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REVIEW PAPERS

The Determination of the Influence of Physical Workload on the Speed of Choice Reaction among Fencers During a Fencing Combat

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Abstract

Fencing sport is fast, athletic, and psychologically very sophisticated. In combat sports, it is necessary to react as fast as possible, because combat tactics includes performing attacking and defensive moves during the entire combat. Reaction time, which is one of the factors determining speed, became one of the main athletic input factors for achievement in fencing. Experience gained in other countries shows that physical load has influence on the manifestations of fencers' reaction speed. In other countries, the impact of physical load on fencers' reaction speed was studied using laboratory tests rather than in real environments. The aim of this study is to determine fencers' choice reaction speed under varying intensity loads in real fencing combat circumstances. Research methods: 8 male national foil fencing teams subjects 17–27-year-old participated in the study; the subjects fenced in 16 combats until 5 points and in 16 combats until 15 points, with 32 combats being recorded, and the speed of choice reaction was analysed using a previously developed protocol, using heart rate monitoring to determine heart rate frequency in both subjects during the combat. Analysing the results of the study, it can be concluded that workload intensity influence reaction speed. Both fencers showed decrease in reaction speed in the 3rd and 4th HR zones. The impact of fatigue is significant for reaction stability, therefore a better-trained athlete with a higher level of aerobic and anaerobic training will be able to react more sustainably during fencing combats, facilitating the production of better results.

Keywords: fencing, reaction speed, workload intensity.

Introduction

Fencing is an elegant and even aristocratic sport, which facilitates the development of reaction, coordination, endurance, and ability to think fast. It is a type of combat sport that requires the performance of sophisticated bodily movements and efficient combat strategies (Soler, 2019). Fencing employs three types of weapons: the foil, the épée and the sabre. The foil weighs 200 g and is 90 cm long. According to a Russian fencing coach, when fencing with a épée, the fencers have the least time, 40 milliseconds (ms), to hit the opponent after meeting an attack themselves (Тышлер, 2010). Fencing is a high-intensity anaerobic sport (Turner, 2017).

In fencing, an athlete's achievements and performance depend on multiple factors. In addition to technical and tactical training, the main factors determining success are aerobic and anaerobic capacity, speed, endurance, agility, flexibility, and coordination (Ince, 2012). Fencers' activity during combat is constituted by a combination of complex movements characterising the reflexive corelation of all the multiplicity of givens and qualities made up by the athlete's functional system (Russell, 2015). During combat, the fencer's activity can have variegated manifestations, demonstrating complicated movement structure that encompass various reaction components (Тышлер, 2010).

Speed is the human ability to perform an activity in minimum time (Liepiņš, 2000). There are numerous physiological and other factors influencing reaction speed, such as age, gender, experience, practice, stimulus intensity, prediction, general health condition, and genetics (Mackenzie, 1998). Reaction speed is the ability to react quickly with the correct position and control on such stimuli as sound and sight (Bhojans, 2015). Reaction speed is one of the basic skills to be possessed by an athlete (Dilworth, 2008). It is the time between the command and the first muscular reaction. Albeit this time of reaction is genetically determined, it can be developed. An audial stimulus requires only 8–10 ms to reach the brain, but a visual stimulus takes 20–40 ms. This means that, the faster the stimulus reaches the motor structure, the shorter will be the reaction time to the stimuli. Thus, given that an audial stimulus arrives before the visual stimulus, reaction to an audial stimulus is faster than that to a visual stimulus (Shelton, 2010). Most researchers indicate that both visual and audial reactions are better in trained athletes than in untrained people. Reaction speed itself is inborn, but total reaction speed can be improved through practice. A shorter reaction time depends on the brain stimulation, so that the brain would process information as quickly as possible. Genetics and reaction speed go hand in hand. Unfortunately, reaction speed can be improved by only 10–20% above the given biological factors (Kikka, 2019). There are many factors that can affect reaction speed in sports, such as age, gender, height, experience, vision, sleep, training, food (Silavskis, 2006).

After training reaction, the athlete's brain learns to react to the moving object (in fencing, to the weapon) and its speed, therefore an athlete sees the moving object move slower and can decide on the best reaction in the given situation (Roi, Bianchedi, 2008). The coach and the athlete should analyse the skills and requirements of their sport in determining possible achievements in total reaction time (Mackenzie, 2008).

Reaction speed is divided into two types: simple and choice reaction. Simple reaction is a response to a previously known signal, such as sprint start. Choice reaction is a response to an unexpected changeable signal. Choice reaction can be of two forms: reaction to a moving object and choice reaction (Liepiņš, 2002). The time of complex reaction to a moving object can be 0.25 to 3.0 – 4.0 sec. The sensory phase lasts approximately 0.05 sec. Thus, in increasing reaction speed, the principal role is taken by the ability to see an object moving at great speed and the motor reaction phase. Training process should aim at these components, using exercises that target reaction to a moving object. In the case when an object is noticed already before the movement begins, reaction time is significantly shorter (Līcis, 2013).

Physical exercises can influence reaction speed. Active training improves choice reaction time, but only eight minutes after the beginning of the exercise. The statement of an 8-min. cycle is true about such sports as baseball and cricket, where active workload time is not long, therefore after warm-up the athletes have the best reaction. Athletes show the best reaction time when their heart rate has reached 115 bpm, or warmup rate zone (Kosinski, 2010). A person who does not do sport has the average reaction time for a visual signal of 0.24 sec., while an athlete as the average reaction time of 0.15 to 0.20 sec, sometimes even from 0.10 to 0.12 sec. Reaction to a sound is usually faster. An untrained person has the period of latency of 0.17 to 0.27 sec, and a high-level athlete 0.05 to 0.07 sec (Ķīsis, 2002).

The speed of reaction in fencing means recognising the target zone, foreseeable attack of the opponent, a definite reaction speed, and movement performance (Bianchedi, 2008). In difference from other biathlon events, where physical power has considerable impact on performance, in fencing reaction time and muscular coordination level during movement are important (Harmenberg, 1992). It is known well that in sport a short reaction time makes teams and individuals win a competition (Turan, 2019).

Fencers are subject to various stimuli, mostly visual and palpable, during training and competition, which means that fencing can be considered a sport where reaction time has significant impact on the total activity of attack and defence. During combat, fencers need to decide quickly to which movements they are to react and which movements they are to ignore. A shorter reaction time depends on the brain stimulus, so that it would process information as fast as possible. Through performing reaction development trainings, an athlete's brain learns to react to the moving object (in fencing, a weapon) and its speed, therefore an athlete sees the object move slower and can decide on the best reaction in a specific situation (Roi & Bianchedi, 2008). Reaction speed is formed by multiple sensory and motor parts, and, while the latent reaction time can hardly be trained at all, the motor reaction period can be perfected in terms of speed (Ābele, 2018). According to Dr paed. Renārs Līcis, 55 studies show that human reaction time decreases until the age of 20–30, when it reaches its optimum value, following which reaction time gradually increases again (Līcis, 2013). Joseph J. Thompson, Mark R. Blair, and Andrev J. Henrey from the US conducted studies on the age period when reaction time decreases, with 3,305 people aged 16 to 44 participating in the study, and they found that reaction time decreases around the age of 24 by 0.5 ms a year (Thompsons, 2014).

Choice reaction can be developed more efficiently in an athlete with good aerobic capabilities. To objectively determine an athlete's aerobic ability level, the method used was beep test with lactate concentrations in the blood at various intensity physical loads. Based on this data, a training programme can be developed for athletes to increase activity optimisation choice reaction speed (Līcis, 2015).

Prof E. Brēmanis indicates that workload is an intensified activity of the bodily systems caused by an athlete's physical work and his/her psychic manifestations during exercise (Brēmanis, 1991). Prof A. Fernāte describes the amount of training and competition workload according to its impact on the athlete's body. Training load is divided into internal and external load. External load is described by volume and intensity. External load describes the volume and intensity of workload, and internal – the impact of workload on the body and its physical, biochemical, psychic, and other changes (Grasis, 2006). Training volume and intensity increase have a determining role on the improvement of the athlete's skill. Workload likewise increases through competition against stronger opponents. It is particularly important, because during competitions athletes undergo psychological stress, thus improving the requisite psychological endurance and stress resistance (Fernāte, 2002). Physical workload is divided into small, average, sub-maximum, and maximum (Fernāte, 2002).

Heart rate zones are divided into 5 zones:

- Zone 1 – considered the target range for warm-up and recovery work and should be around 50–60% (104–114 bpm) of your maximum heart rate.
- Zone 2 – Endurance. This is the zone where the effort required to complete the task still feels light and when you spend time in this zone. The heart rate should be around 60–70% of (114–133 bpm) maximum heart rate.
- Zone 3 – Aerobics. Zone 3 is the aerobic endurance work range and should reach around 70–80% (133–152 bpm) of maximum heart rate.
- Zone 4 – speed endurance. Zone 4 is much more difficult than Zone 3. Zone 4 is for anaerobic capacity, the limit of energy your body can produce through anaerobic means, and should be around 80–90% (152–171 bpm) of maximum heart rate.
- Zone 5 – Maximum effort. Zone 5 target zone for short burst speed workouts and should be around 90–100% (171–190 bpm) of HR max (Krauksts, 2022; Burke, 2023; Wirth & Stoler, 2023; Nurvv, 2024).

An international fencing tournament can last between 9 and 11 hours. Fencing combats take up 18% of the competition time with efficient combat time between 17 and 48 minutes (Bianchedi, 2008). L.W. Oates conducted a study on the physical demands on fencers. The study concluded that the participants spend 82,2% and 76,4% of combat time over 80% of HR maximum during elimination and group combats, respectively. Fencing combats up to 5 points take place in 2–3 minutes on the average with HR 75% to 95%. Fencing elimination combats up to 15 points take up between 7 and 15 minutes with HR 65% to 98%, because a combat until 15 points, in difference from a combat up to 5 points, requires lower intensity activity with fatigue increasing at the end. In every combat, a fencer can cover 250 to 1,000 m in fencing position (Turner, 2014). Oates concluded that energy expenditure in group combat and elimination combat is respectively ~ 12.7 $kcal.\cdot min.^{-1}$ and ~ 12.8 $kcal.\cdot min.^{-1}$ (Oates, 2019).

One physiological restriction that may have more influence on athletic achievement is fatigue. Fatigue develops when the substrates that are responsible for providing the energy for muscular contraction run out or by-products of metabolism accumulate in active muscles (Williams, Ratel, 2009). Fatigue is a transitory yet specific human condition arriving because of continuous or intensive work. Fatigue from performing one and the same workload is manifested in the decrease of muscular work power endurance, movement coordination, and reaction speed. Fatigue can impact the entire body, including the muscles, the bodily organs, and the brain. There are two phases of fatigue:

Compensated fatigue – work intensity can be kept up with increased energy expenditure.

Uncompensated fatigue – an athlete cannot keep up work efficiency, movements become imprecise, and movement speed decreases. The factors facilitating an athlete's fatigue are physiological, psychological, medical, sport psychological, and material technical (Fernāte, 2002).

Fencing competition elimination stage takes place up to 15 points, and the combat consists of three 3-minute periods with 1-minute breaks between them. The aim of sport scientist's R. Milia's study was to understand physiological abilities at the basis of the fencing capability. The average group energy expenditure during combat was (average ± SD) 10,24 ± 0,65 kcal.·min.$^{-1}$. Oxygen uptake and heart rate were always below the anaerobic level, which was assessed previously at the initial incremental test, while lactate in the blood achieved the maximum value of 6,9 ± 2,1 mmol·L^{-1} during the last break between the rounds. The study data shows that energy expenditure among the higher-level fencers is average and that both aerobic energy metabolism and anaerobic lactate energy sources are averagely involved. This should be born in mind by the coaches in preparing athletic training programmes (Milia, 2014).

In studying reaction speed in fencing among various intensity loads with 40 subjects, D. Delignieres and J. Brissvalter concluded that better trained athletes have lower reaction speed decrease at increased workloads than less trained athletes, which enables the conclusion that athletes with a higher functional condition have better reaction speed, as athletes adapt to workload situation more efficiently, preserving greater energy resources (Delignieres, Brissvalter, 2003).

In a study on the impact of physical workload on simple reaction time involving 68 subjects, H. Tsorbatzoudis and V. Barkoukis's results did not support the view that average or higher intensity exercises have substantial impact on the cognitive ability among subjects with trained or untrained aerobic endurance (Tsorbatzoudis; Barkoukis, 1998).

E. Zemkova's study considers the connection between physical workload intensity and reaction time in a group of 16 karate athletes. The results show that at the beginning of the load at heart rate of approximately 120 bpm reaction time slightly decreased to 19 ms. When workload increased, especially above 160 bpm, the speed of reaction at 180 bpm increased by approximately 60 ms. It can be concluded that average intensity exercises facilitate faster reaction to visual stimuli, while the fatigue caused by intense workload is related to the increase in reaction time (Zemková, 2009).

L. Stuarts and G. Bernards conducted a study in 2013 on the impact of physical workload on reaction time, concluding that at heart rate frequency of 115 bpm reaction time becomes longer, thus concluding that an increase kin heart rate frequency is related to longer reaction time (Stuarts, Bernards, 2013).

S. Jin, B. Eason, and M. Lofti's had set the main goal of their study as researching the impact of the intensity and duration of exercise on choice reaction time among 15 subjects. They concluded that the fastest choice reaction time was 75% from the maximum of physical power. The corelation between VO 2 max and choice reaction time throughout the duration of the exercise was very low (Jin, Eason, Lofti, 2015).

A 2019 study of 11 epee fencers examined the relationship between reaction speed and a moving and stationary target. Research methods were used to determine accuracy and reaction time, this was measured with an innovative simulator, (fencing target wall), which captures fencer's lunge punches on signal in moving and uncertain conditions. The results of the study showed that accuracy decreased as the target moved under uncertain conditions and was negatively correlated with reaction speed. Results showed an increased response rate of up to 24% and 20% compared to moving and unmoving conditions, respectively ($p < 0.05$) (Sorel, Plantard, Bideau, Pontonnier, 2019).

Materials and Methods

The study was conducted in 2024. It involved 8 male national foil fencing teams fencers 17–27 year old, with the fencing combats being recorded and analysis undertaken of choice reaction and the influence of workload on choice reaction under combat circumstances, which necessitated the use of video recording and heart rate monitoring. NVIO 14 coding program was used to analyze the reaction speed from the video of fencing fights.

The study subjects conducted a 20-minute warmup before the fencing combat, including running and dynamic flexibility exercises, jumps, coordination, and power exercises with own weight.

The study subjects fenced to 5 points, as in competition group combat, and another time to 15 points as it is done after group combats during elimination combats to 15 points, that is, 3 periods of 3 min.

Following a purpose-made combat analysis criteria protocol, sufficiently fast reactions in fencing attack and defence during combat were analysed. To record hits and defences, fencing points and a hit-recording electronic device were used. The electronic device employed was a screen apparatus showing the time, points, and lights in three colours: a red light at the left, a green light at the right, and yellow lights on both sides. The red light registers a hit in the target zone for the fencer on the right-hand side, and the green lamp records hits in the target area for the opponent, the fencer on the right-hand side. The yellow lights show unauthorized hits in both target zones, e.g., a hit in the arms and legs in fencing with the épée, which is the fencing weapon (discipline) selected for this study. In 14 m from the screen, there were two wires connecting the screen and the wire on the fencer's protective clothing, thus making the electronic device record and show touches to the fencers and the referees during the combat. This fencing equipment is used at all competitions and trainings. Therefore, to objectively determine the speed of special reactions in real fencing combat circumstances, touch recording and point scoring electronic devices for fencing are used. Fencers had their HR recorded during the fencing combats. HR was determined using a HR belt and Polar mobile application connected to the belt.

To determine the statistical differences in two independent entities, Excel 2016 software was used, applying Student's t-test criteria for independent entities.

Results

To determine HR frequency and reaction speed in fencers, control group conducted 16 combats to 5 points and 16 combat to 15 points. Control group data was analyzed for the combat to 5 points and the combat to 15 points.

Figure 1 shows the results of HR frequency during the fencing combat to 5 points. The average HR frequency was 137 bpm, and the maximum 182 bpm. 33 % were spent in the 3th HR zone, which is the longest time for any of the HR zones. The second longest time of 27 % was spent in the 2nd HR zone. The third longest time of 19 % was spent in 4nd HR zone or anaerobic zone. 17 % was spent in was spent in 1nd HR zone. The 5th HR zone, characterised by the highest HR frequency, accounted for 4 %. Analysing the results, one can see that the control group overall spent more than half of the time during the combat in aerobic conditions, with 23 % of the time spent in the anaerobic conditions.

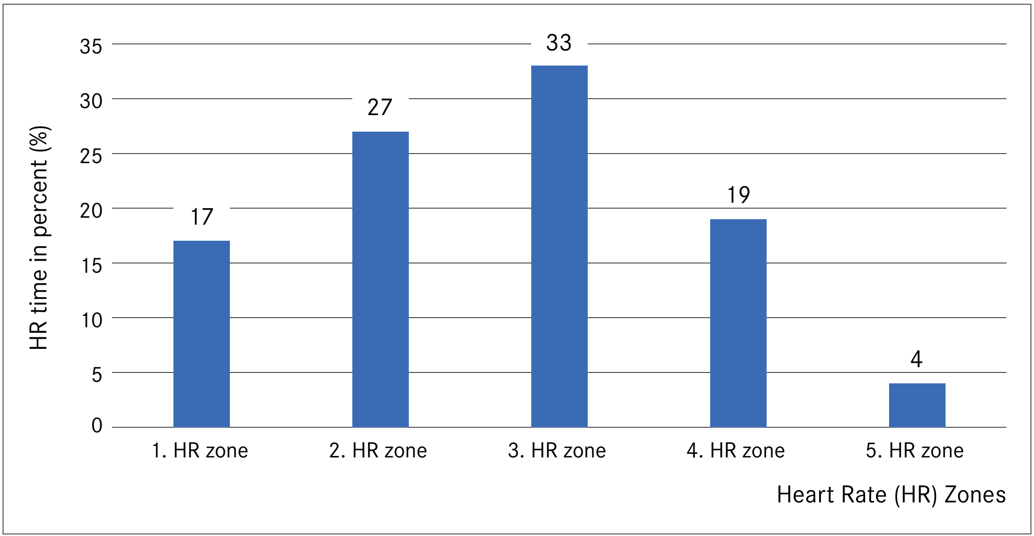

Figure 1. **Analysis of control group HR zones in the combat to 5 points**

Figure 2 shows the results of successful and failed reactions at speed in the combat to 5 points. The fencing combat was spent in the 1nd – 5th HR zone at 50–90% of the HR maximum. In the 1st HR, reaction speed was 55% successful, and 45% failed, but the important thing is that the short fighting time was spent in zone 1 and the reaction situations were much less than in other HR zones. 2nd HR zone subjects were able to respond best compared to other HR zones, was 73% successful, and 23% failed. In the 3rd HR zone (70–80% of HR maximum), 52% of reaction speed was successful, but 48% of reaction speed failed. In the 4th HR zone, reaction speed was successful 55% and 45% of reaction speed was failed. In the 5st HR, reaction speed was 53% successful, and 47% failed. In the 3th HR zone, the results confirm that the previously studied reaction speed decrease is influenced by the athlete's HR frequency being above the 3rd HR zone as (Stuarts, Bernards, 2013; Zemková, 2009). It is also important to mention how the time spent in fencing HR zones and reaction speed depends on the opponent's attacks and the time the athlete spends in the corresponding HR zone (minutes or seconds), as well as the level of technical mastery.

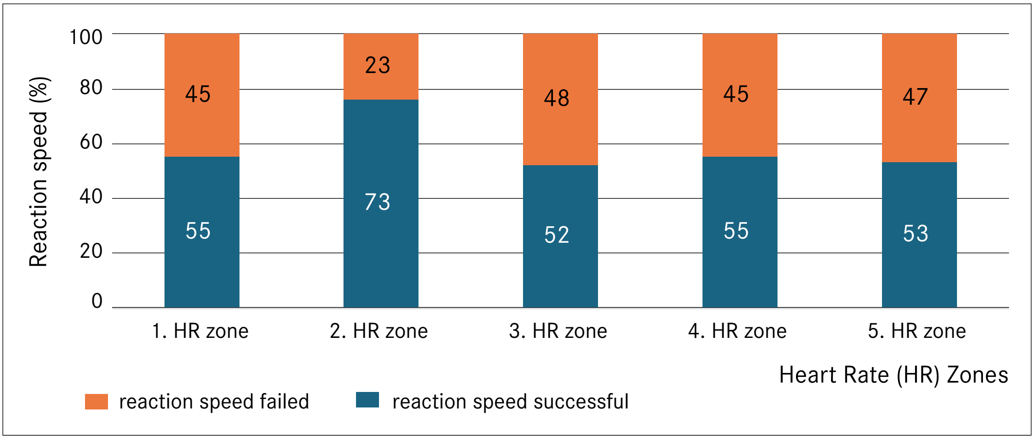

Figure 2. **Results of successful and failed reaction speed for control group in the fight to 5 points**

Figure 3 shows the results of the HR frequency of control group in the combat to 15 points. The average HR frequency in the combat to 15 points was 151 bpm, and the maximum 193 bpm. 32% of the time was spent in the 3th HR zone. The second highest time of 23% was spent in the 5st HR zone or max effort zone. The third longest time of 23% was spent in 4nd HR zone or anaerobic zone. 13% was spent in was spent in 2nd HR zone and 7% in 1st HR zone. Analyzing the results, it can be concluded that in the fencing battles the subjects worked with a very high load up to 15 points, and the fight took place in an anaerobic and maximal mode. The cause of these indicators is fatigue and slow recovery from previous fights and training, as well as the use of offensive tactics in the fight. Combats to 15 points are longer, and the fatigue is higher as compared to the combats to 5 points, explaining the high HR (Oates, 2019).

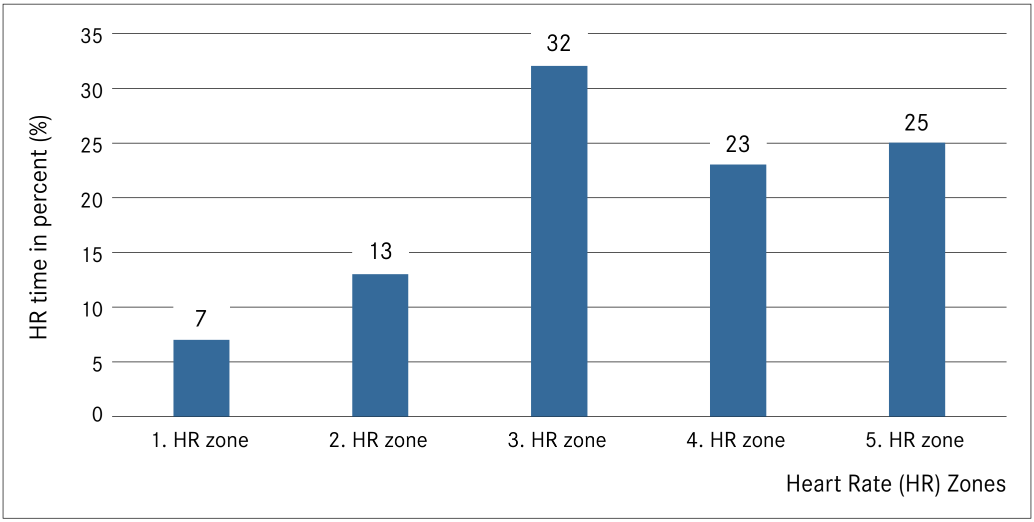

Figure 3. **Analysis of control group HR zones in the combat to 15 points**

Figure 4 shows successful and failed reaction speed results for control group in fencing combats to 15 points. In the 1rd HR zones, 65 % of the reaction speeds were successful, and 35 % failed. 2nd HR zone subjects were able to respond best compared to other HR zones, was 66 % successful, and 34 % failed. In the 3rd HR zone, the reaction speed remained longer, 56 % of reaction speed was successful, but 44 % of reaction speed failed.

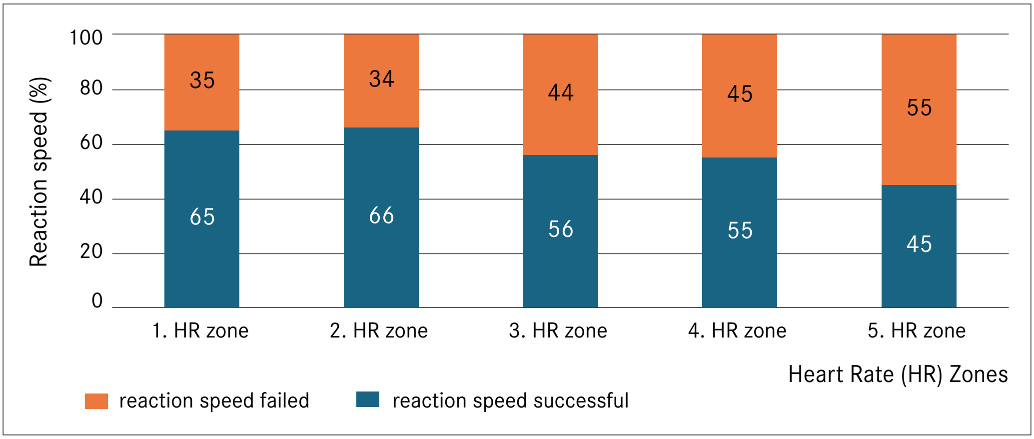

Figure 4. **Analysis control group reaction speed in the combat to 15 points**

In the 4th HR zone, reaction speed was successful 55 % and 45 % of reaction speed was failed. In the 5th HR zone, 55 % of the athlete's reaction speed failed, and 45 % of reaction speed was successful, this can be explained by high fatigue, decreased coordination, and body performance at the maximum of 90–100 % from the HR maximum. The results of control group show confirm the decrease of reaction speed at the increase of HR activity above the 3rd HR zone (Stuarts, Bernards, 2013; Zemková, 2009).

Applying Student's t-test criteria for independent entities, analyzing the results of HR frequency up to 5 points and up to 15 points for the experimental group, a statistical difference was found ($P > 0.05$). But applying Student's t-test criteria for independent entities, a statistically significant difference ($P < 0.05$) was found for the response speed in fights both up to 5 and 15 points.

Discussion

Reaction time is one of the basic skills an athlete can possess (Dilworth, 2008). Many factors can affect the reaction speed. Analyzing the results of this study on the intensity of the load in fencing fights and comparing it with other studies, it can be concluded that the results of this study also confirm the previously studied results in fencing fights up to 5 points 2. On average 3 minutes with HR from 75% to 95%. Fencing knockout bouts up to 15 points take between 7 and 15 minutes with a HR of 65% to 98%, because a bout up to 15 points, unlike a bout up to 5 points, requires a lower intensity of activity and fatigue increases at the end. In this study, the HR of fights up to 15 points was higher, it was between 75–98% than in previous studies (Oates, 2019). The Oates study explored epee fencers and this study explored at foil fencers, so that might be the difference because foil fencing is more intense. Analyzing various studies on the HR frequency and reaction speed and comparing their conclusions to the results of the present study, it can be concluded that previously observed correlations between the HR zone and reaction speed overall hold good. Thus, L. Stuarts and G. Bernards found in their study conducted in 2013 on the influence of physical workload on reaction time that at the HR frequency 115 bpm an athlete shows better reaction time, while at the HR frequency 175 bpm reaction time is longer; likewise in the present study it was found that in the 1st and 2nd HR zone the study subjects reacted quickly enough and successfully deflected the opponent's attacks, with the worst reaction shown in the 3rd to 5th HR zone (Stuarts, Bernards, 2013). It is also important to mention how the time spent in fencing HR zones and reaction speed depends on the opponent's attacks and the time the athlete spends in the corresponding HR zone (minutes or seconds), as well as the level of technical mastery. Another important factor is the age of the subjects of the experiment, because from the age of 24 the reaction time starts to deteriorate, which could have affected the results of the experiment (Silavskis, 2006). An important factor in reactions to speed in fencing is accuracy, that accuracy decreased when the target moved in uncertain conditions, it is negatively correlated with reaction speed, so the reaction speed becomes less accurate for the athlete. Results in a study of reaction speed and accuracy in fencing showed increased reaction speed of up to 24% and 20% compared to moving and uncertain conditions, respectively ($p < 0.05$) (Sorel, Plantard, Bideau, Pontonnier, 2019).

E. Zemkova's study also examines the relationship between physical exercise intensity and reaction time in combat sports. The results showed a similar effect of exercise on reaction speed, when at the beginning of the exercise at a heart rate of about 120 beats per minute (2 nd HR zone), the reaction speed decreased slightly to 19 ms. As the workload increased, especially above 160 bpm (4th HR zone), the response speed at 180 bpm increased by approximately 60 ms. H. Tsorbatzouda and V. Barkouka concluded in their study that physical workload does not influence simple reaction time, but their conclusion contradicts the outcome of the present study, which showed noticeable decrease in reaction speed at high HR frequency (Tsorbatzoudis, Barkoukis, 1998). The results of the study by D. Delignieres and J. Brissvalters on reaction time in fencing at varying intensity workloads show that better-trained athletes display less decrease in reaction speed at increased workloads than less well-trained athletes, confirming the results of the present study, as, in analyzing HR frequency indicators and the time spent in each HR zone, it can be concluded that the heart of a better-trained athlete works more economically and the athlete's reaction time is shorter and stabler than those of the athlete whose aerobic conditioning is worse (Delignieres, Brissvalter, 2003). HR frequency indicators lead to questions about the length of fatigue and the duration of time to be spent in each HR zone to objectively determine the influence of HR zone on reaction speed. Both this and other studies confirmed that reaction speed is mutually related to workload intensity and the athlete's level of endurance is correlated to maximum reaction speed and to the stability of reaction speed.

Conclusions

Having analysed the results, it can be concluded that workload intensity influences reaction speed. Both study subjects experienced decrease in reaction time in HR 3 HR 4 zone. The influence of fatigue is essential for the stability of reaction speed, thus a better trained athlete with a higher level of aerobic and anaerobic conditioning can react longer, which can facilitate winning more combats. The results of this study can be considered as indicators of workload impact on reaction speed in fencing. In future, it is necessary to perform similar studies of reaction speed with a larger number of participants and greater data volume.

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