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Neurocognitive and Relational Mechanisms Underlying Player Status and Team Performance in Elite Junior Handball

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Abstract: *The present study investigates the role of the coach–athlete relationship (CAR) in shaping individual player status and collective team performance in youth handball. In addition, the study explores CAR as a potential contextual factor influencing cognitive and decision-making processes in sport performance. The sample consisted of 270 athletes (aged 13–19 years) from 18 teams competing in the Romanian National Handball Championship. The coach–athlete relationship was assessed using the Coach–Athlete Relationship Questionnaire (CART-Q; 3+1C model: closeness, commitment, and complementarity), alongside objective indicators of team performance (final ranking and win rate). The results revealed strong intercorrelations among CAR dimensions, supporting the coherence of the construct. No significant associations were identified between CAR and collective team performance, and regression analyses indicated a lack of predictive capacity in this regard. However, significant differences were observed between starting and rotation players, with starters reporting higher levels of closeness, commitment, and complementarity. Furthermore, CAR emerged as a significant predictor of player status, while age was not significant, although a negative association between age and relationship quality was identified. These findings suggest that the coach–athlete relationship plays a relevant role in differentiating individual player status and may contribute to performance through indirect, cognitively mediated mechanisms, rather than directly influencing collective outcomes. The study highlights the importance of relational dynamics in athlete development and supports a multidimensional perspective on performance in team sports.*

Keywords: *coach-athlete relationship; handball team; team performance; player status; sport psychology.*

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1. Introduction

Handball represents one of the most popular team sports, and the development of performance in handball involves a complex interaction of multiple factors, including physical, technical, tactical, and psychological preparation, as well as the overall quality of training processes (Rohozneanu, 2024). Athlete performance and coaching effectiveness are closely interconnected, influencing one another through emotional states, athlete well-being, and psychological variables, thereby contributing to the overall performance of the team (García-Herrero et al., 2022). In team sports such as handball, decision-making does not solely reflect the efficiency of perceptual-cognitive processes operating under time constraints, but is also influenced by the relational context, in which the quality of the coach–athlete relationship may modulate how athletes process information and act in dynamic game situations (Hinz et al., 2022).

In team sports, decision-making represents a complex emergent process that arises from the continuous integration of perceptual-cognitive information under conditions of temporal constraints and environmental uncertainty. Nevertheless, these cognitive operations are not executed in isolation, but are inherently embedded within a relational framework that may shape their efficiency and expression. The coach–athlete relationship, conceptualised through dimensions such as closeness, commitment, and complementarity (Jowett & Shanmugam, 2016), may function as a regulatory mechanism that influences attentional control, cognitive resource allocation, and the management of performance-related pressure.

Furthermore, existing evidence suggests that stress appraisal and coping processes can significantly modulate cognitive functioning and decision-making efficiency in sport contexts (Nicholls et al., 2016). In this regard, a high-quality relational climate may attenuate cognitive-emotional interference and facilitate optimal processing of task-relevant information, whereas dysfunctional relational dynamics may disrupt executive functioning and impair performance outcomes. Consequently, the coach–athlete relationship may represent a critical contextual factor that underpins the cognitive mechanisms involved in decision-making during dynamic game situations.

Researchers in sport psychology have highlighted that, in recent decades, increasing attention has been given to the coach–athlete relationship, as it is considered a fundamental component of coaching effectiveness and athletic performance development (Jowett et al., 2017). Handball coaches are required to approach game structure differently from the past, as they must adopt strategies based on rapid decision-making to counter opponents' tactics, while simultaneously integrating pre-planned strategies, interpersonal communication processes, and reflective decision-making (Petiot et al., 2024; Gençoğlu & Gümüş, 2025).

The literature indicates that throughout the athlete's performance pathway, from early talent identification stages to final selection and even career termination, the coach plays a decisive role, influencing both the learning process and performance progression (Silva et al., 2019). In the same direction, recent studies show that coaches, through their leadership behaviours and the quality of the coach–athlete relationship, influence athletes' psychological variables, including well-being, confidence, motivation, and ultimately, sport performance (Liu et al., 2025).

In the current context, Denkova and Bajramovska (2018) define communication as both a tactical and human component of performance. A key aspect highlighted in this study is bidirectional communication. The research emphasises team cohesion and the relationship between coaches and athletes, suggesting that coaches must provide continuous, clear, and constructive feedback while remaining open to addressing athletes' concerns and actively engaging in problem-solving. Denkova and Bajramovska (2018) also report that the absence of a clear communication strategy within handball clubs has been associated with suboptimal results and decreased athlete motivation.

Similarly, Debanne and Fontayne (2009) demonstrated that handball team management involves four key dimensions, with effective communication between players and coaches being one of them. The study showed that communication breakdowns and inefficient collaboration

contributed to the loss of a world title; however, following the identification and correction of these issues, the team achieved a major subsequent success.

Transformational leadership and the quality of the coach–athlete relationship represent essential factors in promoting positive youth development. Vella et al. (2013) found that coaches who demonstrate individualized consideration, stimulate athletes' thinking, and provide positive behavioural models can create an educational environment that supports both personal and athletic development.

During childhood and adolescence, the brain undergoes significant neural development, characterised by synaptic remodeling and the reorganisation of neural networks involved in executive functions and cognitive control. Neuroscientific research indicates that physical activity and sport participation can positively influence brain structure and functioning, contributing to improvements in memory, attention, decision-making processes, and cognitive recovery following effort (Stillman et al., 2020; Erickson et al., 2019).

Performance sport represents a complex system in which outcomes emerge from the interaction of multiple determinants. Beyond physical and technical preparation, the literature highlights the crucial role of psychological and psychosocial variables, such as motivation, team cohesion, and interpersonal relationships within the team (Lochbaum et al., 2022; Ramírez Muñoz et al., 2023; Ayrancı & Aydın, 2025).

Participation in performance sport during youth fosters the development of essential life skills, while a positive team climate enhances athletes' motivation and well-being (Lochbaum et al., 2022). Contemporary models of sport development emphasise the importance of generating positive psychological outcomes alongside performance achievements (Cronin & Allen, 2018).

Athlete engagement within the team is influenced by the coach–athlete relationship (Longakit et al., 2024), which can be shaped through the development of closeness, commitment, and complementarity (Gu et al., 2023). Furthermore, psychological well-being within the team is strongly influenced by the support provided by the coach (Coussens et al., 2025). Numerous studies suggest that the coach–athlete relationship has a significant positive effect on athletes' performance (Bora, 2025).

The coach–athlete relationship (CAR) is conceptualised as a psychological construct characterised by the interdependence of coaches' and athletes' thoughts, feelings, and behaviours, reflecting both functional and dysfunctional interactions within the sport context (Roberto de Andrade do Nascimento Junior et al., 2024).

Freire et al. (2024) highlight that the coach–athlete relationship is structured around three core dimensions: closeness, commitment, and complementarity. The strengthening of this relationship contributes to team cohesion, increased motivation, enhanced performance, and higher levels of athlete satisfaction. These findings are supported by research on collective efficacy, defined as the shared belief among team members in their collective ability to organise and execute actions required for success, which plays a crucial role in team performance and in reducing athlete burnout (Jiahao & Jing, 2024).

Empirical studies indicate that teams characterised by higher levels of organisation, stronger collective efficacy, and trust-based relationships with their coach tend to set and achieve more ambitious goals, develop higher levels of motivation, and ultimately achieve superior performance outcomes (Atkinson, 2016). In this context, coach behaviour represents a key determinant of collective efficacy, as leadership style, feedback, social support, and communication influence athletes' perceptions of team capability and success potential (Høigaard et al., 2016; Bora, 2025).

Gledhill et al. (2017) emphasise the role of psychosocial factors in athlete development, while Brown and Fletcher (2017) demonstrate that psychological interventions and psychosocial variables significantly influence sport performance. Furthermore, Morgan et al. (2019) show that these variables contribute to resilience and performance in team sports.

Zhang and Rhim (2024) further supports this perspective, indicating that the coach–athlete relationship is a significant predictor of sport behaviour and performance. The study reported a

strong positive association between CAR dimensions (closeness, commitment, and complementarity) and motor behaviour ($\beta = 0.6457$, $p < 0.001$), with the satisfaction of basic psychological needs mediating this relationship, accounting for approximately 41.56% of the association between relationship quality and sport behaviour. Nicholls et al. (2016) suggest that when athletes perceive performance goals as difficult to achieve, coaches should intervene through goal restructuring and motivational support strategies, which facilitate task-oriented adaptation and contribute to psychological well-being.

As previously highlighted, the coach–athlete relationship represents a central element in achieving sport performance. The work of Jowett and Ntoumanis (2004) introduced the Coach–Athlete Relationship Questionnaire (CART-Q), a widely used instrument consisting of 11 items that assess the quality of the relationship through three dimensions: closeness, commitment, and complementarity (Roberto de Andrade do Nascimento Junior et al., 2024). Closeness reflects the emotional bond between coach and athlete (e.g., trust, respect, appreciation), commitment refers to the intention to maintain the relationship over time, and complementarity captures behavioural interactions, such as cooperation and coordination (Phillips et al., 2026).

The validity of the CART-Q was examined by Woolliams et al. (2021), who analysed its psychometric properties on a sample of 251 coaches and athletes using Rasch analysis and confirmatory factor analysis. The findings supported the reliability and validity of the instrument for assessing the coach–athlete relationship.

The CART-Q has been applied across a wide range of team sports (football, basketball, handball, cricket, volleyball, ice hockey, curling, aerobics, rugby, softball, netball) (Balduck & Jowett, 2010; Gu et al., 2023; Freire et al., 2024), as well as in individual sports (judo, cycling, rowing, athletics, gymnastics, tennis, triathlon, swimming, archery, figure skating) and across diverse cultural contexts (Yang & Jowett, 2012). Some studies have also approached the coach–athlete relationship using qualitative methodologies, employing interviews based on the 3+1C conceptual model (Rhind & Jowett, 2010). Overall, the Coach–Athlete Relationship Questionnaire (CART-Q) remains one of the most widely used and validated instruments in sport psychology for assessing the quality of the coach–athlete relationship, enabling researchers to objectively examine essential dimensions such as closeness, commitment, and complementarity.

The coach–athlete relationship (CAR) has been traditionally examined through affective, motivational, and behavioural dimensions; however, recent perspectives suggest that interpersonal dynamics in sport environments may also play a critical role in shaping cognitive processes underlying performance. Specifically, relational quality may influence attentional control, decision-making efficiency, and the athlete's capacity for self-regulation under pressure.

From a cognitive standpoint, high-quality relationships characterised by trust, closeness, and mutual commitment can reduce uncertainty and perceived threat, thereby lowering cognitive load and freeing attentional resources for task-relevant processing. This mechanism is particularly relevant in high-tempo sports such as handball, where athletes must continuously process dynamic information, anticipate opponents' actions, and make rapid decisions in time-constrained contexts.

Moreover, this perspective aligns with contemporary research in sport and cognitive neuroscience, which emphasises the interaction between emotional states, interpersonal context, and executive functioning. Supportive environments have been associated with improved attentional focus and reduced interference from anxiety-related cognitions, ultimately facilitating more efficient performance execution (Wagstaff, 2014).

Importantly, these mechanisms may be especially salient during adolescence, a developmental period marked by ongoing maturation of executive functions, including inhibitory control, working memory, and cognitive flexibility (Diamond, 2013; Voss et al., 2011). In this context, the CAR may function not only as a socio-emotional resource but also as a cognitive-regulatory framework that supports optimal performance.

From a neuroscience perspective, the coach–athlete relationship may be understood as a contextual factor that modulates cognitive and self-regulatory processes underlying performance,

highlighting the need for an integrative approach that connects relational dynamics with brain-based mechanisms of behaviour in sport (Beauchamp & Eys, 2014).

2. Neurodevelopmental and Interpersonal Mechanisms Underlying Performance in Adolescent Team Sports

2.1. Adolescent Neurodevelopment

Brain development is far from complete at birth; the maturation process continues throughout childhood and adolescence and extends well into adulthood, when age-related changes in brain structure and function (including the formation of fewer nerve cells) still occur. Research over the past few decades has shown that adolescence is a time of profound structural and functional changes in the brain. These changes, along with hormonal changes and other biological processes, interact with cultural, economic, and psychosocial influences to help shape how adolescents think, feel, and act.

Our understanding of how the brain develops during adolescence is evolving at an accelerated pace, supported by increasingly precise data on the normally developing human brain, obtained through continuous advances in imaging technologies. Magnetic resonance imaging (MRI) and other similar methods have proven extremely useful in describing both the size and connections between different brain regions at different ages. They also allow researchers to analyse changes in the activation patterns of different brain areas during tasks such as risk-taking, decision-making, or other cognitive activities.

2.1.1. Synaptic pruning and myelination

Brain development combines growth and shrinkage processes. In the first phase, many more nerve cells (neurons), responsible for processing and transmitting information, and their synaptic connections, are generated than will be maintained in the long term. This excess followed by selective elimination serves to ensure a correct organisation of neural networks, with only those functional connections being preserved, while the inappropriate ones disappear.

Although these reduction processes are more intense in early childhood, they continue to a certain extent, throughout life. In particular, the elimination of synapses is a defining element of the brain changes of adolescence. During this period, the process is very precise and sometimes accentuated, which can lead to the loss of approximately half of the synaptic connections in certain areas of the brain, while other regions are much less affected. This phenomenon is thought to contribute to the reorganisation of neural networks, bringing them into a pattern characteristic of adulthood and, at the same time, offering later opportunities for the manifestation of brain plasticity. Synapses involve high energy consumption, and the reduction in their number probably contributes to the more efficient functioning of the brain during adolescence, an aspect highlighted by the decrease in cerebral energy consumption observed in both humans and other species. Not all the changes that occur in the brain during adolescence are regressive; on the contrary, some neurons continue to extend their branches and create new synaptic connections. At the same time, important changes occur in the speed and rhythm with which information circulates through the brain, which influences the way in which different brain regions communicate with each other.

At this stage, the transmission of information between more distant areas becomes faster and more efficient. This is because the axons of neurons that connect certain regions are gradually coated in a white substance, rich in lipids, called myelin. This “insulation” allows electrical impulses to circulate much faster along the axons and, at the same time, reduces the energy consumption required for this process.

Although the myelination process begins in childhood and continues until adulthood, it noticeably intensifies during adolescence, which leads to an acceleration of the flow of information between distant regions of the brain and an increase in its impact.

2.1.2. Regional specificity, changes in connectivity, and refinement of networks

The development of the cortex typically occurs in successive, "wave-like" stages. Gray matter thinning occurs relatively early, before adolescence, in cortical areas responsible for basic sensory and motor functions. In contrast, this process continues throughout adolescence in the prefrontal cortex (PFC) and other frontal regions involved in complex cognitive processes. At the same time, noncortical structures also play an important role in shaping adolescent-specific behaviours. Among the most studied subcortical regions are those involved in the regulation of social, emotional, and aversive stimuli, such as the amygdala. Also relevant are areas associated with reward processing, such as those containing dopamine (DA)-releasing neurons, as well as structures that receive these signals, such as the ventral striatum.

Brain development cannot be reduced to a simple sequence of immature stages, in which different regions become active one after the other. In the current view, brain maturation is seen as a dynamic process, in which distinct networks of areas with similar functions gradually become better integrated. This is achieved by reducing the connections between different networks and, in parallel, by strengthening the connections within each network, especially those that link distant regions. The strengthening of these networks may underlie the changes observed in the way the brain activates throughout development: activation typically becomes more concentrated and precisely delimited in task-relevant areas, rather than being diffusely spread out.

Theories on brain development during adolescence largely converge on the idea that delayed maturation of the prefrontal cortex (PFC) and other frontal areas underlies the immaturity observed in cognitive control, response inhibition, attention regulation and other more complex cognitive functions.

Although young people may perform well on tasks involving these skills in certain contexts, performance difficulties frequently arise when demands increase or when intense emotional states and high levels of arousal occur. In fact, stressful or emotionally charged situations have been shown to decrease activity in the PFC and other frontal regions, while simultaneously increasing activity in subcortical structures involved in emotional reactions, such as the amygdala (Spear, 2013).

2.2. Biopsychology of Performance in Team Sports

The social experience and expression of emotions are essential components of human existence. Emotions gain meaning in social interactions, fulfilling various communication and motivational roles that differ according to personality, social context, culture and situation. Although there are many definitions of emotions, a central element is the idea that factors such as cognitive evaluations, subjective experiences, expressive behaviours and physiological reactions influence each other over time, generating emotional states. These processes do not only take place at the individual level, but also between people.

In the field of sports, the expression of emotions plays an important role in transmitting social objectives, both in collaborative and competitive situations. Emotions facilitate the communication of needs, intentions and goals between individuals. Athletes openly express their emotions and communicate them frequently to those around them. In the field of psychology and sports science, the focus has been mainly on negative emotions, while positive ones have received less attention. However, studies show that positive emotions have a significant impact on essential processes, such as the ability to concentrate, the way of thinking and the quality of interpersonal relationships.

One of the neuropeptides most closely associated with positive emotions and social brain function is oxytocin. It is made up of nine amino acids and is produced primarily by specialised cells located in the paraventricular and supraoptic nuclei of the hypothalamus. Oxytocin has a dual

role in the body, acting both centrally as a neurotransmitter or neuromodulator and peripherally as a hormone. In the brain, it influences numerous regions, including key areas involved in emotion processing, such as the amygdala and hypothalamus. In both humans and other species, oxytocin contributes to the regulation of positive social behaviours and cognitive processes, being involved in the tendency to approach, in social memory and recognition, as well as in the formation and maintenance of attachment.

In the field of sports, numerous socio-emotional interactions take place. It is believed that social emotions can trigger emotional reactions among those who observe them. When a person manifests a certain affective state, it can generate similar feelings in those around them who witness its expression. Thus, emotions are transmitted and influence the emotions, feelings and behaviours of other people, contributing to an alignment of emotional states and moods.

Human empathy is a complex concept that encompasses both the cognitive and emotional reactions that a person has to the observed experiences of another. Cognitive empathy refers to the ability to mentally put oneself in the other person's shoes, that is, to adopt their psychological perspective through a conscious process of understanding. In the case of athletes, it is often necessary to interpret the internal states of other people in order to understand or anticipate their behaviour. This ability is essential, as it allows them to correctly identify the possible actions or intentions of teammates or opponents.

The transmission of emotions between people, through the phenomenon of emotional contagion, has a significant impact on trust, generosity, and altruistic behaviours. Moreover, the experience of being imitated contributes to increased levels of trust and generosity. These psychological mechanisms are particularly relevant in team sports, because they promote group cohesion. This is a dynamic process, manifested by the desire of members to remain united and collaborate to achieve common goals, but also to satisfy each other's emotional needs. A high degree of cohesion within the team is correlated with superior sporting results.

It has been shown that the spread of positive emotions among group members contributes to increased levels of cooperation. Mutual cooperation is an essential element for performance in team sports. This implies, at the same time, both the willingness (motivation) to cooperate and the trust that other group members will act in the same way. To deepen the understanding of the role of oxytocin in cooperative behaviour, Declerck et al. investigated how oxytocin, incentives, and social information influence decision-making in social contexts characterised by interdependence and uncertainty. Their hypothesis was that oxytocin promotes cooperation only in the presence of social information and that this effect becomes more pronounced in situations where there are strong incentives for cooperation, compared to those where the reasons for cooperation are contradictory (Pepping & Timmermans, 2012).

2.3. Interpersonal Neural Synchrony in Coach–Athlete Communication Dynamics

Communication between the coach and the athlete plays an essential role in the sporting context, having a direct impact on the athlete's physical and mental state, on the level of performance and on his long-term evolution. An effective interaction between the two is based on several fundamental principles, such as the development of well-adapted communication skills, the ability to resonate empathically, the use of mirroring mechanisms and reaching a state of attunement, all of which contribute to a better mutual understanding and to the strengthening of the relationship.

In the field of interpersonal neuroscience (which studies the interaction between two people), interpersonal neural synchrony (INS) describes the concordance or closeness of brain activity patterns between individuals during interaction. The key point is that INS should not be understood as a direct reflection of identical thoughts or shared mental representations, but rather as a relational, context-dependent indicator of the extent to which participants are mutually involved, coordinated, and "on the same wavelength" in a given situation.

Current approaches highlight that INS results from the dynamic interplay between perception, action, and communication. It is influenced by factors such as task structure, role distribution, goals, and environmental constraints, and is not a fixed or uniform phenomenon.

In the context of CAR, the use of hyperscanning can reveal relevant patterns regarding the synchronisation and coordination of neural responses, which are associated with good attunement between participants. This is particularly important in situations that involve continuous feedback and the need for rapid adjustments in communication. For example, INS has been correlated with better goal alignment, faster reactions, and more effective mutual understanding in real-time interactions.

Furthermore, studies show that synchronising brain activity between individuals can improve communication efficiency by supporting joint attention and shared intentionality. This process contributes to the creation of a collaborative and flexible learning environment. Such an insight is extremely useful in demanding contexts, such as performance sports, where feedback exchanges occur quickly and under difficult conditions.

In training, hyperscanning can shed light on the neural processes involved in how feedback is received and how athletes adapt to coaching instructions. This could reveal how athletes' brain responses change from session to session as they gradually learn the guidance they receive. Studies indicate that the synchronisation of neural activity can reflect both the level and depth of engagement in training and the degree of alignment between coach and athlete. Furthermore, in competitive situations, where rapid adaptation to immediate changes is required, hyperscanning can identify those moments when feedback contributes to maintaining optimal synchronisation or, conversely, disrupts it, influencing performance.

In conclusion, in sport, the quality of communication between the coach and the athlete plays an essential role, having a direct impact on the athlete's physical and mental state, on his/her performance and on his/her long-term evolution. An effective relationship between the two is based on several fundamental principles: the ability to communicate clearly and appropriately, authentic empathy, reflection of behaviours and emotions, as well as interpersonal synchronisation — all of which contribute to better mutual understanding and strengthening the relationship (Crivelli & Balconi, 2026).

3. Inconsistent Evidence on the Impact of the Coach–Athlete Relationship on Team Performance

Despite the growing body of literature emphasising the importance of the coach–athlete relationship (CAR) in athlete development and sport performance, existing findings remain inconsistent regarding its direct influence on objective team performance indicators. While numerous studies have reported positive associations between CAR and psychological outcomes such as motivation, well-being, and athlete satisfaction, empirical evidence supporting its impact on collective performance outcomes, particularly in team sports, is still limited and inconclusive.

Moreover, the role of the coach–athlete relationship in differentiating players' status within teams (e.g., starting players versus rotation players) remains insufficiently explored. Similarly, the extent to which CAR varies according to athletes' age in youth competitive environments is not yet fully understood.

In addition, research focusing specifically on handball, as well as studies conducted in Eastern European contexts, particularly in Romania, are relatively scarce in the current literature.

Therefore, further investigation is required to clarify the role of the coach–athlete relationship in both individual and team-level outcomes, and to address the existing gaps in the literature by providing empirical evidence from youth performance handball.

4. Conceptualization and Measurement of the Coach–Athlete Relationship

The coach–athlete relationship (CAR) is considered one of the most important psychosocial variables in performance sport. Recent studies have shown that this relationship positively influences several relevant outcomes, including the development of psychological skills, motivation,

competitive performance, and athlete satisfaction. In this context, Jowett's 3+1C conceptual model explains the quality of the coach–athlete relationship through the dimensions of closeness, commitment, and complementarity, which reflect emotional, behavioural, and cognitive interdependence between coaches and athletes.

Closeness refers to the affective bond between coach and athlete and includes trust, respect, and mutual appreciation. Commitment reflects the intention of both parties to maintain the relationship over time and to invest in it consistently. Complementarity describes the degree of cooperation, responsiveness, and coordinated interaction between coach and athlete during training and competition. Together, these dimensions provide a comprehensive framework for understanding the quality of interpersonal dynamics in sport settings.

The literature suggests that a high-quality coach–athlete relationship contributes to positive developmental and performance-related outcomes. In youth sport, CAR has been associated with greater athlete engagement, improved well-being, enhanced motivation, and better adaptation to competitive demands. At the same time, the relationship between coach and athlete is shaped by contextual and individual variables, such as age, communication style, leadership behaviours, and the athlete's role within the team.

To assess this construct, Jowett and Ntoumanis (2004) developed the Coach–Athlete Relationship Questionnaire (CART-Q), one of the most widely used instruments in sport psychology. The questionnaire evaluates the main dimensions of the relationship and allows researchers to examine the perceived quality of interaction between coaches and athletes in an objective and structured manner. Previous validation studies have confirmed its reliability and psychometric robustness across different sports and cultural contexts.

Given the complexity of performance sport, the coach–athlete relationship should be understood not only as an interpersonal factor, but also as a relevant psychosocial mechanism that may influence athlete development, team dynamics, and role differentiation within competitive environments.

5. Materials and Methods

The relationship between the athlete and the coach represents one of the most important psychological variables in the context of performance sport. Recent studies have shown that this relationship positively influences key outcomes, such as the development of psychological skills, motivation, competitive performance, and athlete satisfaction. In this context, the 3+1C conceptual model proposed by Jowett analyses this relationship through the dimensions of closeness, commitment, and complementarity, which reflect emotional, behavioural, and cognitive interdependence.

The present study investigates the extent to which athletes' perceptions of the coach–athlete relationship are associated with a series of independent variables, such as age, team status (whether they are part of the starting seven or not), and the sporting results achieved by the team in which they compete.

5.1. Research Design

The research has a quantitative, cross-sectional design, aiming to investigate the relationship between athletes' perceptions of the coach–athlete relationship and team performance indicators. The study examines how the quality of the coach–athlete relationship is associated both with individual characteristics of athletes and with the sporting results achieved by the teams they belong to.

5.2. Participants

The study included a sample of 270 athletes (male and female) (n = 270), from 18 teams practicing performance handball in junior competitions (Junior III, II, and I categories), with each team represented by 15 players. All participants were part of teams competing in the National

Handball Championship, organised under the Romanian Handball Federation. The teams were selected randomly and were not limited to a specific geographical area.

In addition to questionnaire data, socio-demographic variables such as age were collected in order to analyse the potential influence of maturity and sporting experience on the perception of the coach–athlete relationship.

Athletes also answered a question regarding their status within the team, distinguishing between players who are part of the starting seven (starting players) and those who are part of the team rotation.

5.3. Instruments

CART-Q (Coach–Athlete Relationship Questionnaire)

To assess the relationship between athletes and coaches, the CART-Q questionnaire was used, an instrument developed by Jowett and Ntoumanis (2004) and widely applied in sport psychology research.

The questionnaire evaluates the coach–athlete relationship through three main dimensions:

Closeness – reflects feelings of mutual respect, appreciation, and trust between coach and athlete

Commitment – illustrates the willingness of both parties (coach and athlete) to maintain a stable and long-term relationship

Complementarity – indicates the level of coordination and cooperation between athletes and coaches during training and competition

Table 1. Sample items from the CART-Q questionnaire

Item / Statement	1	2	3	4	5	6	7	Age	Team status
1. I am close to my coach									
2. I am committed to my coach									
3. I like my coach									
4. When I am coached by my coach, I am at ease									
5. I trust my coach									
6. I feel that my sport career is promising with my coach									
7. When I am coached by my coach, I am responsive to his/her efforts									
8. I respect my coach									
9. I appreciate my coach's sacrifices in order to improve performance									
10. When I am coached by my coach, I am ready to do my best									
11. When I am coached by my coach, I adopt a friendly stance									

Note. Responses were recorded on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree).
Team status was coded as follows: 1 = starting player; 0 = non-starting player.

The questionnaire is based on a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree), and includes 11 items. Higher scores indicate a more positive perception of the relationship between the two fundamental parties involved in performance.

The present study uses the athlete version of the questionnaire, where athletes evaluate their own perception of the relationship with their coach.

5.4. Analyzed Variables

Within this study, both individual variables and objective indicators of team performance were analyzed.

First, athletes' age was recorded as a socio-demographic variable, as the literature suggests that with increasing age, athletes tend to become more open in their relationship with the coach, and their perceptions become more realistic, providing clearer and more honest responses.

Additionally, player status within the team represented another variable, distinguishing between players who are part of the starting seven (starting players) and those used alternatively (rotation players).

Sport performance was evaluated using two objective variables:

the team's ranking at the end of the group stage of the competition

the number of victories achieved by the team in the last 10 matches played

5.5. Testing Procedure

Data collection respected ethical and integrity standards for each team. Team coaches agreed to the administration of the questionnaire to the athletes, thus facilitating access to participants and the distribution of the questionnaires.

Participation in the study was voluntary. Athletes were informed about the purpose of the research, and it was emphasised that their responses would remain anonymous. All participants provided informed consent before completing the questionnaire.

The data collection procedure complied with the ethical principles of the Declaration of Helsinki regarding research involving human subjects.

5.6. Statistical Analysis

For statistical analysis, IBM SPSS Statistics software was used. The first stage consisted of calculating descriptive statistics for the analysed variables.

The reliability of the CART-Q questionnaire was assessed using Cronbach's alpha coefficient.

Normality tests (Shapiro–Wilk) were used to assess data distribution, and when assumptions of normality were not met, Spearman correlation analyses were applied. The influence of the coach–athlete relationship on team performance was investigated using linear regression.

Additionally, the independent samples t-test was used to analyse differences between starting players and rotation players, and to confirm the results, non-parametric Mann–Whitney U tests were also applied. Effect size was calculated to evaluate the magnitude of the differences.

To investigate predictors of player status, binary logistic regression was used, including the coach–athlete relationship and age as independent variables.

5.7. Research Hypotheses

- H1. The coach–athlete relationship is significantly associated with team performance (win rate and standardised ranking).
- H2. The coach–athlete relationship differs significantly between starting players and rotation players.
- H3. The coach–athlete relationship is significantly associated with athletes' age.

For data analysis, IBM SPSS Statistics software was used. The Cronbach's alpha coefficient ($\alpha = 0.951$) indicated a very high internal consistency of the instrument used to assess the coach–athlete relationship (CART-Q), thus confirming its reliability.

The normality of data distribution was tested using the Shapiro–Wilk test ($N = 18$) and the Kolmogorov–Smirnov test ($N = 270$), both indicating deviations from normality ($p < 0.05$). Considering the large sample size, both parametric and non-parametric statistical methods were applied, in accordance with recommended statistical practices.

6. Results and Discussion of the Coach-Athlete Relationship in Youth Handball

6.1. Relationships Between Coach–Athlete Relationship Dimensions and Team Performanced

Using Spearman correlation analysis, strong and statistically significant correlations were identified between the three dimensions of the coach–athlete relationship (closeness, commitment, and complementarity), with values ranging between $\rho = 0.972$ and $\rho = 0.990$ ($p < 0.001$). These results indicate a high internal consistency of the construct.

No significant correlations were found between the coach–athlete relationship and team performance indicators (team ranking or win rate in the last 10 matches) ($p > 0.05$).

A strong positive correlation was identified between the win rate in the last 10 matches and the final team ranking ($\rho = 0.894$, $p < 0.001$).

6.2. Influence of the Coach–Athlete Relationship on Overall Team Performance

A linear regression analysis was conducted to test the predictive role of the coach–athlete relationship on team performance. The results indicated that the model was not statistically significant, $F(1,16) = 0.014$, $p = 0.906$, explaining only 0.1% of the variance in performance ($R^2 = 0.001$).

An important observation is that the coach–athlete relationship does not appear to be a fundamental predictor of collective performance ($\beta = 0.030$, $p = 0.906$). These findings suggest that the coach–athlete relationship does not significantly influence direct team performance outcomes, which are likely determined by multiple other factors of tactical, technical, or contextual nature.

6.3. Differences Between Player Status (Starting Players vs. Rotation Players) in Relation to the Coach–Athlete Relationship

As shown in Table 2, the comparative results indicate significant differences between rotation players and starting players (those included in the starting seven at the beginning of the match).

Table 2. Differences between starting players and substitutes in the coach–athlete relationship

Variable	Group	Mean (M)	SD	t	p	Effect size (r)
Closeness	Substitutes	6.01	0.91	-2.51	0.013	0.18
	Starters	6.28	0.83			
Commitment	Substitutes	6.07	0.91	-2.53	0.012	0.22
	Starters	6.35	0.92			
Complementarity	Substitutes	6.08	0.92	-2.60	0.010	0.16
	Starters	6.35	0.81			

Note. *t*-values represent independent samples t-tests comparing starters and substitutes. Effect size (*r*) was calculated based on the test statistic. Statistically significant differences were observed for all three dimensions ($p < .05$).

Players frequently used as starters reported significantly higher levels of commitment ($t = -2.53$, $p = 0.012$), complementarity ($t = -2.60$, $p = 0.010$), and emotional closeness ($t = -2.51$, $p = 0.013$), compared to players used in rotation (substitutes). To fully confirm these results, the non-parametric Mann–Whitney U test was also applied, which clearly indicated significant differences for all tested dimensions ($p < 0.01$).

The coach–athlete relationship contributes to the differentiation of athletes within the team (player status), but it does not represent an exclusive factor. Effect size values ranged from small to moderate (r = 0.16–0.22).

Among the three dimensions analysed, commitment showed the highest effect size (r = 0.22), suggesting a more important role in differentiating starting players compared to those used in rotation within the team.

6.4. Predictive Models of Player Status

To examine the extent to which the coach–athlete relationship and age influence player status within the team, a binary logistic regression analysis was conducted (see Table 3).

Table 3. Binary logistic regression predicting player status (starter vs. rotation player)

Predictor	**B**	**SE**	**Wald**	**p**	**Exp(B)**	**95% CI for Exp(B)**
Coach–athlete relationship	0.451	0.156	8.350	.004	1.569	1.150 – 2.142
Age	-0.072	0.043	2.840	.092	0.930	0.853 – 1.013
Model indicators						
χ^2 (2)	9.888			.007		
Nagelkerke R^2	.048					

Note. Logistic regression analysis predicting team status (1 = starter; 0 = substitute). Exp(B) represents odds ratios. Confidence intervals are reported at 95%.

The model was statistically significant, $\chi^2(2) = 9.888$, $p = 0.007$, indicating a relevant contribution of the included variables. However, the explanatory power of the model was low (Nagelkerke $R^2 = 0.048$).

The coach–athlete relationship represents a central and primary factor in player selection within the team (B = 0.451, p = 0.004). The value Exp(B) = 1.569 indicates that an improvement in the coach–athlete relationship increases the likelihood of being selected as a starting player by approximately 57%. In other words, athletes who reported a higher-quality relationship with their coach had greater chances of being starters.

On the other hand, no significant relationships were identified between athletes' age and their status within the team ($\rho = 0.051$, $p = 0.403$).

6.5. Relationships Between Variables at the Individual Level

The previous findings are further supported by Spearman correlation analysis between the coach–athlete relationship and player status within the team ($\rho = 0.203$, $p = 0.001$). Athletes who reported a more developed relationship with their coach were more likely to occupy a starting position.

Additionally, a significant negative correlation was observed between the coach–athlete relationship and age ($\rho = -0.195$, $p = 0.001$), indicating that younger athletes tend to report more positive relationships with their coaches.

No significant relationship was found between age and player status ($\rho = 0.051$, $p = 0.403$).

The results of the present study confirm the important role of the coach–athlete relationship (CAR) dimensions in shaping interactions between coaches and athletes; however, they do not support the existence of a direct impact on collective performance. Instead, the coach–athlete relationship appears to play a significant role in differentiating players' competitive status, constituting a relevant factor in processes of selection, integration, and retention within the core team structure. This finding represents an important contribution to the literature, suggesting that

CAR may play a more critical role in shaping individual performance pathways and role differentiation than in directly influencing collective outcomes.

These results partially contrast with the existing literature, which predominantly highlights the role of the coach–athlete relationship in athlete development and performance optimisation. For instance, Freire et al. (2024) demonstrate that the dimensions of the 3C model contribute to the development of young handball players. However, these discrepancies may be explained by the distinct nature of the analysed variables, as sport performance represents a multifactorial construct influenced by technical-tactical, physiological, and somatic factors, whereas psychosocial variables primarily reflect the quality of interpersonal relationships. Moreover, this discrepancy may also reflect differences in performance operationalisation, as previous studies often rely on individual performance indicators, while the present study focuses on collective team outcomes. In this regard, the literature suggests that the coach–athlete relationship should be understood as a complex construct, whose effects on performance are likely indirect, contextual, and mediated by psychological and organizational variables (Lajčin & Bočková, 2023; Luo et al., 2025; Phillips et al., 2026).

The use of the CART-Q questionnaire is supported by robust evidence regarding its validity and reliability. Recent validation studies conducted on Portuguese athletes have demonstrated high internal consistency ($\alpha = 0.86–0.94$), good temporal stability (ICC = 0.84–0.90), and an adequate model fit (CFI = 0.979; RMSEA = 0.068), confirming the robustness of the instrument (Pinho et al., 2024). Furthermore, strong associations between CART-Q dimensions and athletes' enjoyment support the idea that the coach–athlete relationship represents a key psychosocial factor influencing the quality of the sporting experience and optimal functioning in competitive contexts.

Consistent with these findings, the present results indicate that the coach–athlete relationship is not significantly associated with team performance, measured through win rate and final ranking. Statistical analyses confirmed the absence of a significant predictive effect ($F(1,16) = 0.014$, $p = 0.906$; $R^2 = 0.001$), suggesting that relational variables alone are insufficient to explain variations in collective performance. This finding can be interpreted in the context of the multifactorial nature of handball performance, which involves game-specific coordination, strength and power (Manchado et al., 2013), anthropometric characteristics (Michalsik et al., 2015), and the integration of tactical, cognitive, and social factors (Wagner et al., 2014), all embedded within a complex system of sport development (Massuça et al., 2014; Tyshchenko et al., 2019).

From an integrative perspective, literature in neuroscience and sport psychology suggests that the coach–athlete relationship is involved in fundamental neurocognitive processes, such as emotional regulation, reward processing, motivation, and trust development, which are functionally associated with dopaminergic and limbic networks (Berridge & Robinson, 2016; Adolphs, 2009). These processes may contribute to differences in attentional focus, decision-making, and behavioural regulation during training and competition, thereby influencing athletes' ability to perform consistently and adapt to competitive demands. In this context, the higher CAR scores observed among starting players may reflect more efficient socio-cognitive functioning, including enhanced attentional control, faster decision-making, and improved responsiveness to coaching feedback. These mechanisms are consistent with theoretical models linking interpersonal trust and motivation to executive functioning in sport performance contexts. However, in the absence of direct cognitive or neurophysiological measurements, these mechanisms should be interpreted as theoretical explanations. Therefore, the results indicate a dissociation between individual and collective performance, suggesting that the coach–athlete relationship functions primarily as a proximal factor of individual performance, with indirect and context-dependent effects on team performance.

This interpretation is supported by the significant differences identified between starting players and substitutes. Starters reported higher levels of the coach–athlete relationship, which may be explained by greater competitive involvement, more frequent interactions, and increased exposure to coaching decisions and feedback. In addition, stronger coach–athlete relationships may

facilitate enhanced cognitive engagement, attentional control, and responsiveness to tactical instructions, which are essential for maintaining a starting position. At the same time, the literature highlights the role of sport leadership in assigning status and distributing playing time, factors that influence athletes' perceptions of fairness and motivation (Soto et al., 2021; Brailsford, 2015).

Additionally, previous research shows that substitute players tend to report more negative emotional experiences, lower perceived control, and reduced motivation (Woods & Thatcher, 2009), while differences in physical demands and competitive exposure between starters and substitutes are substantial (Furtado Mesa et al., 2023). These findings indicate that competitive status reflects not only a formal role, but also distinct psychological and physical experiences that shape perceptions of the coach–athlete relationship.

Moreover, individual variables such as personality traits influence relationship quality and communication patterns (Prabowo et al., 2024), further supporting the indirect nature of the relationship's influence on performance. Similarly, the coach–athlete relationship has been associated with autonomy support and athlete well-being (Lafrenière et al., 2011), while closeness and commitment contribute to effective coaching behaviours (Jowett et al., 2017). However, these effects are context-dependent, with some studies reporting variability across dimensions (Kunal et al., 2019).

Interventions aimed at strengthening the coach–athlete relationship, such as establishing shared goals, fostering trust, and providing support, may enhance athlete engagement and commitment (Gu et al., 2023), although they do not necessarily guarantee improvements in collective performance. Thus, team performance should be understood as the outcome of complex interactions among multiple factors and agents, which can also be interpreted through the lens of complex adaptive systems.

In this sense, the lack of a significant association at the collective level suggests that relational processes operate primarily at the individual level, whereas team performance reflects emergent dynamics resulting from nonlinear interactions among team members. Therefore, the coach–athlete relationship can be considered a facilitating factor of performance, rather than a direct determinant of collective success.

Overall, the findings support a mediation-based interpretation, in which the coach–athlete relationship influences performance indirectly through psychological variables such as self-efficacy, intrinsic motivation, and team cohesion.

These variables contribute to the optimisation of individual behaviours, task engagement, and decision-making processes, thereby reinforcing the role of CAR as a latent but meaningful factor in performance development.

Additionally, the findings can be interpreted within the broader framework of team relational dynamics, where interactions extend beyond the coach–athlete dyad and involve complex networks of relationships among team members. In this context, the influence of the coach–athlete relationship may be attenuated at the collective level by athlete–athlete interactions, group cohesion, and collective tactical strategies. This perspective reinforces the idea that team performance represents an emergent outcome of multiple social interactions, where psychosocial variables contribute in an indirect and context-dependent manner.

Regarding the study's limitations, the geographically distributed sample and the use of a self-report instrument may introduce variability and subjective bias. Additionally, the cross-sectional design limits causal interpretations.

Future research directions include expanding the sample, incorporating senior-level athletes, and employing longitudinal designs to better understand the relational mechanisms involved in sport performance.

From a practical standpoint, the results suggest that interventions aimed at improving the coach–athlete relationship should not only focus on strengthening interpersonal dimensions, but also on integrating these aspects into broader performance development strategies. Coaches may use the coach–athlete relationship as a tool to enhance athlete engagement, motivation, and satisfaction,

thereby supporting long-term development. At the same time, optimising collective performance requires an integrated approach that includes technical-tactical, physical, and organisational factors, highlighting the need for a multidimensional perspective on sport training. Therefore, the present study contributes to a more nuanced understanding of performance in team sports, highlighting that relational quality operates as a foundational, yet indirect, determinant within a complex system of interacting performance factors.

7. Digital Application in Monitoring the Coach–Athlete Relationship: The TeamCore Platform

In light of the findings of the present study, which emphasise the role of the coach–athlete relationship (CAR) in differentiating player status and influencing cognitive processes underlying performance, the use of applied digital tools becomes particularly relevant for optimising coaching interventions.

In this context, the TeamCore application (available online at https://brain.edusoft.ro/apps/teamcore and illustrated in Figure 1, Figure 2, and Figure 3) represents an example of integrating sport psychology principles into a practical, field-ready instrument designed for rapid assessment of athletes' psychological states.

7.1. Conceptual Framework of TeamCore

TeamCore may be conceptualised as a psychological "dashboard" for coaches, providing concise and actionable insights into athletes' emotional and cognitive states immediately prior to performance. Unlike traditional performance indicators (e.g., speed, strength, or tactical execution), the application targets internal determinants of performance, such as perceived stress, emotional regulation, and the quality of the coach–athlete relationship.

This perspective aligns with contemporary sport psychology literature, which highlights that athletes' decision-making efficiency and behavioural responses under pressure are significantly influenced by their emotional states and interpersonal dynamics within the team. By translating complex neuropsychological and relational constructs into an accessible interface, TeamCore facilitates real-time awareness and informed decision-making for coaches.

7.2. Operational Structure and Data Collection

The application is designed for use on mobile devices (smartphones or tablets) and requires less than two minutes to complete, thereby ensuring minimal disruption to pre-competition routines. The data collection process is structured into three sequential stages:

First, athletes provide basic identification information, including their name and playing status (starter or substitute).

This distinction is particularly relevant in light of the present study's findings, which indicate significant differences in CAR dimensions between these groups.

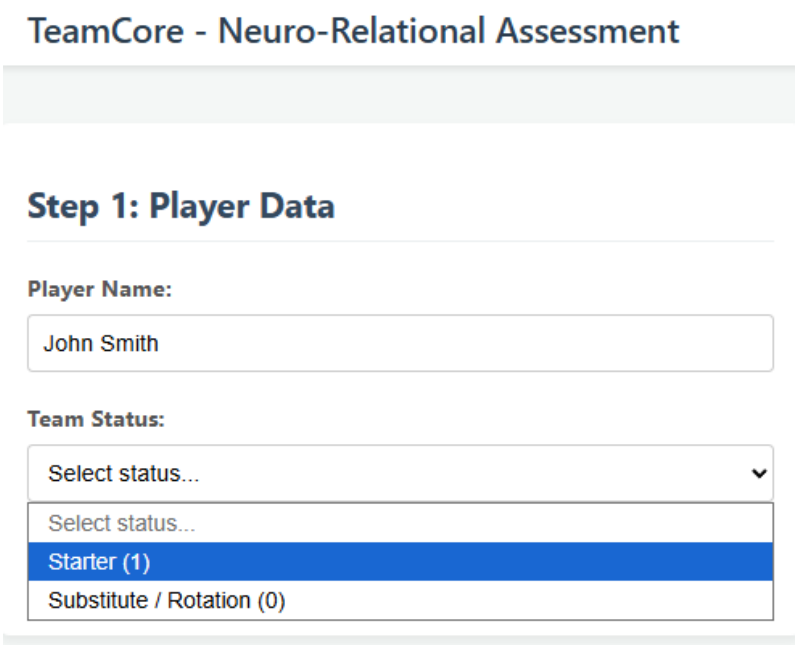

Figure 1. Athletes provide basic identification information

Second, athletes are required to report their current emotional state using a simplified "stress barometer," selecting from three intuitive categories that are visually represented (calm, agitated, or highly stressed/panicked). This component is grounded in neuropsychological principles, particularly the interaction between cortical processes responsible for rational cognition and subcortical structures, such as the amygdala, which mediate emotional and stress responses. Elevated stress levels have been associated with reduced cognitive flexibility and impaired information processing—factors that are critical in fast-paced sports such as handball.

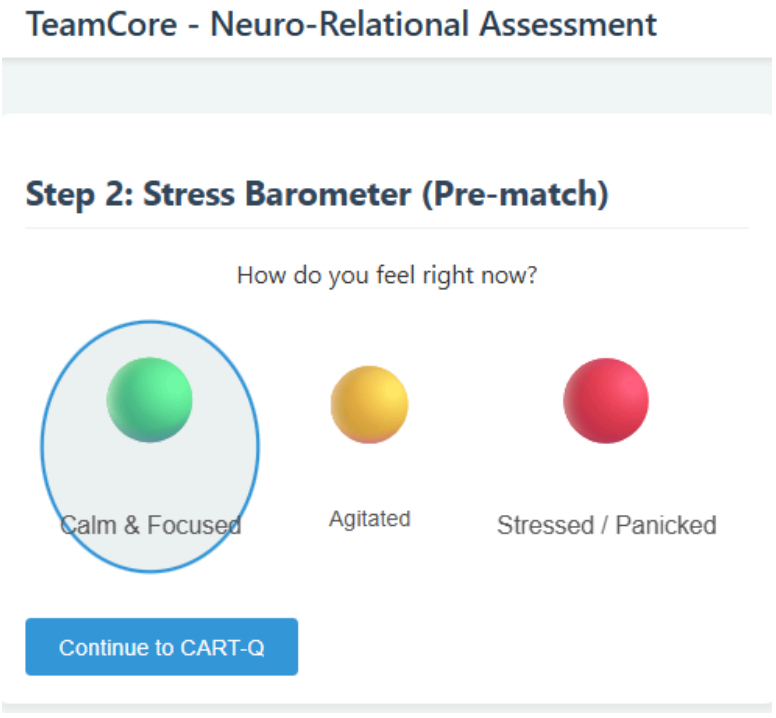

Figure 2. Stress barometer

Third, athletes respond to a set of 11 brief items designed to assess key dimensions of the coach–athlete relationship, including trust, commitment, and perceived relational quality.

This step examines the quality of the coach–athlete relationship by asking athletes to rate a series of 11 statements on a 7-point Likert scale, ranging from *strongly disagree* to *strongly agree*. These items are designed to capture the core interpersonal dimensions outlined in the 3+1C model, which provides a well-established framework for understanding relational dynamics in sport.

These dimensions are conceptually aligned with the 3+1C model underlying the CART-Q instrument employed in the present study.

More specifically, this step addresses the following key psychological and relational questions:

1. Closeness (Emotional Bond)

Items such as *"I am close to my coach"*, *"I like my coach"*, and *"I trust my coach"* explore:

- To what extent does the athlete feel emotionally connected to the coach?
- Is there mutual trust, respect, and interpersonal warmth?
- Does the athlete experience comfort and psychological safety in the coach's presence?

This dimension reflects the affective quality of the relationship and is essential for open communication and emotional support.

2. Commitment (Long-term Orientation)

Statements like *"I am committed to my coach"* and *"I feel that my sport career is promising with my coach"* assess:

- How dedicated is the athlete to maintaining the relationship over time?
- Does the athlete believe in the coach's ability to support their long-term development?
- Is there a sense of shared investment in future success?

Commitment indicates the stability and durability of the coach–athlete partnership.

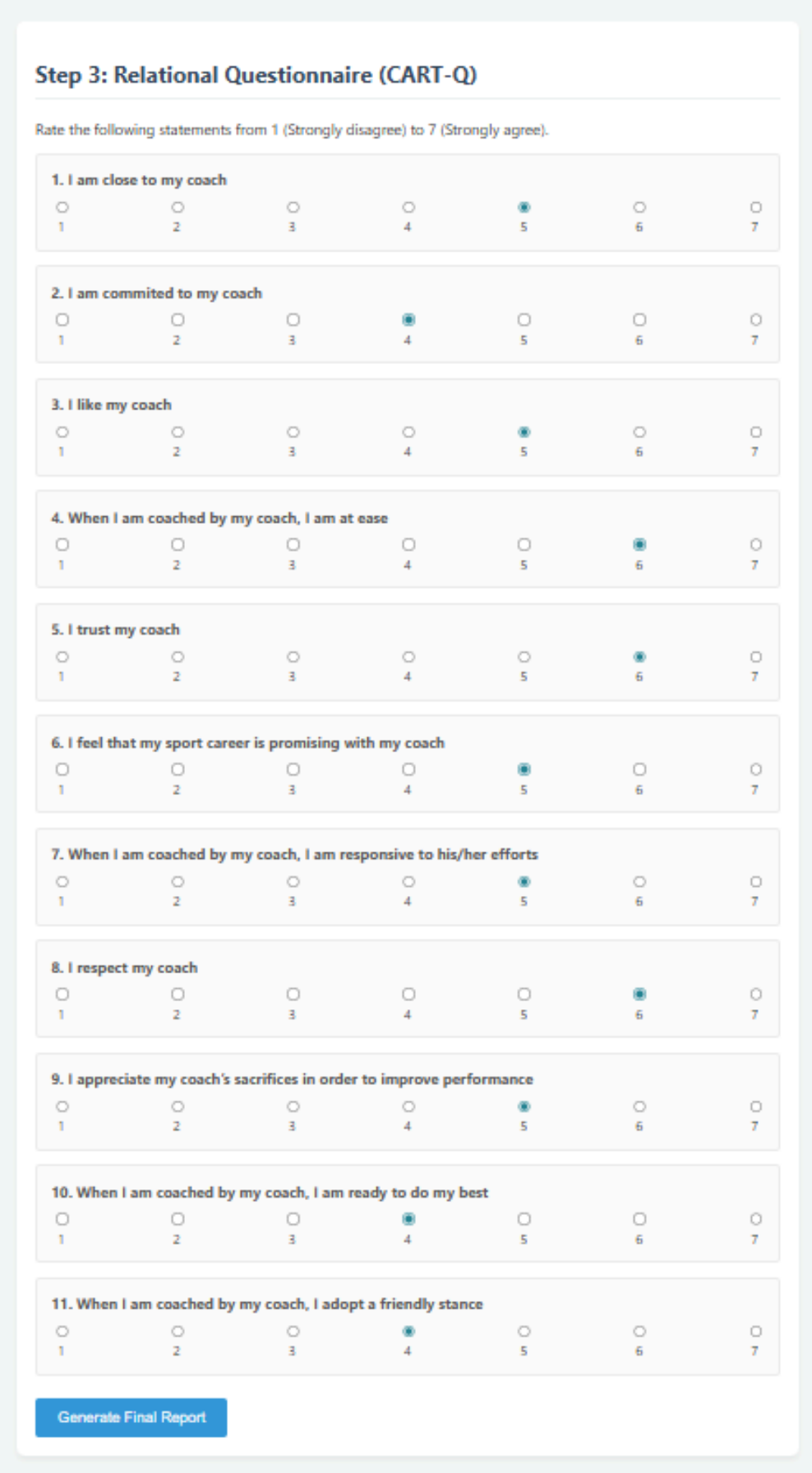

Figure 3. Relational questionnaire (CART-Q)

3. Complementarity (Behavioural Interaction)

Items such as *"When I am coached by my coach, I am responsive to his/her efforts"* and *"I am ready to do my best"* examine:

- How well do the athlete's behaviours align with the coach's guidance?
- Does the athlete actively engage, cooperate, and respond constructively during training?
- Is there effective two-way interaction during performance contexts?

This dimension reflects how smoothly the coach and athlete work together in practice.

4. Co-orientation (Shared Understanding)

Statements like *"I respect my coach"*, *"I appreciate my coach's sacrifices"*, and *"I adopt a friendly stance"* relate to:

- Whether the athlete perceives the relationship in a way that aligns with mutual expectations
- The degree of shared values, understanding, and respect
- How both parties interpret and evaluate their relationship

Co-orientation captures the cognitive alignment between coach and athlete.

Taken together, these questions aim to determine:

- How strong and functional the coach–athlete relationship is
- Whether the relationship supports performance, motivation, and well-being
- Which relational dimensions may require improvement (e.g., trust, communication, engagement)

The responses can be used to generate a relational profile, offering insights into interpersonal dynamics that are critical for success in high-performance sports such as handball (Figure 4).

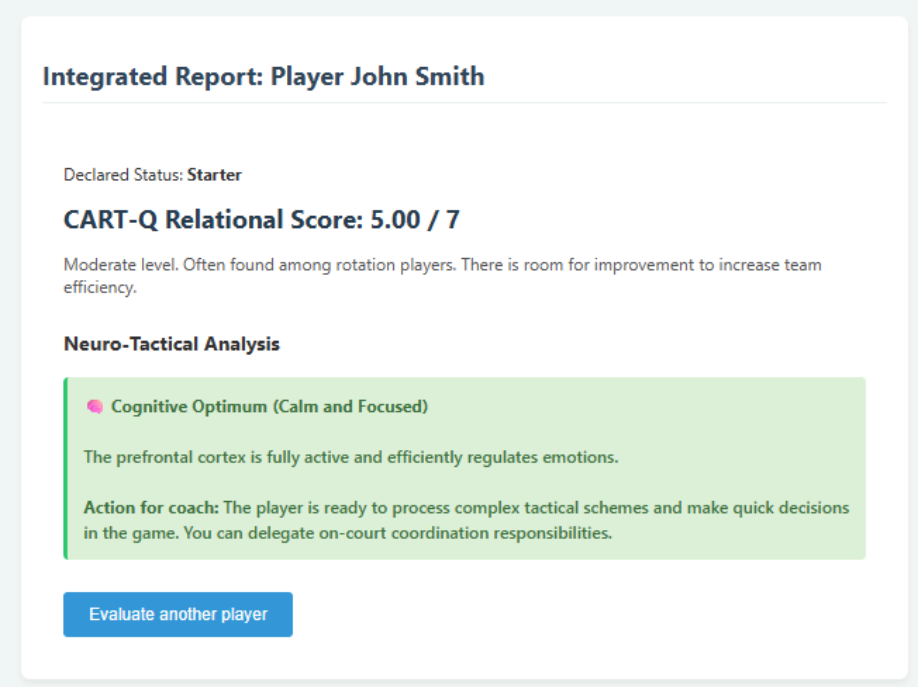

Figure 4. Integrated report

7.3. Practical Utility and Applied Implications

A defining feature of TeamCore lies not merely in data collection, but in its capacity to generate immediate, actionable feedback for coaches. The application translates athletes' responses into context-sensitive recommendations that support adaptive coaching behaviours.

For instance, when an athlete reports a high level of stress, the system alerts the coach to the potential impairment of cognitive processing, advising against the use of complex tactical instructions and instead recommending emotionally supportive communication aimed at regulation and reassurance. This function helps prevent situations in which athletes are expected to execute cognitively demanding tasks while experiencing psychological overload.

Furthermore, the application is particularly valuable in monitoring substitute players, who, as evidenced in the present study, tend to report lower levels of closeness, commitment, and complementarity within the coach–athlete relationship. By identifying early signs of reduced motivation or relational disengagement, TeamCore enables timely interventions (e.g., individual feedback, encouragement, or role clarification), potentially mitigating dropout risk and enhancing long-term athlete development.

At the team level, the platform contributes to the development of a more cohesive and responsive performance environment. By differentiating between athletes who require tactical guidance and those who primarily need emotional support, coaches can tailor their communication strategies more effectively. This, in turn, may facilitate faster and more accurate decision-making during competition, aligning with the study's broader argument that performance is mediated by cognitive and relational factors rather than solely by physical or technical attributes.

In summary, TeamCore operationalises key constructs from sport psychology and relational theory into a practical tool that supports evidence-based coaching. By bridging the gap between theoretical knowledge and real-time application, the platform offers a promising avenue for enhancing both individual athlete experience and team functioning within elite junior handball.

Author contributions

Alexandru-Rareș Puni, Ștefan Ciobanu, Ileana-Monica Popovici, Constantin Nacu, and Beatrice-Aurelia Abalasei contributed equally to the conceptualisation, methodology, data analysis, and writing of the manuscript. All authors have read and approved the final version of the manuscript.

References

Adolphs, R. (2009). The social brain: Neural basis of social knowledge. *Annual Review of Psychology, 60*(1), 693–716. https://doi.org/10.1146/annurev.psych.60.110707.163514

Atkinson, F. (2016). *The relationship between athletes' perceptions of coaching efficacy and collective efficacy in collegiate soccer* (Doctoral dissertation, University of North Dakota).

Ayrancı, M., & Aydın, M. K. (2025). The complex interplay between psychological factors and sports performance: A systematic review and meta-analysis. *PLOS ONE, 20*(8), e0330862. https://doi.org/10.1371/journal.pone.0330862

Balduck, A. L., & Jowett, S. (2010). Psychometric properties of the Belgian coach version of the coach–athlete relationship questionnaire (CART-Q). *Scandinavian Journal of Medicine & Science in Sports, 20*(5), 779–786. https://doi.org/10.1111/j.1600-0838.2009.01020.x

Berridge, K. C., & Robinson, T. E. (2016). Liking, wanting, and the incentive-sensitization theory of addiction. *American Psychologist, 71*(8), 670–679. https://doi.org/10.1037/amp0000059

Bora, M. V. (2025). The impact of coach–athlete relationship quality on young athletes' performance: A meta-analysis. *International Journal on Studies in Education, 7*(4), 1004–1027. https://doi.org/10.46328/ijonse.5815

Brailsford, K. (2015). *An investigation into coaching efficacy and effectiveness in gymnastics* (Master's thesis, University of Birmingham).

Brown, D. J., & Fletcher, D. (2017). Effects of psychological and psychosocial interventions on sport performance: A meta-analysis. *Sports Medicine, 47*, 77–99. https://doi.org/10.1007/s40279-016-0552-7

Coussens, A. H., Stone, M. J., & Donachie, T. C. (2025). Coach–athlete relationships, self-confidence, and psychological wellbeing: The role of perceived and received coach support. *European Journal of Sport Science, 25*(1), e12226. https://doi.org/10.1002/ejsc.12226

Crivelli, D., & Balconi, M. (2026). Exploring interpersonal neural synchrony in coach–athlete interactions: Insights from naturalistic EEG hyperscanning in competitive tennis. *Frontiers in Sports and Active Living, 8*, 1751291. https://doi.org/10.3389/fspor.2026.1751291

Cronin, L. D., & Allen, J. (2018). Examining the relationships among the coaching climate, life skills development and well-being in sport. *International Journal of Sports Science & Coaching, 13*(6), 815–827. https://doi.org/10.1177/1747954118787949

Debanne, T., & Fontayne, P. (2009). A study of a successful experienced elite handball coach's cognitive processes in competition situations. *International Journal of Sports Science & Coaching, 4*(1), 1–16. https://doi.org/10.1260/1747-9541.4.1.1

Denkova, J., & Bajramovska, M. (2018). The role of communication management in sports with special emphasis on handball. *Journal of Process Management and New Technologies, 6*(4). https://doi.org/10.5937/joupроman6-19001

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Erickson, K. I., Hillman, C., Stillman, C. M., Ballard, R. M., Bloodgood, B., Conroy, D. E., Macko, R., Marquez, D. X., Petruzzello, S. J., Powell, K. E., & Physical Activity Guidelines Advisory Committee. (2019). Physical activity, cognition, and brain outcomes: A review of the 2018 guidelines. *Medicine & Science in Sports & Exercise, 51*(6), 1242–1251. https://doi.org/10.1249/MSS.0000000000001936

Beauchamp, M. R., & Eys, M. A. (Eds.). (2014). *Group dynamics in exercise and sport psychology*. Routledge.

Freire, G. L. M., Cronin, L. D., Jowett, S., Costa, N. L. G., Fiorese, L., & do Nascimento Junior, J. R. A. (2024). Coach–athlete relationships and life skills development among Brazilian handball players: A prospective study. *Quaderns de Psicologia, 26*(1), e2051. https://doi.org/10.5565/rev/qpsicologia.2051

Furtado Mesa, M., Stout, J. R., Redd, M. J., & Fukuda, D. H. (2023). Accumulated workload differences in collegiate women's soccer: Starters versus substitutes. *Journal of Functional Morphology and Kinesiology, 8*(3), 78. https://doi.org/10.3390/jfmk8020078

García-Herrero, J. A., Soto-García, D., Carcedo, R. J., Martínez-Martín, I., & Delgado-Floody, P. (2022). Analysis of the relationship between satisfaction with the coach and comparative social feedback in elite female handball players. *International Journal of Environmental Research and Public Health, 19*(13), 7680. https://doi.org/10.3390/ijerph19137680

Gençoğlu, C., & Gümüş, H. (2025). Disciplinary strategies or reactive measures? An analysis of coach sanctions in elite Danish handball leagues. *International Journal of Sports Science & Coaching, 20*(6), 2309–2317. https://doi.org/10.1177/17479541251360847

Gledhill, A., Harwood, C., & Forsdyke, D. (2017). Psychosocial factors associated with talent development in football: A systematic review. *Psychology of Sport and Exercise, 31*, 93–112. https://doi.org/10.1016/j.psychsport.2017.04.002

Gu, S., Peng, W., Du, F., Fang, X., Guan, Z., He, X., & Jiang, X. (2023). Association between coach–athlete relationship and athlete engagement in Chinese team sports: The mediating effect of thriving. *PLOS ONE, 18*(8), e0289979. https://doi.org/10.1371/journal.pone.0289979

Hinz, M., Lehmann, N., Aye, N., Melcher, K., Tolentino-Castro, J. W., Wagner, H., & Taubert, M. (2022). Differences in decision-making behavior between elite and amateur team-handball players in a near-game test situation. *Frontiers in Psychology, 13*, 854208. https://doi.org/10.3389/fpsyg.2022.854208

Høigaard, H., De Cuyper, B., Fransen, K., Boen, F., & Peters, D. M. (2016). Perceived coach behavior predicts collective efficacy in female elite handball players. *International Journal of Sport Psychology, 46*(6), 321–336. https://doi.org/10.7352/IJSP.2015.46.321

Jiahao, L., & Jing, L. (2024). Examining the link between coach–athlete relationship and athlete burnout among college soccer players: The mediating role of training satisfaction. *Frontiers in Psychology, 15*, 1409609. https://doi.org/10.3389/fpsyg.2024.1409609

Jowett, S., & Ntoumanis, N. (2004). The coach–athlete relationship questionnaire (CART-Q): Development and initial validation. *Scandinavian Journal of Medicine & Science in Sports, 14*(4), 245–257. https://doi.org/10.1111/j.1600-0838.2003.00338.x

Jowett, S., & Shanmugam, V. (2016). Relational coaching in sport: Its psychological underpinnings and practical effectiveness. In R. Schinke, K. R. McGannon, & B. Smith (Eds.), *Routledge international handbook of sport psychology* (pp. 471–484). Routledge.

Jowett, S., Nicolas, M., & Yang, S. (2017). Unravelling the links between coach behaviour and coach–athlete relationships. *European Journal of Sports & Exercise Science, 5*(3).

Kunal, Singh, S., & Kushwaha, A. (2019). Coach–athlete relationship among selected team games. *International Journal of Research and Analytical Reviews, 6*(1), 534–542.

Lafrenière, M. A. K., Jowett, S., Vallerand, R. J., & Carbonneau, N. (2011). Passion for coaching and the quality of the coach–athlete relationship: The mediating role of coaching behaviors. *Psychology of Sport and Exercise, 12*(2), 144–152. https://doi.org/10.1016/j.psychsport.2010.08.002

Lajčin, D., & Bočková, K. (2023). Descriptive statistical analysis of the coach–player relationship with CART-Q and SCI. *HighTech and Innovation Journal, 4*(2), 249–269. https://doi.org/10.28991/HIJ-2023-04-02-01

Liu, R., Wang, S., & Li, J. (2025). How coach leadership behavior influences athletes' performance: The chain-mediated role of the coach–athlete relationship and psychological fatigue. *Frontiers in Psychology, 15*, 1500867. https://doi.org/10.3389/fpsyg.2024.1500867

Lochbaum, M., Stoner, E., Hefner, T., Cooper, S., Lane, A. M., & Terry, P. C. (2022). Sport psychology and performance meta-analyses: A systematic review. *PLOS ONE, 17*(2), e0263408. https://doi.org/10.1371/journal.pone.0263408

Longakit, J., Toring-Aque, L., Aque, F., Sayson, M., & Lobo, J. (2024). The role of coach–athlete relationship on motivation and sports engagement. *Physical Education of Students, 28*(5), 268–275. https://doi.org/10.15561/20755279.2024.0503

Luo, Y., Li, S., Cao, Y., & Luo, Z. (2025). The predictive role of coach–athlete relationship quality in training engagement and skill development among adolescent basketball players. *Frontiers in Psychology, 16*, 1648082. https://doi.org/10.3389/fpsyg.2025.1648082

Manchado, C., Tortosa-Martínez, J., Vila, H., Ferragut, C., & Platen, P. (2013). Performance factors in women's team handball: Physical and physiological aspects—A review. *Journal of Strength and Conditioning Research, 27*(6), 1708–1719. https://doi.org/10.1519/JSC.0b013e3182891535

Massuça, L. M., Fragoso, I., & Teles, J. (2014). Attributes of top elite team-handball players. *Journal of Strength and Conditioning Research, 28*(1), 178–186. https://doi.org/10.1519/JSC.0b013e318295d50e

Michalsik, L., Bojsen-Møller, J., & Aagaard, P. (2015). Technical match characteristics and influence of body anthropometry on playing performance in male elite team handball. *Journal of Strength and Conditioning Research, 29*(2), 416–428. https://doi.org/10.1519/JSC.0000000000000595

Morgan, P. B. C., Fletcher, D., & Sarkar, M. (2019). Developing team resilience: A season-long study of psychosocial enablers and strategies in a high-level sports team. *Psychology of Sport and Exercise, 45*, 101543. https://doi.org/10.1016/j.psychsport.2019.101543

Nicholls, A. R., Levy, A. R., Carson, F., Thompson, M. A., & Perry, J. L. (2016). The applicability of self-regulation theories in sport: Goal adjustment capacities, stress appraisals, coping, and well-being among athletes. *Psychology of Sport and Exercise, 27*, 47–55. https://doi.org/10.1016/j.psychsport.2016.07.011

Pepping, G. J., & Timmermans, E. J. (2012). Oxytocin and the biopsychology of performance in team sports. *The Scientific World Journal, 2012*. https://doi.org/10.1100/2012/567363

Petiot, O., Visioli, J., & Kermarrec, G. (2024). The coach's emotional labor in sport: Lessons from a three-season collaboration with an elite handball coach. *Journal of Sport Psychology in Action, 15*(1), 44–56. https://doi.org/10.1080/21520704.2023.2166183

Phillips, K., Jowett, S., Krukowska-Burke, A., & Rhind, D. J. (2026). Building strong partnerships: Understanding the mechanisms by which quality coach–athlete relationships affect objective performance in professional cricket. *International Journal of Sports Science & Coaching, 21*(1), 19–29. https://doi.org/10.1177/17479541251371558

Pinho, A., Monteiro, D., Jacinto, M., Matos, R., Rodrigues, F., Amaro, N., Teques, P., Fonseca, T., & Antunes, R. (2024). Initial validation of the coach–athlete relationship questionnaire in a sample of Portuguese athletes. *Perceptual and Motor Skills, 131*(4), 1360–1377. https://doi.org/10.1177/00315125241254437

Prabowo, I., Pratama, A. K., & Risyanto, A. (2024). The relationship between personality and handball coach–athlete intimacy. *Indonesian Journal of Sport Management, 4*(4), 534–542.

Ramírez Muñoz, A., Vega-Díaz, M., & González-García, H. (2023). Team cohesion profiles: Influence on the development of mental skills and stress management. *Journal of Sports Science & Medicine, 22*, 637–644. https://doi.org/10.52082/jssm.2023.637

Rhind, D. J. A., & Jowett, S. (2010). Relationship maintenance strategies in the coach–athlete relationship: The development of the COMPASS model. *Journal of Applied Sport Psychology, 22*(1), 106–121. https://doi.org/10.1080/10413200903474472

Roberto de Andrade do Nascimento Junior, J., Morais Freire, G. L., Ribeiro Contreira, A., Quinaud, R. T., Jowett, S., Gonçalves, M. P., Vicentini de Oliveira, D., & Fiorese, L. (2024). Psychometric properties of the coach–athlete relationship questionnaire (CART-Q) in a sample of Brazilian youth and adult athletes. *International Journal of Sports Science & Coaching, 19*(1), 5–18. https://doi.org/10.1177/17479541231194758

Rohozneanu, D. (2024). A study concerning the men handball team UCM Reșița in the first years of the third millennium. *Studia Universitatis Babeș-Bolyai Educatio Artis Gymnasticae, 69*(3), 5–16. https://doi.org/10.24193/subbeag.69(3).17

Silva, A. S., Barreiros, A., & Fonseca, A. M. (2019). Exploring the importance of coaches in the development of the sports career in handball: The perception of athletes from higher and lower levels of success. *Cuadernos de Psicología del Deporte, 19*(1), 106–120. https://doi.org/10.6018/cpd.314221

Soto, D., García-Herrero, J. A., & Carcedo, R. J. (2021). Perception of coach according to the role of starter or substitute in the final stage of the season. *Sustainability, 13*(12), 6960. https://doi.org/10.3390/su13126960

Spear, L. P. (2013). Adolescent neurodevelopment. *Journal of Adolescent Health, 52*(2 Suppl 2), S7–S13. https://doi.org/10.1016/j.jadohealth.2012.05.006

Stillman, C. M., Esteban-Cornejo, I., Brown, B., Bender, C. M., & Erickson, K. I. (2020). Effects of exercise on brain and cognition across age groups and health states. *Trends in Neurosciences, 43*(7), 533–543. https://doi.org/10.1016/j.tins.2020.04.010

Tyshchenko, V., Lisenchuk, G., Odynets, T., Cherednichenko, I., Lytvynenko, O., Boretska, N., & Semeryak, Z. (2019). The concept of building control for certain components of the system for training handball players. *Journal of Physical Education and Sport, 19*(S4), 1380–1385. https://doi.org/10.7752/jpes.2019.s4200

Vella, S. A., Oades, L. G., & Crowe, T. P. (2013). The relationship between coach leadership, the coach–athlete relationship, team success, and the positive developmental experiences of adolescent soccer players. *Physical Education and Sport Pedagogy, 18*(5), 549–561. https://doi.org/10.1080/17408989.2012.726976

Voss, M. W., Nagamatsu, L. S., Liu-Ambrose, T. Y., & Kramer, A. F. (2011). Exercise, brain, and cognition across the life span. *Journal of Applied Physiology, 111*(5), 1505–1513. https://doi.org/10.1152/japplphysiol.00210.2011

Wagner, H., Finkenzeller, T., Würth, S., & von Duvillard, S. P. (2014). Individual and team performance in team-handball: A review. *Journal of Sports Science & Medicine, 13*(4), 808–816.

Wagstaff, C. R. D. (2014). Emotion regulation and sport performance. *Journal of Sport and Exercise Psychology, 36*(4), 401–412. https://doi.org/10.1123/jsep.2013-0257

Woods, B., & Thatcher, J. (2009). A qualitative exploration of substitutes' experiences in soccer. *The Sport Psychologist, 23*(4), 451–469. https://doi.org/10.1123/tsp.23.4.451

Woolliams, D., Spencer, K., Walters, S., & Krägeloh, C. (2021). Resolving uncertainties of the factor structures of the coach–athlete relationship questionnaire (CART-Q). *Australian Journal of Psychology, 73*(2), 212–222. https://doi.org/10.1080/00049530.2021.1882275

Yang, S. X., & Jowett, S. (2012). Psychometric properties of the coach–athlete relationship questionnaire (CART-Q) in seven countries. *Psychology of Sport and Exercise, 13*(1), 36–43. https://doi.org/10.1016/j.psychsport.2011.07.010

Zhang, R., & Rhim, Y.-T. (2024). The effect of coach–athlete relationships on motor behaviour in college athletes—Mediating effects of psychological needs. *Behavioral Sciences, 14*(7), 579. https://doi.org/10.3390/bs14070579