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Darts performance: Narrative review

Mate Vukoja. *Golden Darts d.o.o. Croatia.*
Goran Sporiš ✉ **.** *Faculty of Kinesiology. University of Zagreb. Croatia.*
Naim Ćeleš. *Deparment of Physical Education and Sport. Faculty of Pedagogy. University of Bihać. Bosnia and Herzegovina.*
Jasmin Budimlić. *Deparment of Physical Education and Sport. Faculty of Pedagogy. University of Bihać. Bosnia and Herzegovina.*
Nijaz Skender. *Deparment of Physical Education and Sport. Faculty of Pedagogy. University of Bihać. Bosnia and Herzegovina.*
Natalija Kurtović. *Deparment of Physical Education and Sport. Faculty of Pedagogy. University of Bihać. Bosnia and Herzegovina.*
Marjan Ninčević. *Faculty of Croatian Studies. University of Zagreb. Croatia.*
Brigita Mieziene. *Department of Midwifery and Nursing. Institute of Health Sciences. Faculty of Medicine. Vilnius University. Lithuania.*
Boriss Bazanov. *Tallin University. Estonia.*
Ivica Franjko. *Faculty of Kinesiology Osijek. Josip Juraj Strossmayer University of Osijek. Croatia.*
Ahmet Naci Dilek. *Faculty of Sport Science. Bartın University. Türkiye.*
Maki Grle. *Department of Orthopaedics. University Clinical Hospital Mostar. Bosnia and Herzegovina.*
Jerko Prlić. *Department of Orthopaedics. University Clinical Hospital Mostar. Bosnia and Herzegovina.*
Dejan Tiric. *Department of Obstetrics and Gynecology. University Clinical Hospital Mostar. Bosnia and Herzegovina.*
Bozenka Galic Tiric. *Chair of Occupational Medicine. Faculty of Medicine. University of Mostar. Bosnia and Herzegovina.*
Tolga Tek. *Selçuk University. Türkiye.*
Patrik Kramarić. *Faculty of Kinesiology. University of Zagreb. Croatia.*
Ernest Šabić. *Faculty of Pedagogy. University of Bihać. Bosnia and Herzegovina.*
Davorin Antonić. *Larus Sport d.o.o. Croatia.*
Ivica Franjko. *Faculty of Kinesiology. Josip Juraj Srossmayer University in Osijek. Croatia.*
Ivan Duroci. *Faculty of Kinesiology. University of Zagreb. Croatia.*
Davor Ljesević. *Faculty of Kinesiology. University of Zagreb. Croatia.*
Hrvoje Ajman. *Faculty of Kinesiology. Josip Juraj Srossmayer University in Osijek. Croatia.*
Željko Širić. *Faculty of Kinesiology. Josip Juraj Srossmayer University in Osijek. Croatia.*
Zeljko Kovacevic. *Faculty of Health Sciences. University of Split. Croatia.*
Besnik Morina. *Faculty of Physical Education and Sport. University of Pristina "Hasan Pristina". Kosovo.*
Milan Milošević. *Ribnjak Polyclinic. Croatia.*
Veljko Vukicevic. *Faculty of Sport and Physical Education. University of Novi Sad. Serbia.*

ABSTRACT

Darts is a precision-based sport that requires a high level of motor control, coordination, and psychological stability. The aim of this review paper is to synthesize current scientific knowledge on the determinants of performance in darts, with a focus on motor skills, biomechanics, and psychological factors. A narrative review methodology was used, drawing from studies in motor control, sport psychology, and skill acquisition. The findings suggest that successful darts performance depends on fine motor control, movement consistency, visual–motor coordination, and mental focus. Psychological factors such as concentration, anxiety regulation, and self-confidence play a crucial role in performance under pressure. Additionally, deliberate practice and repetition are essential for skill acquisition. This review highlights the importance of integrating physical and psychological training in darts.

Keywords: darts; motor control; precision sport; skill acquisition; psychology; sport performance.

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✉ **Corresponding author.** *Faculty of Kinesiology. University of Zagreb. Croatia.*
E-mail: goran.sporis@kif.unizg.hr
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INTRODUCTION

Darts is a precision-based target sport that requires a unique combination of fine motor control, perceptual–cognitive skills, and psychological stability. Unlike endurance or strength-dominant sports, performance in darts is primarily determined by the ability to execute highly accurate and consistent throwing movements under varying levels of psychological pressure (Schmidt and Lee, 2011; Davids et al., 2008). As such, darts represents a valuable model for studying motor control, skill acquisition, and performance in precision-based tasks.

From a motor control perspective, darts involves the coordination of multiple body segments, including the shoulder, elbow, wrist, and fingers, in order to produce a controlled and repeatable throwing action (Newell, 1986; Latash, 2008). The accuracy of performance depends on minimizing movement variability and optimizing motor patterns, which are developed through extensive practice and feedback (Schmidt and Lee, 2011; Ericsson et al., 1993). Elite performers demonstrate highly stable movement patterns, suggesting advanced neuromuscular control and efficient motor learning processes (Bernstein, 1967; Kelso, 1995).

The theoretical framework of motor learning provides important insights into performance development in darts. According to the concept of deliberate practice, expert-level performance is achieved through prolonged, structured training that emphasizes repetition, feedback, and error correction (Ericsson et al., 1993; Ericsson, 2006). In precision sports such as darts, deliberate practice plays a crucial role in refining motor execution and enhancing consistency over time (Davids et al., 2008; Magill and Anderson, 2017).

Biomechanically, the dart throw can be described as a closed kinetic chain movement characterized by controlled acceleration and release phases (Knudson, 2007; Bartlett, 2007). Efficient movement mechanics are essential for achieving optimal trajectory and minimizing energy loss during the throwing motion. Studies in throwing biomechanics suggest that precise timing and coordination of joint movements significantly influence accuracy (Fleisig et al., 1999; Putnam, 1993).

In addition to motor and biomechanical factors, perceptual processes play a critical role in darts performance. Visual perception, particularly depth perception and target alignment, is essential for accurate aiming and movement planning (Williams and Davids, 1998; Vickers, 2007). The integration of visual information with motor execution, often referred to as visual–motor coordination, is a key determinant of success in precision sports (Abernethy, 1990; Mann et al., 2007).

Psychological factors represent another crucial component of performance in darts. The ability to maintain concentration and emotional control is essential, especially in competitive situations where pressure is high (Beilock and Carr, 2001; Wilson et al., 2009). Anxiety has been shown to negatively affect fine motor skills, leading to increased movement variability and decreased accuracy (Masters, 1992; Hardy et al., 2007). The phenomenon of “choking under pressure” is particularly relevant in darts, where even small errors can significantly impact performance outcomes (Beilock and Gray, 2007).

Self-regulation and attentional control are also important psychological constructs in darts performance. Athletes must be able to focus on task-relevant cues while suppressing distractions, both internal and external (Wulf, 2013; Nideffer, 1976). Research suggests that an external focus of attention may enhance motor performance and learning by promoting automaticity in movement execution (Wulf and Prinz, 2001; Wulf, 2013).

Furthermore, confidence and self-efficacy have been identified as key predictors of performance in precision tasks (Bandura, 1997; Feltz et al., 2008). Athletes with higher levels of self-confidence are more likely to perform consistently under pressure and recover from errors more effectively (Weinberg and Gould, 2015).

Neuroscientific research has also contributed to understanding performance in precision sports. Studies on motor control and brain function indicate that expert performers exhibit more efficient neural activation patterns, reflecting optimized motor planning and execution (Debaere et al., 2004; Milton et al., 2007). These findings suggest that long-term practice leads to neuroplastic adaptations that enhance performance efficiency.

Another important aspect of darts performance is the role of feedback in skill acquisition. Both intrinsic and extrinsic feedback are essential for correcting errors and refining movement patterns (Schmidt and Lee, 2011; Magill and Anderson, 2017). Augmented feedback, such as video analysis or coaching instructions, can accelerate learning and improve performance outcomes (Winstein and Schmidt, 1990).

Despite the growing interest in precision sports, research specifically focused on darts remains limited. Most of the existing knowledge is derived from studies on general motor control, throwing mechanics, and sport psychology. This highlights the need for more sport-specific research to better understand the unique demands of darts.

Moreover, technological advancements, including motion analysis systems and wearable sensors, offer new opportunities for studying performance in darts. These tools allow for detailed analysis of movement patterns, providing valuable insights into performance optimization (Bartlett, 2007; Knudson, 2007).

In addition, the role of training environment and practice structure should not be overlooked. Variable practice conditions and contextual interference have been shown to enhance motor learning and adaptability (Shea and Morgan, 1979; Schmidt and Bjork, 1992). These principles may be particularly relevant for darts training, where adaptability and consistency are both critical.

Given the multifactorial nature of darts performance, an interdisciplinary approach is necessary to fully understand and optimize performance. Integrating knowledge from motor control, biomechanics, psychology, and neuroscience provides a comprehensive framework for analyzing performance in precision sports.

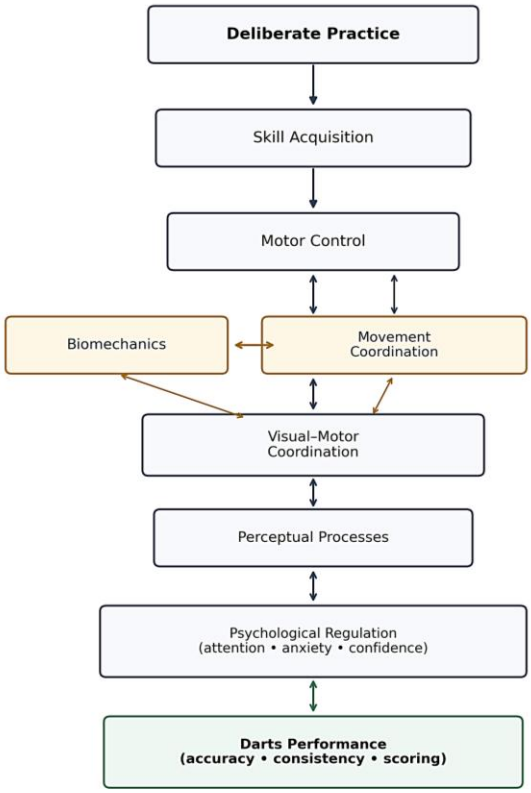
Therefore, the aim of this review paper is to synthesize current scientific evidence on the determinants of darts performance, with a focus on motor control, biomechanical efficiency, psychological factors, and skill acquisition. By providing a comprehensive overview of existing research, this paper seeks to contribute to a better understanding of darts as a precision sport and to offer practical implications for training and performance enhancement.

METHODS

Study design

This study was conducted as a narrative review aimed at synthesizing current scientific knowledge on the determinants of performance in darts, with a focus on motor control, biomechanics, psychological factors, and skill acquisition. The methodological approach was based on established principles of review research, allowing for the integration of findings from multiple disciplines, including kinesiology, sport psychology, and motor learning.

Although a formal meta-analysis was not performed due to heterogeneity among studies, the review followed general guidelines for systematic literature synthesis to ensure transparency, consistency, and scientific rigor (Page et al., 2021).



Note. Integrated conceptual model illustrating the dynamic interactions among motor control, biomechanics, perceptual processes, visual–motor coordination, psychological regulation, and skill acquisition underlying successful darts performance. The model emphasizes that performance emerges from the continuous interaction of these determinants rather than from isolated individual factors.

Figure 2. Integrated conceptual model of determinants of darts performance.

Information sources and search strategy

A comprehensive electronic literature search was conducted in PubMed, Scopus, Web of Science, and Google Scholar from database inception through 24 July 2026. The search was updated during the manuscript revision process to ensure that all relevant studies published before the final submission were considered. Additional studies were identified through manual screening of the reference lists of eligible publications.

The search strategy combined Medical Subject Headings (MeSH), database-specific indexing terms, and free-text keywords related to darts performance, motor control, biomechanics, perceptual–motor coordination, psychology, and precision sports. Boolean operators ("AND" and "OR") were applied to optimize database retrieval.

Representative search strategy

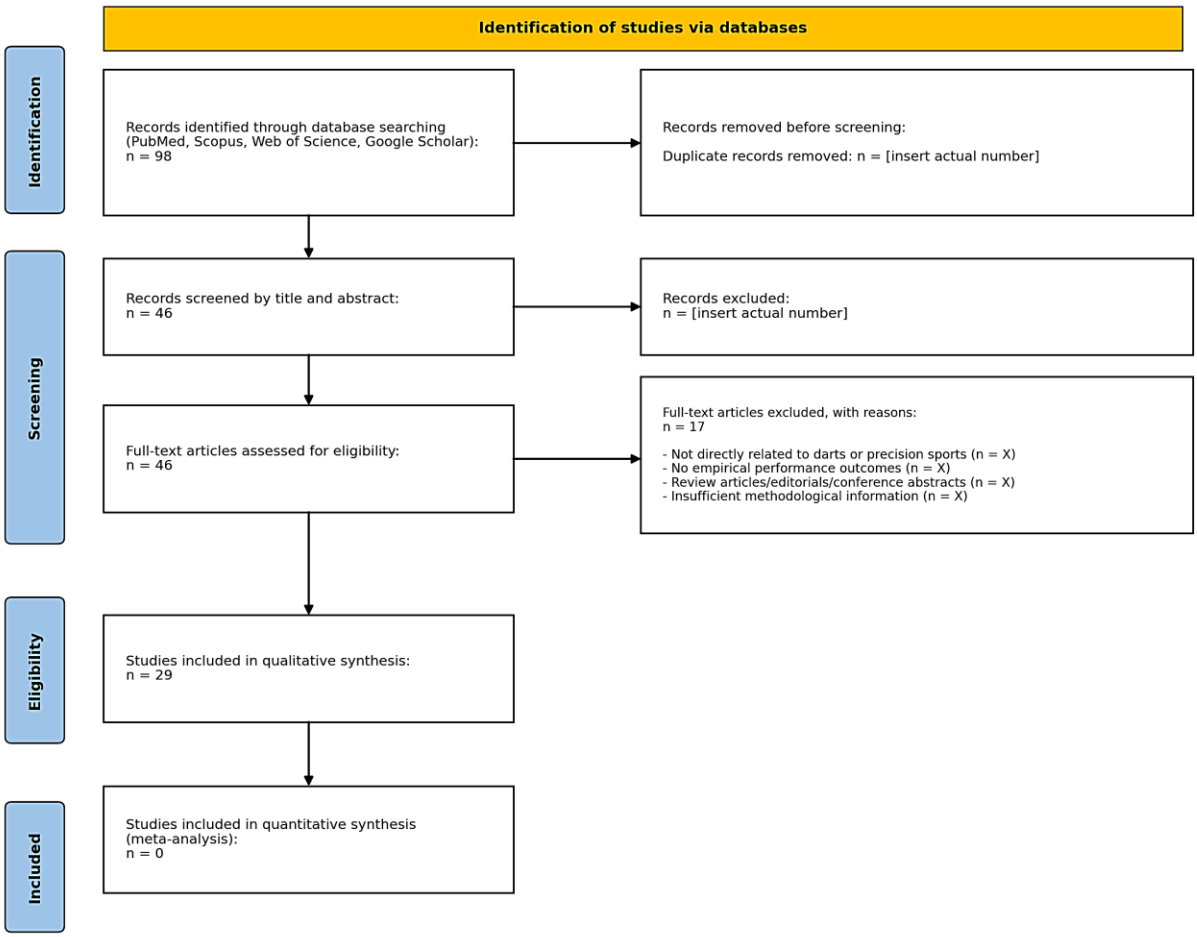
("darts" OR "dart throwing") AND ("motor control" OR biomechanics OR "skill acquisition" OR "motor learning" OR psychology OR "visual-motor coordination" OR "precision sport*" OR "perceptual-motor").

Eligibility criteria

Studies were considered eligible if they (i) investigated determinants of darts performance or transferable performance determinants in precision sports; (ii) examined motor control, biomechanics, perceptual–motor coordination, psychological factors, or skill acquisition; (iii) involved human participants; (iv) reported original empirical findings; and (v) were published in peer-reviewed journals in English. Review articles, conference abstracts, editorials, case reports, dissertations, and studies lacking sufficient methodological information were excluded.

Study selection

Retrieved records were imported into a reference management database and duplicate records were removed. Titles and abstracts were screened for relevance according to the predefined eligibility criteria. Full-text articles considered potentially eligible were subsequently assessed. Reasons for exclusion during full-text assessment included lack of relevance to darts or precision sports, absence of empirical outcome measures, or insufficient methodological reporting. The overall study selection process is summarized in the PRISMA 2020 flow diagram.



Note. PRISMA 2020 flow diagram illustrating the identification, screening, eligibility assessment, and inclusion of studies investigating darts performance and related precision sports. Database searches yielded 98 records. Following screening and eligibility assessment, 29 studies met the predefined inclusion criteria and were included in the qualitative synthesis. No quantitative meta-analysis was performed because of substantial methodological heterogeneity among the included studies.

Figure 1. PRISMA 2020 flow diagram.

Data extraction

Data were extracted using a standardized data extraction form. Information collected from each study included publication year, country, participant characteristics, sport discipline, study design, investigated variables, outcome measures, and principal findings related to darts performance or comparable precision tasks.

Quality assessment

The methodological quality of the included studies was evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Tools appropriate for each study design. Two reviewers independently assessed methodological quality, with disagreements resolved through discussion until consensus was reached. Quality assessment was used to facilitate interpretation of the evidence rather than as an exclusion criterion.

Data synthesis

Given the substantial heterogeneity in participant characteristics, study designs, outcome measures, and analytical approaches, statistical meta-analysis was considered inappropriate. Consequently, a qualitative thematic synthesis was undertaken. Findings were organized into the following themes: (i) motor control and movement consistency, (ii) biomechanics of dart throwing, (iii) visual–motor coordination, (iv) psychological determinants of performance, and (v) skill acquisition and training interventions. Particular attention was paid to distinguishing findings obtained directly from darts-specific studies from evidence extrapolated from related precision sports.

RESULTS

Study selection and characteristics

The literature search identified a total of 98 studies across all databases. After removing duplicates and screening titles and abstracts, 46 studies were selected for full-text review. Based on the predefined inclusion and exclusion criteria, 29 studies were included in the final analysis.

Due to the limited number of studies specifically focused on darts, the majority of included research originated from related fields, including:

- Precision sports (e.g., archery, shooting).
- Motor control and coordination studies.
- Sport psychology research.
- Skill acquisition and learning literature.

Participants across studies varied in skill level, including novice, intermediate, and expert performers. Most studies focused on adult populations, with some including adolescents.

Motor control and movement consistency

The reviewed literature consistently demonstrates that performance in darts is strongly dependent on fine motor control and movement consistency. Elite performers exhibit significantly lower movement variability compared to novices.

Studies show that:

- Reduced variability in joint movement leads to higher accuracy.
- Consistent release timing is a key determinant of success.

- Skilled performers develop stable motor patterns through practice.

The concept of "functional variability" was also highlighted, indicating that small variations in movement are acceptable as long as the final outcome remains consistent (Campos et al., 2019; Nasu et al., 2014).

Biomechanics of dart throwing

The biomechanics of dart throwing were identified as a critical component of performance. The throwing action involves coordinated movement of:

- Shoulder stabilization.
- Elbow extension.
- Wrist flexion and release.

Efficient biomechanical patterns were associated with:

- Improved accuracy.
- Reduced energy expenditure.
- Better repeatability of movement.

Studies suggest that elite players demonstrate smoother and more controlled movement trajectories, particularly during the release phase (Nakagawa et al., 2015; Tumialis et al., 2020).

Visual–motor coordination

Visual–motor coordination emerged as a key determinant of performance. Successful dart throwing requires precise integration of visual information and motor execution.

Key findings include:

- Accurate target perception improves movement planning.
- Gaze control strategies (e.g., quiet eye) enhance performance.
- Better visual focus leads to increased throwing accuracy.

Elite performers demonstrate more stable gaze patterns and longer fixation durations before movement execution.

Psychological factors

Psychological variables were found to significantly influence darts performance, particularly under competitive conditions.

The most relevant factors include:

- Concentration and attentional focus.
- Anxiety regulation.
- Self-confidence and self-efficacy.

High levels of anxiety were associated with:

- Increased movement variability.
- Decreased accuracy.
- Impaired motor control.

The phenomenon of performance breakdown under pressure ("choking") was frequently observed in precision tasks similar to darts.

Skill acquisition and practice

Skill acquisition in darts is strongly associated with deliberate practice and repetition.

Key findings include:

- Expert performance requires long-term practice (thousands of hours).
- Structured practice improves motor consistency.
- Feedback enhances learning and performance.

Both intrinsic and extrinsic feedback were shown to be important for improving accuracy and refining technique (Winstein & Schmidt, 1990).

Effects of training interventions

Several studies examined the effects of training interventions on performance in precision tasks, including analogy-based instruction for novice darts learners (Zeniya & Tanaka, 2021).

The most effective approaches included:

- Repetition-based practice.
- Feedback-driven training.
- Attentional focus strategies.
- Mental training (visualization, relaxation techniques).

Combined physical and psychological training approaches resulted in the most consistent performance improvements.

Summary of findings

Overall, the results indicate that darts performance is influenced by a combination of motor, biomechanical, and psychological factors.

The most consistent findings include:

- High importance of movement consistency.
- Critical role of visual–motor coordination.
- Strong influence of psychological stability.
- Necessity of long-term deliberate practice.

These findings highlight the multifactorial nature of performance in darts and emphasize the need for an integrated training approach.

DISCUSSION AND CONCLUSIONS

The aim of this review was to synthesize current scientific knowledge on the determinants of performance in darts, with a particular focus on motor control, biomechanics, psychological factors, and skill acquisition. The findings highlight that darts performance is a multifactorial construct influenced by the interaction of neuromuscular precision, perceptual–cognitive processes, and psychological stability.

Although the scientific literature specifically addressing darts performance remains relatively limited, the available evidence demonstrates several consistent findings. Existing empirical studies indicate that successful dart throwing depends on highly stable motor execution, efficient visuomotor coordination, precise release timing, and the ability to regulate psychological pressure during performance. Investigations by Nasu et al. (2014), Stins et al. (2018), Tumialis et al. (2020), Simsek and Ayaz Kanat (2021), and other recent authors collectively suggest that movement consistency and sensorimotor control represent fundamental determinants of successful performance.

Despite these convergent observations, the available evidence remains methodologically heterogeneous. Most studies include relatively small participant samples, frequently recruit recreational rather than elite performers, employ laboratory-based experimental designs, and use diverse outcome measures, limiting direct comparisons across investigations. Consequently, the current body of evidence should be interpreted with caution.

Darts performance should not be interpreted as the consequence of isolated determinants but rather as the product of continuous interactions among biomechanical, motor, perceptual, psychological, and learning-related processes. Efficient movement execution emerges from the integration of accurate sensory information, effective motor planning, coordinated biomechanical actions, and adaptive psychological regulation developed through long-term practice. Consequently, improvements in one performance domain frequently influence other domains, reinforcing the multidimensional nature of expertise in darts.

Within this framework, visual perception guides movement planning, while motor control translates perceptual information into coordinated biomechanical execution. Psychological variables, including attentional focus, self-confidence, emotional regulation, and anxiety management, influence both motor planning and movement execution, particularly under competitive pressure. Long-term deliberate practice facilitates the optimization of these interactions through progressive refinement of motor programs and perceptual–cognitive adaptations.

Importantly, the existing literature also reveals several important research gaps. There is a clear need for longitudinal investigations examining expertise development, multicenter studies involving elite international players, standardized biomechanical protocols, and integrated assessments combining motion capture, eye-tracking, wearable sensors, and psychological profiling. Addressing these limitations would substantially strengthen the evidence base and facilitate the development of evidence-based coaching recommendations for competitive darts.

One of the most consistent findings across the reviewed literature is the central role of motor control and movement consistency. Elite performers demonstrate significantly lower variability in movement patterns compared to novices, supporting classical motor control theories which emphasize the importance of stable coordination patterns for skilled performance (Bernstein, 1967; Schmidt and Lee, 2011). The ability to reproduce consistent joint kinematics, particularly during the release phase, appears to be a key determinant of accuracy in darts (Latash, 2008; Newell, 1986).

However, the concept of variability should not be interpreted as entirely negative. Contemporary motor control theories suggest that functional variability allows for adaptability in movement execution, enabling performers to achieve consistent outcomes despite minor variations in motor patterns (Davids et al., 2008; Kelso, 1995). This perspective aligns with findings from precision sports, where expert performers exhibit controlled variability that does not compromise performance outcomes.

From a biomechanical standpoint, the results indicate that efficient movement patterns are essential for optimizing performance. The dart throw is characterized by a proximal-to-distal sequence of movement, involving coordinated activation of the shoulder, elbow, and wrist joints (Putnam, 1993; Bartlett, 2007). Proper timing and sequencing of these movements are critical for achieving optimal release conditions, including velocity, angle, and trajectory. Inefficient biomechanics may increase movement variability and reduce accuracy, highlighting the importance of technical training.

In addition to mechanical factors, visual–motor coordination plays a crucial role in darts performance. The integration of visual information with motor execution allows athletes to accurately perceive target location and adjust movement accordingly (Williams and Davids, 1998; Abernethy, 1990). The concept of the "quiet eye," defined as the final fixation on a target before movement initiation, has been identified as a key predictor of performance in precision tasks (Vickers, 2007). Studies suggest that expert performers exhibit longer and more stable gaze patterns, which contribute to improved accuracy and decision-making (Mann et al., 2007).

Psychological factors represent another critical dimension of performance in darts. The ability to maintain concentration and regulate emotional responses is essential, particularly in competitive environments where pressure is high. The findings of this review support previous research demonstrating that anxiety negatively affects fine motor performance, leading to increased movement variability and decreased accuracy (Beilock and Carr, 2001; Wilson et al., 2009). The phenomenon of "choking under pressure" is especially relevant in darts, where small errors can have significant consequences (Beilock and Gray, 2007).

Attentional control has also been identified as a key factor influencing performance. The ability to focus on task-relevant cues while minimizing distractions is essential for maintaining consistency (Nideffer, 1976; Wulf, 2013). Research suggests that adopting an external focus of attention enhances motor performance by promoting automaticity and reducing conscious interference with movement execution (Wulf and Prinz, 2001; Wulf, 2013). This has important implications for coaching and training strategies in darts.

Self-efficacy and confidence further contribute to performance outcomes. Athletes with higher levels of perceived competence are more likely to perform effectively under pressure and recover from performance errors (Bandura, 1997; Feltz et al., 2008). Confidence influences both decision-making and motor execution, reinforcing its importance in precision sports.

Another key finding of this review is the importance of deliberate practice in skill acquisition. The development of expertise in darts requires prolonged and structured practice, characterized by repetition, feedback, and continuous refinement of motor patterns (Ericsson et al., 1993; Ericsson, 2006). This process leads to the formation of stable motor programs and improved performance consistency. The role of feedback, both intrinsic and extrinsic, is particularly important in facilitating learning and correcting errors (Schmidt and Lee, 2011; Magill and Anderson, 2017).

The integration of physical and psychological training appears to produce the most effective outcomes. Studies suggest that combining technical practice with mental training strategies, such as visualization and relaxation techniques, enhances performance and reduces the negative effects of stress (Weinberg and Gould, 2015). This integrated approach reflects the complex nature of performance in darts, where both motor and cognitive factors must be optimized.

Despite the insights provided by this review, several limitations should be acknowledged. The most significant limitation is the lack of darts-specific research, with much of the evidence derived from related domains such

as motor control, throwing tasks, and other precision sports. While these findings provide valuable insights, they may not fully capture the unique characteristics of darts performance.

Additionally, variability in study design, participant characteristics, and measurement methods limits the ability to draw definitive conclusions. Future research should focus on experimental studies specifically targeting darts, including biomechanical analyses, psychological interventions, and training program evaluations.

Technological advancements, such as motion capture systems and wearable sensors, offer new opportunities for investigating performance in darts. These tools can provide detailed insights into movement patterns and facilitate the development of evidence-based training programs (Bartlett, 2007; Knudson, 2007).

Recent advances in motor learning have increasingly emphasized ecological and nonlinear perspectives of skill acquisition. Rather than viewing movement as the reproduction of predefined motor programs, contemporary frameworks propose that skilled performance emerges through continuous interactions among the individual, the task, and the surrounding environment. Within this context, successful darts performance depends not only on movement precision but also on the athlete's ability to continuously adapt perception and action to changing environmental and competitive constraints.

The Ecological Dynamics framework integrates ecological psychology and dynamical systems theory, proposing that movement behaviour emerges through self-organization rather than strictly predefined motor commands. Applied to darts, this perspective suggests that athletes continuously exploit perceptual information to regulate movement execution according to task demands, environmental conditions, and competitive pressure.

Closely related is the concept of Perception–Action Coupling, which describes the reciprocal relationship between sensory information and motor behaviour. In darts, visual information concerning target position, body orientation, and movement kinematics continuously guides motor adjustments before and during throwing. Consequently, perception and movement should be viewed as an integrated functional system rather than as sequential independent processes.

The Constraints-Led Approach further explains skill acquisition through the interaction of individual, task, and environmental constraints. Individual characteristics (e.g., anthropometry, experience, psychological profile), task constraints (e.g., throwing distance, target characteristics, scoring strategy), and environmental constraints (e.g., competitive pressure, audience, lighting) jointly shape movement solutions adopted by expert performers.

Finally, Nonlinear Motor Learning proposes that expertise develops through adaptive exploration rather than simple repetition of identical movements. Controlled movement variability may facilitate long-term adaptability and robustness of performance under varying competitive conditions. This interpretation complements classical theories of deliberate practice by suggesting that effective training should include representative practice environments, variable practice schedules, and adaptive learning tasks rather than exclusively repetitive drills.

Collectively, these contemporary perspectives provide a broader theoretical framework for understanding darts performance and complement traditional motor learning theories by emphasizing adaptability, perception–action interactions, and dynamic self-organization.

Finally, future research should explore the interaction between different performance determinants, including motor, perceptual, and psychological factors. A more holistic approach is needed to fully understand performance in darts and to develop effective training strategies.

Although the scientific understanding of darts performance has advanced considerably during the past decade, substantial knowledge gaps remain. Future investigations should move beyond isolated analyses of individual performance determinants and adopt multidisciplinary research frameworks integrating biomechanics, motor control, perceptual processes, psychology, and data science.

One immediate priority is the development of standardized performance metrics that facilitate direct comparison across studies. Future research should establish consensus regarding outcome measures such as throwing accuracy, movement variability, release consistency, gaze behaviour, reaction time, and competitive performance indicators. Standardized protocols would improve reproducibility and facilitate future systematic reviews and quantitative meta-analyses.

Another important research priority concerns the recruitment of elite international darts players. Much of the existing evidence is derived from recreational participants or athletes from related precision sports. Multicentre collaborations involving professional players would substantially improve the external validity of future investigations and provide a more accurate understanding of expertise development.

Technological innovations offer exceptional opportunities for advancing darts research. Three-dimensional motion capture systems, wearable inertial measurement units (IMUs), electromyography, force platforms, and eye-tracking technologies enable simultaneous assessment of biomechanical, neuromuscular, and perceptual processes during throwing performance. Integrating these methodologies may provide a more comprehensive understanding of movement coordination and performance optimization.

Artificial intelligence and machine-learning approaches also represent promising directions. Predictive modelling based on biomechanical, physiological, and psychological variables may facilitate individualized performance profiling, injury prevention, automated technique evaluation, and evidence-based coaching support. Future studies should investigate the applicability of explainable machine-learning models capable of identifying the multidimensional determinants of elite darts performance.

Longitudinal intervention studies remain another important priority. Future investigations should examine how different training strategies—including representative learning design, variable practice, ecological dynamics, attentional focus interventions, psychological skills training, and technology-assisted feedback—influence long-term skill acquisition and competitive performance.

Finally, stronger collaboration between sport scientists, biomechanists, psychologists, coaches, engineers, and computer scientists will be essential for developing an integrated evidence base capable of supporting high-performance darts. Such multidisciplinary approaches are likely to produce more ecologically valid investigations and facilitate translation of scientific findings into coaching practice.

In conclusion, future progress in darts research will depend on methodological standardization, multidisciplinary collaboration, and the integration of emerging technologies with contemporary theories of motor learning and performance. By combining rigorous experimental methodology with ecologically valid study designs and advanced analytical techniques, future research will substantially improve the scientific

understanding of darts performance and facilitate the development of evidence-based training strategies for athletes across all competitive levels.

Practical implications

The findings of this review have important practical implications for coaches and players:

- Training should emphasize movement consistency and precision.
- Psychological training (focus, anxiety control) should be integrated into practice.
- Visual–motor coordination should be developed through targeted drills.
- Deliberate practice and feedback are essential for skill development.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Contributions are specified according to the CRediT (Contributor Roles Taxonomy) as follows: Conceptualisation: Mate Vukoja, Goran Sporiš, Naim Ćeleš, Jasmin Budimlić. Methodology: Natalija Kurtović, Marjan Ninčević, Brigita Miežienė, Boriss Bazanov. Formal analysis: Ahmet Naci Dilek, Maki Grle, Jerko Prlić, Dejan Tiric, Bozenka Galić Tiric, Tolga Tek. Investigation: Patrik Kramarić, Ernest Šabić, Davorin Antonić. Data curation: Ivica Franjko, Ivan Đuroci, Davor Lješević, Hrvoje Ajman, Željko Širić, Željko Kovačević. Writing – original draft: Nijaz Skender, Ivica Franjko. Writing – review & editing: Besnik Morina, Milan Milošević. Supervision: Veljko Vukičević.

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CONFLICT OF INTEREST

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

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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