Title: The physiological demands of elite epée fencers during competition

Running Title: Physiological Demands Epée

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ABSTRACT

The aim of this study was to determine the physiological demands of epée fencing performance. Eight elite male epée fencers competed in a competition consisting of 7 Poule and 7 Direct Elimination (DE) fights. Core temperature (TC), heart rate (HR), movement patterns, training load, and differentiated ratings of perceived exertion (RPE) were collected for all Poule and DE fights. Expired gas, and energy expenditure (EE) were measured using breath-by-breath gas analysis during selected fights, along with blood lactate concentration. Maximal HR and RPE were greater in DE than Poule fights. There was a tendency for greater increases in TC in DE compared to Poule fights ($p = 0.052$). Blood lactate concentration decreased during the competition from Poule to DE suggesting reliance on phosphocreatine and aerobic energy sources during fencing. High oxygen consumption (~50 $ml.kg^{-1}.min^{-1}$) and EE (~13 $kcal.min^{-1}$) were recorded in both Poule and DE. Fencers covered 3 times more distance in DE than Poule fights. High training load scores were also recorded. This is the first study to show an increased physiological strain, with high aerobic and anaerobic demands, as fencing competition progressed from Poule to DE. Additionally, there was a considerable energy demand exhibited during epée competition.

INTRODUCTION

Understanding of the demands of specific sports is becoming an important aspect for coaches and athletes. The majority of research tends to be more focused within team based and well funded sports such as football, tennis, rugby and cycling (Cunniffe, Proctor, Baker, & Davies, 2009; Dempsey, Gibson, Sykes, Pryjmachuk, & Turner, 2018; Drust, Atkinson, & Reilly, 2007; Fernandez-Fernandez, Sanz-Rivas, & Mendez-Villanueva, 2009; Santalla, Earnest, Marroyo, & Lucía, 2012). However, there is little research assessing the demands of the Olympic sport of fencing (sabre, foil or epée). With international epée fencing competitions lasting between 9-11 hours (Roi & Bianchedi, 2008) and comprise of Poule fights (3 minute first to 5 points fights) which seeds knockout direct elimination (DE) fights (3 x 3 minute first to 15 points fights). Fencing is characterised by an intermittent nature, which places an importance on the phosphocreatine system and glycolysis (Roi & Bianchedi, 2008; Turner et al., 2014). Work to rest ratios have been reported in the literature as 1:1 and 8s:10s for men's epée, and 2:1 for women's epée (Aquili et al., 2013; Bottoms, Sinclair, Gabrysz, Szmatlan-Gabrysz, & Price, 2011; Roi & Bianchedi, 2008), with an effort lasting around 15 seconds in epée (Roi & Bianchedi, 2008). In spite of the severe demand on the anaerobic energy systems, there is a heavy reliance on the aerobic system (Bottoms et al., 2011).

There is limited research reporting the physiological demands within elite level male epée fencing during competition. The majority of research within epée has utilised simulated fights in a laboratory setting (Bottoms et al., 2011; Bottoms, Sinclair, Rome, Gregory, & Price, 2013; Iglesias & Rodríguez, 2000). Iglesias and Rodriguez (1995) showed male epée fencers achieved an average heart rate of

166 ± 8 beats.min^{-1}, with blood lactate concentration post fight averaging 3.2 ± 0.7 mmol.L^{-1} during competition. Oxygen consumption was estimated to be 54 ± 4 ml.kg^{-1}.min^{-1}, with estimated energy expenditure to be 15.4 kcal.min^{-1} in international competition compared to 12.3 kcal.min^{-1} in a national competition (Iglesias & Rodríguez, 1999, 2000). During a simulated competition Bottoms et al. (2013) showed relatively low heart rate responses with heart rates recorded between 150-170 beats.min^{-1} during both Poule and DE fights. In addition, there were modest ratings of perceived exertion (RPE) shown during the simulated competition with RPE being greater in the DE compared to the Poule rounds (13 vs. 10 respectively). However, as these fights were simulated fencing bouts and not actual competition the physiological response is likely to lower due to potential lack of motivation from the fencers to compete or also due to lower catecholamine release (Hoch, Werle, & Weicker, 1988).

To determine movement patterns, such as speed and distance covered, within fencing research has traditionally used time motion analysis (Aquili et al., 2013; Wylde, Tan, & O'Donoghue, 2013; Wylde & Yong, 2015). Within recent years the analysis of movement has changed due to technological advances and has been undertaken using tri-axial accelerometer based systems (Barbero, Granda-Vera, Calleja-González, & Del Coso, 2014; Chandler, Pinder, Curran, & Gabbett, 2014; Dempsey et al., 2018; Montgomery, Pyne, & Minahan, 2010; Twist et al., 2014). However, there has been no research assessing the movement demands of epée fencing performance. Using this method could be more advantageous for fencing as it is less time consuming to analyse, a larger range of variables are available, allow external and internal training loads to be determined, and it can be more accurate than time motion (Roberts, Trewartha, & Stokes, 2006; Scott, Scott, & Kelly, 2016).

Therefore, the aims of this study were: to determine the physiological demands of epée fencing performance during competition and compare how the physiological demands change during different phases of the competition from Poule to DE. Furthermore, the movement demands during epée fencing competition would be ascertained using a tri-axial accelerometer based system.

METHODS

Participants

Eight male well-trained epée fencers (ranked within the top 35 in the United Kingdom) volunteered to take part in this study. All participants were informed of the benefits and risks of the study and all gave written informed consent to participate, which was approved by the University Ethics Committee. All fencers competed at a club or international level, had previous epée training history and trained regularly in epée (Table 1). This represented a typical fencing cohort at a national competition.

TABLE 1 AROUND HERE

Procedures

This study used an observational design at an epée fencing competition at an established fencing centre. Participants competed in 7 Poule (first to 5 points, 3-minute fights) and 7 Direct Elimination (DE; first to 15 points, 3 x 3 minute fights) fights as per a standard fencing competition. To ensure a complete data collection the DE fights were competed as a Poule Unique, whereby, all fencers fought each other in a round robin style based upon seeding from the Poule fights. Top seeded fencers, therefore, had the easiest route to the final as would occur in a competition. Eight fencers were recruited to enable the correct number of fights to be completed and replicate a true competition. Due to the nature of the DE fights being a Poule Unique style the winner was determined on fights won, then point difference, then points scored. All testing was performed using the participant’s own fencing equipment and participants were instructed to prepare as they would for competition. A staggered monetary incentive was given for all placing within the competition to ensure the fencers gave maximal effort, with first place taking the greatest prize and last place the lowest.

Environmental conditions during the competition were monitored throughout the day (mean ± SD: Wet Bulb Globe Temperature 16.4 ± 0.7°C, black bulb temperature was 19.4 ± 0.4°C, ambient temperature was 19.5 ± 0.5°C and humidity was 63.4 ± 4.9%). Body mass, wearing shorts only, was measured pre-Poule, post-Poule and post-DE to the nearest 0.1 kg (Seca Clare 803, Seca, Birmingham, UK).

Core Temperature Measures

Upon arrival the participants were required to consume an ingestible telemetric core temperature pill (CorTemp, HQ Inc., Palmetto, FL, USA) a minimum of 2 hours before the start of the Poule fights. This allowed the pill to enter the digestive tract for accurate core temperature measurements. The CorTemp pill has previously been shown to be a valid measure of TC (Byrne & Lim, 2007; Ruddock, Tew, & Purvis, 2014) and transmits a signal via magnetic flux to the data recorder. The data recorder (HQ Inc., Palmetto, FL, USA) was held 2-3 cm behind the participants back (and thus fencing jacket) for all core temperature measurements as per the manufacturer instructions. During the competition TC was measured pre and post each fight for each fencer. Pre-fight TC readings <36.0°C and post-fight TC readings <36.5°C were excluded due to being outside what would be seen as normal human ranges. Out of 56 fights completed, in 9 fights abnormal TC values were recorded possibly due to the fencing jacket interfering with the readings, therefore the remaining 47 were analysed and reported.

Heart Rate Monitoring and Movement Tracking

Participants were fitted with a heart rate monitor and athlete tracking system (Polar Team Pro 2, Polar Electro, Kempele, Finland). The heart rate and movement data were tracked continuously throughout the competition using an accelerometer, gyroscope and digital compass system recording at 200Hz. Average heart rate (HR_{av}), maximum heart rate (HR_{max}) during the fight, time spent above 80% of age-predicted HR_{max}, and time spent in each heart rate zone were analysed for all Poule and DE fights. The following heart rate zones were utilised: zone 1 – 50-59% HR_{max}, zone 2 – 60-69% HR_{max}, zone 3 – 70-79%, zone 4 – 80-89% HR_{max}, and zone 5 – 90-100% HR_{max}. Distance covered, distance covered per minute, peak speed, average speed, and number of accelerations and decelerations in each zone during all fights were analysed. Accelerations and decelerations were split into the following zones: zone 1 – accelerations 0.50-0.99 $m.s^{-2}$ and decelerations -0.50- -0.99 $m.s^{-2}$; zone 2 – accelerations 1.00-1.99 $m.s^{-2}$ and decelerations -1.00- -1.99 $m.s^{-2}$, zone 3 – accelerations > 2.00 $m.s^{-2}$ and decelerations > - 2.00 $m.s^{-2}$.

Training Load

Training load was calculated using the Polar Team Pro 2 algorithms within the software, which uses the participant's anthropometry, heart rate dynamics during exercise, mechanical impact of the exercise, and energy expenditure (Nissila & Kinnunen, 2008), training load per minute was also calculated. The training load calculation reflects the non-fat energetic cost of exercise, with fat being seen as an infinite energy source (Nissila & Kinnunen, 2008). Carbohydrate stores and protein via gluconeogenesis are seen as finite stores that need to be recovered (Nissila & Kinnunen, 2008).

Ratings of Perceived Exertion

Differentiated ratings of perceived exertion (RPE) were recorded using the Borg 6-20 category scale (Borg, 1982). Participants subjectively rated their exertion for their arms (RPE_A), legs (RPE_L) and overall (RPE_O) after each Poule and DE fight. Participants were familiarised on how to use the differentiated RPE to ensure accurate readings.

Gas Analysis

During two fights in both the Poule and DE participants were required to wear a mask underneath their fencing mask in order for expired gas to be collected. The subject's opponent during the fight also had expired gases analysed so as not to disadvantage each participant during the fight. Expired gas was recorded continuously during each fight using a portable breath-by-breath gas analysis system (Cosmed K4b2, Cosmed, Rome, Italy). The gas analysis system was calibrated following manufacturer instructions. Expired gas data was averaged over 5-second periods of time during the fight to calculate: average and maximum oxygen consumption (VO_2), energy expenditure (EE) during each fight. Due to a technical issue with one of the gas analysers being damaged during one of the fights, thirteen fights during the DE were analysed from seven participants.

Blood Lactate Analysis

Blood lactate concentration was measured by taking a 10µl capillary blood sample from a fingertip on the non-sword arm. Blood lactate was then analysed using an enzymatic-amperometic analyser (Biosen C-Line, Ekf Diagnostics, Cardiff, UK). Blood lactate was measured at the following time points: baseline, after the participants had rested for a minimum of 10 minutes, post-Poule round 1 and 7, and post-DE after every other round i.e. DE 1, DE 3, DE 5, and the final DE round (DE 7). Blood lactate was measured within 3 minutes of the fight terminating.

Statistical Analysis

Data are presented as mean ± standard deviation, with 95% confidence intervals. Data was analysed using a statistical software package (SPSS version 24, IBM, Armonk, NY, USA). Data were checked for normality using the Shapiro-Wilk test. Paired-students t-test analysis was undertaken to compare variables from all the Poule and all the DE fights for HR_{av}, HR_{max}, percentage of time spent in heart rate zones, RPE_O, RPE_A, RPE_L, distance covered, peak speed, average speed, training load, and percentages of accelerations in acceleration zones. Paired students t-test analyses were also undertaken for selected Poule and DE fights (with a total of two fights for each fencer for both Poule and DE) for average VO_2 during the fight, maximum VO_2 achieved during the fight, and energy expenditure. Effect sizes (ES) for differences between Poule and DE fights were calculated using Cohen's d (Cohen, 1988) and considered to be trivial (ES < 0.20), small (0.21 – 0.60), moderate (0.61 – 1.20), large (1.21 – 2.00), or very large (ES > 2.00) (Hopkins, Marshall, Batterham, & Hanin, 2009). A one-way repeated measures analysis of variance (ANOVA) was undertaken to compare the blood lactate response and body mass changes across the competition. A two-way repeated measures ANOVA (fight x time) was also undertaken to compare core temperature responses between Poule and DE fights and within each fight comparing pre to post fight. Partial eta squared (η^2) effect sizes (Cohen, 1988) were calculated for within and between group differences and considered to be small (η^2 0.10 – 0.24), moderate (η^2 0.25 – 0.39) and large (η^2 >0.40) (Cohen, 1988).

RESULTS

Physiological Demands

TABLE 2 AROUND HERE

There were significantly greater ($p < 0.001$) HR_{max}, RPE_O, RPE_A and RPE_L in the DE compared to the Poule fights (Table 2). Differences for HR_{max}, HR_{max} percentage of age-predicted HR_{max} were small and moderate respectively. Differences for RPE_O, RPE_A, and RPE_L were large, moderate and moderate respectively. There were no significant differences for HR_{av} between Poule and DE fights, as shown in Table 2.

FIGURE 1 AROUND HERE

There was a significant main effect for time for TC ($F_{(1,46)} = 73.8$, $p < 0.001$, $\eta^2 = 0.68$), revealing that TC increased from pre-fight to post-fight (37.65 vs. 38.06 °C respectively). A significant main effect for fight type ($F_{(1,46)} = 32.97$, $p < 0.001$, $\eta^2 = 0.86$) was also observed between Poule and DE, whereby TC was greater in all DE compared to all Poule fights (38.11 vs. 37.59 °C respectively). Although no significant interaction was observed between time and fight for TC, it did approach significance ($F_{(1,46)} = 3.978$, $p = 0.052$, $\eta^2 = 0.08$) with a tendency for a greater increase in the DE in comparison to the Poule fights (Figure 1) (0.49 vs. 0.31 °C average increase respectively). There were no significant differences ($p = 0.313$, $\eta^2 = 0.15$) for body mass pre-Poule, post-Poule and post-DE (72.4 ± 4.8

kg (68.4, 76.4) vs. 72.2 ± 4.7 kg (68.3, 76.1) vs. 72.3 ± 4.7 kg (68.4, 76.3) respectively).

The participants spent 82.2% and 76.4% of the fight time above 80% HR_{max} for DE and Poule respectively. There were no significant differences ($p > 0.05$, ES range = 0.05-0.33) shown between time spent in the different heart rate zones between Poule and DE fights (Figure 2).

FIGURE 2 AROUND HERE

A significant difference ($F_{(5,35)} = 6.9$, $p < 0.001$, $\eta^2 = 0.50$) was observed for blood lactate concentration responses during the competition. Post-hoc analysis showed that blood lactate concentration was greater in Poule 1 in comparison to Poule 7 ($p = 0.020$), DE 5 ($p = 0.038$) and DE 7 ($p = 0.038$) as demonstrated by Figure 3. Thus, there was a decrease in blood lactate concentration as the competition progressed from Poule rounds to DE rounds.

FIGURE 3 AROUND HERE

Mean VO_2 was similar between Poule and DE fights (37.0 ± 4.5 $ml.kg^{-1}.min^{-1}$ (34.3, 39.7) vs. 37.3 ± 6.4 $ml.kg^{-1}.min^{-1}$ (33.4, 41.1); $p = 0.885$, ES = 0.05). Maximum VO_2 recorded was similar between Poule and DE fights (49.1 ± 6.1 $ml.kg^{-1}.min^{-1}$ (45.5, 52.8) vs. 51.2 ± 9.3 $ml.kg^{-1}.min^{-1}$ (45.6, 56.8); $p = 0.411$, ES = 0.27). Furthermore, EE was also similar between Poule and DE fights (12.7 ±

1.7 kcal.min^{-1} (11.6, 13.7) vs. 12.8 ± 2.4 kcal.min^{-1} (11.3, 14.2); $p = 0.793$, ES = 0.05).

Movement Patterns

Movement tracking data is shown in Table 3. Average DE fight duration was significantly greater than Poule fight duration ($p < 0.001$) with a very large ES. Furthermore, participants covered 3 times as much distance in DE in contrast to Poule fights ($p < 0.001$, ES = 2.81), however there was no significant difference between Poule and DE for distance covered per minute ($p = 0.066$, ES = -0.21). Participants achieved a faster peak speed in the DE when compared to the Poule ($p < 0.001$); however, average speed was lower in the DE when compared to the Poule fights ($p < 0.001$). Differences in peak and average speed were both moderate. Training load ($p < 0.001$) and Training load per minute ($p = 0.001$) were significantly greater in DE when compared to Poule fights with a very large and small difference determined respectively. Average training load scores for the competition 412 ± 73 (351, 473). There were a significantly greater percentage of accelerations occurring in zone 2 which coincided with a lower percentage of accelerations occurring within zone 1 between DE and Poule fights. There were no significant differences for accelerations in zone 3 between DE and Poule fights.

TABLE 3 AROUND HERE

DISCUSSION

The aims of this study were to determine the physiological demands of epée fencing during competition and if there are differences between the phases of competition (Poule and DE). Secondly, this is the first study to determine the movement demands of epée fencing performance using a tri-axial accelerometer based system.

Physiological Demands

When compared to research by Bottoms et al. (2013), during simulated competition in male epée fencers, HR_{max} and HR_{av} were greater in the current study in Poule fights (HR_{max}: 92.4% vs. 89.0% of age-predicted HR_{max}, and HR_{av}: 86.3% vs. 79.4% of age-predicted HR_{max}). During DE fights in this study HR_{av} was 169 ± 14 bpm (86.5% of age-predicted HR_{max}). This is similar to HR_{av} recorded in previous research by Iglesias and Rodriguez (1995), in national level male epée fencers (166 ± 3 bpm) and Bottoms et al. (2011) in female epée fencers (87% of age-predicted HR_{max}). However, HR_{av} was lower in research by Bottoms et al. (2013; 82% of age-predicted HR_{max}). Maximum heart rate during DE fights in this study was shown to be greater (96.0% vs. 91.7% of age-predicated HR_{max}) than those recorded previously (Bottoms et al., 2013). The higher heart rates exhibited in this study could be due to the non-competitive nature of simulated fights of the previous studies causing a decreased heart rate response. Additionally, there could have been a decreased catecholamine (in particular adrenaline) release causing a lower HR response in the simulated fights compared to competition (Hoch et al., 1988). Further research has shown an increased sympatho-adrenal system activation, with an increase in cortisol, during competitive versus non-competitive performances (Fernandez-Fernandez et al., 2016; Viru et al., 2010).

The participants spent the majority of the fight within zone 4 and 5 for both Poule (76.4%) and DE (82.2%). The percentage of time spent above 80% HR_{max} in this study was greater than those determined within elite male foil fencers in both Poule (76.4% vs. 68.0%) and DE (82.2% vs. 74.0%) fights (Turner et al., 2017). This suggests epée performance is exhibiting a high cardiovascular strain and is producing a greater physiological demand than other weapons.

Core temperature showed an increase from pre-fight to post-fight as well as between Poule and DE fights. There was a tendency for a greater increase in TC in the DE pre-fight to post-fight ($p = 0.052$) compared to the Poule (0.49°C vs. 0.31°C respectively). Additionally, some of the fencers had TC greater than 39°C recorded in the DE. Epée fencing performance despite being relative short in duration (~13 minutes for a DE fight) can contribute to a potential cardiovascular and heat stress through a raised TC. This raised TC could be associated with the increased HR_{max} achieved during DE, as well as the increased time above 80% HR_{max}. The increased heat production could cause an increase in heart rate to distribute blood flow to the skin to dissipate heat from the core. Furthermore, participants had a mean starting TC ~0.42°C higher in the DE compared to the Poule. This could, therefore, indicate the participants struggled to reduce TC to baseline levels between fights. The added influence of protective equipment and layers worn by the fencers could impact upon their ability to dissipate heat effectively, especially evaporative heat loss mechanisms (Gavin, 2003; Pascoe, Shaley, & Smith, 1994). Further the use of helmets within certain sports reduces a vital surface area for heat dissipation, i.e. the head (Pascoe, Bellingar, & McCluskey, 1994). The head has been shown to provide significant heat loss during exercise, with heat loss increasing as workload and ambient temperature increase (Rasch, Samson, Cote, & Cabanac, 1991). Therefore, fencers could potentially benefit from implementing cooling strategies between fights to reduce TC. However, further research is warranted to explore the most effective and practical cooling strategy to improve fencing performance.

Ratings of perceived exertion were greater in the DE when compared to the Poule fights for RPE overall (15 vs. 11), arms (12 vs. 10), and legs (13 vs. 11), with larger increases in RPE_O than RPE_A and RPE_L. Thereby showing an increased perceptual strain as the competition progressed into DE fights. Bottoms et al. (2013), during simulated fencing performance in male fencers (n=7), showed a similar trend with RPE being significantly greater for RPE overall (13 vs. 11), arms (12 vs. 10), and legs (13 vs. 10) for DE fights in comparison to Poule fights. The increased perceptual strain as the competition progresses from Poule to DE could be linked to the increased cardiovascular strain as highlighted in this study by a greater HR_{max}, TC, and percentage of time spent above 80% HR_{max} (82% vs. 76%).

Blood lactate concentration in this study tended to show a decrease throughout the competition. Blood lactate concentration peaked after Poule 1 (4.54 ± 1.21 $mmol.L^{-1}$), with lower blood lactate concentration after Poule 7 (2.67 ± 0.58 $mmol.L^{-1}$). Furthermore, blood lactate concentration was lower in the DE

5 (2.40 ± 0.68 mmol.L^{-1}) and DE 7 (2.08 ± 1.26 mmol.L^{-1}) when compared to Poule 1. Similar blood lactate concentrations have been reported in the literature (Bottoms et al., 2011; Iglesias & Rodríguez, 1995). Iglesias and Rodriguez (1995) recorded average Blood lactate concentration during international competition in national level male fencers to be ~3.7 mmol.L^{-1}; and Bottoms et al. (2011) during simulated DE fights determined blood lactate concentration to be ~2.8 mmol.L^{-1} within female national level fencers. This is the first study within epée showing blood lactate concentration changes over a competition. The results from this study and previous research highlights the importance of the alactic energy systems during fencing performance (Bottoms et al., 2011; Turner et al., 2014). However, it cannot be ignored that fencers could be heavily reliant on energy to be derived from aerobic sources as a competition progresses from Poule to DE (Bottoms et al., 2011). This could be explained by the lower blood lactate concentration determined in the DE fights in this study. It is evident that repeated numbers of high intensity actions during exercise causes an increase in energy to be supplied from aerobic sources especially if there is insufficient recovery time (Bogdanis, Nevill, Boobis, & Lakomy, 1996; Gaitanos, Williams, Boobis, & Brooks, 1993).

Maximum and mean oxygen consumption recorded during the competition was similar between the Poule and DE fights (maximum: 49.1 vs. 51.2 ml.kg^{-1}.min^{-1}, mean: 37.0 vs. 37.3 ml.kg^{-1}.min^{-1} Poule vs. DE respectively). Comparable VO_2 responses (~54 ml.kg^{-1}.min^{-1}) have been reported in the literature (Bottoms et al., 2011; Iglesias & Rodríguez, 1999). Mean VO_2 values recorded in female epée athletes by Bottoms et al. (2011) were shown to be ~35 ml.kg^{-1}.min^{-1} (~75%

VO_{2peak}). Overall results from the current study and previous studies suggest that fencers must possess a high level of aerobic fitness in order to deal with the demands of competition.

Within the current study EE was shown to be ~12.7 kcal.min^{-1} and ~12.8 kcal.min^{-1} for Poule and DE fights respectively, which is similar to those previously reported of ~12.0 kcal.min^{-1} in national level female and male fencers (Bottoms et al., 2011; Iglesias & Rodríguez, 1999). Determining the energy cost of fencing performance is important to note, as despite being relatively short, high EE values are apparent. Using EE values obtained in this study and the average fight times for Poule and DE it could be estimated that average EE of reaching the final of a competition could be ~1500 kcal.min^{-1} (not taking into account energy expended during rest periods between fights). Therefore, it could be integral to apply appropriate nutritional support and plans for fencing athletes to enable them to be appropriately fuelled for performance due to the long nature of a competition.

Movement Patterns

The mean distance covered during Poule and DE during this study was 283 ± 93 m and 833 ± 261 m which is similar to that reported previously in the literature (Roi & Bianchedi, 2008). However, there was a wide range of distance covered with participants covering 120-670 m and 435-1652 m in Poule and DE fights respectively. This shows the varying nature of epée fencing performance whereby the demand placed upon the body could be largely determined by the individual fight i.e. attacking vs. defensive opponent. Total training load scores in this study were 412 ± 73 indicating a high and varied training load over the period of the competition. A high training load indicates the stress placed upon the fencers during competition and is normalised to an arbitrary value. This enables practitioners to monitor training and competition stress for each athlete. Training load can be a useful tool to help improve performance through periodization of training and injury prevention (Vanrenterghem, Nedergaard, Robinson, & Drust, 2017). Within fencing training load threshold scores should be determined that may indicate a potential increased injury risk.

There were no significant differences for accelerations in zone 3 between DE and Poule fights. However, there was a greater percentage of accelerations occurring in zone 2 with a lower percentage of accelerations in zone 1 during DE fights in comparison to Poule fights. There was also a greater peak speed achieved in the DE than Poule fights. This could indicate a tactical shift within the DE fights whereby the fencers are initiating more high intensity attacks (through more lunge or fleche attacks) to score points, especially when losing in a fight. The greater percentage of zone 2 accelerations in DE fights could, therefore, increase the mechanical load experienced during fencing. Understanding the physical demands of epée performance can ensure coaches and athletes maximise their training and recovery to be prepared for competition.

CONCLUSIONS

This study showed that there is an increased physiological strain observed as an epée competition progresses. This is exhibited through increased HR_{max}, greater RPE_O, RPE_A, RPE_L and a tendency for a greater increase in TC in the DE compared to the Poule. Additionally, participants spent ~80% of a fight above

80% age-predicted HR_{max}. There seems to be an increasing demand on the alactic and aerobic energy system as a competition progresses as blood lactate concentration decreased from Poule 1 to DE 7. This study has also suggested fencers may benefit from cooling interventions between fights to lower TC to baseline levels. Energy expended during the competition was also shown to be high stressing the importance of adequate fuelling to improve/maintain performance. This is the first study to assess movement patterns of epée fencing performance using a tri-axial accelerometer athlete tracking system. This study has shown despite epée being short in duration high mechanical loads are exhibited during a competition through high training load scores. There also seems to be a greater mechanical load on fencers during DE compared to Poule fights with participants recording greater peak speeds and percentage of accelerations in zone 2.

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Figure 1. Core temperature response in Poule compared to DE. TC = Core Temperature, DE = Direct Elimination. 95% CI for pre-Poule 37.20-37.72°C, post-Poule 37.53-37.98°C, pre-DE 37.64-38.09°C, post-DE 38.08-38.64°C.

Figure 2. Time spent in heart rate zones during Poule and DE fights. Zone 1 = 50-59% HR_{max}, zone 2 = 60-69% HR_{max}, zone 3 = 70-79%, zone 4 = 80-89% HR_{max}, zone 5 = 90-100% HR_{max}, and DE = Direct Elimination. 95% CI for Poule: zone 1 0.7-2.8%, zone 2 3.2-6.4%, zone 3 11.6-22.5%, zone 4 31.6-47.2%, and zone 5 26.9-47.1%. 95% CI for DE: zone 1 0.2-1.2%, zone 2 2.9- 5.6%, zone 3 10.5-15.4%, zone 4 35.7-45.4%, and zone 5 34.5-48.6%.

Figure 3. Blood lactate responses during Epée fencing performance during Poule and DE fights. DE = Direct Elimination. 95% CI for Baseline 1.50-2.00, Poule 1 3.53-5.55, Poule 7 2.18-3.15, DE 1 2.65-4.24, DE 3 2.21-3.62, DE 5 1.83-2.97, DE 7 1.02-3.13. * significant difference to Poule 1 ($p < 0.05$)

Table 1. Participant characteristics

Table 2. Physiological demands of Epée fencing performance for Poule and DE fights (mean ± SD (95% CI)).

Table 3. Physical demands of Epée fencing performance for Poule and DE fights (mean ± SD (95%CI)).