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Reviews

Physiological demands of fencing: A Narrative review

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Background and Aim

Fencers compete over long competition days (9-11 hours) wearing full body protective clothing whilst performing high-intensity explosive movements interspersed with low intensity preparatory or recovery movements. Therfore the aim of this review is to provide contemporary perspectives of the literature discussing the physiological and thermoregulatory demands of fencing to inform training, competition, and recovery practices.

Methods

Research articles were searched through three online databases (Pubmed, SPORTDiscus, and Google Scholar; 1985-2022) and included results discussing physiological demands for all three weapons (epée, foil, and sabre).

Results

The physiological demands of fencing performance are high and increase as fencers move from Poule fights to knockout Direct Elimination fights. Fencers compete at 75-100% of maximum heart rate, and ~75% maximal oxygen consumption in Direct Elimination fights. Fencing performance is reliant on the phosphocreatine and aerobic energy systems as shown through low blood lactate concentrations. Considerable variation in distance covered during competition is generally reported (i.e., 435 to 1652m in Direct Elimination fights). Despite fencers competing in full body protective clothing with a potentially large thermoregulatory challenge only one study has examined thermoregulatory responses during fencing whereby fencers' gastrointestinal temperature can peak at >39°C.

Conclusions

Future research highlighted by the findings of this review includes studies of all weapon types especially foil and sabre, during actual competitive environments. Thermoregulatory responses of fencing need to be determined including measures of skin temperature, mask temperature (as a measure of micro-climates) and thermal sensation, allowing for appropriate cooling strategies to be applied between fights to maintain or improve performance.

Practical Applications

A greater understanding of the physiological demands of fencing performance will allow athletes, coaches, and practitioners to design training to prepare athletes for competition and allow fencing specific protocols to be developed to determine recovery strategies within fencing.

1. INTRODUCTION

Fencing has been a part of every Olympic Games in the modern era with 36 fencing medals to be won in 12 individual and team events. Fencing, in an amended form, is also part of Modern Pentathlon competitions. Fencing is split into three weapon categories: sabre, épée, and foil with fencers required to wear full body protective clothing for all categories of competition. Differences between the weapons are highlighted by different areas of the body that can be targeted, and by a system of "priority".[1] Priority in foil and sabre is whereby a point can only be scored by the fencer being judged to be attacking by the referee, whereas during épée either or both fencers can be adjudged to have scored a point.[2] During competition fencers compete in a number of fights over a 9-11 hour period, comprising of

5-7 Poule and up to 8 knockout, or Direct Elimination (DE), fights.[1] During Poule fights fencers compete against 6-8 other fencers in a round-robin format and are defined as first to 5 points or most points after a maximum fight time of 3-minutes. Direct Elimination fights are seeded based upon results of Poule rounds and comprise of first to 15 points or a maximum fight time of 3x3 minute bouts with 1 minute of rest between bouts. However, due to interruptions during a fight, fights can last longer with average DE fight times at the Tokyo 2020 Olympic games reported as 16:39 ± 3:19 mins for épée, 18:21 ± 6:15 mins for foil, and 11:31 ± 3:14 for sabre.[3] Fencing is a high intensity intermittent sport with explosive movements such as lunge and flèche movements to score points interspersed with low intensity preparatory movements before initiating these explosive actions.[4,5] Therefore, over a long competition day a fencer's ability to repeatedly perform high intensity movements in multiple fights and recover from these are likely important determinants of performance. Moreover, the requirement to wear full body protective clothing likely adds considerable cardiovascular and thermal strain with performance decrements especially in high pressure DE rounds.

Two previous reviews have considered the physiological demands of fencing,[1,4] however discussion of the specific physiological demands were relatively brief, but importantly noting the variability of fencing performance,[1] focussing predominantly on the physical characteristics of fencers, injuries within fencing and biomechanics of fencing.[1,4] Furthermore, in the review by Turner et al. (2014)[4] there is dismissal of the aerobic system's importance during fencing performance and recovery despite <10% of performance being high intensity actions.[5–9] Understanding the physiological demands of fencing performance is important for athletes, coaches, and practitioners to design training to prepare for the demands of competition and reduce injury risk. Understanding fencing physiology may additionally facilitate development of recovery strategies between fights to maintain or improve performance especially as fencing competitions last between 9-11 hours and can contain up to 15 total fights. Therefore, this paper reviews studies specifically relating to the physiological demands of fencing competition, and due to the limited research incorporates studies within all weapon, considers épée, foil, and sabre disciplines. The implications of the physiological demands for fencing performance and areas for future research are discussed.

2. METHODS

This narrative review deals with the physiological demands of fencing due to the relative paucity of data within fencing there was no restriction on the inclusion of sex of participants and the weapon researched for this review, thus all weapons épée, sabre and foil were included. Articles (systematic reviews, meta-analysis, narrative reviews, and original investigations) were searched through three online databases (Pubmed, SPORTDiscus, and Google Scholar; 1985-2022) and search terms comprised various combinations of the following terms: physiology, physiological, physical, demands, characteristics, responses, thermoregulatory, thermoregulation, heart rate, oxygen consumption, fencing, épée, sabre, foil, and performance. The reference lists of those articles selected for inclusion were manually searched for additional literature.

3. PHYSICAL AND PHYSIOLOGICAL DEMANDS OF FENCING

3.1. MOVEMENT CHARACTERISTICS OF FENCING PERFORMANCE

Fencing is categorised by high intensity intermittent actions whereby a fencer will undertake multiple explosive actions to win points. The intermittent nature of fencing is highlighted through the work to rest ratios reported in previous research. Épée fencing tends to have work to rest ratios of ~1:1-2:1,[4,5,10] whereas foil and sabre tend to have greater rest periods than épée with work to rest ratios of ~1:1-1:3 and ~1:5-1:6 respectively.[10] Furthermore, it has been shown that fencers will work for longer during épée (15 seconds), than in foil (5 seconds) and sabre (2.5 seconds) during a point.[1,4,10] Therefore, there are distinct differences between the weapons with sabre being more explosive and épée having more of a submaximal component to performance. The system of priority also likely influences the work pattern for each weapon. When competing in foil and sabre engaging in the first attacking movement is vital for performance to be deemed the attacking fencer by the referee and thus score points. With épée, as there is no system of priority, competition is more tactical to outscore the opponent as there is no system of priority.

Previous research within fencing has used time-motion analysis within fencing,[5,7,8,10] which shows understanding of the movement demands of fencing. Research by Aquili et al. (2013)[10] and Bottoms et al. (2013)[5] used time-motion analysis to determine work to rest ratios within fencing as noted above. Additionally, Bottoms et al. (2013)[5] used the time motion analysis of simulated competition to create a simulated fencing protocol for épée. The authors highlighted the importance of arm movement as well as leg movement within fencing training due to similar ratings of perceived exertion (RPE) for arms and legs when compared to overall RPE. Research by Wylde et al. (2013)[7] and Wylde and Yong (2015)[8] determined the different intensity of movements within foil fencing using time-motion analysis. They determined that ~8%, ~41% and ~51% of movements were high, moderate, and low intensity movements, respectively. Due to the subjective nature of time-motion analysis, there could be misinterpretation of movement types by researchers, coaches and practitioners when prescribing training from the movement category definitions. This is shown through different movement definitions by Wylde et al. (2013)[7] and coach derived definitions by Bottoms et al. (2013).[5] Specific movement definitions should, therefore, be determined for fencing movement analysis. Furthermore, there is extremely limited data in all three fencing weapons regarding movement data.

With technological advances in sport science Global Position System (GPS) or accelerometer-based systems have become a popular and more practical option to analyse sporting performance than time motion analysis.[11,12] These systems provide real-time detailed information on the external load of athletes (and internal load if physiological variables such as heart rate (HR) are measured), such as accelerations, speed, distance covered and can provide an overall training load score.[13] One previous study has utilised an accelerometer-based system to quantify movement data within fencing.[6] Research by Oates et al. (2019)[6] during simulated épée competition showed fencers covered 283 ± 93m (78 ± 15 $m.min^{-1}$) during Poule fights and 833 ± 261m (75 ± 13 $m.min^{-1}$) during DE fights. Furthermore, it was determined that fencers achieved peak speeds of 3.4 ± 0.7 $m.s^{-1}$ and 3.9 ± 0.8 $m.s^{-1}$ and average speeds of 1.3 ± 0.2 $m.s^{-1}$ and 1.1 ± 0.2 $m.s^{-1}$ in Poule and DE fights respectively. It was also shown that ~4%, ~42% and ~54% of movements were considered high, moderate, and low intensity in Poule fights and ~4%, ~45% and ~51% of movements were considered high, moderate, and low intensity in DE fights. This is similar to previously determined time-motion based movement characteristics in foil.[7,8] Further research should be conducted using these technological advancements to determine the movement characteristics of sabre and foil as well as confirming the épée results. As well as movement intensity, the speed of movement, and change of direction which consists of accelerations and decelerations are important determinants of fencing performance.[4] Providing coaches and practitioners with speed, acceleration, deceleration, distance covered, and training load data could allow them to plan training programmes to match the demands of competition. Additionally coupling the external demands of fencing with internal demands (such as HR, oxygen consumption ($\dot{V}O_2$), blood lactate concentration, and body temperature) would enable a clearer understanding of fencing performance. Furthermore, understanding the movement demands of fencing could allow for appropriate performance tests to be developed, thus facilitating the design and evaluation of recovery strategies between fights and between competition days.

3.2. HEART RATE RESPONSES DURING FENCING

Measuring HR is a simple and cost-effective method for measuring internal load of exercise intensity and internal load.[14,15] The measurement of HR during competition enables coaches and practitioners to plan training programmes to allow athletes to work at competition intensity during training. Heart rate during fencing has been recorded in both simulated fencing[5,6,16–19] and competition[8,20] as shown in Table 1. Fencing can produce high HR with most of the previous research showing average heart rate (HR_{av}) of between 75-100% of maximum heart rate (Table 1). Therefore, this suggests there could be a high cardiovascular strain when competing. Peak heart rate also tends to be greater (~5%) during DE fights compared to Poule fights likely as a result of the longer fight duration[6] and the more competitive part of the knockout competition phase increasing catecholamine levels.[21]

As shown in Table 1 simulated fencing tends to produce a lower HR response than competition, however there is limited competition data available. Furthermore, there is a lack of research determining the peak HR that can be achieved in fencing with no current research assessing peak competition HR. Peak HR measurements could: indicate the maximum cardiovascular strain experienced by a fencer when competing, inform training sessions to meet the maximal demands of performance, and inform recovery strategies. There are also large standard deviations in the research for both average and peak HR potentially due to different fencing styles employed e.g., offensive, and defensive styles and, also, reporting of absolute HR as opposed to relative percentage of maximum HR. Moreover, previous fencing research has used participants of varying ages within the same study. Participants of different ages could impact the standard deviation as maximum HR tends to decline with age,[22,23] therefore reporting relative percentages could be a better method of presenting HR data. More experienced fencers could have a lower HR than inexperienced fencers due to greater adaptations to fencing training and thus be able to compete at a higher intensity. Therefore, fencer development training could assess fencing HR to assess training adaptation and skill acquisition. Future research is warranted to assess this hypothesis.

3.3. OXYGEN CONSUMPTION AND ENERGY EXPENDITURE DURING FENCING

Due to the practical challenges of measuring expired gas during fencing (i.e. competitors wearing the fencing mask) there is limited research assessing $\dot{V}O_2$ responses and energy expenditure (EE).[6,16,17,24,25] During a national competition $\dot{V}O_2$ was estimated to be 54 ± 4 $ml.kg^{-1}.min^{-1}$ in male épée fencers and 40 ± 7 $ml.kg^{-1}.min^{-1}$ in female foil fencers with average $\dot{V}O_2$ of between 56-74% of maximal oxygen consumption ($\dot{V}O_{2max}$) with peak $\dot{V}O_2$ during the fight reported as between 75-99% of $\dot{V}O_{2max}$.[24,25] During simulated épée competition[6,16] there were similar $\dot{V}O_2$ responses with mean $\dot{V}O_2$ of ~35-37 $ml.kg^{-1}min^{-1}$ (~75% of $\dot{V}O_{2max}$ with $\dot{V}O_{2max}$ determined from an incremental treadmill test[16]). During simulated épée fencing research by Iglesias et al. (2019)[17] showed greater relative $\dot{V}O_2$ than Bottoms et al. (2011)[16] and Oates et al. (2019)[6] but lower relative $\dot{V}O_2$ (~44.2 vs. ~53.9 $ml.kg^{-1}.min^{-1}$) than earlier research by Iglesias and Rodríguez (1999, 2000).[24,25] More specifically, Poule fights were reported to have lower $\dot{V}O_2$ than DE fights (~39 $ml.kg^{-1}.min^{-1}$ vs. ~47 $ml.kg^{-1}.min^{-1}$) by Iglesias et al. (2019).[17] In contrast Oates et al. (2019)[6] reported similar mean $\dot{V}O_2$ (~37 $ml.kg^{-1}.min^{-1}$) and peak $\dot{V}O_2$ (~50 $ml.kg^{-1}.min^{-1}$) in Poule and DE fights. However, $\dot{V}O_2$ responses have only been measured during simulated fencing and not actual competition[6,16,17] or estimated using HR data.[24,25]

Energy expenditure within fencing has previously been reported.[6,16,17,19,24,25] Iglesias and Rodríguez (1999, 2000)[24,25] reported estimated EE for international and national competition were ~15.4 $kcal.min^{-1}$ and ~12.3 $kcal.min^{-1}$, respectively, with greater EE recorded in male than female fencers (~19.5 vs. ~10.7 $kcal.min^{-1}$). Similar EE for male regional standard épée fencers was reported for simulated fencing at 17.5 ± 2.9 $kcal.min^{-1}$ for Poule and 19.3

Table 1. Heart rate responses during simulated and actual competition fencing (mean ± SD).

Authors	Weapon	Participant Sex	Simulated or Competition Fencing	Mean Heart Rate (beats.min^{-1}) (% maximum HR if reported)	Peak Heart Rate (beats.min^{-1}) (% maximum HR if reported)
Bottoms et al. (2011)[14]	Épée	Female	Simulated	DE: ~ 173 (87 ± 3%)	NS
Bottoms et al. (2013)[5]	Épée	Male	Simulated	Poule: 155 ± 14 DE: 157 ± 14	Poule: 173 ± 15 DE: 179 ± 15
Iglesias & Rodriguez (1995)[18]	Foil	Female	Competition	Poule and DE grouped: 173 ± 7	NS
Iglesias & Rodriguez (1995)[18]	Épée	Male	Competition	Poule and DE grouped: 166 ± 8	NS
Iglesias et al. (2019)[15]	Épée	Male	Simulated	Poule: 152 ± 22 DE: 164 ± 11	Poule: 170 ± 14 DE: 179 ± 8
Li et al. (1999)[16]	Épée	Female	Simulated	Poule: 150 ± 7	Poule: 178 ± 7
Milia et al. (2013)[17]	NS	Male	Simulated	DE: ~160-170	NS
Oates et al. (2019)[6]	Épée	Male	Simulated	Poule: 168 ± 12 (86 ± 7%) DE: 169 ± 14 (87 ± 6%)	Poule: 180 ± 11 (92 ± 6%) DE: 187 ± 13 (96 ± 5)
Wylde & Yong (2015)[8]	Foil	Female	Competition	Absolute HR NS (Poule: 93%, DE: 97%)	NS

± 3.7 kcal.min^{-1} for DE fights. Lower EE (~11-13 kcal.min^{-1}) was determined in the studies by Bottoms et al. (2011),[16] Milia et al. (2013)[19] and Oates et al. (2019).[6] The study by Milia et al. (2013)[19] did not state which weapon was used and is therefore difficult to interpret, although speculatively, the shorter work durations in both foil and sabre could possibly explain lower values. Further, EE was only measured during simulated DE fights in the study by Bottoms et al. (2011)[16] and Milia et al. (2013)[19] which would not be representative of a true EE during competitive fencing. As highlighted above future research should be undertaken to assess the EE during competitive fencing across all weapons.

3.4. BLOOD LACTATE CONCENTRATION RESPONSES DURING FENCING

To determine energy system contribution within fencing blood lactate concentration has been reported (Table 2).[6,16,18–20,26] Relatively low blood lactate concentration values have been reported, generally being below the commonly used threshold of the onset of blood lactate accumulation (OBLA - <4.0 mmol.L^{-1}). In contrast, Milia et al. (2013)[19] reported blood lactate concentration of ~7.0 mmol.L^{-1} following one DE fight (3x3 minutes). As the protocol undertaken by Milia et al. (2013)[19] involved only one DE fight fencers may have performed more explosive movements knowing only one fight was to be completed. Nevertheless, there have been conflicting reports in the literature regarding the energy system that is predominantly used in fencing. Several studies have stated that fencing may rely on alactic and glycolytic energy systems[1,4,6,26] with one suggesting the aerobic system is not of key importance.[4] This could be due to points being scored through high intensity explosive movements. Research by Bottoms et al. (2011),[16] Oates et al. (2019)[6] and Yang et al. (2022),[9] however, suggests fencers may also be reliant on aerobic energy sources, in particular, during épée which is characterised by longer working periods than foil and sabre. It was determined by Yang et al. (2022)[9] that ~80-90% of a fencing fight utilises the aerobic energy system and increases as a fight progress. The aerobic system is of importance during low intensity preparatory movements before attacking movements and anaerobic system recovery to maintain repeated high intensity movement performance.[6,9,16] There is general agreement however, that fencing does rely on the phosphocreatine energy system to provide explosive movements.[4,6,16]

Interestingly, when reporting blood lactate concentration previous research has tended to group Poule and DE fights together and are not able to determine whether any change in energy system reliance occurs over a competition. Two studies have determined blood lactate concentration across a competition.[6,26] For example, a decreasing in blood lactate concentration was observed during DE from the last 8 to the final from ~4.5 to ~3.2 mmol.L^{-1} in sabre.[26] Moreover, Oates et al. (2019)[6] reported a similar decrease in blood lactate concentration from first Poule fight (~4.5 mmol.L^{-1}) to the final DE fight (~2.1 mmol.L^{-1}) in epée, with decreasing blood lactate concentration throughout the DE fights. Due to the length of a full day fencing competition fencers may fatigue and become more reliant on aerobic energy sources to provide energy, especially in épée where the length of fights and work periods are longer than for foil and sabre which have longer recovery periods to restore phosphocreatine stores. Therefore, more research

Table 2. Blood lactate concentration during for simulated and competitive fencing. Approximate values reported due to measurement and grouping of blood lactate concentration at different time points during fencing protocols.

Authors	Weapon	Participant Sex	Fight Type (Poule or DE)	Blood Lactate Concentration (mmol. L^{-1})
Bottoms et al. (2011)[14]	Épée	Female	DE (Simulated)	~2.8
Iglesias & Rodríguez (1995)[18]	Épée	Male	Poule and DE grouped	~3.2
Li et al. (1999)[16]	Épée	Female	Poule	~3.2
Oates et al. (2019)[6]	Épée	Male	Poule	~3.6
Oates et al. (2019)[6]	Épée	Male	DE	~2.7
Iglesias & Rodríguez (1995)[18]	Foil	Female	Poule and DE grouped	~4.2
Turner et al. (2018)[24]	Sabre	Male	Poule	~3.0
Turner et al. (2018)[24]	Sabre	Male	DE	~3.6
Milia et al. (2013)[17]	NS	Male and Female	DE	~7.0

needs to be conducted to establish whether there are changes in energy system reliance across a competition. Understanding the energy requirement of fencing, across all weapons, is important for coaches and practitioners to develop training programmes to target the correct energy systems to help athletes prepare optimally for competition.[26]

3.5. PERCEPTUAL RESPONSES DURING FENCING

Subjective ratings of an athlete's exertion are a good indicator of performance intensity and are a simple measurement for coaches and practitioners to assess during training and competition.[15] There has, however, been limited reporting of RPE within fencing.[5,6,26] During simulated épée competition similar RPE values were observed during Poule fights[5,6] with overall RPE (RPE_O) of ~11, leg RPE (RPE_L) of ~ 11 and arm RPE (RPE_A) of ~10. In contrast, greater exertion was observed during DE fights by Oates et al. (2019)[6] than Bottoms et al. (2013)[5] for RPE_O (~15 vs. ~13), and RPE_L (~14 vs. ~12), with similar RPE_A (~12 vs. ~13). Such differentiated RPE measures would be useful for fencing to assess development of local fatigue in the arms from sword movements and in the legs through repeated high intensity lunging movements during a fight.[4] For sabre, fencing competition[26] elicited similar mean RPE_O to épée Poule (12 ± 2) and DE (14 ± 3) fights. Furthermore, when considered round by round during the sabre DE there was an increase in RPE_O from the first DE (~12) to the last DE (~15). Increasing perceptions of effort may indicate that as competition progresses into the knockout rounds and opponents become tougher (i.e., better seeded fencers from the Poule phase) there may be an increased perception of effort from fencers due to more intense fights (physiologically and psychologically).

Research by Bottoms et al. (2013)[5] also highlighted that local muscle fatigue from the arms and legs may impact performance and fatigue in fencing with similar ratings of exertion as recorded for overall RPE. This could be due to the sword arm could become fatigued due to the weight of the blade with an outstretched arm when in the en guard stance and forces required when deflecting an opponent's sword to defend an attack (parry). The legs are likely to become fatigued due to repeated lunging to attack an opponent,[4] high intensity attacking movements and retreating movements to avoid an attack. Fencers are also constantly moving forwards and backwards (bouncing) to maintain distance from their opponent and to initiate attacking and defensive movements which could cause fatigue in the legs. Future research in fencing should incorporate differentiated RPE to assess fencers' subjective perceptions of effort in relation to performance during competition and to complement objective physiological measurements.

3.6. THERMOREGULATORY CONSIDERATIONS DURING FENCING

Fencing poses thermoregulatory challenges to the body. Firstly, fencing competitions can last between 9-11 hours,[1] therefore there will be multiple fights throughout a day with potentially large amounts of heat being produced by both the active upper body and lower body muscles and stored by the body. Secondly, and most importantly, whilst competing fencers are covered head to toe in multi-layered protective clothing which could pose challenges to heat dissipation. Fencers protective clothing consists of a thick protective outer jacket made from cloth, undergarment consisting of a protective under-plastron (to protect the vital areas of the upper body), breeches, trousers, long socks, glove for the sword arm, protective chest guard (females only), and fencing mask, additionally fencers wear sports apparel below this protective clothing. The protective clothing must also meet the safety requirements outlined by the International Fencing Federation.[27] Foil and Sabre athletes also are required to wear an additional conductive jacket, called a lame, due to the electric scoring system. There has been no previous research specifically addressing the thermoregulatory demands of fencing. Although, gastrointestinal temperature (T_{gast}) has been reported[6] with mean post Poule fight T_{gast} of 37.8°C and 38.4°C post DE fights, importantly, peak values of >39°C were reported in some DE fights. Furthermore, pre-fight T_{gast} was ~0.4°C greater in DE than Poule fights, suggesting heat storage before DE rounds.

Due to the time required to don the protective clothing and rest periods between fights being just 10-15 minutes fencers often only remove their mask and glove between fights. Anecdotally, fencers have a fear of cooling down too much if they remove their protective clothing, which they believe could impact their power when performing if their muscles cool down too much. During fencing, however, evaporative and convective heat loss mechanisms will be affected due to the skin being covered and there will be an added insulative resistance from the thick protective clothing.[28] Therefore, heat loss post fight is important for fencers to lower skin temperature and the associated cardiovascular strain in the recovery between fights.[29] Fencers are, also, unlikely to become cold when removing protective clothing between fights due to the hot micro-climate created from protective clothing[30] and fencers being able to re-warm up before the subsequent fight. Furthermore, the use of a fencing mask may impede a valuable source of heat loss from the head during exercise. It has been shown the head can act as a heat sink and provide valuable heat loss especially as ambient temperature increases.[31] The fencing mask could cause an increase in temperature around the face and influence thermal sensation and comfort due to local thermoreceptors[32–34] which could lower the drive to perform and impact fencing performance. Therefore, there could be an exaggerated perception of effort during fencing, as the temperature of the face has been shown to have a disproportionately large effect on perceptual responses to heat stress[35] and could affect fencers' decision making. The use of protective clothing coupled with the long competition day could impact the body's ability to dissipate heat and cause an increase in thermal load through high core temperatures, skin temperatures, heat storage and perceptual responses.[36] This imbalance in heat gain and loss could cause a decrease in fencing performance and early development of fatigue especially in the latter stages of competition (i.e., DE rounds) which has been shown in other sports with protective clothing.[37–43] Future research should examine the thermoregulatory responses to fencing performance incorporating measurements of skin temperature, thermal sensation, and fencing mask temperature.

4. CONCLUSIONS AND PRACTICAL IMPLICATIONS

Previous research has quantified movement data during simulated and competitive fencing.[5–8] Fencing fights consist of ~40-45% low intensity, ~50% moderate intensity, and ~4-10% high intensity movements,[6–8] highlighting the importance of the aerobic and phosphocreatine energy systems. The distance covered by fencers within a fight is varied and depends upon the specific weapon discipline. Similarly, to movement data heart rate responses to fencing vary in the literature and can reach between 85-100% of maximum heart rate during épée[6,16] and foil.[8] In addition, mean $\dot{V}O_2$ during épée has been shown to be ~75% $\dot{V}O_{2max}$.[6,16,25] Due to relatively low blood lactate concentrations reported for simulated and competition fencing, which tends to remain below $4mmol.L^{-1}$,[4,6,16,26] there is likely a heavier reliance on aerobic energy systems as a competition progresses, especially during épée. Wearing protective clothing when competing that covers the whole body from head to toe in conjunction with the intermittent high physiological demands of fencing, poses a challenge to heat dissipation, potentially causing a decrease in performance (as unreported in the literature) due to fatigue and rising core and skin temperatures as seen in other sports.[38,43] Rating of perceived exertion is greater during DE fights compared to Poule fights, particularly in more competitive scenarios, however, from the limited data available, appear similar between épée and sabre disciplines.

Understanding the physiological demands of fencing performance has implications for athletes, coaches, and practitioners. Firstly, understanding the physiological demands of competition performance enables coaches and practitioners to attempt to match the training demands to competition to allow athletes to be optimally prepared for competition. There seems to be a reliance on both the phosphocreatine and aerobic energy systems during fencing performance and these should be targeted within training to help athletes prepare for competition. Additionally, where possible, collecting physiological data from competition conditions would enable appropriate recovery strategies to be implemented between fights to maintain or improve performance. Practically simple measurements such as heart rate and RPE could give a good indication to athletes, coaches, and practitioners of the demands of fencing performance if more sophisticated equipment is not available such as accelerometer-based systems are not available.

Summary Box

- The physiological demands of fencing performance are high with fencers competing at 75-100% of maximum heart rate and ~75% maximal oxygen consumption.
- There is agreement within the literature that fencing performance is reliant on the phosphocreatine energy system, however more recent developments have highlighted the importance of the aerobic energy system during fencing.
- The thermoregulatory responses of fencing performance are not known. The use of protective clothing coupled with the long competition day could impact the body's ability to dissipate heat and cause an increase in thermal load. This imbalance in heat gain and loss could cause a decrease in fencing performance and early development of fatigue especially in the latter stages of competition.

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CONFLICTS OF INTEREST / COMPETING INTERESTS

LO, and MP declare that they have no conflict of interest. LB is on the British Fencing Medical Committee and conducts contract research with Leon Paul a fencing equipment supplier.

AVAILABILITY OF DATA AND MATERIAL

Not Applicable.

AUTHORS CONTRIBUTIONS

Each of the authors were fully involved in the review and preparation of the manuscript and have read and concur with the content in the final document.

ETHICS APPROVAL

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CONSENT TO PARTICIPANT

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