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Physiological demands of standing and wheelchair fencing in able-bodied fencers

*Xavier Iglesias[1], Ferran A. Rodríguez[1], Rafael Tarragó[2], Lindsay Bottoms[3], Lisímaco Vallejo[1], Lara Rodríguez-Zamora[1] and Michael Price[4]

[1] INEFC-Barcelona Sports Sciences Research Group, Institut Nacional d'Educació Física de Catalunya (INEFC), Universitat de Barcelona, Spain; [2]GISEAFE, Institut Nacional d'Educació Física de Catalunya (INEFC), Universitat de Barcelona, Spain; [3]School of Life and Medical Science, University of Hertfordshire, Hatfield, UK; [4]Department of Biomolecular and Sports Sciences, Coventry University, Coventry, UK

*Corresponding Author: Prof. Xavier Iglesias, Institut Nacional d'Educació Física de Catalunya (INEFC), Av. de l'Estadi, 12-22, 08038 Barcelona, Catalonia (Spain). Email: xiglesias@gmail.com

ABSTRACT

BACKGROUND The purpose of this study was to determine the cardiorespiratory demands of standing and wheelchair (seated) fencing in a group of able-bodied fencers during simulated competitive bouts.

METHODS Participants were a group of ten regional level able-bodied fencers with previous training experience in wheelchair fencing. After a standardised warm-up participants performed two series of simulated competitive épée bouts (5 and 15 touches) in a random order, either while standing or while sitting in a wheelchair. Expired gas was analysed for oxygen consumption ($V\square O_2$) and respiratory exchange ratio (RER) and heart rate were continually monitored. Energy expenditure (EE) was subsequently calculated.

RESULTS The $V\square O_2$, HR and EE peak responses were greater during standing than seated fencing ($p< .05$). The mean $V\square O_2$ (% peak) during the seated 5 and 15 touch bouts were 54% ±15% and 58% ±11% of the standing bouts. Mean HR during the standing 5 and 15 touch bouts was 77% ±12% and 85% ±11% of that recorded during the seated bouts. HR, $V\square O_2$ and EE data also suggested that the 15 touch bouts were more physiologically demanding than the 5 touch bouts ($p< .10$). The HR-$V\square O_2$ relationship was similar between both fencing modes. The duration of the 5 and 15 touch bouts were shorter for the seated than the standing bouts ($p<.05$).

CONCLUSIONS The physiological demands of seated fencing are lower than those for standing fencing. Furthermore, the physiology of 5 vs. 15 touch bouts similar to those undertaken in fencing competition also differs.

Key words: adapted sport, adapted physical activity, heart rate, oxygen consumption, energy expenditure

TEXT

Introduction

Fencing performance is predominantly based on technical and tactical factors[1]. However, in recent years fencers have faced increasingly larger training and competitive loads imposing high physiological demands from both competition and training. During the last decade efforts have been made to improve our knowledge of the cardiorespiratory responses and energy demands of fencing during real and simulated competition[1-6]. Furthermore, the physiological profiles of competitive fencers with respect to age, gender, weapon, and performance levels have been examined[2, 7, 8]. For example, able-bodied competitive fencers typically exhibit maximal oxygen uptake ($V\square O_{2max}$) values within the range of ~50-60 $ml \cdot kg^{-1} \cdot min^{-1}$ for men[6] and ~40-50 $ml \cdot kg^{-1} \cdot min^{-1}$ for women[3]. The mean estimated oxygen cost of fencing assaults during an international competition has been found to be greater in males than in females with an average relative exercise intensity of 56-74% of $V\square O_{2max}$, and peak values of 75-99% of $V\square O_{2max}$. With this in mind, the cardiorespiratory demands during fencing tournaments should not be underestimated and need to be considered as an important training component[2].

Wheelchair fencing has been part of the Paralympic Games since its inception in 1960. However, to the best of our knowledge, only one study has reported the physiological responses to wheelchair fencing activity[9]. Here, oxygen consumption ($V\square O_2$) values of 25.0 ± 4.4 $ml \cdot kg^{-1} \cdot min^{-1}$ during a simulated competition in six Paralympic fencers corresponding to 73.0% ± 3.1% of the $V\square O_{2max}$. The athletes tested consisted of 4 in class B (all with

paraplegia), and two in class A (1 with poliomyelitis and 1 with transtibial amputation). However, little normative information is available regarding variables such as V□O_2 and energy expenditure (EE) for other disability groups involved in this sport. As prediction of EE for wheelchair activities based on able-bodied norms significantly overestimate EE values[10], the need for more specific EE reference values is apparent. More accurate EE values will enable improved nutritional advice as well as more informed training programmes for this population.

Although cardiorespiratory demand and EE data is available for wheelchair fencing training in athletes with heterogeneous disabilities of the lower extremities[9], a wide range of athletes with different impairments/disorders compete together within each fencing classification. According to the Official Paralympic Classification (www.paralympic.org), Category A fencers have good trunk control and have full function of their arms. Not all fencers in this category use a wheelchair in their daily life and therefore, may have similar recruitable muscle mass to those of able-bodied fencers. Consequently, obtaining cardiorespiratory and EE data for able-bodied fencers undertaking seated fencing may provide an insight into the underlying physiological demands of wheelchair fencing. Furthermore, using a population of trained fencers accustomed to both standing and wheelchair fencing overcomes differences in skill level, which may be observed with untrained, or novice participants. Therefore, it was the aim of this study to determine the physiological responses of well-trained able-bodied fencers to simulated fencing competition in both standing and wheelchair-seated positions. We hypothesised that energy expenditure and cardiorespiratory demands would be lower during wheelchair fencing due to the smaller muscle mass involved and the relatively static type of exercise undertaken.

Materials and Methods

Participants

Ten able-bodied male fencers (mean ± SD: age 23.3 ± 7.6 years; body mass 70.8 ± 9.3 kg) volunteered to participate in the study, which had been approved by the Clinical Research Ethics Committee of the Catalan Sports Ministry (Chair: Sra. Anna Pruna, protocol number: 0099S/2912/2010 Ref. 2607/LA) on 7th April 2010 and followed the principles outlined in the Declaration of Helsinki. Prior to data collection and after a thorough description of the risks involved within the study written informed consent was obtained from each subject. Participants had at least 3 years experience of training in épée fencing at regional level and participated weekly in wheelchair fencing. All participants were in a rested state prior to testing having refrained from alcohol and vigorous exercise in the 24 hours prior to testing and caffeine and food ingestion in the 2 hours prior to testing. There were two fixed wheelchairs, which were used by all fencers to prevent differences in performance.

Study design

A counterbalanced within-subjects design was chosen with participants undertaking either the seated wheelchair (WC) or standing (ST) fencing, and the 5 or 15 touch bouts first, in a balanced order. All fencing was undertaken in an air-conditioned sports hall which was maintained at approximately 25 ºC.

Procedure

After a 10-min warm-up consisting of stretching and fencing movements, participants were assigned into five pairs of similar ability. Each participant always competed with the same rival when standing and sitting so as to maintain the same level of competitive difficulty in both combat situations. The first fencing bouts whether standing or sitting consisted of 5 or 15 touches, simulating 5 or 15 points scored, followed by a 3-min rest and a further bout of

15 or 5 touches, simulating 15 or 5 points scored. Total bout time was recorded for both 5 and 15 touches for both modes of fencing. These fights represent the points required within the 'poule' and 'direct elimination' components of fencing competition. Following a 10-min rest a second 5 and 15 touch bout were undertaken in the alternative fencing mode (Figure 1). When fencing in the seated position the WC was clamped to a heavy metal strip as used in WC competitions. Room temperature was maintained at approximately 25 ºC.

--- Figure 1 near here---

Throughout all fencing bouts, gas analysis and heart rate (HR) were measured using a portable telemetric breath-by-breath gas analyser (Cosmed K4 b^2, Italy) connected to an oronasal Hans-Rudolph 7400 mask (Hans Rudolph Inc., Shawnee, Kansas, USA) that fitted comfortably under a conventional fencing mask. HR was measured using a telemetric chest strap. Gas analysis data was analysed for oxygen uptake ($V\square O_2$), respiratory exchange ratio (RER), pulmonary minute ventilation (V_E), and breathing rate (RR). Prior to each test, analysers were calibrated with gases of known concentration and the linearity of the gas meter was checked by a 3-litre calibration syringe according to manufacturer's instructions. All gas analysis variables and HR data for each 5 and 15 touch bout were analysed in order to produce mean, maximum and minimum values. EE was estimated from $V\square O_2$ and $V\square CO_2$ averaged over the same time periods using the Cosmed K4 b^2 software which is based on the Weir equation [11].

Statistical analysis

Values are expressed as means ± standard deviations. Normal distributions were tested with the Shapiro-Wilks test. Data for $V\square O_2$, HR, RER and bout duration were analysed using two-way analysis of variance (2-way ANOVA) with repeated measures on both factors: bout (5-15 touches) x mode (ST-WC fencing). Where significance was achieved the magnitude of

the difference between pairwise comparisons required for significance was calculated [12] and the precise p-value was indicated. Pearson's linear correlation coefficient (r) was used to establish the relationship between variables. Significance was accepted at the level of $P < .05$. All statistical analyses were performed using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

Table 1 summarises the physiological responses for each of the 5 and 15 touch bouts during ST and WC fencing.

--- Table 1 near here---

Although no interactions were observed for V□O_2, main effects were noted for both fencing mode and bout for mean V□O_2 ($P = .0001$; $P = .009$, respectively) and maximum V□O_2 ($P = .0001$; $P = .008$, respectively). The mean V□O_2 during all ST bouts (5 and 15 touch) was 44% greater than in WC fencing (44.2 ± 7.8 vs. 24.7 ± 5.6 $ml \cdot kg^{-1} \cdot min^{-1}$) (Table 2).

--- Table 2 near here ---

Similar results were obtained for HR. Both mean HR and maximal HR were greater during ST fencing when compared to WC fencing (main effect for mode; $P < .001$ for both variables). The main effects for bout approached significance for both mean ($P = .086$) and maximal HR ($P = .052$). Mean V_E tended to be higher during ST fencing ($P = .09$) but RR was not significantly different ($P = .22$). No interaction was observed for EE however, a main effect was observed for mode ($P = .000$) with EE being significantly greater for ST compared to WC. The main effect for bout approached significance ($P = .085$). An interaction was observed for bout duration ($P = .023$). The 5 touch bouts were shorter in duration than the 15

touch bouts for both fencing modes ($P < .05$). Similarly, the 5 and 15 touch bouts were shorter during WC than ST fencing ($P < .05$).

The V□O_2 during the 5 touch bouts was 77% ± 12% and 85% ± 11% of that observed for the 15 touch bouts for ST and WC fencing, respectively. The V□O_2 for WC fencing bouts when compared to the ST bouts was 54% ± 15% and 58% ± 11% for the 5 and 15 touch bouts, respectively. A significant correlation was observed between mean V□O_2 during the WC and ST 15 touch bouts (r= .639, $P = .046$) but not between the 5 touch bouts (r= .319; $P = .368$). The relationships between HR and V□O_2 for WC (r= .646, $P = .002$) and ST (r= .559, $P = .010$) fencing were significant (Figure 2). When considered individually as 5 and 15 touch bouts the HR-V□O_2 relationships were significant for WC fencing (r= .630, $P = .050$; r= .644; $P = .046$, respectively) but not for ST (r= .598, $P = .105$; r= .542, $P = .067$, respectively).

--- Figure 2. near here ---

Discussion

The current study investigated the EE and cardiorespiratory demands of wheelchair and standing fencing in able-bodied participants. This was done to obtain a comparison between both fencing modes within the same athletes, free of variations imposed by their cardiorespiratory capacity and fencing skill. The results demonstrate clearly that relative V□O_2 requirements, energy expenditure and heart rate during WC are lower when compared to ST fencing (44.1%). These differences are attributable for the most part to the lower muscle mass involved and the more static exercise pattern during WC fencing[10].

The mean V□O_2 values for ST fencing (44.2 ml·kg^{-1}·min^{-1}) are similar to previous reports of male fencers (41.4 ml·kg^{-1}·min^{-1}) and greater than values for female fencers (27.6 ml·kg^{-1}·min^{-1}) during simulated fights of similar duration [5]. However, Bottoms *et al.* [13] reported

greater values for elite female fencers (35 ml·kg^{-1}·min^{-1}) during simulated fencing bouts of 3 min in duration. The estimated EE values for conventional (ST) fencing (19.3 kcal·min^{-1}) in the present study are similar to values estimated from competition (19.5 ± 2 kcal·min^{-1})[3, 4] but greater than those which could be predicted for fencing training from the exercise science literature (11.2 kcal·min^{-1})[14].

As expected, the mean relative V□O$_2$ and EE during WC fencing in this group of able-bodied athletes (24.7 ± 5.6 ml·kg^{-1}·min^{-1}) was lower (44.1%) than during ST fencing. These values are almost identical to those reported by Bernardi *et al.* [9] during 15-touch WC simulated fencing combats (25.0 ± 3.6 ml·kg^{-1}·min^{-1}) obtained from six Paralympic athletes (4 paraplegics, 1 poliomyelitic and 1 transtibial amputee). While both modes require similar upper body movements, WC fencing does not allow lower body movements to occur and involves one hand gripping the wheelchair wheel resulting in a 'quasi static effort' in counterbalancing trunk movements. As V_E only tended to be greater during ST fencing and RR was not different from WC fencing, the seated position does not seem to limit the athlete's ventilatory effort. Furthermore, since the neurological function in these athletes was intact, full activation of the muscles required for the specific activity patterns is assured. Therefore, assuming comparable levels of training adaptation and fencing skill, it seems logical to attribute the observed differences in the oxygen cost and EE of WC and ST fencing to the lower recruitable muscle mass for exercise and the predominantly more static type of activity.

Examining data from both the 5- and 15-point exercise bouts enables an analysis of the physiological responses with respect to the structure of Olympic and Paralympic fencing competition in the 'poule' and 'direct elimination' phase. The V□O$_2$ during the 5-point bouts was 77% and 85% of that observed for the 15-point bouts for ST and WC fencing, respectively. HR tended to be greater for the 15-point when compared to the 5-point bouts, as

was estimated EE, with the difference in mean HR between bouts being greater for ST (~12 beats·min^{-1}) when compared to WC fencing (~6 beats·min^{-1}). The current data not only demonstrates greater physiological strain during the 15-point bouts reflecting the greater bout duration but also shows a greater impact of fight durations in ST rather than WC fencing. Additionally, the low correlation between mean V□O_2 during ST and WC fencing suggests different levels of specific cardiorespiratory demands in both modes of exercise.

The relationship between HR and V□O_2 is often used to predict EE in competitive situations. This relationship has previously been used in fencing[3, 4], although it has shown to overestimate direct V□O_2 measurements [5]. The HR-V□O_2 relationships demonstrated similar gradients and intercepts for both fencing modes. Bernardi *et al.*[9] observed that during WC fencing HR rate increased to a greater extent than V□O_2 when compared to wheelchair basketball and table tennis. However, the sample studied included 4 athletes with paraplegia, 3 of whom had high injury levels, which may have affected cardiovascular function and requirements. In spite of not having found differences in the HR-V□O_2 relationships for the able-bodied athletes in the present study, data from previous studies does suggest different disabilities may have different HR-V□O_2 responses which could ultimately affect EE values obtained.

Knowledge of the different energetic demands between Olympic and Paralympic fencing can undoubtedly contribute to a greater specificity of training and nutritional strategies in wheelchair athletes. The preparation of wheelchair athletes should be individual, although based on a general reference model. This article provides the first approximation of a neutral model, without a specific type of disability, of the bioenergetic demands of wheelchair fencing. With this, it is possible to facilitate the optimisation of training by the coaches, due to knowing the differences with the Olympic fencing and secondly having a reference value on which to adapt the specificity of each athlete.

The individuals participating in this study were able-bodied, which can be considered a study limitation. However, it is only with such subjects that a comparison between standing and wheelchair fencing can be established, since a) only able-bodied fencers can perform both ST and WC fencing bouts, and b) comparing two samples of disabled and abled-bodied fencers would be biased by the effects of different cardiorespiratory, neuromuscular, and metabolic capacities of both groups of athletes. Therefore, this counterbalanced within-subjects design seemed to be the best viable approach to the problem of quantifying and comparing the physiological demands of ST and WC fencing during two different time formats.

Conclusions

In conclusion, the physiological requirements of WC fencing are lower than those of ST fencing. These differences appear to be due to the lower recruitable muscle mass for exercise and the more static activity pattern of WC fencing. The difference in physiological demands between 5 and 15 point bouts is also greater for ST when compared to WC fencing. Our results provide specific oxygen requirements and energy expenditure values for able-bodied athletes and may act as reference values for comparison to future studies of wheelchair fencers. These data will not only help in understanding the physiology of fencing but will also be a useful reference for future studies of wheelchair fencing and other wheelchair based sports. Studies on wheelchair fencers with various disabilities and levels of disability should be undertaken in order to establish specific metabolic and cardiorespiratory requirements for this sport.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Table 2. Physiological responses to standing and wheelchair fencing in able-bodied fencers (n=10) in a set of consecutive 5 and 15 touch bouts in random order interspersed with 3 min rest

TITLES OF FIGURES

Figure 1. Schematic representation of the study protocol. The four conditions (wheelchair and standing fencing mode and 5 and 15 touch bouts) were performed in random order against the same rival

Figure 2. Heart rate as a function of oxygen consumption for wheelchair and standing fencing

Table 1. Physiological responses to standing and wheelchair fencing during 5 and 15 touch fencing bouts in able-bodied regional level fencers (n=10)

	Standing		Wheelchair	
	5 touch	15 touch	5 touch	15 touch
VO_2 ($L \cdot min^{-1}$)				
Mean*	2.73 ± 0.54	3.24 ± 0.68‡	1.44 ± 0.43	1.88 ± 0.48‡
Maximum*	3.68 ± 0.56	4.03 ± 0.75‡	2.07 ± 0.53	2.47 ± 0.69‡
Minimum	1.38 ± 0.52	1.41 ± 0.39	0.87 ± 0.29	0.85 ± 0.27
Heart rate ($beats.min^{-1}$)				
Mean*	152 ± 22	164 ± 11‡	134 ± 14	139 ± 13‡
Maximum*	170 ± 14	179 ± 8‡	148 ± 11	153 ± 13‡
Minimum	120 ± 22	117 ± 29	117 ± 15	114 ± 17
Energy expenditure ($kcal \cdot min^{-1}$)*	17.5 ± 2.9	19.3 ± 3.7	10.0 ± 2.5	11.7 ± 3.2
Bout duration (s)†	123 ± 38	366 ± 103‡	99 ± 77	232 ± 59‡

Values are mean ± standard deviation

* Significant main effect for fencing mode ($P < 0.05$)

‡ Significant main effect for bout ($P < 0.05$)

† Significant interaction ($P < 0.05$)

Table 2. Physiological responses to standing and wheelchair fencing in able-bodied fencers (n=10) in a set of consecutive 5 and 15 touch bouts in random order interspersed with 3 min rest

	Standing	Wheelchair	Difference (% S)	t-test (p-value)
Absolute $\dot{V}O_2$ ($L \cdot min^{-1}$)	3.12 ± 0.63 (2.21 – 4.16)	1.76 ± 0.49 (1.10 – 2.79)	43.5	0.000
Relative $\dot{V}O_2$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	44.2 ± 7.8 (32.5 – 56.3)	24.7 ± 5.6 (18.0 – 37.6)	44.1	0.000
RER ($VCO_2/\dot{V}O_2$)	0.78 ± 0.04 (0.71 – 0.84)	0.78 ± 0.05 (0.70 – 0.84)	0.0	0.92
Pulmonary ventilation ($L \cdot min^{-1}$)	66.5 ± 13.9 (50.8 – 90.9)	48.9 ± 24.5 (28.5 – 111.6)	26.4	0.09
Respiratory rate ($1 \cdot min^{-1}$)	40.0 ± 6.2 (25.9 – 50.6)	37.5 ± .56 (27.8 – 49.4)	6.3	0.22
Heart rate ($beats \cdot min^{-1}$)	161 ± 13 (135 – 176)	137 ± 14 (113 – 158)	14.9	0.001
Energy expenditure ($kcal \cdot h^{-1}$)	892 ± 190 (626 – 1207)	499 ± 173 (229 – 868)	44.1	0.001

Values are mean ± standard deviation and range (minimum – maximum)