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Research article

The Mediating Effect of Change of Direction Speed in the Relationship between the Type of Sport and Reactive Agility in Elite Female Team-Sport Athletes

Jarosław Domaradzki [1], Marek Popowczak [1]✉ and Teresa Zwierko [2]
[1] Faculty of Physical Education and Sport, University School of Physical Education in Wroclaw, Poland
[2] Institute of Physical Culture Sciences, Laboratory of Kinesiology in Functional and Structural Human Research Centre, University of Szczecin, Poland

Abstract
The main aim of this study was to examine the mediating effect of the change of direction speed (CODs) on reactive agility (RA) in female players participating in different team sports (TS). In total, there were 31 elite female players from the Polish national basketball (n = 12, aged 24.98 ± 3.38) and handball (n = 19, aged 27.34 ± 4.68) teams participated in this study. Two experiments using the 'five-time shuttle run to gates' test with similar movement patterns were used to determine the players' RA and CODs. A simple mediation model was utilised to investigate the potential mediation role of CODs and its effect on RA. The results revealed a primary, statistically significant effect of TS on RA (B = 0.796, $p = 0.005$), which decreased and became statistically insignificant after including the CODs variable into the model of mediation analysis (B = 0.337, $p = 0.192$). The RA test results were mediated by changes in CODs (B = 0.764, $p < 0.001$). Likewise, TS affected CODs (B = 0.602, $p = 0.016$). The general conclusion is that the relationship between TS and RA is not inherent. The direct effect of TS on RA disappears in the presence of the mediator CODs. Study results confirm the relevance of using the mediation analysis to apply in sport training. Identification of the critical ingredients of the athletes' agility performance can improve training programs by focusing on effective components.

Key words: Competitive sport, motor performance, performance analysis.

Introduction

Agility is a multidimensional skill, defined as a rapid whole-body movement with a change in velocity or direction in response to a stimulus (Sheppard et al., 2006b; Sheppard et al., 2014; Paul et al., 2016; Young and Farrow, 2006, Young et al., 2015). Agility manoeuvres require a 'perception-action coupling' (Farrow and Abernethy, 2003; Young et al., 2021), in which the adaptive movement and stimulus affect each other. In this perspective, agility is comprised of two subcomponents: change of direction speed (CODs) and a perceptual and cognitive component (Dos'Santos et al., 2018; Fiorilli et al., 2017a; Freitas et al., 2019; Young et al., 2002). However, the CODs is also defined as an ability based on a pattern of movements and is classified as a pre-planned and closed skill (Brughelli et al., 2008; Jones et al., 2009). Reactive agility (RA) refers to non-planned movements when athletes make a change in direction as an adaptation of their motor response to relevant stimuli (Sheppard et al., 2006b; Spiteri et al., 2018).

Based on previous study results, the potential relationship between CODs and RA is unclear. Some research findings have shown relatively low correlations between test results of RA and CODs (Matlak et al., 2016; Pehar et al., 2018; Simonek et al., 2016), suggesting that specific methods are required for training and testing RA and CODs as independent variables (Young et al., 2015). Moreover, it has been observed that kinematic profiles that describe athletes' biomechanical aspects during running, such as knee joint mechanics, are different in RA and CODs tasks (Spiteri et al., 2015a; Thomas et al., 2020). On the other hand, when the same movement patterns for CODs and RA assessments were tested, several significant positive correlations were found between RA and CODs (Čoh et al., 2018). Fiorilli et al. (2017b) found strong significant correlations between CODs and RA in male football players in age groups U12–U18. Moreover, it has been observed that when using the same training method both CODs and RA test results were improved, suggesting that CODs and RA mainly seem to rely on similar neuro-muscular factors (Born et al., 2016). The ambiguity of the relationship between CODs and RA led to the deeper analysis of this issue in the current research.

Type of sport (TS) has been considered as a significant factor affecting athletes' agility performance (Mackala et al., 2020; Sheppard and Young, 2006a; Zemková and Hamar, 2014). In relation to the team sports training, the most common player's manoeuvre requiring a combination of physical, technical, and tactical attributes is RA. It has been identified as one of the most important determinants for an athlete to recognise and formulate an adaptive movement response to for various tasks during games (Horníková et al., 2021; Morral-Yepes et al., 2020; Paul et al., 2016; Spiteri et al., 2018). It has been indicated that agility components should be integrated in varied and complementary ways in team sports training (Mota et al., 2021), therefore there is a need to comprehend interaction between agility components (RA and CODs) and the specific requirements of sport. To our best knowledge there is no evidence as to what extent CODs component contributes to RA in different types of sport. Thus, we examined the parallel relationships of TS, RA, and CODs when the same movement patterns for CODs and RA assessments were applied in highly-trained basketball and handball players. In our opinion, this issue may have a significant application value in relation to the design of agility training programs.

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Previous studies (Čoh et al., 2018; Fiorilli et al., 2017b; Mackala et al., 2020; Matlak et al., 2016; Pehar et al., 2018; Sekulic et al., 2017; Zemková and Hamar, 2014) explain the determinants of RA used univariate methods with TS as the independent variable and RA as the dependent variable. However, multivariate analysis or procedures involving the influence of more than two variables to explore the TS–RA model are limited. Multivariate analysis has the advantage of assessing the simultaneous influence of two independent variables on the outcome variable in parallel with the assessment of the relationship between the independent variables. This possibility is provided through mediation analysis. Moreover, mediation analysis additionally allows for insight into the mechanism underlying a known relationship by exploring the role of a third variable (mediator) by which (potentially) one variable influences another variable. Therefore, the aim of the study was to explain the association between TS with RA and whether COD mediated this association. The proposed relationship is based on a mediator between the independent and dependent variables and provides a reason for such a relationship to exist. Taking into account the previously confirmed effect of TS on RA (Bilge et al., 2020; Mackala et al., 2020; Zemková and Hamar, 2014), but also the possible relationship between CODs and RA (Born et al., 2016; Čoh et al., 2018; Fiorilli et al., 2017b), we hypothesised that CODs is a mediator in the relationship between TS and RA.

Methods

Study design

To test the mediation hypotheses we used mediation analysis, which is a variety of hierarchical regression, in order to verify whether both the TS (training programme) and RA (outcome) covary with the hypothesised mediating variable (CODs), and whether controlling for CODs would explain part of the TS variable (Baron and Kenny, 1986). The study uses Jamovi's mediation model to analyse the relationship between the specifics of a TS and RA (Figure 1). The arrows show hypothesized associations between all variables. The analytical strategy was based on this procedure to assess the positive, indirect effect of TS on RA through the mediating role of CODs.

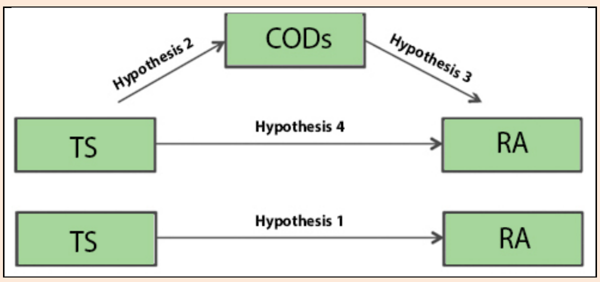

Figure 1. Hypothesized mediation model: indirect effect of TS on (RA) through CODs and total effect of independent variable on dependent variable (Baron and Kenny, 1986)

Participants

The study group included 31 elite female players from either basketball (n = 12; mean age 24.98 ± 3.38 years; 95%CI 22.83 - 27.14; body height 1.82 ± 0.07 m, 95%CI 1.77 – 1.86 m; body weight 74.4 ± 8.5 kg, 95%CI 68.9 - 79.8 kg) and handball (n = 19; mean age 27.34 ± 4.68 years; 95%CI 25.09 - 29.6; body height 1.76 ± 0.07 m, 95%CI 1.72 – 1.79 m; body weight 71.1 ± 8.3 kg, 95% CI 67.1 - 75.1 kg). Detailed descriptive statistics and comparisons between both groups of players were registered in the AZON repository: https://deponuj.azon.e-science.pl/entry/57850/detailredirect. All the basketball players belonged to the same team, competing in the 2018-19 season in the EuroCup Women and in the 1st National League (Energa Basket Liga Women). Similarly, all the handball players in the 2018-19 tournament belonged to the same team, competing in the EHF Women's Cup and in the 1st National League (Polish PGNiG Women's Superliga). The criterion for inclusion was the participation in the previous season in the 1st National League as a starter player and preparation for participation in EuroCup for the next season. The study was conducted one week following a preparatory period.

This study was approved by the Research Bioethics Committee of the Faculty Senate of the University School of Physical Education in Wrocław (adopted on 07/06/2013) and conducted in accordance with the ethical principles for medical research involving human subjects contained in the Declaration of Helsinki by the World Medical Association. The study also met the 'Ethical standards in sport and exercise science research' (Harriss and Atkinson, 2015). All participants were asked to provide written informed consent prior to the study and the purpose and characteristics of the research were explained.

Measures and Procedures

All tests were carried out in a sports hall. The player's positions were not included in the analysis. Anthropometric parameters were measured by the same experienced researchers. The height of the athletes was measured with a GPM anthropometer 101 (DKSH, Zurich, Switzerland) with a precision of 1 mm. Body weight was measured when the athletes were shoeless with minimal clothing, using an InBody 230 system (Tanita Corp., Tokyo, Japan).

Before the start of the measurements, the participants underwent a standardised 15-min warm-up procedure. The 'five-time shuttle run to gates' test was then carried out (in order to determine the CODs and RA). A Fusion Smart Speed System (Fusion Sport, Coopers Plains, QLD, Australia) was used during this test. The system includes five gates which are equipped with a photocell with an infrared transmitter and a light reflector, a Smart Jump mat integrated with a photocell and radio frequency identification (RFID) reader for identifying the athletes, and computer software (Figure 2). The testing apparatus measured running time with an accuracy of 0.001 s. The data from the tests were recorded in a computer PDA (HP iPAQ 112) with the participants' names.

The 'five-time shuttle run to gates' test measures the running time with changes of direction as a reaction to a light stimulus. The 'stop'n'go' method was used in the movement scenarios. The Fusion Smart Speed System was applied to trigger light in a fixed (pre-planned) or randomly selected gate (non-planned), according to the procedures proposed by Popowczak et al. (2016). The subjects had to run the distance from the mat to the gate lines five times (placed between the photocells and the reflectors, 1 m long) and return to the mat. Mats integrated with a photocell were placed at the start and finish lines. The layout of gates, mat, and RFID reader in the five-time shuttle run to gates test is illustrated in Figure 2. As soon as both feet were in contact with the central part of the mat, the participant received a light signal indicating the gate they should run to. The start to the gate was not delayed.

In the 'five-time shuttle run to gates' test (pre-planned), which measured the CODs speed, the subjects ran to the gates in an order which was the same for all participants (from 1 to 5). The angle of CODs in the gate was ≅180°, while the manoeuvre on the mat jump was performed at an angle of ≅135°. The COD test was repeated twice, and the best result (overall duration) of the run was used in the analysis.

In contrast, in the 'five-time shuttle run to gates' test (non-planned), which measured RA, the subjects ran to randomly selected gates. The order was different for every participant, but the distance remained the same. During the RA sprints, the participants were instructed to not predict which exit gate they would be required to sprint through. The RA test was repeated twice, and the best result (overall duration) of the run was used in the analysis. The 'stop'n'go' scenario of the test, using the subject's reaction to a light signal, are characterised by much higher levels of reproducibility and reliability (ICC: >70%) (Morral-Yepes et al., 2020; Paul et al., 2016).

Statistical analysis

The descriptive statistics are presented as means, standard deviations, and 95% confidence intervals (CI). The mediation analysis provides total and specific indirect effects (through the proposed mediator[s]) of the predictor (TS) on the outcomes (RA). The procedure proposed originally by Baron and Kenny (1986) is based on four cardinal steps: (1) examine statistically significant associations between independent and dependent variables, (2) examine the statistically significant association between the independent variable and mediator (3) show that the mediator affects the dependent variable, (4) show that the association between the independent and dependent variable weakens and becomes statistically insignificant when the mediator is adjusted for in the model. This procedure is useful not only in social sciences, but also in motor performance examinations (Haapala et al., 2018). Mediation analysis was performed using the methods described by Preacher and Hayes (2008) with the accompanying Jamovi's Advanced Mediation Models 1.0.4 module (Jamovie, v. 1.6, 2020).

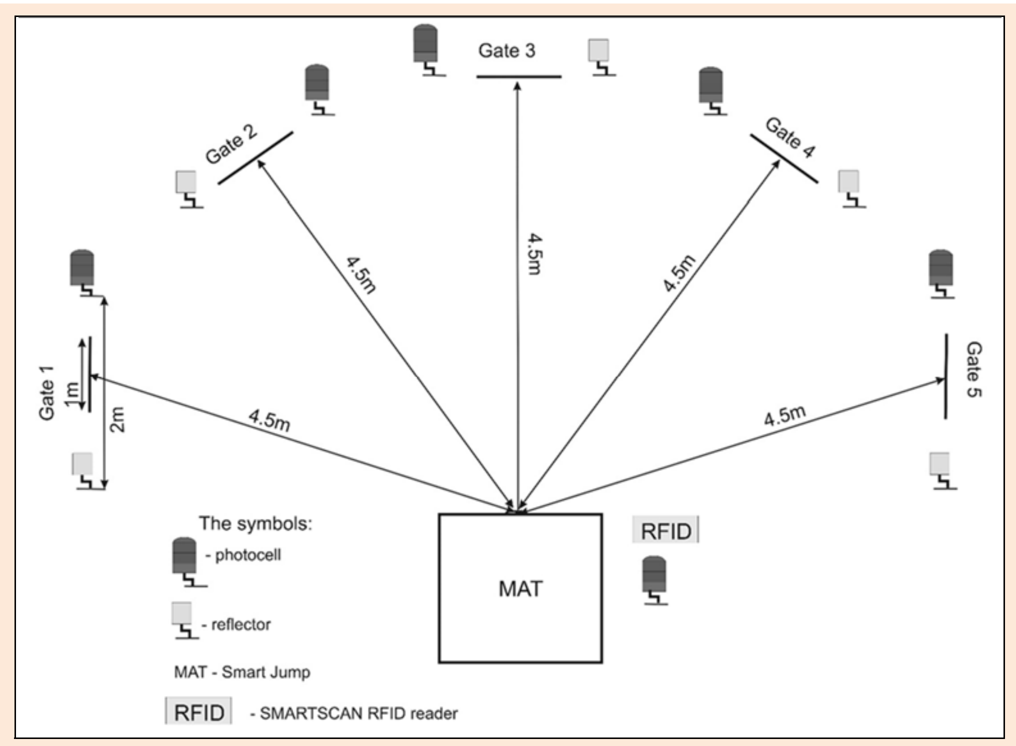

Figure 2. **The five time shuttle run to gates test (based on Popowczak et al., 2016).**

Results

The Shapiro-Wilk's test was used to evaluate the normality of the distribution of the continuous variables. All the variables showed a normal distribution. The results of the mediation analysis are presented in Table 1 and Table 2 and Figure 3.

Hypothesis 1 established that the independent variable impacts the dependent variable. In our study it was necessary to prove that TS impacted RA. For this hypothesis, the results reflecting the total effect of TS on RA confirmed that TS impacted RA. Basketball players (coded -1) received poorer RA results than handball players (B = 0.796, p = 0.006) (Table 1).

Table 1. **Mediation effects: total, direct and indirect (in model) with % of mediation.**

Effect	B	SE	95% CI	Z	p	% Mediation
Total	0.796	0.287	0.224 – 1.350	2.77	0.006	100.0
Direct	0.337	0.252	-0.187 – 0.801	1.33	0.182	42.2
Indirect	0.460	0.221	0.071 – 0.944	2.08	0.037	57.8

B – estimated regression, SE – standard error of the regression, CI – confidence interval, Z – scale, p–value

Table 2. **Mediation model: indirect effect of type of sport (TS) on reactive agility (RA) through changes in change of direction speed (CODs)**

Path between variable	B	SE	95% CI	Z	p
TS→ CODs	0.602	0.249	0.110 – 1.087	2.42	0.016
CODs→ RA	0.764	0.108	0.541 – 0.973	7.07	< .001
TS→ RA	0.337	0.252	-0.187 – 0.801	1.33	0.182

TS – type of sport (independent variable), RA – reactive agility (dependent variable), CODs – change of direction (mediation variable), B – estimated regression, SE – standard error of the regression, CI – confidence interval, Z – scale, p–value

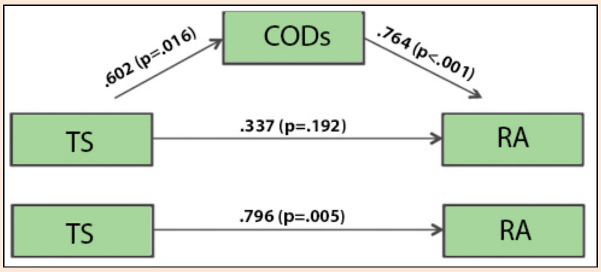

Figure 3. **Results of the mediation model: Indirect effect of TS on (RA) through CODs and total effect of independent variable on dependent variable (B – estimated regression, p-values).**

The second step was to test hypotheses 2 and 3. Both established statistically significant associations: the independent variable impacts the mediator and the mediator is associated with dependent variable. In regards to hypothesis 2, we also confirmed that TS affected COD (B = 0.602, $p < 0.016$). Results of CODs for basketball players were worse in comparison to handball players. Furthermore, as proposed in hypothesis 3, the improvement in RA relates to changes in CODs (B = 0.764, $p < 0.001$) (Table 2).

The last step was to test hypothesis 4 which established that the positive direct effect independent variable disappeared if the mediator was included into the model. Hence, the results in respect to hypothesis 4 suggest that the positive direct effect of TS on RA (B = 0.337, p = 0.192) disappears if the mediation of COD in that relationship is taken into account (Tables 1 and 2).

Discussion

This study examined the associations between three variables: TS, CODs, and RA. Specifically, the main objective was to examine the indirect relationship between the particularities of TS and RA, and to prove the mediating role of the CODs. There are several important findings in this study, (1) TS predicted the occurrence of the RA variable; (2) TS predicted CODs variable; (3) CODs was shown to predict RA and takes into account the primary predictor (TS); (4) when CODs was included as a predictor of RA (together with TS), TS was no longer a predictor of RA; TS did not affect RA directly. The hypothesis that CODs plays a mediating role in the relationship between TS and RA was confirmed.

From a practical perspective, our results suggest that the slower and less agile players with poor initial RA (regardless of the sport discipline) would be likely to demonstrate a high ability to react to a stimulus quickly and efficiently during movements with high speed (known as reactive agility) by developing their CODs technique. This statement may be useful in relation to designing agility training programs in team sports. CODs technique training relating to biomechanical and neuromuscular movement patterns, directed to reduce lateral trunk flexion and lateral foot plant distances, lower centre of gravity, increased knee flexion, and control stopping movements, would be advantageous for a faster agility performance (Dos'Santos et al., 2019a; Hewit et al., 2013). Consequently, CODs technique may provide a foundation for RA. This is important considering that during unplanned stopping movements, which usually occur in RA tasks, the central nervous system does not provide sufficient muscle coordination and the shorter stopping time results in a higher impulsive force and generates large multi-planar knee joint loads, causing a greater injury risk (Brown et al., 2014; Dos'Santos et al., 2019a).

More recently however, it has been postulated that CODs task, as an isolated component of agility, can lack sufficient ecological validity to reflect the agility demands of competition in open-skills sports like team games, therefore agility should be treated as an integral skill without isolating the CODs component (Young et al., 2021). This highlights the need to create training environments that expose athletes to sport-specific stimuli, enabling players to successfully integrate perception and action under rapid, dynamic and ecologically valid conditions for a game situation (Spiteri et al., 2018). However, in light of our findings, the mediating effect of CODs on RA may suggest that a sport-specific CODs technique can be the basis for more complex agility tasks in highly-skilled athletes. This may be related to experienced players' technique in agility tasks that are involved with greater motor control, mainly through increased neuromuscular adaptations in an extensive training process (Spiteri et al., 2015a; Spiteri et al., 2015b). In a study of football players (Krolo et al., 2020) found that the first stage of agility training should be oriented toward achieving an accurate and effective movement technique rather than the development of conditioning capacities, which contribute to RA and CODs. Furthermore, in some agility training programs it is proposed to integrate gradually two or more activities into a given motor task, such as CODs and RA together (Fiorilli et al. 2017b; Mota et al., 2021; Safaric and Bird, 2011). These studies support the need for emphasis on CODs technique practice in team sports training leading to improve RA performance.

Next, our results of the initial stages of mediation analysis corroborate earlier findings indicating a positive effect of TS on RA and CODs (Dos'Santos et al., 2018; Bilge et al., 2020; Zemková and Hamar, 2014). In the curent study, for both RA and CODs tests, handball players had better results than the basketball players. Similar to our findings, Bilge et al.(2020) found that compared to basketball players, handball players presented better performance in RA tasks, however in their study, basketball players were significantly faster than handball players in CODs tasks. Interestingly, in another study it has been reported that basketball players during reactive task execution, present consistently shorter reaction times for stimulus located in the upper visual field compared to the controls (Stone et al., 2019). These findings suggest that sport experience-dependent plasticity of perceptual-cognitive function (basketball players spend significant amount of time processing upper visual field information) may also impact RA performance. Moreover, our study indicated that the positive effect of TS on agility performance have manifested in highly trained players, whereas in beginners, agility performance does not usually differ in relation to the type of team games (Popowczak et al. 2020; Silva et al., 2013). It is likely that perceptual/cognitive skills enables athletes to produce a faster and more accurate response, through enhanced perception–action coupling in an extensive training process (Farrow and Abernethy, 2003; Spiteri et al., 2018) and can be modulated by the type of sport. Certainly, other factors, such as perceptual-cognitive, motor and anthropometric, are important facets of agility tasks (Pehar et al., 2018; Scanlan, et al. 2014; Spiteri et al., 2018), which were not analysed in this study and may have an impact on the observed differences between basketball and handball players. For a better understanding of this issue, further analyses of the factors associated with RA in team games are needed.

It is important to note certain aspects that may limit the interpretation of the present findings. Firstly, because of the relatively small number of participants in each group and the cross-sectional design of our study, it is not possible to establish a clear causal relationship between TS, CODs, and RA. Secondly, we used an unequal distribution of players in the sample, which displayed a bias towards basketball players. However, as stated before, we consider that it is a sample that represents the average distribution of players in the main squad in top-class basketball and handball teams. Thirdly, our study included only women, which limits the generalisability to the population of all athletes. Taking into account the observed gender differences in agility performance and the asymmetries between team-sport athletes (Dos'Santos et al., 2019b) and posible interaction between playing positions (Sekulic et al., 2017), future research on male subjects and players at different playing positions will be fundamental for a better understanding of the mediating effects of CODs in the relationship between specific aspects of TS and RA. Finally, because of certain similarities in the mechanical determinants of changing the direction of movement in basketball and handball players based on stop'n'go RA patterns (Taylor et al. 2017), further study using mediation methodology in different types of sport should be addressed.

Conclusion

The results of the three-variable parallel analysis used in the study indicate that the relationship between TS and RA is not inherent. Our results suggested that a sport-specific CODs technique can be the basis for more complex agility tasks in team games. From a practical point of view, training programmes should target CODs for maximum benefit in RA. Implementing drills that incorporate the conventional CODs technique to develop movement competency as a foundation to more complex agility will allow athletes to efficiently adapt to movement output in response to unplanned situations in sport-specific environments. In training aimed at improving RA, more attention to shaping the CODs manoeuvres will increase the benefit in RA. Taking into account the lack of similar studies, a new area of interest to be explored was identified. Further work is therefore needed to establish the focus of training programmes on the specific sport environments. Strategies to improve RA should focus on other potential components related to RA performance.

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Key points

- The three-variable parallel analysis used in the study indicates that the relationship between type of sports and reactive agility is not inherent in professional team game players.
- The direct effect of the type of sport on the reactive agility disappears in the presence of the mediator change of direction speed.
- The sport-specific change of direction technique can be the basis for more complex agility tasks in team sports.

AUTHOR BIOGRAPHY

Jarosław DOMARADZKI
Employment
Assoc. Prof., Faculty of Physical Education and Sport, University School of Physical Education in Wroclaw, Poland
Degree
Ph.D.
Research interests
Auxology, motor ability development
E-mail:
jaroslaw.domaradzki@awf.wroc.pl

Marek POPOWCZAK
Employment
Faculty of Physical Education and Sport, University School of Physical Education in Wroclaw, Poland
Degree
Ph.D.
Research interests
Talent identification in team sports, motor ability development.
E-mail:
marek.popowczak@awf.wroc.pl

Teresa ZWIERKO
Employment
Assoc. Prof., University of Szczecin, Institute of Physical Culture Sciences, Functional and Structural Human Research Centre, Szczecin, Poland
Degree
Ph.D.
Research interests
Sensorimotor processing; visual-motor performance in team sports; motor control.
E-mail: teresa.zwierko@usz.edu.pl

✉ **Marek Popowczak**
Faculty of Physical Education and Sport, University School of Physical Education in Wroclaw, Poland