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Research article

Does Physical Loading Affect The Speed and Accuracy of Tactical Decision-Making in Elite Junior Soccer Players?

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Abstract
A soccer player's capability to control and manage his behaviour in a game situation is a prerequisite, reflecting not only swift and accurate tactical decision-making, but also prompt implementation of a motor task during intermittent exercise conditions. The purpose of this study was to analyse the relationship between varying exercise intensity and the visual-motor response time and the accuracy of motor response in an offensive game situation in soccer. The participants (n = 42) were male, semi-professional, soccer players (M age 18.0 ± 0.9 years) and trained five times a week. Each player performed four different modes of exercise intensity on the treadmill (motor inactivity, aerobic, intermittent and anaerobic activity). After the end of each exercise, visual-motor response time and accuracy of motor response were assessed. Players' motion was captured by digital video camera. ANOVA indicated no significant difference (p = 0.090) in the accuracy of motor response between the four exercise intensity modes. Practical significance (Z-test = 0.31) was found in visual-motor response time between exercise with dominant involvement of aerobic metabolism, and intense intermittent exercise. A medium size effect (Z-test = 0.34) was also found in visual-motor response time between exercise with dominant involvement of aerobic metabolism and exercise with dominant involvement of anaerobic metabolism, which was confirmed by ANOVA (897.02 ± 57.46 vs. 940.95 ± 71.14; p = 0.002). The results showed that different modes of exercise intensity do not adversely affect the accuracy of motor responses; however, high-intensity exercise has a negative effect on visual-motor response time in comparison to moderate intensity exercise.

Key words: Accuracy of motor response, visual-motor response time, game situation, exercise intensity.

Introduction

Perceptual-cognitive skills related to visual processing, such as anticipation and pattern recognition, are capable of contributing valuable evidence to better understand the psycho-physiological attributes of elite level athletes (Jackson et al., 2006). Within the sport domain, visual processing skills that affect depth perception, such as analysing the speed and trajectory of a moving object, require further investigation. Previous research in the field of neuroscience has provided a more specific descriptor for this process, termed 'speed discrimination' (Clifford et al., 1999; Huang et al., 2008; Overney et al., 2008). The significance of cognition in the tactical context of soccer is readily apparent. Roca et al. (2014) have already highlighted the relevance of studying perceptual and motor structures in order to understand central cognitive processes such as decision-making. In soccer, decision making is regarded as being an attribute of 'game intelligence', which is a factor that separates successful from less successful players due to its vital role in selecting and executing actions that are more suitable and more likely to succeed in a particular scenario (Williams and Ford, 2013).

Earlier studies researching decision-making speed and accuracy of motor response in soccer were based on the presentation of tachistoscopic static slides in a laboratory (McMorris and Graydon, 1996a, 1996b; McMorrison and Beazeley, 1997; Frýbort and Kokštejn, 2013). However, a common concern within psychological research disciplines is that laboratory tasks may fail to reproduce the environmental characteristics of many real-world settings (Hogarth and Kareláia, 2007; Van der Kamp et al., 2008). Recent findings have indicated more reliable and clearer outcomes under natural (in situ) experimental conditions than in ubiquitous video simulation laboratory settings (Mann et al., 2007).

The ability to perform a motor action is represented by reaction time and action movement speed (Magill, 2003). Together, reaction time plus action movement speed result in visual-motor response time (VMRT) (Bressan, 2000; Erickson, 2007). During involvement in a game situation, an athlete's cognitive activity is influenced by the level of fatigue (Thomson et al., 2009). Essentially, this means that VMRT can be negatively affected by fatigue or, more precisely, by the level of fatigue which is caused by the level of exercise intensity. Tomporowski (2003) presented a detailed overview of studies examining the effects of exercise on cognitive function. The major conclusion drawn was that submaximal exercise resulted in an improvement in cognitive tasks such as reaction time and memory, whereas, tasks that involved bouts of exercise leading to voluntary exhaustion did not result in any significant improvement in cognitive performance. A recent meta-analysis relate to performance in perceptual-cognitive skills by Chang et al. (2012) represented by the accuracy of motor response and decision-making speed shows that when the exercise is hard, very hard, or maximal, there is no significant effect on cognitive function immediately after exercise. However, these authors note that most studies included in this meta-analysis investigated the acute cognitive effects of continuous rather than intermittent exercise.

The studies of Fontana et al. (2009) and McMorris and Graydon (1997) show that apart from various levels of exercise intensity, different performance standards also play a key role in speed and accuracy of VMRT. Accord-

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ing to the results of Fontana et al. (2009), experienced players (those with a higher performance level) tend to execute faster decision-making and greater accuracy of motor response in exercise with different levels of intensity compared to rest. However, in this study, the speed of decision-making was assessed using a voice command device, which did not enable the performance or measurement of the motor action itself. McMorris and Graydon (1997) found that cognitive performance in decision-making speed of experienced soccer players while undertaking both moderate and maximal exercise was significantly better than their cognitive performance at rest. However, accuracy of motor response was not significantly affected by different exercise.

The results of the studies mentioned above, which focused on the effect of different physical intensity on VMRT and accuracy of motor response, seem to be very inconsistent. These studies also used different devices for the assessment of VMRT and accuracy of motor response (voice command device or video simulation). Therefore, with respect to more ecological experimental conditions, the aim of this study was to assess the VMRT and accuracy of motor response in elite junior soccer players in response to four different exercise intensities.

Methods

Participants

Participants (n = 42) were male semi-professional soccer players playing in the national junior first league in the Czech Republic (mean age 18.0 ± 0.9 yr; training experience: 9.0 ± 1.3 yr) and trained five times a week. The participants performed a stress test on a treadmill to determine ventilation anaerobic threshold and training intensities. All participants consented to be involved in testing in conjunction with medical assessments. All the selected players participated in the research voluntarily and the research was approved by the Ethics Committee of the Faculty of Physical Education and Sport of Charles University in Prague.

Design of the research

According to the classification system of authors Trochim (2001) and Thomas, Nelson, and Silverman (2005) this study was an intra-group quasi-experiment with a single factor and various levels. The aim of the study was to analyse the relationships between visual-motor response time, the accuracy of motor response and intensity of exercise.

Diagnostic tool (apparatus)

The diagnostic tool designed by the present authors consisted of the following components:

1. Administration of four different intensity exercise modes.
2. Projection of four two-dimensional videos of offensive game situations (GS) on a large screen.
3. Video recording and then assessment of the response to videos of offensive GS (VMRT and the accuracy of motor response).

Through the presentation of videos of offensive GS, the diagnostic tool we designed enabled us to simultaneously assess VMRT and the accuracy of motor response after different exercise intensity modes administered on a treadmill (Cybex 750T Treadmill) in a research laboratory. The individual offensive GS were started by the researcher using a laptop (ACER Aspire 6920) and simultaneously displayed on a projection screen (projector Sharp PG-DX40W3D).

Testing procedures (task and procedures)

Before testing the participants were acquainted with the whole measurement process (running on a treadmill and different modes of physical load, transfer to a large screen, and coding of motor responses). Each participant was tested successively in different modes of exercise intensity (according to a protocol - see description of independent variables below). The modes of exercise intensity were ranked as: motor inactivity mode, mode with dominant involvement of aerobic metabolism, intense intermittent exercise mode, and mode with dominant involvement of anaerobic metabolism. The participants were required to move to a previously defined mark at a distance of 5 m in front of a large screen (size 240 cm x 170 cm) and to do so within 3 seconds of the termination of the respective exercise intensity mode. A ball was placed at a distance of 50 cm from the mark and the central axis of the body. Participants started from a static standing position. A 3-second video of an offensive GS was played. When the video ended, the participants' task consisted of choosing the most accurate motor response as soon as possible, and performing the motor response in the shortest time possible. VMRT was measured in milliseconds (ms). The motor response comprised the following seven variants of offensive game activities: forward pass, pass to the right, pass to the left, diagonal pass to the right, diagonal pass to the left, beating a defender and dribbling with the ball. On the whole, participants were presented with four different videos of offensive GS after completion of a mode of exercise intensity. Four different videos of offensive GS were randomly assigned for each mode of exercise intensity.

The accuracy of motor response and VMRT was recorded using a SONY HDR PJ220E camcorder. The camcorder was situated behind the participant being tested, at an angle of 45° from the central axis and at a distance of 5 m. This position of the camcorder reliably and simultaneously captured the moment when the video of the offensive GS stopped and the moment when a lower limb touched the ball (Figure 1). VMRT comprised the period of time from the moment when the video of the offensive GS stopped to the moment when the ball touched the participant's lower limb. The accuracy of motor response was represented by the choice of one of seven motor response alternatives (Figure 2). The duration of the exposure to offensive GS during which the participant had to choose as quickly as possible the most effective variant of motor response was no more than 2 seconds. The total duration of the presentation of four offensive GS fell within an interval of 16 to 20 seconds. This ensured that the energy metabolism of the exercise mode only just performed had the dominant involvement. Especially for an intermittent and anaerobic mode of physical load, we adopted this precaution based on the findings of Ostojic et al. (2010). These authors found the minimal decrease of HR (93,6±2,7% beats min^{-1}) at 20 seconds after the maximal treadmill running test. VMRT was assessed using Dartfish software (Swiss Federal Institute of Technology, Lausanne, Switzerland) with a precision of 0.04 seconds.

Description of independent variables

The first mode was the mode of motor inactivity (M-IN), which is characterized by inactivity and values of resting HR for a period of time of 2 to 4 minutes depending on the speed at which resting HR was reached.

The second mode was an intense exercise mode with dominant involvement of aerobic metabolism (M-AEM). The duration of M-AEM was 4 minutes with boundary values of HR = HR_{ANT} - 6% for individual participants. Therefore, the speed of the treadmill was adjusted to achieve the desired HR using a range of 12.0 to 14.5 km/hr to mimic locomotive activities at moderate speeds.

The third mode was one of intense intermittent exercise (M-INTERM). The total duration of M-INTERM was 4 minutes. This mode was characterized by repeated short-term to medium-term work intervals of running locomotion with almost maximum effort for a duration of 15 to 40 seconds, which were bound by a value of HR = HR_{ANT} + 6% where the speed of the treadmill was 17 to 19 km/h (locomotion activity at high speeds) with an incline of 5°. After reaching that value of HR, the participants replaced the work interval with a recovery interval consisting of physical rest or walking. The resting interval lasted between 15 to 40 seconds and was bound by the values of HR= HR_{ANT} - 6 %.

Figure 1. The moment when the video of the offensive GS stopped and the moment when a lower limb touched the ball.

The fourth mode was an intense exercise mode with dominant involvement of anaerobic metabolism (M-ANAEM). The total duration of M-ANAEM was 30 seconds with values of HR= HR_{ANT} + 6% for individual

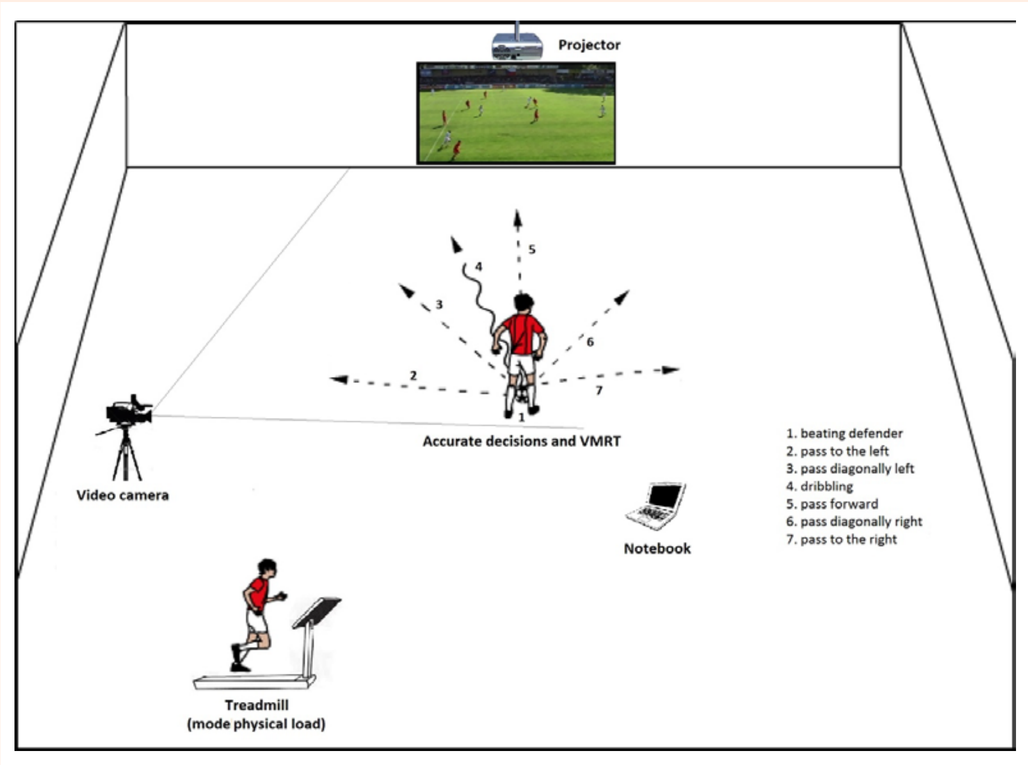

Figure 2. Experimental setup.

participants. After reaching $HR = HR_{ANT} + 6\%$, a continuous speed ranging from 18.0 to 20.0 km/h (locomotion activity at high speeds, sprint) was maintained on the treadmill, with an incline of 5°.

Expert assessment of offensive game situations and content validity of selected indicators

The expert group (individual members of the expert group) was formed by six licensed coaches with UEFA Pro licences, who were also university teachers. The first task of the expert group was to identify in each offensive GS five of the seven total possible variants of motor response and, at the same time, to always rule out two variants as completely irrelevant. The motor response was realized by one of the following alternatives as a reaction on game action: forward pass, pass to the right, pass to the left, diagonal pass to the right, diagonal pass to the left, beating a defender and dribbling with the ball. Such game activities are among the most frequent offensive game activities during matches.

At the same time, the expert group scored the motor responses in a range (Likert scale) from 1 to 5 for each GS (1 – the most effective motor response, 2 – a very good motor response, 3 – a good motor response, 4 – an unsuitable motor response, 5 – an ineffective motor response). The variant of motor response with the lowest score was classified as the most effective motor response. The variant of motor response with the highest score was classified as an ineffective motor response.

The content validity was determined according to Lawshe (1975) on the basis of the degree of conformity among the individual panellists. For six offensive GS, there was a 100% degree of conformity among the panellists; for three offensive GS, there was an 84% degree of conformity; for four offensive GS, there was a 68% degree of conformity; and for three offensive GS, there was a 52% degree of conformity among the panellists. Each offensive GS was scored from the most effective to an ineffective variant of motor response. The remaining 12 videos of offensive GS were not included in the selection on the grounds of a low degree of concord among the panellists.

Data analysis

Shapiro Wilcox and Kolmogorov-Smirnov tests rejected data normality. Therefore effect size by Z-test and non-parametric repeated measure ANOVA (the Friedman test; $p < 0.05$) with subsequent post-hoc analysis was applied to determine the significance of differences in the VMRT and accuracy of choice of motor response in the four different modes of exercise intensity. The relationship between VMRT and the accuracy of motor response in the different modes of exercise intensity was assessed by Spearman's rank correlation coefficient ($p < 0.05$).

Results

The results of accuracy of motor response after the administration of four different exercise intensity modes: The resulting value of the accuracy of motor response as a sum of the values of offensive GS1-GS4 for each exercise intensity mode for 42 participants is shown in Table 1. The results of our research concerning the accuracy of the motor response from GS1-GS4 suggest a marked tendency of the participants to choose, after M-IN, within the range of 1 to 5 a motor response ranked as 3 – "a good motor response" (Me 2.75), after M-AEM (Me 2.5), after M-INTERM (Me 2.5) and after M-ANAEM (Me 2.5). Apart from the M-IN mode the most chose responses in other modes (M-AEM, M-INTERM and M-ANAEM) were ranked 2 – "very good motor response" and 3 – "good motor response". Friedman test indicated no significant difference (Chi-square (H) (3, 39) = 6.75 p = 0.08) for the accuracy of motor response between the four modes of exercise intensity.

Table 1. **Resulting accuracy of motor response out of the total score of GS1-GS4 after administration of four exercise intensity modes.**

Exercise intensity mode	Mean (±SD)	Variance s^2	Median (Me)
M-IN	2.66 (.57)	.33	2.75
M-AEM	2.62 (.70)	.49	2.50
M-INTERM	2.32 (.60)	.36	2.50
M-ANAEM	2.52 (.62)	.38	2.50

Mode of motor inactivity (M-IN), exercise mode with a dominant involvement of aerobic metabolism (M-AEM), mode of intense intermittent exercise (M-INTERM) and exercise mode with a dominant involvement of anaerobic metabolism (M-ANAEM).

Resulting average values of visual-motor response time among the four modes of exercise intensity: Significant medium size effect (ES = 0.60) was found in VMRT between M-AEM and M-INTERM however without significant confirmation in ANOVA. Significant medium size effect (Z-test = 0.34) was also found in VMRT between M-AEM and M-ANAEM, which was confirmed by Friedman test (M = 897.02, SD = 57.46 vs. M = 940.95, SD = 71.14; Chi-square (H) (3, 39) = 15.36 p = 0.002; Table 2 and Table 3). No other significant differences were observed between exercise intensity modes and VMRT.

Table 2. **Resulting average values of visual-motor response time among the individual exercise modes expressed by way of Cohen's *d*.**

Exercise intensity mode	M-IN	M-AEM	M-INTERM
M-AEM	.37		
M-INTERM	.21	.60†	
M-ANAEM	.35	.67†	.17

Mode of motor inactivity (M-IN), exercise mode with a dominant involvement of aerobic metabolism (M-AEM), mode of intense intermittent exercise (M-INTERM) and exercise mode with a dominant involvement of anaerobic metabolism (M-ANAEM), *d* – Cohen's coefficient of effect size, † medium practical difference.

Resulting correlation of the visual-motor response time and the accuracy of motor response in the individual exercise modes: No significant correlations were reported between the values of VMRT and the accuracy of motor response among the individual modes of exercise intensity (r = -0.04 – -0.23; Table 4).

Table 3. **Total values of VMRT after the administration of four exercise intensity modes.**

VMRT and exercise intensity mode	Mean (±SD)	Variance s^2	Median (Me)
VMRT after M-IN	918.2 (56.7)	3210.8	925
VMRT after M-AEM	897.0 (57.5)*	3302.5	908
VMRT after M-INTERM	930.1 (52.3)	2736.0	940
VMRT after M-ANAEM	941.0 (71.1)*	5061.3	950

* significant ($p < 0.05$) difference between M-AEM and M-ANAEM, Mode of motor inactivity (M-IN), exercise mode with a dominant involvement of aerobic metabolism (M-AEM), mode of intense intermittent exercise (M-INTERM) and exercise mode with a dominant involvement of anaerobic metabolism (M-ANAEM), VMRT – visual motor response time.

Table 4. **Resulting correlation between VMRT and the accuracy of motor response after the administration of four exercise intensity modes.**

Exercise intensity model	VMRT Mean (±SD) (ms)	Accuracy of MR Median (Me)	Correlation
M-IN	918.2 (57.0)	2.75	-.09
M-AEM	897.0 (57.5)	2.50	-.23
M-INTERM	930.1 (52.3)	2.50	-.04
M-ANAEM	941.0 (71.1)	2.50	-.07

Mode of motor inactivity (M-IN), exercise mode with a dominant involvement of aerobic metabolism (M-AEM), mode of intense intermittent exercise (M-INTERM) and exercise mode with a dominant involvement of anaerobic metabolism (M-ANAEM), VMRT – visual motor response time, accuracy of MR – accuracy of motor response.

Discussion

The purpose of this study was to analyse the relationship between different intensities of exercise and visual-motor response time and the accuracy of motor response in an offensive game situation in soccer.

Our results showed no significant differences in the accuracy of motor response between different exercise intensity modes. The participants most frequently chose the second most effective motor response ranked as 2 – "a very good motor response" - and the third most effective motor response ranked as 3 – "a good motor response". Moreover, the results indicate that the participants tended to choose a more effective motor response (better accuracy) after the mode of intense intermittent exercise rather than in other exercise intensity modes, but without any significant differences (see Table 1). The results of our study confirmed previous findings regarding visual-motor response time because we found significantly faster VMRT after M-AEM (moderate intensity exercise) compared to M-ANAEM (maximal intensity exercise). However, we did not observe any other significant differences in VMRT between different exercise intensity modes.

A number of studies have focused on fatigue, or the intensity of exercise in relation to the cognitive processing of soccer players (Thomson et al., 2009). According to cue utilization theory, athletes in a highly fatigued state were able to complete the speed discrimination task quickly, but were unable to successfully focus on relevant cues necessary to make decisions as accurately compared to in a non-fatigued state (Easterbrook, 1959). Many physical activities (e.g. soccer) involve intermittent exercise intensities, while at the same time requiring participants to perform perceptual-cognitive motor skills that must be completed as quickly and accurately as possible (Chmura et al., 2002; Meeusen, 2002; Rendi et al., 2007). Accurate decision-making in sport has been identified as a significant factor in successful elite performance (Baker et al., 2003).

Our findings on accuracy are in accordance with a previous study by McMorris and Graydon (1996a; 1996b) and Fontana et al. (2009) who found that intense exercise by soccer players did not affect the accuracy of motor response between examined levels. Moreover, Brisswalter et al. (2002), and Tomporowski (2003) suggest that different intensities of exercise do not affect the accuracy of motor response; however, they concluded that the pattern is less clear for maximal exercise intensities. In contrast, Casanova et al. (2013) found that intermittent exercise leads to a significant decrement in anticipation accuracy in both high- and low-level soccer players. Similarly to our research design the authors used realistic filmed sequences of offensive play from the perspective of a central defender for assessment of accuracy of perceptual cognitive processes. One possible explanation for the same accuracy in decision-making through all four intensity modes in our study could be a player´s perspective view when watching the videos. We suggest that perspective view can give players some visual advantage in decision making. In contrast, reaction to stimulus in the position of real-field view could lead to an increase in the spatial time pressure which is present in the game.

The performance of perceptual-cognitive skills involving tasks such as choice reaction time or VMRT typically improves during the completion of exercise tasks of increasing intensities until maximal energy expenditure is reached. The results of speed of decision-making in our study are also in accordance with the studies of Chmura, et al. (2002), McMorris and Graydon (1996a), Davranche et al. (2006a), and Davranche, et al. (2006b). These authors found decision-making speed faster after rest and intense exercise at a level about 70% VO_{2max} in comparison to intense exercise at a level of 100% VO_{2max}. According to Chmura et al. (2002) a maximal (anaerobic) physical load led to a quick and significant increase of catecholamine concentration in soccer players, and a subsequent significant decrease in reaction time. However, these findings are in contrast with the results of research by Ando et al. (2005), and Frýbort and Kokštejn (2013). These authors found that VMRT is significantly faster after exercise intensity with the dominant involvement of anaerobic metabolism (maximal intensity exercise), compared to exercise with the dominant involvement of aerobic metabolism (moderate intensity exercise). However, these authors assessed VMRT only by a simple and selective reaction, where players do not have to think about how to solve typical game situations.

Similarly, McMorris and Graydon (1997) reported that soccer player's decision-making speed after moderate (aerobic) exercise intensity and at maximal exercise intensity was significantly better than at rest. Simultaneously, Fontana et al. (2009) demonstrated significantly faster decision-making after exercise intensity of 60% VO_{2max}, and 80% VO_{2max} in comparison to rest in experienced and inexperienced soccer players in the age category of 19 years. The authors point out that more experienced players display significantly faster decision-making speed, by 400 ms on average compared with inexperienced players. Baker et al. (2003) explain these findings by indicating that expert decision-makers within sport use advanced cues, a larger knowledge base, and superior anticipation in order to make faster and more accurate decisions than their lesser-skilled counterparts.

Overall, the pattern of results found in our study reflects the possibility that high intensity exercise has a negative effect on the speed of decision-making involving cognitive elements (e.g., participants must search for relevant information and retrieve information from memory). However, this strategy leads to the maintaining the stability (accuracy) of motor response. It seems that the criterion of accuracy of motor response is more important in cognitive performance than decision-making speed in players of the present competitive standard of play.

One possible limitation in our study could appear in consideration of ecological validity, due to the use of laboratory testing conditions. According to the ecological dynamics approach of Araújo et al. (2006), there are behaviour patterns that emerge from interactions between individuals and the environment. Although we consistently tried to formulate the testing procedure with in situ conditions by using typical game situations and different modes of physical load, the assessment of game situations from a perspective view may reduce the ecological validity.

Conclusion

The results of this research showed that anaerobic, high intensity exercise adversely affects VMRT. On the other hand no significant changes were found in the accuracy of motor response during high intensity exercise, intense intermittent exercise, intense aerobic exercise and motor inactivity. Moreover, we did not find a significant relationship between reaction time and accuracy in motor response. Therefore, we suggest that the accuracy of decision-making in typical game situations represents rather an automatic mechanism (variants in game situation). These mechanisms could be determined, for instance, by long-term soccer experience. In contrast, the speed of motor response is dependent on physiological fatigue manifestation, which could lead to a slowed reaction. Further research should be focused on assessment of VMRT and accuracy in motor response during different physical intensity conditions from a real-field position view. This approach would allow an increase in the ecological validity of research one of the most important factors in estimating real behavior.

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Key points

- Different exercise intensity modes did not affect the accuracy of motor response.
- Anaerobic, highly intensive short-term exercise significantly decreased the visual-motor response time in comparison with aerobic exercise.
- Further research should focus on the assessment of VMRT from a player´s real - field position view rather than a perspective view.

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