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Original

Fencing Training with Reaction Time Lights

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ABSTRACT

Objective: evaluate different reaction times in fencing training with reaction time lights

Method: This manuscript proposes four specific exercises for evaluating the simple reaction time (SRT), the elective reaction time (ERT), the go/no-go response time (G/NG) and the decision decision-making after lunge (DML), march (DMM) and braking (DMB) in fencers. The sample consisted of 48 fencers (22 males and 17 females; age: 21 ± 13 years) from several fencing clubs in the region of Andalusia, competing at amateur (10 athletes), regional (17 athletes), national (7 athletes), and international (5 athletes) in the three official fencing weapons: Epee (E), Saber (S), and Foil (F). The exercises were developed for the Queling Sport lighting system, connected by Bluetooth with the ReactionX android application, which controlled the activation of the lights and recorded the reaction time and the correction of the execution for each trial.

Results: The results by gender did not show significant differences. Considering the results by weapon, the foil fencers were fastest than saber fencers, in all the exercises, but they were only significantly faster in the DML and DMM exercises. The performance in all the exercises was directly related with the competition level of the fencer, but only significantly better in foil fencers than in sable fencers when the exercise required decision-making processes.

Conclusions: We propose a reference scale to evaluate the perceptive ability of the fencers that could be applied in talent detection processes and for evaluating the specific perceptive ability of the fencers.

Entrenamiento de esgrima con luces de tiempo de reacción

RESUMEN

Objetivo: evaluar diferentes tiempos de reacción en el entrenamiento de esgrima con luces de tiempo de reacción.

Método: Este manuscrito propone cuatro ejercicios específicos para evaluar el tiempo de reacción simple (SRT), el tiempo de reacción electivo (ERT), el tiempo de respuesta ir/no ir (G/NG) y la toma de decisiones en ejercicios básicos de esgrima como el fondo (DML), la marcha (DMM) y romper (DMB). La muestra estuvo formada por 48 tiradores (22 hombres y 17 mujeres; edad: 21 ± 13 años) de varios clubes de esgrima de la región de Andalucía, que competían en las categorías amateur (10 deportistas), autonómica (17 deportistas), nacional (7 deportistas), e internacional (5 atletas) en las tres armas oficiales de esgrima: espada (E), sable (S) y florete (F). Los ejercicios fueron desarrollados para el sistema de iluminación Queling Sport, conectado por Bluetooth con la aplicación android ReactionX, que controlaba la activación de las luces y registraba el tiempo de reacción y la corrección de la ejecución para cada prueba.

Resultados: Los resultados por género no mostraron diferencias significativas. Considerando los resultados por arma, los esgrimistas con florete fueron más rápidos que los esgrimistas con sable en todos los ejercicios, pero sólo fueron significativamente más rápidos en los ejercicios DML y DMM. El rendimiento en todos los ejercicios estuvo directamente relacionado con el nivel de competición del tirador, pero sólo significativamente mejor en los tiradores de florete que en los de sable cuando el ejercicio requirió procesos de toma de decisiones.

Conclusiones: Proponemos una escala de referencia para evaluar la capacidad perceptiva de los tiradores que podría ser aplicada en procesos de detección de talentos y para evaluar la capacidad perceptiva específica de los tiradores.

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Treinamento de esgrima com luzes de tempo de reação

RESUMO

Objetivo: avaliar diferentes tempos de reação no treinamento de esgrima com tempos de reação.

Método: Este manuscrito propõe quatro exercícios específicos para avaliar o tempo de reação simples (SRT), o tempo de reação eletivo (ERT), o tempo de resposta ir/não ir (G/NG) e a tomada de decisões em exercícios básicos de esgrima como el fundo (DML), la marcha (DMM) e romper (DMB). A mostra foi formada por 48 tiradores (22 homens e 17 mulheres; idade: 21 ± 13 anos) de vários clubes de esgrima da região da Andaluzia, que competiram nas categorias amador (10 desportistas), autonómico (17 desportistas), nacional (7 desportistas), e internacionais (5 atletas) nas três armas oficiais de esgrima: espada (E), zibelina (S) e florete (F). Os comandos foram desenvolvidos para o sistema de iluminação Queling Sport, conectado por Bluetooth ao aplicativo Android ReactionX, que controlava a ativação das luzes e registrava o tempo de reação e a correção da execução para cada teste.

Resultados: Os resultados por género não mostram diferenças significativas. Considerando os resultados por arma, os esgrimistas com florete foram mais rápidos do que os esgrimistas com sable em todos os exercícios, mas só foram significativamente mais rápidos nos exercícios DML e DMM. O desempenho em todos os exercícios está diretamente relacionado ao nível de competição do tirador, mas só é significativamente melhor nos tiradores de florete do que nos de zibelina quando o exercício exige processos de tomada de decisão.

Conclusões: Propomos uma escala de referência para avaliar a capacidade perceptiva dos tiradores que poderia ser aplicada em processos de detecção de talentos e para avaliar a capacidade perceptiva específica dos tiradores.

Introduction

Fencing is one of the oldest sports, as it was created in the 16th century[1]. The traditional rules were gradually transformed to create modern fencing in the late 19th century, becoming one of the first Olympic sports. The International Fencing Federation (Fédération Internationale d'Escrime, FIE) prescribes very strict standards[2] for the organization of fencing competition.

Fencing practice essentially involves touching the opponent in the fastest and most precise manner while avoiding being touched in return. So that, precision and speed of the movements and ability to react to the actions of the opponent are crucial for improving the performance in this sport, both for the amateur athlete and the high-performance athlete[3].

Sports vision involves a comprehensive visual analysis, including a complete assessment of the athlete's visual skills, not only visual acuity but also other skills relevant to the sport. After the initial evaluation, sports optometrists can assist fencers by prescribing optical compensation, whether glasses or contact lenses, to reach the visual skill up to the maximum levels. Additionally, they can provide fencers with vision training exercises and other techniques for improving their visual skills and enhance their performance on the track[4].

This visual training involves the use of many techniques and exercises specifically designed to improve visual skills as hand-eye coordination, visual reaction time, and dynamic visual acuity[5]. Currently, several digital devices are used for training the visual skills on athletes, including virtual reality goggles[6], stroboscopic eyewear[7], and devices with lights[8].

Fencing is very fast and visually demanding sport that requires quick reflexes, excellent hand-eye coordination, and the ability to anticipate and react to an opponent's movements[9]. Therefore, not only a good vision is essential for success in fencing, but also a good use and application of the visual skills on the sport practice.

In recent studies, reaction time light systems having been used for evaluating and training the visual skills of athletes. They consist of a several LED illuminated devices controlled by a software that have been installed in a tablet or personal computer and allows the athlete to be shown many visual stimuli in a random manner[10,11]. These devices are used as targets for the athlete, who must activate or deactivate them according to the program's requirements. These systems are designed to collect performance data related to visual, cognitive, and dynamic reactions. They are primarily used as a measurement instrument, but they can also serve as a training tool to improve performance, primarily reaction time, movement time, and other sensorimotor-cognitive abilities. They are portable and easy to set up and use systems; characteristics that makes them a very useful tool for both training and testing purposes[12] in individual and collective sports.

In this manuscript, we aim to showcase the possibilities of applying digital devices in a programmed visual training, in order to assist coaches to improve the sport performance. The main objective of this study is to demonstrate that working the reaction time with lighting systems allow coaches and athletes to know, measure, and improve their reaction times. The secondary objectives include designing exercises that athletes can transfer to real combat and measuring reaction times as a starting point in a training program to enhance shooters' performance.

Materials and Methods

Sample

The sample consisted of 48 fencers (22 males and 17 females; age: 21 ± 13 years) from several fencing clubs in the region of Andalusia, competing at amateur (10 athletes), regional (17 athletes), national (7 athletes), and international (5 athletes) levels in the three official fencing weapons: Epee (E), Saber (S), and Foil (F). The study was conducted with the voluntary participation of all athletes after signing an informed consent. The sample included 22 (45% of the sample) fencers younger than 18 years, in those cases, the parental consent was requested.

All the participants completed a previous anamnesis including questions about health status and basic visual evaluation including, among others, visual acuity and ocular motility. Subjects who reported having health problems in the last week, had monocular (right or left) visual acuity lower than 0.7, binocular visual acuity lower than 0.8, and altered ocular motility were excluded from the sample.

Materials

To carry out the data collection, we deployed two sets of four Queling Sport lights (Queling China). The 8 lighting devices were synchronized by Bluetooth version 5.0 with the ReactionX application (Queling, China), designed for Android devices. The diameter of the lighting devices is 9 cm and they were attached with Velcro to vertical panel of 1.6 x 1.0 meters with an image of a fencer (Figure 1). The lighting devices have a maximum operational range of 35 to 40 meters and a battery life of 3 hours. It is also worth noting the responsiveness of the devices to diverse stimuli, including vibrational cues, tactile interactions, close-range proximity (8 to 15 cm), or distal proximity (30-40 cm). We selected the "tactile interaction" mode for this testing, so that the device was activated only when any part of its surface was touched.

Figure 1. Arrangement of the lights as a target in all exercises. Positioned as two lateral rights on the arm and left on the chest, one on the waist, and one on the mask.

For carrying out the test in all the conditions, plastic weapons of the same length as those used in actual combat were employed. These weapons featured different grips, allowing athletes to choose the one closer to their own combat weapon.

In addition, it was used a tablet running on the Android operating system with the ReactionX application installed to control and synchronize activation of the light systems and recording the reaction times of the fencers in all the evaluated tasks.

Procedures

In collaboration with coaches, four exercises were designed and conducted to systematically train reaction times and decision-making, simulating the controlled scenarios and actions that fencers face during a bout. (See figure 1).

All measurements were taken during a fencing training session. The duration of all the tested conditions (exercise 1 to 4) was around 10 minutes. All the exercises were explained and practiced for 3 minutes first with the hand, and later with the plastic weapon.

For all the exercises, the data provided by the system included the results for all trials (times and correctness), the fastest, the slowest, and the average of all trials. The quantity and color of the lights for each trial were also indicated.

To test reaction abilities, four exercises were conducted, with different levels of uncertainty:

Exercise 1 for Simple Reaction Time (SRT):

The ReactionX application was configured on the device in "Order" mode, with lights positioned according to Figure 1. Only one light, following a specific sequence known to the athlete, was illuminated in a single color (green) and the fencer had to switch it off with a contact of the weapon. The interval between the extinguish of the light and the activation of the next light was randomized with times between 0.5 and 1.5 seconds.

The fencer was positioned at a distance allowing them to reach the lights with their weapon (typically around 80-90 cm, depending on the athlete's height) and he/she started the test in a fencing guard position with the weapon pointed towards the lights and the target was to switch off the green lights as soon as possible when they appear.

Given the athlete's foreknowledge of the upcoming light, anticipatory responses occasionally resulted. Responses faster than 100 ms were considered as anticipations and they were discarded. Additionally, responses longer than 1000 ms were considered as blockages of the fencers and they were also discarded.

The average number of trials (lights exhibited) in the minute of testing was 33 ± 10, and the total number of discarded trials for anticipation or blockage for all tested subjects was 33 (2.08% of the trials).

Exercise 2 for Elective Reaction Time (ERT):

The ReactionX application was set to "Standard" mode, and the reaction time lights were arranged as per the previous exercise (Figure 1). Here, only one light out of the four illuminated randomly in a single color, while all other configurations of the app were the same that the preceding exercise. Athletes were requested to identify, locate, and react for touching only the illuminated light as fast as possible. Elective Reaction Time (ERT), was defined as the time an individual takes to make a decision and respond to the visual stimulus which, in this case, had four possible options.

Responses faster than 100 ms were considered as anticipations and they were discarded. Additionally, responses longer than 1000 ms were considered as blockages of the fencers and they were also discarded.

The average of trials (lights exhibited) in the minute of testing were 27.69 ± 3.31 and the total number of discarded trials for anticipation of blockage for all the tested subjects were 22 (1.61% of the trials).

Exercise 3 Go/Non-Go Exercise (G/NG):

One of the main decisions a fencer must make is whether to enter in striking distance, to increase the possibility of touching during a bout. To assess this decision-making skill, the Reaction X application was set in "True-False" mode. In each trial a single green light (or none) was lightened with a 0.5-second delay between the extinguishing of the previous trial. The rest of the lights (or the four) were illuminated in red or yellow. In each trial, the lights remained illuminated for a maximum of 2 seconds.

The fencer was asked to extinguish only the green lights and disregarding lights of other colors. The sequence of the lights was always randomized by the system. The fencer positioned themselves at the same distance as in previous exercises, commencing from the fencing guard position. In this exercise, we measured time included apart from the elective reaction time, the go/non-go response time. The fencer had to react to the colors of the lights to execute a touch or to stay in the guard position. The application provided acoustic feedback on incorrectly extinguished lights, as well as lights that were missed.

Responses faster than 100 ms were considered as anticipations and they were discarded. Additionally, responses longer than 1000 ms were considered as blockages of the fencers and they were also dicharded.

The average of trials (lights exhibited) in the minute of testing were 17.27 ± 3.61 and the total number of discarded trials for anticipation of blockage for all the tested subjects were 3 (0.24% of the trials).

Exercise 4 Decision-Making Exercise (DM)

This is an evolution of the previous exercise where the fencer had to perform a specific type of exercise based on prior instructions, depending on the color of the light observed. The Reaction X application was configured on the device with the "Combined" mode. Only one lamp out of the four would light up randomly with one of the three predetermined colors (i.e. blue, red and green), each associated with a specific movement.

Table 1. Results of the four considered test by sex (times in ms).

	All (n=48)	Males (n=25)	Females (n=23)	*K-W / t*	P	Cohen d
SRT1*	388 ± 146	429 ± 164	360 ± 121	*0.843*	*0.358*	
ERT2*	543 ± 115	541 ± 146	546 ± 68	*0.396*	*0.529*	
G/NG3*	570 ± 79	556 ± 85	576 ± 73	*0.038*	*0.845*	
DML4	1083 ± 185	1104 ± 159	1016 ± 211	0.841	0.405	0.243
DMM4	1325 ± 234	1331 ± 220	1275 ± 251	0.827	0.412	0.291
DMB4	1627 ± 268	1612 ± 256	1675 ± 281	-0.809	0.423	-0.234
DM complete	1336 ± 319	1338 ± 291	1323 ± 348	0.241	0.810	0.040

Note *In exercises marked with "*" Kruskal-Wallis test (K-W) analysis is reported, in other cases Student's T test (t) was applied.*

When the lamp illuminated with green light, the subject had to perform a lunge to touch the lights as quickly as possible (DML). If the illuminated light was red, the subject executed a marching movement to touch (DMM), and when the illuminated light was blue, they had to perform a breaking movement before executing a march or lunge to touch the activated device (DMB).

With the reaction time lights located in the same position as the others exercise (Figure 1), the fencers stood in the guard position at a distance from the lights that allowed them to touch the lights by making a typical fencing displacement with the weapon (usually about 100-120 cm from the target). In each module of the exercise (i.e. DML, DMM and DMB), the times taken to turn off the lights for each module were displayed.

Responses faster than 100 ms were considered as anticipations and they were discarded. Additionally, responses longer than 2500 ms were considered as blockages of the fencers and they were also discarded.

The average of trials (lights exhibited) in the minute of testing were 9.85 ± 4.24 and the total number of discarded trials for anticipation of blockage for all the tested subjects were 45 (3.17% of the trials).

It must be noted that, both fencers and coaches, were more interested in the fourth exercise as it closely resembled real combat.

Statistical Analysis

For the descriptive statistics, the average of all the attempts of each exercise was obtained, after discarding the anticipated responses and blockings.

The normality of all the considered variables was tested by the Shapiro-Wilk test. The normality was assumed only for the results of the DM4 exercises, but not the ERT, SRT and G/NG exercises. Given the limited sample size, in the results section of the manuscript both parametric and non-parametric test have been shown in the tables, according to the sample distribution. For all the statistical test the level of significance was set at $\alpha = 0.05$)

Kruskal-Wallis test were done for searching differences on the response times in the ERT, SRT and G/NG exercises by weapon, level of the fencer and gender, applying standard post hoc test for defining significant differences among groups.

ANOVA for independent samples were done for searching differences on the response times by weapon and level of the fencer, applying Tukey post hoc test for defining significant differences among groups. Additionally, the η^2 was determined to define the effect size, considering values <0.01 as small effect, values >0.01 and <0.14 as medium effect and values >0.14 as high effect size.

Finally, Student's t test for independent samples was run for evaluating differences by gender in the results of the fourth exercise (DM4), and Cohen d was indicated to express the effect size of the differences by gender <0.2 as small effect, values >0.2 and <0.8 as medium effect and values >0.8 as high effect size.

Results

General results

Table 1 summarizes the mean values for each exercise for the entire sample. We note that the simple reaction time (SRT1) was (388 ± 146 ms), and the elective reaction time (ERT2) was (543 ± 115 ms). The mean value for the go/no-go exercise time (570 ± 79 ms) is quite similar to the elective reaction time. In the decision-making exercises, the fastest movement was the lunge (DML4) (1083± 185 ms), followed by the marching movement (DMM4) (1325 ± 234 ms), and the slowest was the breaking (DMB4) (16271 ± 268 ms).

Results by sex

The table 1 also displays the results separated by gender (males and females). As can be observed the Kruskal-Wallis test or the Student's T test (depending in the character of the sample) do not show significant differences between genders in all the exercises) (p>0.05), and the results are quite similar without a clear trend on the differences by gender.

Results by weapon

Table 2 shows the averaged values by the fencer's weapon. The ANOVA analysis pointed to significant differences only in the decision-making exercises, in the DML4 (F=4.741; p<0.05) and DMM4 (F=6.196; p<0.05), but not in the DMB4 (F=1.073; p=0.350). When the average of the three decision-making exercises were considered (DM4), the results showed also significant differences by fencers weapon (F=4.688; p<0.05). In all the cases, the Tukey post-hoc analysis indicated that the significant differences were between Sabre and Foil groups (p<0.05), with higher decision-making values in the Sabre group and lower values in the Foil group. In all the cases, the Eppe group had intermediate results without significant differences among the other two groups.

Results by level of the fencer

In Table 3 is can be seen the average results by the level of the fencer. The general trend of the results indicates the worst performance (longer times) in amateur fencers, followed by regional and national level fencers, with the best performance (shorter times) seen in international level fencers. However, the one-way ANOVA or Kruskal-Wallis analysis only exhibits significant differences (p<0.05) for the ERT2 (K=8,649; p<0.05) and the DMM4 (F=4.539; p<0.05) exercises, and for average of the three decision-making exercises (DM4) (F=4.688; p<0.05). In all the cases, the Tukey post-hoc analysis indicated significant differences were between the amateur and international level fencers (p<0.05). Additionally, for the decision-making exercises (DMM4 and DM4) they were also found significant differences between amateur and national level fencers (p<0.05).

Proposal of reference values

With all the registered data, we have created a proposal of evaluation scale of the different exercises considered in the study (Table 4), which can be used for estimating the score of any fencer on

Table 2. Results of the four considered test by weapon (times in ms).

	Epee (a) (n=17)	Sabre (b) (n=18)	Foil (c) (n=13)	*K-W / F*	P	η^2
SRT1*	397 ± 113	473 ± 178	366 ± 115	*3.358*	*0.187*	
ERT2*	561 ± 141	581 ± 117	544 ± 68	*0.942*	*0.625*	
G/NG3*	564 ± 66	602 ± 99	568 ± 59	*1.198*	*0.549*	
DML4	1110 ± 186	**1192 ± 188**[c]	**999 ± 121**[b]	**4.741**	**0.014**	**0.174**
DMM4	1274 ± 215	**1432 ± 211**[c]	**1166 ± 210**[b]	**6.196**	**0.004**	**0.216**
DMB4	1611 ± 282	1714 ± 308	1584 ± 165	1.073	0.350	0.046
DM4	1332 ± 309	**1446 ± 320**[c]	**1250 ± 299**[b]	**4.688**	**0.011**	**0.062**

Note In exercises marked *with* "*" KruskalWallis test analysis (K-W) is reported, in other cases one way ANOVA (F) was applied.**a, b, or c** Significant differences between groups from the Tukey post-hoc test analysis is indicated with the letter of the group in superscript

Table 3. Results of the four considered test by level of the fencer (times in ms).

X	Amateur (a) (n=12)	Regional (b) (n=19)	National (c) (n=10)	International (d) (n=7)	K-W / F	P	η^2
SRT1*	480 ± 194	435 ± 134	369± 101	329 ± 79	*5,347*	*0,148*	
ERT2*	620 ± 127[d]	572 ± 128	543 ± 479	**479 ± 71**[a]	*8,649*	*0,034*	
G/NG3*	620 ± 96	577 ± 72	580 ± 63	547± 89	*2,471*	*0,481*	
DML4	1178 ± 240	1125 ± 160	1058 ± 190	1033 ± 100	1,277	0,294	0,080
DMM4	1486 ± 156 [c,d]	1287 ± 188	**1180 ± 291**[a]	**1215 ± 226**[a]	**4,539**	**0,007**	0,236
DMB4	1763 ± 389	1666 ± 205	1595 ± 161	1439 ± 191	2,655	0,060	0,153
DM	1476 ± 363 [c,d]	1360 ± 292	**1277 ± 317**[a]	**1229 ± 241**[a]	4,688	**0,011**	**0,062**

Note In exercises marked with "*" Kruskal-Wallis test analysis (K-W) is reported, in other cases one way ANOVA (F) was applied.**a,b,c or d** Significant differences between groups from the Tukey post-hoc test analysis are indicated with the letter of the group in superscript.

Table 4. Proposed reference scale in points (0 to 10) for assessing the level of the fencers in the different exercises considered in the study.

Points	SRT1		ERT2		G/NG3		DML4		DMM4		DMB4	
	#Trials	Time	#Trials	Time	#Trials	Time	#Trials	Time	#Trials	Time	#Trials	Time
0	15	781	16	1012	10	762	4	1623	3	1684	3	2480
1	21	634	24	671	11	680	7	1340	6	1606	5	1967
2	28	508	25	634	13	656	8	1297	7	1535	6	1763
3	30	459	26	591	14	610	9	1250	9	1505	7	1718
4	30	426	27	567	15	590	10	1141	9	1358	9	1651
5	32	388	28	543	16	570	11	1090	10	1326	10	1627
6	36	352	28	525	18	548	12	1048	11	1272	11	1573
7	37	324	29	502	20	524	12	992	11	1151	11	1534
8	41	297	30	479	23	508	13	933	13	1065	12	1468
9	43	264	31	457	25	484	13	906	13	1004	14	1351
10	49	197	33	407	28	468	16	809	15	779	14	997

Note Time = Values expressed in ms; #Trials = average number of trials presented in one minute.

Table 5. Scores in points (0 to 10) for the fencers by level of competition, considering the reference score proposed in Table 4.

	Points	*Time*	*Points*	*Time*	*Points*	*Time*	*Points*	*Time*	*Points*	*Time*	*Points*	*Time*
Amateur	*2.6*	480	*2.3*	620	*2.8*	620	*3.7*	1178	*3.1*	1486	2.0	1763
Regional	*3.7*	435	*3.8*	572	*4.7*	577	*4.3*	1125	*5.7*	1287	3.8	1666
National	*5.5*	369	*5.0*	543	*4.5*	580	*5.8*	1058	*6.8*	1180	5.6	1595
International	*6.8*	329	*8.0*	479	*6.1*	547	*6.3*	1033	*6.5*	1215	8.3	1439

Note Time = Values expressed in ms; #Trials = average number of trials presented in one minute.

each exercise. For better understanding and interpretation of the evaluation scale, we have applied it to obtain the points of the average values on each exercise for the four competition levels of fencers (shown in Table 3).

Discussion

Reaction time lights are employed to enhance visual skills across various sports. The analysis of reaction time and visual anticipation should be integral to the design and implementation of a visual training program aimed at improving athletes' visual skills to enhance their sports performance[13]. They have demonstrated their validity in specific training sessions for fencers of varying levels to enhance the physical performance of fencers[2,14,15].

Based on this premise and with the assistance of coaches, we formulated specific exercises for evaluating the simple and elective reaction time and decision-making in fencers. We will discuss the obtained results, first in general and, later, according the gender, the weapon and the level of the fencer and we will propose a draft of a reference scale to establish the level of the fencers on those visual skills.

General results

The general results indicated that the reaction and decision-making times are directly related to the difficulty of the task. The fastest times corresponds to the SRT1 (388 ± 146 ms) because it was used a single light and there is a lack of cognitive processing in the task. The fencer just touched the light when it was switched on.

The second exercise in term of cognitive complexity was the ERT2 (543± 115 ms), in which the fencers had four lights and they had to touch only the light that it was switch on.

If we consider the SRT2 and ERT2 results, we can observe the differences of the fencers' reaction times between planned and unplanned actions; when the fencers knew which light would be illuminate (SRT1), the times were shorter than when they were unaware (ERT1), these results are slightly different in absolute values but similar with the findings from other researchers with other sport and protocols[10,16].

The results for third exercise G/NG3 were quite similar to the ERT (570 ± 79 ms), similar to those found by other authors[17] 0.523 ± 0.074 ms. At this point, it must be considered that, as it was mentioned in the data collection protocol, the number of mistakes or blockages in the ERT2 exercise was higher (22 discarded; 1,61% of the whole) than in the G/NG3 (3 discarded; 0.24% of the whole). That point is very important to interpreter the results because in the ERT2 exercise, the fencers started the movement when the four lights were activated, and the action could be optimized during the movement of the weapon. However, in the G/NG3 the action could not be corrected once the movement was started, and it could not be modified the trajectory of the weapon; so that, the decision-making had to be completely and perfectly done before starting the action. Tasks such as Go/No-Go, addressing choice and decision speed during exercise, and they can identify defects in visuomotor control and balance that may persist after recovery[18].

The most difficult tasks from a cognitive point of view were those included in exercise 4 (DML4, DMM4, DMB, and DM4 as the average of the three tasks). Considering all the decision-making exercises, we obtained results closely related to the technical aspects of the movements required of the fencer, even when significant differences between the exercises were not found. (p>0.05). The fastest movement was the lunge (DML4) (1083± 185 ms), which is the fastest attack in fencing, followed by the marching movement (DMM4) (1325 ± 234 ms), and the slowest results were for the breaking action (DMB4) (16271 ± 268 ms), because this movement requires a previous step backwards before starting the attack action. These times were higher than those obtained by other authors[19] (1083± 185 ms vs. 601 ± 82ms); these differences may be due not only to the different methodology of the studies, but also to the different level of the fencers, as they had only had elite fencer of aiming weapons: foil and epee, and in our sample we had also non-elite level athletes including saber fencers. The saber fencers normally touch with the edge of the weapon and they start from a different guard position; these conditions were different to the requested in the exercises. Other authors who measured accuracy and touch times in fencing with a protocol similar to ours obtained closer exercise times 1336 ± 319 ms vs. 1680 ± 250 ms[20,21] (1336 ± 319 ms vs. 1194 ± 86 ms)

Results by sex

The results separated by gender do not show significant differences between males and females in any of the exercises. (p>0.05), being the results quite similar in most of the exercises without a clear trend on the differences by gender. Although other authors also found no significant differences in attack speed between gender with a sample of 9 males and 13 female young fencers 13.4±0.85 years old (men 3.6 ± 0.90 m/s and women 2.90 ± 0.72 m/s)[4]. Other studies on fencing did show differences in the attack times of men compared to those carried out by women[22] with a sample of 13 men aged 25.9 ± 2.8 years and 13 women aged 25.8 ± 3.1 years foil fencer finalists from the FIE competitions.

Results by weapon

When we analyze the data by weapon, the average values of the foil fencers were the fastest, in all the exercises, being the differences statistically faster than the sabre fencers in the decision-making exercises DML4 (Foil= 999 ± 121 ms vs Sabre= 1192 ± 188 ms) (F=4.741; p<0.05) and DMM4 (Foil= 1166 ± 210 ms vs Sabre= 1432 ± 211 ms) (F=6.196; p<0.05), but not in the DMB4 (F=1.073; p=0.350). When the average of the three decision-making exercises were considered (DM4), the results showed also significant differences by fencers' weapon (F=4.688; p<0.05), with higher decision-making values in the sabre group and lower values in the foil group (Foil= 1250 ± 299 ms vs Sabre= 1446 ± 320 ms). In all the cases, the Eppe group had intermediate results without significant differences among the other two groups.

These results were expected because, although the Sabre fight is faster, its touch requires less accuracy and the usual touch is with the edge of the weapon, which is less accurate and not the requested technique in the exercises. Besides, the sabre fencers start from a different guard position, and they were not used the guard position requested on the exercises. These times were higher than those obtained (1110 ± 186 ms vs. 601 ± 82ms)[19] for sword fencer, and (999± 121 ms and 1194 ± 86 ms)[21] for foil fencers, because these authors only had elite foil and epee fencers and in our sample were included fencers of different practice levels including amateur fencers.

Results by level of the fencer

When the averages obtained in the four exercises were separated by the level of competition of the athletes, The general trend of the results indicates the worst performance (higher times) in amateur fencers, followed by regional and national level fencers, with the best performance (lower times) seen in international level fencers, and the best results (lower times) were for the international level fencers, like other authors found for different sports (Van de Water et al., 2017). This is logical because the faster and more accurate is an athlete, the better can qualify in the championships; however, Kruskal-Wallis analysis only exhibited significant differences (p<0.05) for the ERT2 between the amateur fencer group and the international fencer group, (International= 479 ± 71 ms vs Amateur= 620 ± 127 ms) (K=8.649; p<0.05).

When analyzed one way ANOVA, significant differences were shown in the DMM4 exercises between the amateur fencer group (1486 ± 156 ms) compared to the national (1180 ± 291 ms) and international (1215 ± 226 ms) fencer groups (F=4.539; p<0.05), and for average of the three decision-making exercises (DM4) with lower times for the amateur group 1476 ± 363 ms) compared with the International (1229 ± 241ms) and National (1277 ± 317 ms) groups (F=4.688; p<0.05). In all the cases, the Tukey post-hoc analysis indicated significant differences were between the amateur, and national, international level fencers (p<0.05).

Application of the reference values

After evaluating the fencers on any of the exercises considered in this manuscript, their results can be scored with the proposed reference scale (Table 4). The example shown in the Table 5 allows see in a glance that the level of performance is directly related with the competition level of the fencer. This reference scale could also be applied in processes of talent detection as an easy way to evaluate the specific perceptive ability of the fencer, or to check the effect of the perceptive trainings, just comparing the scores before and after the intervention program.

Conclusions

This manuscript proposes four specific exercises for evaluating the simple and elective reaction time and decision-making in fencers. The general results indicate that the reaction and decision-making times are directly related to the difficulty of the task. As other previous studies, we confirm that the fastest times corresponds to the SRT exercise followed by, at the same level by the ERT and G/NG3 exercise; however, the number of blockage and mistakes and the technique of the required action must be considered in these cases.

The most difficult tasks from the cognitive point of view were the decision-making exercises (DML, DMM and DMB) in which the results are close related to technique of the movements requested to the fencer. The fastest movement was the lunge (DML), followed by the march (DMM) and the slowest was the breaking action (DMB).

The results separated by gender did not show significant differences between males and females in all the exercises. Considering the results by weapon, the foil fencers were faster than the saber fencers in all exercises, but they were only significantly faster in the DML and DMM exercises. In all the cases, the Eppe group had intermediate results without significant differences among the other two groups. Finally, when results were analyzed by the level of competition, performance in the all exercises was directly related with the competition level of the fencer.

We have edited a reference scale to evaluate the perceptive ability of the fencers that could be applied in processes of talent detection and for evaluating the specific perceptive ability of the fencers.

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