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Tactical Knowledge, Decision-Making, and Brain Activation Among Volleyball Coaches of Varied Experience

Gustavo C. Costa[1], Henrique O. Castro[2,3], Isabel R. Mesquita[4], José Afonso[4], Guilherme M. Lage[5], Herbert Ugrinowitsch[5], Gibson M. Praça[3], and Pablo J. Greco[3]

Abstract

This study compared decision-making (DM) of experienced and novice volleyball coaches while measuring blood flow brain activation with functional near-infrared spectroscopy. We sampled 34 coaches (mean [*M*] age of 32.5, standard deviation [*SD*] = 9.4 years) divided into two experience groups: (a) novice ($M = 2.8$, $SD = 1.9$ years) and (b) experienced ($M = 19$, $SD = 7.2$ years). We evaluated coaches' DM through their responses to video-based scenarios of attacks performed in the extremities of the net within the Declarative Tactical Knowledge Test in Volleyball. We

[1]Faculty of Physical Education and Dance, Sport Pedagogy Laboratory, Federal Universidade de Goiás, Brazil
[2]Physical Education School, Group of Studies in Physical Education and Sports, Centro Universitario Estácio Brasília, Brazil
[3]Physical Education School, Center of Studies in Cognition and Action, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
[4]Center for Research, Training, Innovation, and Intervention in Sport, Faculty of Sport, Universidade do Porto, Portugal
[5]Physical Education School, Group of Studies in Motor Development and Learning, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Corresponding Author:
Gustavo C. Costa, Faculdade de Educação Física e Dança, Universidade Federal de Goiás, Avenida Esperança s/n, Campus Samambaia, CEP 74690-900, Goiânia, Goiás, Brazil.
Email: conti02@hotmail.com

found no significant DM differences between the two groups of coaches ($p = .063$), though novice (vs. experienced) coaches showed greater blood flow of the prefrontal cortex when visualizing the game situations. While experienced coaches may have better prefrontal neural efficiency during DM in these situations, further research is needed to evaluate other cerebral areas; since blood flow is an indirect measure of neural efficiency, and activity in remaining cortical components was unknown in this study.

Keywords
coaching experience, cerebral blood flow, tactics, volleyball

Introduction

Decision-making (DM) refers to the selection of a response in an environment of multiple possible responses (Hastie, 2001; Sanfey, 2007). It requires various cognitive processes to choose a course and means of action (Williams, 2009). Such cognitive processes, including perception, attention, anticipation, memory, thinking, and intelligence, are implemented in team sports to solve problems that emerge from game situations (Raab & Gigerenzer, 2005). In team sports, the ability to undertake effective decisions depends on having the appropriate orientation for the relevant task indicators (Laureiro-Martínez, Brusoni, Canessa, & Zollo, 2015). In addition, DM in team sports occurs under temporal limitations (Raab, 2012, 2014), meaning that both knowledge and ability are needed for quick extractions of relevant game-related information in search of a best solution (Gréhaigne, Godbout, & Bouthier, 2001). In this context, varied cognitive abilities help interpret and assign meaning to events (Banks & Krajicek, 1991). Previous experience guides the perceptive processes (Stokes, Atherton, Patai, & Nobre, 2012), as prior knowledge of the relevant environment, object, and task purpose contributes to high DM performance (Giesbrecht, Sy, & Guerin, 2013; Hollingworth, 2009; Mack & Eckstein, 2011).

Sports DM research has typically focused on athletes as participants and has shown that, for athletes, greater experience promotes (a) deeper task knowledge, (b) better use of available information, (c) more efficient visual search patterns, (d) more effective information coding and retrieval, and (e) faster and better DM (Abernethy, Baker, & Côté, 2005; Liu, 2015; Mann, Williams, Ward, & Janelle, 2007; Ward & Williams, 2003). A recent investigation using noninvasive blood flow analysis showed that activation of the prefrontal cortex was associated with allocating visuospatial attention to critical aspects of the task (Mihara, Miyai, Hatakenaka, Kubota, & Sakoda, 2008). Thus, in addition to behavioral aspects of decisional expertise, there may be a relationship between the decision maker's experience and his/her cerebral blood flow during problem resolution (Wolf et al., 2014). Consistently, research participants with more experience have shown lower cerebral activation of the prefrontal region, as would be predicted by the neural efficiency hypothesis (Chang et al., 2011; Nussbaumer, Grabner, & Stern, 2015; Wolf et al., 2014). Neural efficiency has been observed in prior research in several different cortical areas. For example, detection of a target or relevant visual signal leads to inhibition of the temporal–parietal junction, preventing inappropriate changes in attention and misdirected attention to irrelevant stimuli (Shulman, Astafiev, Mcavoy, d'Avossa, & Corbetta, 2007). In this context, there is a reduction in the use of brain resources in frontal and other regions to improve task performance (Koshino, Minamoto, Yaoi, Osaka, & Osaka, 2014).

Although past research has shown differences in athletes' brain activation based on their levels of expertise (Abreu et al., 2012; Wright, Bishop, Jackson, & Abernethy, 2013), we are unaware of parallel investigations with coaches as participants. Considering that specific knowledge of a given sport directs DM, we compared volleyball coaches' DM, as differentiated by the coaches' experience levels. For dependent measures, we assessed DM with a test of declarative sport-specific tactical knowledge in which there were opportunities for coaches to demonstrate tactical knowledge through responses to video-based game scenarios, and we measured brain activation through cortical blood flow with functional near-infrared spectroscopy (fNIRS). Following prior research with athletes, we hypothesized that experienced coaches would have better DM and lower brain activation than novice coaches.

Method

Participants

Volunteer participants were 34 volleyball coaches with a mean age of 32.5 years (standard deviation [SD] = 9.4). All coaches were recruited according to intentional and convenience sampling (Etikan, Musa, & Alkassim, 2016). To define their professional experience, we used a criterion of 10 years to classify coaches as either experienced (>10 years) or novice (<10 years; Mesquita, Borges, Rosado, & de Souza, 2011). Novice coaches averaged 2.8 years of experience ($SD = 1.9$), while experienced coaches averaged 19 years ($SD = 7.2$). Both coaching groups had a similar number of years of practice as volleyball athletes; novice coaches averaged 7.1 years as athletes ($SD = 5.4$), while experienced coaches averaged 6.4 years ($SD = 5.4$). The inclusion criterion for study participation was normal vision with no strabismus or other vision problems. The research protocol was authorized by the university research ethics committee under COEP number 821.295 and was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants wrote and signed statements of informed consent before starting the experiment.

Instruments

Volleyball Declarative Tactical Knowledge Test. From the *Volleyball Declarative Tactical Knowledge Test* (TCTD: Vb), we selected nine scenes containing End-Extremity Attack (EA) situations. The TCTD: Vb was originally published in Portuguese (Costa, Castro, Cabral, Morales, & Greco, 2016), with values of 1.00 for clarity of the image, 0.83 for practical relevance, 0.81 for the representativeness of the item, 1.00 for a DM, and a total coefficient of content validation (CVC) of 0.92 for validity. The reliability was 1.00 for all items. These videotaped scenes lasted from 4–6 seconds and were filmed from the top perspective from a distance of about 7–9 meters from the court. This location provided the observer with a full view of the court and depth perception of the different situations. During the test, the response time was five seconds, and, between the different video clips, there were 15 seconds without visual stimulation.

Functional near-infrared spectroscopy. fNIRS uses infrared light to monitor tissue noninvasively. It allows for hemodynamic analysis of oxidative metabolism in the spectral range of 600–1,000 nm. The difference in absorption spectra of oxygenated and deoxygenated hemoglobin (O_2Hb and HHb, respectively) allows for the independent measurement of the concentrations of these two proteins and the derivation of physiologically relevant parameters such as total hemoglobin concentration (total $HB = HHb + O_2Hb$; Torricelli et al., 2014). To measure changes in oxyhemoglobin and deoxyhemoglobin, the brain is illuminated with two different wavelengths of infrared light (Kopton & Kenning, 2014). Increases in O_2Hb and the concomitant decrease in HHb reflect an increase in local arteriolar vasodilation which generates an increase in local cerebral blood flow (Ferrari & Quaresima, 2012). To evaluate the changes in O_2Hb, HHb, and total Hb concentrations in the prefrontal cortex, we used the configuration described in Figure 1, chosen on the basis of the manufacturer's indications (NIRx Medical Technologies).

We performed fNIRS data analysis using two preprocessing methods: artifact movement correction and high- and low-pass filtering (to eliminate respiration, heartbeats, and leads; Piper et al., 2014).

Data Collection

We performed the test in a comfortable low-light environment with no attempts to standardize or record the temperature of the environment, time of day, or the volunteers' previous meals. After positioning the NIRSport cap, participants were instructed on how to complete the TCTD: Vb. They were then seated in front of the computer to watch the nine scenes containing the extremity attack situations. In the TCTD: Vb, the EA scenes start from the volleyball serve and proceed through reception and lifting before pausing at the time of the attack. At the end of each video scene, possible answers appeared on the screen for five seconds.

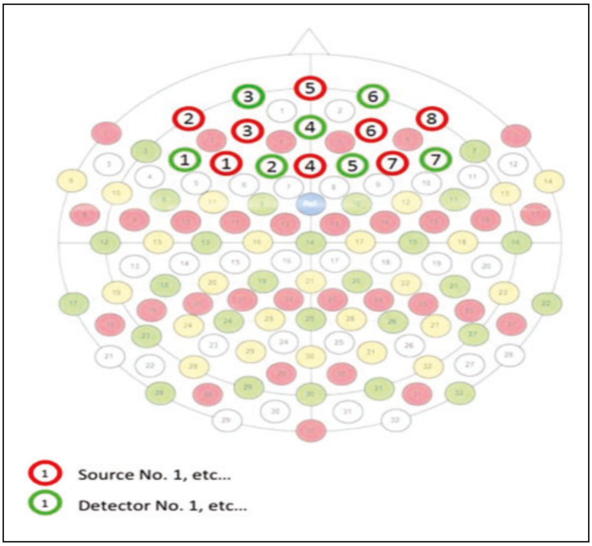

Figure 1. Distribution of NIRSport sources and detectors. Source: NIRx Medical Technologies.

Response possibilities were "crosscourt attack," "parallel attack," "attack exploring the block," and "tip." These options were validated as the only possibilities to obtain the point, as they are mutually exclusive and exhaustive and were previously validated within the TCTD: Vb template (Costa et al., 2016).

The test was multiple choice because pilot studies have shown that the NIRS signal is different for movement or speech. The TCTD: Vb was created and validated based on an analysis of data obtained from five coaches from the Brazilian Volleyball team, all with over 10 years of experience. These coaches indicated the sequence of possibilities, and we considered only the situations where the best response (option pointed out by the coaches) converged with attacker's type of point-gaining attack. At the moment of validation, the experts brainstormed the response options for each scenario from the best to the worst option for each scenario. In the EA situations, the best option was scored with four points, the second with three, the third with two, and the fourth with one point. At the end of the test, points were summed for each participant and used as a measure of DM quality, with a maximum score of 36 points.

Statistical Procedures

Data obtained by fNIRS were analyzed using the NIRSlab software, using the statistical parametric procedure mapping (SPM) Level 2. As some channels may

Table 1. Comparison Between Novice and Experienced Coaches in TCTD: EA Vb.

Attack in the extremities of the net	Novice coaches Mean ± *SD*	Experienced coaches Mean ± *SD*	*p*	95% Confidence interval	
				Lower	Upper
DM score	27.10 ± 4.01	29.50 ± 3.32	.063	−4.93	0.139

Note. DM = decision-making; EA = End-Extremity Attack; TCTD: Vb: Volleyball Declarative Tactical Knowledge Test; *SD* = standard deviation.

present artifacts, we calculated the difference in cerebral activation of each volunteer in relation to their resting state, creating a specific reading for each volunteer. In this context, inconsistencies in the comparisons between groups were limited, and it was possible to analyze the cerebral behavior during the coaches viewing and DM process. To perform multiple post hoc comparisons between the 20 channels, we used a Bonferroni post hoc correction. This implies that the value of p was adapted to the number of correlations performed (Kopton & Kenning, 2014). For these analyses, we adopted an alpha value of $p < .05$. We did not analyze the magnitude of the effect because the software used does not have this capability, and we were unable to export the data systematically. We acknowledge this issue as a limitation of our study.

Results

In this section, we describe DM results from the declarative tactical knowledge test, and then the brain activation analysis, with findings grouped according to participants' coaching experience, that is, all data for the novice coach group, followed by all data for the experienced coach group.

First, regarding DM, an inferential analysis of results from the TCTD: Vb showed no significant DM differences between the two experience-based groups of coaches. These results are shown in Table 1.

Regarding brain activation as measured by fNIRS, there were changes in cerebral oxygenation (Figures 2 to 5) for the novice coaches but not for the experienced coaches. It should be emphasized that the analysis of O_2Hb and HHb occurred by comparing concentrations at a resting state with concentrations at the moment participants analyzed the ECT of EA situations of the TCTD: Vb. None of the groups presented significant variation in the concentration of HHb in the analysis of the situations of the TCTD: Vb. For novice coaches, the concentration of O_2Hb and total Hb increased during the coaches' observations of the EA situations (Figure 1). In addition, there was a reduction in concentration of O_2Hb and total Hb during information processing and the coaches' selections of a response (Figure 2). The most intense increases in O_2Hb (Figure 2(a)) were observed around the Frontal-Antero-Frontal FAF1 and

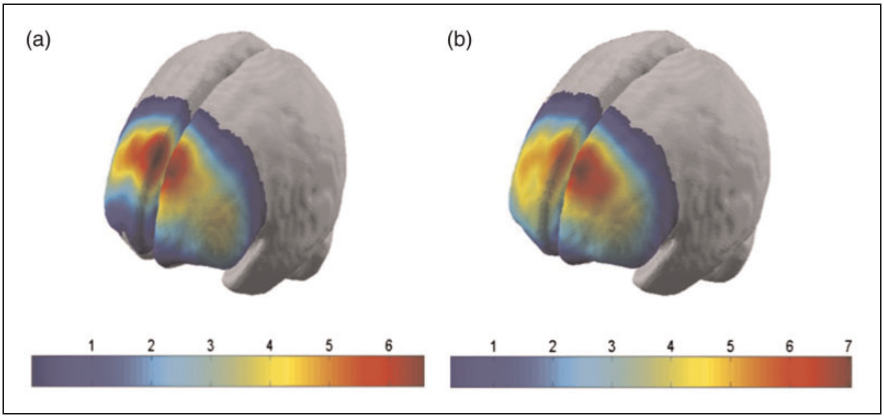

Figure 2. Increased concentration of O_2Hb and total Hb with novice coaches during the observation of EA situations. (a) Concentration of O_2Hb and (b) concentration of total Hb.

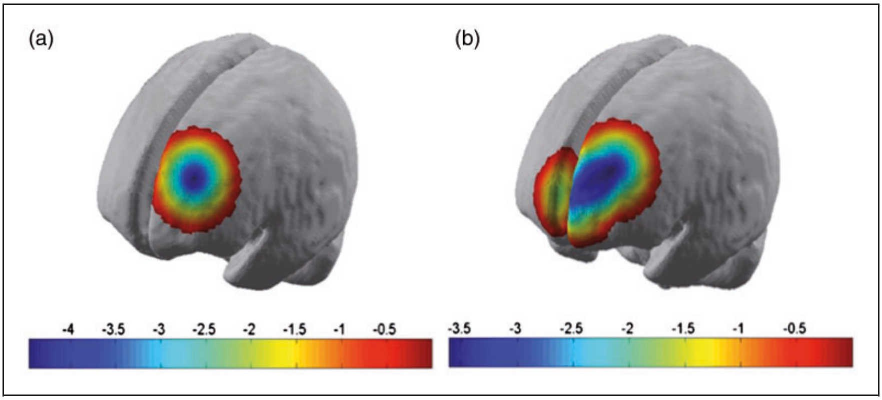

Figure 3. Reduced concentration of O_2Hb and total Hb with novice coaches during the decision-making and selection of the answers to the EA situations. (a) Concentration of O_2Hb and (b) concentration of total Hb.

FAF2 positions, as identified by the reddish coloration and values of t higher than 6.0, $p < .0025$, as well as around the Antero-Frontal (AFz), FAF1, and FAF2 positions (Figure 2(b)), where values for t were higher than 7.0, $p < .0025$.

When analyzing the novice coaches' information processing and response selections related to EA situations (Figure 3), positions FAF5, FAF1, AF3, and F1 reflected an intense reduction (Figure 3(a)) in O_2Hb, identified by the bluish coloration and values for t less than -3.5, $p < .0025$, as well as an intense

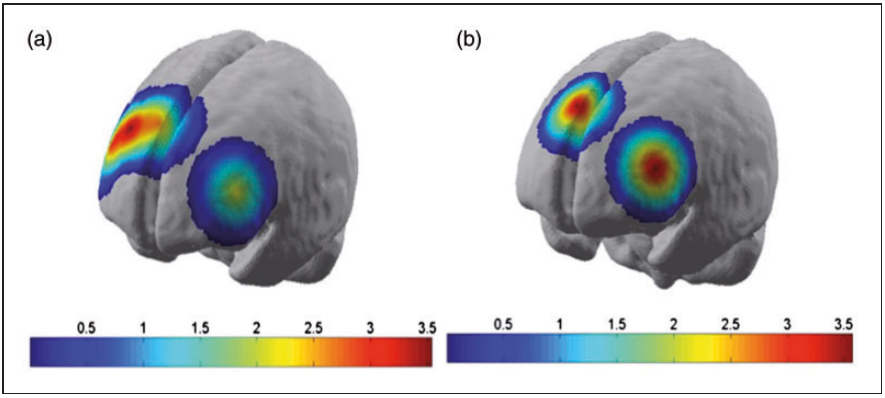

Figure 4. Increased concentration of O_2Hb and total Hb with experienced coaches during the observation of EA situations. (a) Concentration of O_2Hb and (b) concentration of total Hb.

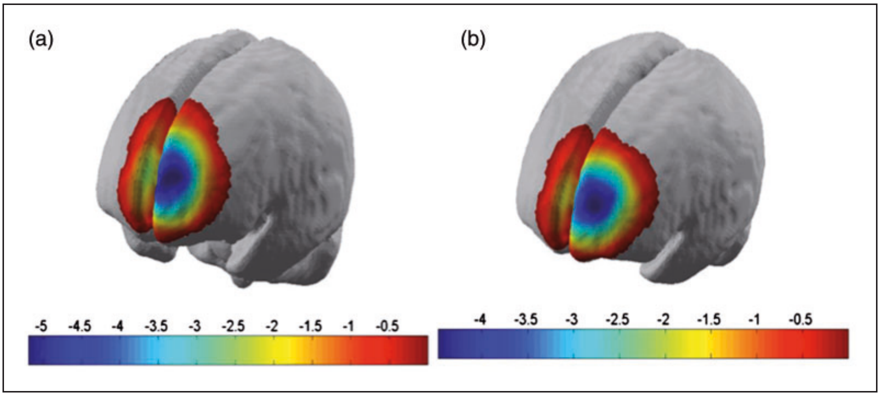

Figure 5. Reduced concentration of O_2Hb and total Hb with experienced coaches during the decision-making and selection of the responses to the EA situations. (a) Concentration of O_2Hb and (b) concentration of total Hb.

reduction in total Hb around the positions FAF5, FAF1, AF3, and AFp1 (Figure 3(b)), identified by values for t less than -3.0, $p < .0025$.

Figure 4 shows that there was an increase in the concentration of O_2Hb and total Hb during the experienced coaches' observation of the EA situations (Figure 4(a)) as well as reduction in the concentration of O_2Hb and total Hb during the coaches' information processing and response selection regarding EA situations (Figure 4(b)). There was an increase in O_2Hb around positions F2 and

F4, identified by the reddish color, as well as an increase in total Hb around the Fz and F5 positions, identified by the reddish coloration and *t* values higher than 3.0, $p < .0025$, in both cases.

For the information processing and experienced coaches' response selections related to EA situations (Figure 5), we found that there was an intense reduction in O_2Hb around the F3 position (Figure 5(a)), identified by the bluish coloration and values of *t* less than −4.5, $p < .0025$, as well as an intense reduction in total Hb (Figure 5(b)) around the AF3, AF2, and FAF1 positions, identified by the bluish coloration and values of *t* less than −3.5, $p < .0025$.

Discussion

This study compared DM and brain activation in novice and experienced volleyball coaches using a test of declarative tactical knowledge to present video-based scenarios for DM assessment and data from fNIRS to measure blood flow brain activation. We hypothesized that experienced coaches would show higher level of DM and lower level of brain activation than novice coaches. Our hypothesis was partially confirmed; because there was no difference in DM, and experienced coaches had lower brain activation.

We found that the two experience-based groups of coaches presented similar levels of DM ability according to their scores on the TCTD: Vb. This finding may be due to the type of situations that comprised the videos in tactical knowledge test (i.e., extremity attack). In volleyball games, there is a preponderance of attacks at the extremities of the net (Afonso, Mesquita & Palao, 2005; Costa et al., 2017), perhaps permitting novice and experienced coaches to gain equivalent skills in analyzing these situations, partly through their similar experience levels as former players. Moreover, all the novice coaches worked with Under-15 athlete groups, for which attacks in the extremities of the net are particularly common. Moreover, these coach analyses and subsequent responses were not performed under time or precision pressure, perhaps also contributing to equivalent recognition of game patterns by coaches of varying experience (Macquet, 2009). Regardless of the reason, our results suggest that experience alone does not differentiate tactical DM among coaches. Rather, it is important to consider other factors related to situational complexity (Williams, Ward, & Chapman, 2003).

In contrast to findings regarding DM within the TCDT: Vb, our results regarding the coaches' brain activation during their analyses of the EA scenes showed that novice (vs. experienced) coaches exhibited greater total area activation in the prefrontal cortex. In other words, among novice coaches, more NIRS channels showed an increased concentration of oxygenated hemoglobin and total hemoglobin in the detection of signals relevant to DM. Experienced coaches, on the other hand, showed an increase in total hemoglobin concentration (Hb + HbO) only on the left prefrontal cortex. Thus, more experienced coaches had lower prefrontal brain oxygenation compared with novice coaches, suggesting that to perform the same task they utilized less brain activation (effort) and showed greater brain efficiency. Although this corroborates past research performed with athletes (Kim et al., 2014; Wolf et al., 2014), our interpretation remains tentative because (a) blood flow is an indirect measure of brain activity and (b) we did not gather data about blood flow in other cerebral areas. Therefore, both groups could present similar overall efficiencies albeit by using distinct sections of the cerebral cortex.

As suggested earlier, it is important to note that decreases in brain activation do not always represent greater neural efficiency. Wei and Luo (2010) observed greater activation of the parahippocampal gyrus in experienced (vs. beginner) athletes when they imagined actions of the sport they practiced. As the parahippocampal gyrus is associated with the coding and retrieval of spatial information (Wei & Luo, 2010), this greater activation suggests an effect of practice. Although our results did not show DM differences between coaches as a function of experience, experienced coaches seemed to need fewer frontal cortical resources, an apparent indication of greater neural efficiency.

We also found deactivation of the prefrontal cortex in both groups after coaches identified the relevant signs in each scenario and during their response selections. These results are in accordance with research by Koshino et al. (2014) who analyzed the activation and deactivation of the prefrontal cortex during a memory task. They observed an increase in cerebral activation and a deactivation of the prefrontal cortex at the moment of task execution. In our study, the deactivation area in experienced (vs. novice) coaches involved more fNIRS channels. This difference is relevant because it suggests greater neural efficiency during DM by experienced (vs. novice) coaches and more efficient targeting of attention to relevant aspects of the task, although respecting the need for cautious analysis suggested previously. Complex brain activities include both the activation of relevant brain structures and the deactivation of irrelevant areas to obtain optimal performance in tasks that require attention (Kudo et al., 2004). In addition, increased information processing through acquired experience may permit DM behavior to occur with less required attention and an associated reduction in brain activation (Mukai et al., 2007).

This study emphasizes that, compared with novice coaches, experienced coaches activated fewer frontal region brain channels during the observation of game situations with no difference in the quality of their DM. This finding suggests a deactivation of more channels during the detection of relevant signals at the moment of DM. Nonetheless, without calculated effect sizes advises nothing can be inferred concerning the magnitude of these differences between novice and experienced coaches, and further research is necessary.

Our pioneering study highlights that it is important for novice coaches to be encouraged to interpret game scenarios and select complex game responses from the early stages of their careers. The complex and dynamic nature of coaching activity requires fast and effective DM (Mesquita, Ribeiro, Santos, & Morgan, 2014), meaning that coach education programs should help rapidly develop coaches' ability to recognize relevant game signals and make effective decisions in a refined, specific, and contextualized manner.

Declaration of Conflicting Interests

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ORCID iD

Herbert Ugrinowitsch http://orcid.org/0000-0003-0317-1940
Gibson M. Praça http://orcid.org/0000-0001-9971-7308

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Author Biographies

Gustavo C. Costa earned MS degree in Sport Science at Universidade do Porto and PhD in Sport Science at Universidade Federal de Minas Gerais (UFMG), Brazil. He is currently an adjunct professor at Department of Physical Education, Universidade Federal de Goiás, Brazil and is the coordinator of cognition and action Lab. His research interests focus on sports pedagogy and game analysis.

Henrique O. Castro has master's degree and is a PhD student in Sports Science in Universidade Federal de Minas Gerais. He is Titular I professor at Centro Universitário Estácio de Brasília, Brazil. His research interests focus on cognition and action in sports, specifically in volleyball.

Isabel R. Mesquita is an associate professor at University of Porto, Portugal. She is director of Master in Training Sport and responsible of Volleyball department. Her research interests are sport pedagogy, sport coaching, tactical decision and match analysis.

José Afonso earned PhD in Sports Sciences at the Faculty of Sport of the University of Porto, Portugal. He is currently a full-time auxiliar professor at that same institution. Currently, he is coordinating most of the volleyball classes and is conducting research on training periodization.

Guilherme M. Lage earned MS degree and PhD in Physical Education at Universidade Federal de Minas Gerais (UFMG), Brazil. He is currently an adjunct professor at Department of Physical Education, Universidade Federal de Minas Gerais, Brazil and is the coordinator of NNeuroM (Nucleus of Neuroscience of Movement). He is currently scientific director of the Brazilian Society of Motor Behavior. His research interests focus on motor control and learning in a neurobiological perspective.

Herbert Ugrinowitsch earned MS degree and PhD in Physical Education at Universidade de São Paulo (USP), Brazil. He is currently associate professor at Sports Department, Universidade Federal de Minas Gerais, Brazil and is the co-coordinator of GEDAM (Group of Studies in Motor Development and Motor Learning). He was vice-president of the Brazilian Society of Motor Behavior from 2012 to 2014. His research interests focus on motor learning, more specifically on changes in motor control during motor learning, and volleyball.

Gibson M. Praça earned MS degree and PhD in Sport Sciences at Universidade Federal de Minas Gerais, Brazil. He is currently adjunct professor at Sports Department, Universidade Federal de Minas Gerais, Brazil and is the co-coordinator of CECA (Center of Study in Cognition and Action. His research interests focuses on soccer match analysis, teaching and training in team sports and cognitive processes regarding tactical action in team sports.

Pablo J. Greco earned MS degree in Sports Sciences at Ruprechts Karls Universitaet Heidelberg, and PhD in Educational Psychology at Universidade Estadual de Campinas (UNICAMP) in São Paulo, Brazil. He is currently full professor at Sports Department, Universidade Federal de Minas Gerais, Brazil and is coordinator of CECA (Group of Studies in Cognition and Action). His research interests focuses on teaching-learning methodology and training of collective sports games. Technical-tactical training in collective sports and cognitive processes in sports, with an emphasis on decision-making and creativity.