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Original Article

Tactical knowledge and visual search analysis of female handball athletes from different age groups

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Abstract
ProblemStatement: Performance in team sports depends on athletes' ability to use their vision to scan the environment for relevant information and to make decisions based on this information. Experience and tactical knowledge seem to affect the quality of the visual search. However, the literature is scarce in the investigation of the relationship between these components, especially in young handball athletes. **Purpose:**The present study aimed to compare the declarative tactical knowledge, number of visual fixations, and fixation duration of female handball athletes from under-17 (U-17) and under-14 (U-14) age groups.**Approach**:Twelve female school handball players aged between 12 and 17 years old were divided into two groups consisting of six volunteers each: U-17 (15.83 ± 0.90) and U-14 (13.29 ± 0.70 years). Athletes' tactical knowledge was assessed using the declarative tactical knowledge (DTK). For this purpose, 15 scenes from videos of handball matches were shown to the athletes, who had to verbally declare what decision the player with the ball should make and justify it, from a given moment when the scene was paused and then disappeared. During this test, the athletes' visual search was registered as the number and duration of visual fixations, using a stationary eye-tracking system. Comparisons between groups were performed using independent t-tests. Effect sizes were reported as Cohens'd.**Results**: The DTK scores were higher in U-17 group athletes compared to the U-14 group athletes(t (10) = 2.307; p = 0.04; d = 1.33). No differences were found in the comparison of the number of fixations(t (10) = 1,948; p = 0.08; d = 1.12) and fixation duration (t (10) = -2.140; p = 0.06; d= 1.23)between groups.**Conclusions:**The U-17 handball athletes had higher DTK than the U-14 group. This highlights a possible pattern of this variable according to age groups and reinforces the importance of enhancing tactical knowledge during the training process. Further research is warranted to investigate the relationship between DTK and visual search in athletes with different age groups.
Key Words: **Decision-making, Relevant Information, Perception, Experience, Training**.

Introduction

Handball is an Olympic sport in which teams work collectively to overcome opponents and score goals. Performance in handball depends, among other factors, on the athletes' ability to use their vision to scan the environment for relevant information (Schorer et al., 2018;Williams et al., 2004)and make decisions (Gréhaigne & Godbout, 1995) in order to solve constraints that emerge during the game (e.g., overcoming the defense). These solutions depend on the athletes' tactical knowledge, which underlies visual perception and decision-making(McPherson, 1994; Poolton et al., 2005).

Tactical knowledge is essential for team sports performance (Gréhaigne et al., 2001)because it favors fast selection of relevant information that assists athletes in making decisions (Raab, 2015; Tenenbaum & Filho, 2017). Athletes will employ this information to understand the game, by making decisions in game situations that require a rapid and accurate response. One way to access athletes' tactical knowledge is through the declarative tactical knowledge (DTK). DTK refers to the athlete's ability to declare (verbally and / or in writing) "what to do," that is, the decision to be made, and to justify it (French & Thomas, 1987; Gréhaigne & Godbout, 1995; McPherson, 1994). Developing DTK during training sessions (e.g., through discussions on how to solve game constraints) facilitates athletes' reflection about the relevant signs perceived and the decisions made in each game situation. Indeed, McPherson (1994)and Williams and Ericsson (2005) indicate the interaction between tactical and cognitive features. Furthermore, evidence indicates that both reflecting through DTK(Araújo et al., 2011) and increased sports experience(Roca et al., 2011) improves players' perception.

The periodic evaluation of cognitive processes underlying tactical knowledge, such as perception(de Oliveira et al., 2009), benefits coaches in the planning of the teaching-learning-training process (Amaral et al., 2018). The relationship between DTK and visual perception helps to understand the progression of visual

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perception (Tenenbaum, 2003) and highlights the interaction between perception, decision-making, and experience (de Oliveira et al., 2009).

Sports performance depends on the relationship between skills and visual perception (Schoreret al., 2018). In handball, for example, the center back perceives the pivot unmarked (visual perception), and then decides (decision-making) to pass the ball to him (motor skill). In order to measure visual information pick-up in sports tasks, researchers as sass the participants' visual search (Kredel et al., 2017).Visual search analysis provides information on how the visual system extracts information from the environment (Afonso & Mesquita, 2013) and indicates the perceptive strategy employed by the athlete(Castro et al., 2017; Vila-Maldonado et al., 2012).Specific knowledge and experience are expected to enhance visual search strategies(Arroyo, 2012). This knowledge guides athletes in priory experienced contexts (Williams et al., 1999), such as training and competitions. Several studies focusing on visual search strategies used the number of visual fixations (e.g., on the ball or in a specific player/area) and fixation duration (Gorman et al., 2015; Natsuhara et al., 2020; Vaeyens et al., 2007)as variables.

The interaction between visual perception and decision-makings stronger in more experienced players and in players with higher tactical knowledge(Oliveira et al., 2009). Nevertheless, more skilled players do not have superior visual skills; instead, they have enhanced cognitive knowledge bases that allow them to be more efficient at identifying and interpreting perceptual information than less skilled peers (Helsen&Starkes, 1999; Vaeyens et al., 2007; Williams & Grant, 1999). This knowledge base can be stimulated through tactical training, since the practice settings and the level of instruction provided may also influence decision-making skills (Vaeyens et al., 2007). Therefore, a more effective visual search is expected in more experienced players, as they have experienced a greater range of game situations acquired during training and competitions.

Previous research indicated that expert athletes extract relevant information from the environment relying on fewer but longer visual fixations to more important areas, compared to novices (for an overview, see; Gegenfurtner et al., 2011; Kredel et al., 2017; Mann et al., 2007). On the other hand, in a recent review, researchers reported that this pattern might be different, especially if we consider the results of studies published in recent years (Klostermann & Moeinirad, 2020). These authors found that most studies published in recent years showed large variance and found non-significant results in terms of the number and duration of fixation. They also found a reduction in the effect size until practically null values in the number of fixations, and an increase in the effect size for fixation duration, but this effect was small(Klostermann&Moeinirad, 2020). The different results found in the visual search studies are influenced by the variety of methods applied (Raab & Johnson, 2007), as well as the complexity of the tasks used in these studies (Williams et al., 1999), the number of players involved in the situations viewed (Martell & Vickers, 2004; Vaeyens et al., 2007), and the type of response (e.g., verbal responses only or verbal and motor response) (Klostermann & Moeinirad, 2020). In line with the aforementioned notions,Vaeyens et al. (2007) stated that athletes might change their visual search strategy as a function of the task constraints. These authors found differences when comparing the visual search in offensive situations with less (2 × 1,3 × 1) and more players (4 × 3, 5 × 3). They suggested that as the number of players involved in the task increases, more response options emerge, which enhances the difficulty and complexity of information processing. These differences were demonstrated by the increase in the number of fix actions and reduction of the fixation duration as the number of players in the game situations increased.

Although we found many visual search studies in sport contexts (Marques et al., 2018), we were only able to find three studies that addressed this topic in handball, which is troublesome, as this knowledge may be relevant in developing methods focused on handball tactical training. Raab and Johnson (2007) evaluated the visual search and the DTK in handball athletes with different experiences on four occasions (one every six months), over a period of two years. Participants continued to train in their teams throughout the study. The authors found higher DTK in more experienced athletes and a reduction in the number and duration of fixations in all groups, which indicates that experts required fewer fixations (Raab & Johnson, 2007). Rivilla-García et al. (2013) investigated the visual search in elite and amateur handball goalkeepers. They found that elite goalkeepers performed more fixations than the amateurs did. Similarly,Loffing et al. (2015) investigated the visual search in elite and non-goalkeepers, but they did not find differences in the number or fixation duration between groups. In addition, most studies have compared experts with novices (Vaeyens et al., 2007; Williams et al., 2002) or with intermediates (Klostermann & Moeinirad, 2020), but the investigation of visual search along with DTK is still scarce.Machado et al. (2017)stated that few studies have evaluated differences and the development of perceptual-cognitive skills among different age groups. In this sense, they studied the visual search in different age groups in soccer. More fixations were found in free space in U-13 athletes than in U-15 and U17 athletes, but all three groups spent a similar time fixating on the different locations in the video test. The lack of studies pointed out by Machado et al. (2017)is true, particularly when considering handball.Roca et al. (2012) highlight the importance of understanding the perceptual-cognitive skills of skilled youth players, since these variables might influence the extraction and processing of information from game-related situations (Machado et al., 2017).

The quality of training and coaches' interventions can influence athletes' decision-making(Vaeyens et al., 2007; Ward et al., 2004). Stimulating athletes' tactical knowledge, for example, is an effective way to build

the interaction between visual perception and decision-making(de Oliveira et al., 2009). Combining the DTK with eye-tracking analysis may help in understanding sports performance (Afonso & Mesquita, 2013; Ericsson & Williams, 2007), since visual perception and tactical knowledge are important components of the decision-making process. Therefore, investigating visual search and DTK in different age groups can help to understand these variables according to the progression of age groups, as well as contribute to coaches' planning of the teaching-learning-training process, such as the search for relevant stimuli in time-restricted situations. This study aimed to compare the DTK, number of visual fixations, and fixation duration of female handball athletes from under-17 (U-17) and under-14 (U-14) age groups. We hypothesized that U-17 athletes would present higher declarative tactical knowledge than U-14 athletes and that the number of visual fixations and the duration of fixations would be similar across groups.

Material Methods

Participants

The sample was defined by convenience and consisted of 12 female school handball players (n = 12), aged between 12 and 17 years, divided into two groups consisting of six volunteers each: U-17 (16.21 ± 0.89 years) and U-14 (13.59 ± 0.92 years), corresponding to the respective age categories of school handball according to Comitê Olímpico do Brasil (COB).The experience time of the two groups was considered similar, since the Mann-Whitney U test did not report significant differences between them (U= 6.500; p = 0.06; r = 0.54).Participants were registered in the school federations of the state of Minas Gerais, Brazil. All volunteers had normal orcorrected-to-normal vision. Table 1provides further sample characterization. The local Ethics and Research Committee approved this research (CAAE: 86435518.6.0000.5149).

Table 1. Means and standard deviations of the sample characteristics.

Group	Practice and Competition experience (in years)	Training sessions duration (in minutes)	Number of weekly training sessions
U-14	3.07± 0.48	130 ± 22.36	3.00 ± 0.58
U-17	4.17 ± 1.11	125 ±26.93	3.16 ± 0.37

Note: U-17= under 17 group; U-14 = under 14 group.

Procedures

Data collection was carried out in two phases: 1) participants filled out a questionnaire, to provide information such as time of experience in the sport, participation in competitions, time of weekly practice and training sessions, and2) data collection from DTK and Visual Search was performed individually. For this purpose, 15 scenes from videos of handball matches were used, similar to Raab and Johnson (2007). Participants watched each scene and verbally declared (as quickly and accurately as possible) from the scene freezing, what would be the appropriate decision as if they were the player in possession of the ball (how/who to pass, throw, feint, among others) and then justified this decision. Visual search data were collected while participants watched the scenes from handball matches that were displayed on the monitor of the equipment that registered the visual search. Data collection took place in a room with a comfortable adjustable seat and the absence of external interference, in the presence of one of the researchers.

Initially, the eye tracker was calibrated by asking participants to fixate on targets presented on a screen across a nine-point grid. This procedure occurred three times, before and after the familiarization, and once again immediately before the beginning of the test, to ensure the accuracy of the procedure. During data collection, each participant remained seated in a chair positioned in front (approximately 60cm away) of a computer screen and with their eyes aligned with it. Then, the researcher emphasized the importance of avoiding sudden movements with the head to prevent the loss of the device's calibration. After calibration, each participant received the instructions and went through the familiarization process, which consisted of watching and responding to three game scenes (Raab& Johnson, 2007) belonging to the same competition from which the evaluation scenes were selected. Finally, if the participants had no doubts, DTK data collection would begin. All participants watched the same scenes, in the same order of presentation. The entire data collection lasted approximately 30 min for each participant.

Instruments

DTK assessment

The DTK measurement protocol consisted of 15 handball game scenes extracted from male and female world championships and watched from a third person perspective. The scenes were selected from an initial sample of 50 scenes following the psychometric procedures suggested by Pasquali (2010). These scenes went through content validation procedures -content validity coefficient (CVC), by the evaluation of three experts for

the following items: image clarity, practical relevance, and theoretical relevance(Aburachid & Greco, 2011). Results were interpreted according to Hernandez, and 15 scenes, which obtained the highest scores in the three CVC items (0.86, 0.86, and 0.87, respectively) were selected.

Each scene lasted between four and nine seconds. The filming angles allowed participants to visualize all the athletes involved in the game situations (6 × 6 + team goalkeeper in defense). Participants received specific instructions regarding data collection and went through familiarization. At a certain time, the scene would freeze and remain paused for three seconds. After that, the scene was occluded. Once the scene was paused, participants had to declare (as quickly as possible) what the player with the ball should do and justify this decision. Verbal responses were recorded using voice recorder computer software (Microsoft Corporation version 10.1510.12110.0).

The responses provided by the participants were compared to the answer template, elaborated by the three experts, who had more than 10 years of national and/or international experience (21.00 ±6.48)as coaches in handball. These responses received scores ranging from zero to five points (75 points in total) according to the following criteria: zero points if the decision and the justification were wrong; one point if the decision was correct, but the justification was wrong; two points if the decision was wrong and the justification was partially correct; three points if the decision was correct and the justification was partially correct; four points if the decision was wrong and the justification was correct; and five points if both decision and justification were correct.

Visual search

Visual search was performed using the Eye-Tracking SMI RED500® system, from Senso Motoric Instruments (SMI). This is a screen-based non-invasive equipment integrated with a 22" monitor, and recorded the mean number of visual fixations, which were the number of times that the volunteer's eyes remained fixed in a spot within a tolerance of movements up to 3º for a period greater than 99 ms (Panchuk & Vickers, 2006; Vickers & Williams, 2017).Mean fixation duration was also recorded, measured in milliseconds (ms) (Roca et al., 2011; Sáez-Gallego et al., 2013). The stationary eye-tracking devices favor appropriate experimental control (Kredel et al., 2017), and facilitate the maintenance of the stable position of the head by the participants, since they perform their tasks seated in front of a computer screen. They also make recalibrationsless frequent and more accurate than mobile devices (Kredel et al., 2017).

Data analysis

The number and duration of visual fixations along with the points obtained in the DTK measurement are described as mean and standard deviation values. Shapiro-Wilk and Levene's tests were used to confirm the normal distribution and homogeneity of variances. Comparisons between groups were performed using independent t-tests. Effect sizes were reported as Cohen's d, classified as small (d = 0.2), medium (d = 0.5), or large (d = 0.8) (Ferguson, 2009). The level of significance was set at 5%. Statistical analyses were performed using IBM SPSS Statistics Version 19.0.

Results

Table 2describes the results from the participants' DTK and visual search. The independent t-test showed significant differences between groups for the DTK. The U-17 group achieved a higher score than the U-14 group and a large effect size (t(10) = 2.307; p = 0.04; d = 1.33). However, there were no differences in the number of fixations (t(10) = 1,948; p = 0.08; d = 1.12) and fixation duration (t(10) = -2.140; p = 0.06; d= 1.23). Although we did not fi nd significant differences, Cohen's d reported a large effect size for both visual search variables.

Table2. Mean and standard deviation DTK and visual search values.

Group	DTK score (points)	Number of fixations	Fixations duration (milliseconds)
U-14	35.50 ± 8.19[a]	222.33 ± 22.70	387.83 ± 67.95
U-17	46.00 ± 7.56	249.16 ± 24.95	308.83 ± 59.65

Note: a = different from U-17

Discussion

This study aimed to compare the DTK, number, and duration of visual fixations in U-14 and U-17 female school handball players. We hypothesized that the DTK would be higher in the U-17 group and that the number and duration of fixations would be similar between groups. Our findings confirmed all the hypotheses of this research, since the DTK was higher in U-17, and no differences were found in the number and duration of fixations. These findings contribute to the understanding of the development of DTK and the visual search throughout the youth age groups in handball.

The tactical knowledge analysis showed that the U-17 athletes had higher DTK scores than the U-14 athletes did. This finding is in line with previous research that compared tactical knowledge in athletes of different ages (Raab& Johnson, 2007). These authors indicate that the level of experience influences option generation in the decision-making process, and the time needed for these options to come to mind. Thus, more experienced individuals would make better decisions in less time, which would allow them more time to perform a motor action, for instance. Although our groups had similar experiences, the quality of the practice/competitive experience, as well coaches' interventions may also contribute to the decision-making process (Ward et al., 2004), and for the higher DTK found in U-17 athletes. Vaeyens et al. (2007) investigated decision making in soccer players aged 13.0 to 15.8 years with similar experience times. These authors compared players' decision-making according to their type of experience: international, national, and regional-level players and non-players. The results showed that, in general, international and national-level players showed better decisions than regional-level players and non-players, which suggests that the specificity of practice and competition environments influences athletes' decision-making. The amount of exposure to a specific context enhances the development of specific knowledge structures, which favors decision-making processes in more experienced players (Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995; Vaeyens et al., 2007).Since the quality of the practice and coaches' interventions influence decision making(Vaeyens et al., 2007; Ward et al., 2004), and that handball specific knowledge may be lower in younger players (Ford et al., 2009; Roca et al., 2012), we speculate that U-17 athletes in our study may have experienced specific training settings that emphasized DTK development. In fact, it has been proposed that as training complexity increases, explicit learning should be emphasized (Raab, 2003). Explicit learning, in turn, stimulates deliberative decision-making (Raab, 2015; Raab et al., 2009) and collaborates to increase DTK. Since the U-17 is a category where the complexity and the specificity of the formal game are prioritized, these athletes may have experienced more complex stimuli and explicit learning. This may contribute to intentional action rule creation, which guides decision-making and consequently enhances DTK. Nevertheless, this hypothesis is speculative, since we did not access the coaches' instructions in the training process applied to the participants of this study. This information could confirm our assumption about possible differences in the age groups analyzed, and this hypothesis could be tested in future approaches.

Regarding the visual search, no differences were found in the number and fixation duration between the groups, which confirms our initial hypothesis and is in line with Klostermann and Moeinirad (2020). These authors also suggested that differences are even less evident when comparing experts with intermediate athletes. In our study, even though we compared players from different age groups, the experience time was similar between groups, which may indicate that the number and duration of fixations may not have been sensitive enough to differentiate athletes from different age groups, which is in line with Machado et al.(2017).

Although no differences were found in the number and duration of fixations, a large effect size was found for these variables, which is different from what Brams et al. (2019) and Klostermann&Moeinirad (2020) found. A possible explanation is that U-17 athletes would have been able to understand and interpret information extracted during fixations in less time (Ryu et al., 2013; Williams et al., 2004) than U-14 athletes did. This may occur because U-17 athletes had more specific knowledge available (Arroyo, 2012; Ericsson et al., 2000), which was acquired through training and game situations, contributing to the effective extraction and processing of relevant information (Roca et al., 2018; Vítor de Assis et al., 2020). Furthermore, visual search can change depending on the task constraints (Klostermann & Moeinirad, 2020; Williams et al., 2004). Vaeyens et al. (2007) suggested that the number of players involved in the game scenes may lead to more visual fixations of smaller durations, indicating a broader attention focus (Roca et al., 2018),as there are more possibilities for interactions between players in the scenes, which increases the complexity of the task. In this research, all the game scenes viewed by participants comprised6 × 6 + goalkeeper situations. Thus, we speculate that the U-17 group may have made more visual fixations of smaller duration because they were more effective in identifying the relevant signs that guide decision-making and in employing a wider attention focus. This may have allowed more information to be extracted and processed(Furley et al., 2010; Roca et al., 2018),possibly due to the specific knowledge(Arroyo, 2012; Ericsson et al., 2000)accumulated during training and competitions.

This study has some limitations, such as the small sample size. This suggests caution when interpreting the results. Another limitation was not analyzing the fixation location when assessing players' visual search. This limitation implies a narrow understanding of the visual search strategies and their relationship with the athletes' levels of tactical knowledge and age groups. Although laboratory studies with stationary eye-tracking devices provide appropriate experimental control(Kredel et al., 2017), and verbal responses in video-based situations are commonly used in the literature (Klostermann & Moeinirad, 2020; Vítor de Assis et al., 2020), future research should also study visual search in perception-action coupling (Klostermann & Moeinirad, 2020) in real game situations, as an effort to make the results more ecologically valid (Kredel et al., 2017).Finally, since number and fixation duration did not differ between groups, future studies should investigate other variables, such as pupil dilatation, which may indicate the level of cognitive effort during the task (van der Wel & van Steenbergen, 2018).

In general, although the visual search was similar in the U-14 and U-17 groups, the DTK was higher in the latter, even with similar visual strategies, the U-17 group made more adequate responses at the DTK assessment. This reinforces the importance of tactical knowledge in the extraction of visual information that is relevant to decision-making, since the interaction between visual perception and decision-making becomes stronger as tactical knowledge increases(de Oliveira et al., 2009).Tactical knowledge is essential for sports performance (Gréhaigne et al., 2001). Thus, coaches should emphasize this aspect when planning training sessions, including stimuli to explicitly observe and create solutions for tactical problems, which helps players to add significance to game situations (e.g., if the left wing defender defends the left back player, this player should pass to the wing player, as the wing player is now unmarked) in order to guide players toward appropriate decisions.

Conclusion

Overall, we conclude that the number and fixation durations were the same between the two groups, and the U-17 handball athletes had higher DTK than the U-14 group. This highlights a possible pattern of this variable according to age groups, as well as possible differences in training settings that emphasized DTK development in the U-17 group.U-17 athletes may also have been able to extract and process relevant information more effectively than U-14 athletes did, due to specific knowledge acquired throughout training and game situations. Our results reinforces the importance of coaches enhancing tactical knowledge during the training process, which favors the perception of relevant signs in order to make appropriate decisions. Further research is warranted to investigate visual search patterns, as well as the relationship between DTK and visual search in athletes from different age groups.

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