first grip. *International Journal of Sports Science & Coaching*, *9*(1), 185–198. https://doi.org/10.1260/1747-9541.9.1.185

Piras, A., Timmis, M., Trofè, A., & Raffi, M. (2021). Understanding the underlying mechanisms of Quiet Eye: The role of microsaccades, small saccades and pupil-size before final movement initiation in a soccer penalty kick. *European Journal of Sport Science*, *21*(5), 685–694. https://doi.org/10.1080/17461391.2020.1788648

Popowczak, M., & Zwierko, T. (2025). Effects of Oculomotor Scanning on Agility Performance: Gender and a Type of Team Sport Comparison. *Journal of Human Kinetics*, *99*, 263–274. https://doi.org/10.5114/jhk/196002

Russell, M., & Kingsley, M. (2011). Influence of exercise on skill proficiency in soccer. *Sports Medicine*, *41*, 523–539. https://doi.org/10.2165/11589130-000000000-00000

Scharfen, H.-E., & Memmert, D. (2021). Cognitive training in elite soccer players: evidence of narrow, but not broad transfer to visual and executive function. *German Journal of Exercise and Sport Research*, *51*(2), 135–145. https://doi.org/10.1007/s12662-020-00699-y

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, *4*(4), 295–312. https://doi.org/10.1016/0959-4752(94)90003-5

Tao, D., Tan, H., Wang, H., Zhang, X., Qu, X., & Zhang, T. (2019). A systematic review of physiological measures of mental workload. *International Journal of Environmental Research and Public Health*, *16*(15), 2716. https://doi.org/10.3390/ijerph16152716

Trecroci, A., Milanović, Z., Rossi, A., Broggi, M., Formenti, D., & Alberti, G. (2016). Agility profile in sub-elite under-11 soccer players: is SAQ training adequate to improve sprint, change of direction speed and reactive agility performance? *Research in Sports Medicine*, *24*(4), 331–340. https://doi.org/10.1080/15438627.2016.1228063

Vater, C., Kredel, R., & Hossner, E.-J. (2017). Disentangling vision and attention in multiple-object tracking: How crowding and collisions affect gaze anchoring and dual-task performance. *Journal of Vision*, *17*(5), 1–13. https://doi.org/10.1167/17.5.21

Vater, C., Luginbühl, S., & Magnaguagno, L. (2019). Testing the functionality of peripheral vision in a mixed-methods football field study. *Journal of Sports Sciences*, *37*(24), 2789–2797. https://doi.org/10.1080/02640414.2019.1664100

Vítor de Assis, J., Costa, V., Casanova, F., Cardoso, F., & Teoldo, I. (2021). Visual search strategy and anticipation in tactical behavior of young soccer players. *Science and Medicine in Football*, *5*(2), 158–164. https://doi.org/10.1080/24733938.2020.1823462

Wallman, K. E., Morton, A. R., Goodman, C., & Grove, R. (2005). Reliability of physiological, psychological, and cognitive variables in chronic fatigue syndrome. *Research in Sports Medicine*, *13*(3), 231–241. https://doi.org/10.1080/15438620500222562

Williams, A. M., Davids, K., & Williams, J. G. P. (1999). *Visual Perception and Action in Sport*. Routledge.

Williams, A. M., Ford, P. R., Eccles, D. W., & Ward, P. (2011). Perceptual-cognitive expertise in sport and its acquisition: Implications for applied cognitive psychology. *Applied Cognitive Psychology*, *25*(3), 432–442. https://doi.org/10.1002/acp.1710

Zago, M., Piovan, A. G., Annoni, I., Ciprandi, D., Iaia, F. M., & Sforza, C. (2016). Dribbling determinants in sub-elite youth soccer players. *Journal of Sports Sciences*, *34*(5), 411–419. https://doi.org/10.1080/02640414.2015.1057210

Zhang, K., Chan, W. S., Lau, H. S., Huang, D., & Chow, D. H. K. (2026). The Crossover Effects of Visuomotor Task Complexity in Training Reactive Agility of Ball Sports Athletes. *Journal of Human Kinetics*, *100*, 5–15. https://doi.org/10.5114/jhk/210502

Zurutuza, U., Castellano, J., Echeazarra, I., & Casamichana, D. (2017). Absolute and relative training load and its relation to fatigue in football. *Frontiers in Psychology*, *8*, 878. https://doi.org/10.3389/fpsyg.2017.00878