

Title page

Title: Physical Characteristics Underpinning Lunging and Change of Direction Speed in Fencing

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Abstract: Lunge velocity (LV) and change of direction speed (CODS) are considered fundamental to success during fencing competitions; investigating the physical characteristics that underpin these is the aim of this study. Seventy fencers from the British Fencing National Academy took part and on average (\pm SD) were 16.83 ± 1.72 years of age, 178.13 ± 8.91 cm tall, 68.20 ± 9.64 kg in mass and had 6.25 ± 2.23 years fencing experience. The relationship between anthropometric characteristics (height, arm-span and adductor flexibility) and measures of lower-body power (bilateral and unilateral countermovement jump height and reactive strength index) were examined in their ability to influence LV and CODS. In testing the former, fencers lunged (over a self-selected distance) to and from a force plate, where front leg impact and rear leg propulsive force was quantified; the lunging distance was divided by time to establish LV. CODS was measured over 12 m involving shuttles of between 2 and 4 m. Results revealed that LV and CODS averaged at 3.35 m/s and 5.45 s respectively and in both cases, standing broad jump was the strongest predictor ($r = 0.51$ and -0.65 respectively) of performance. Rear leg drive and front leg impact force averaged at 14.61 N/kg and 3-times bodyweight respectively, with single leg jumps revealing an asymmetry favoring the front leg of 9%. In conclusion, fencers should train lower-body power emphasizing horizontal displacement, noting that this seems to offset any advantage one would expect fencers of a taller stature to have. Also, the commonly reported asymmetry between legs is apparent from adolescence and thus also requires some attention.

Keywords: lunge; agility; asymmetry; combat; fence

INTRODUCTION

Fencing involves a series of explosive attacks, spaced by low-intensity movements with varying recovery periods, predominately taxing anaerobic metabolism (Wylde, Frankie, & O'Donoghue, 2013; Guilhem, Giroux, Chollet, & Rabita, 2014). The lunge is the most common form of attack, with around 21 per bout (Aquili & Tancredi, 2013) and 140 across elimination bouts (Roi & Bianchedi, 2008). Equally, change of direction speed (CODS) is fundamental to performance; during the elimination bouts of foil and epee, a fencer may cover as much as 1000 m and change direction around 200 times (Roi & Bianchedi, 2008). In sabre, where each point lasts around 2.5 s, there are a reported 7 changes in direction per 5-point bout (Aquili & Tancredi, 2013). As such, lunging and changing direction are the most prevalent actions performed, and well acknowledged as fundamental to success (Roi & Bianchedi, 2008; Tsolakis & Vagenas, 2010). Furthermore, Guilhem *et al.*, (2014) and Tsolakis *et al.*, (2010)

noted that elite fencers are faster than non-expert fencers in both. It is clear therefore, that the physical characteristics that underpin these skills should be identified so that they may be developed as part of a fencer's training programme.

Quantitative data describing the physical determinants of the lunge are sparse and what is available has tended to focus on kinematic data that reveal technical points more relevant to the sports coach (Gholipour, Tabrizi, & Farahmand, 2008; Gutierrez-Davila, 2011; Gresham-Fiegel, House, & Zupan, 2013; Stewart & Kopetka, 2005). Only Tsolakis and Vagenas (2010), Tsolakis *et al.*, (2010) and Guilhem *et al.*, (2014) have examined the relationship between anthropometric, physiological traits and lunging. The former two (using 18 females and 15 males from the Greek national team; sword not specified) looked at time of lunge as measured via four photocells placed at a lunge distance of 2/3-leg length. They found that lunge time was significantly ($p < 0.05$) correlated with body fat percentage ($r = 0.36$), dominant and non-dominant thigh cross sectional area ($r = 0.29$ and 0.28 respectively) and measures of squat jump, countermovement jump and the reactive strength index ($r = -0.46$, -0.42 and -0.41 respectively). While the significance of strength and power can be noted, the validity of the lunge test may be questioned. Arguably, measuring a full, self-selected lunge, rather than one that is determined by leg length dimensions would also account for flexibility and arm span, which have been identified as important factors in tennis based lunges (Cronin, McNair, & Marshall, 2003). This would also enable those that have a longer lunge consequent to enhanced force generation capabilities to be noted. Finally, the time taken for the chest to break through a beam may not represent the time taken for the sword to make contact with the target; it also neglects the significance of arm velocity, which is considered fundamental (Stewart &

Kopetka, 2005). Guilhem *et al.*, (2014) used a 6.6 m-long force plate system where elite female sabreurs (French national team; $n = 10$) performed a lunge preceded by a step, from which displacement and velocity was calculated and compared to dynamometry strength testing of the hip and knee. The fencers' centre of mass travelled 1.49 ± 0.19 m in 1.42 ± 0.08 s and at a peak velocity of 2.6 ± 0.2 m/s, generating a peak force of 496.6 ± 77.4 N. Maximal velocity was significantly correlated to the concentric peak torque produced by the rear hip ($r = 0.60$) and knee ($r = 0.79$) extensor muscles, as well as to the front knee extensors ($r = 0.81$). Again the significance of strength may be noted, but a void still remains across more dynamic tests and with respect to anthropometrics. Also no target was used and thus time to hit still remains an unknown variable.

With respect to CODS, again only Tsolakis *et al.*, (2010) investigated this, via a "shuttle test". Here, photocells were placed at the start and end of a 5 m distance. As fast as possible, the fencer moved with correct fencing steps forward and back between them, covering a total distance of 30 m. Scores attained by elite and sub-elite fencers were 12.43 ± 0.95 s and 13.28 ± 0.93 s respectively and were significantly correlated to height, countermovement jump height and the reactive strength index following a drop jump from a 40 cm box ($r = -.25, -.63, -.44$ respectively). These relationships are suggestive of the positive effects of long limbs (presumably affecting "stride length") and lower-body power. Given that average work times for fencers of epee, foil and sabre are ~ 15 (much of which is sub-maximal), 5 (Roi & Bianchedi, 2008) and 2.5 s (Aquila & Tancredi, 2013) respectively, and changes in direction usually occur over shorter distance than 5 m, results may not best represent "on piste" CODS and thus additional more sport specific tests are required.

Therefore the aim of this study is to identify the physical characteristics that underpin both lunge and CODS performance, using tests that build on the aforementioned research. As such, the lunge will be determined using a force plate system that allows fencers to travel their “optimal” distance to strike a target. Reporting this with respect to time, i.e., lunge velocity, would normalize results for those that could lunge further but may take longer and vice versa. Also, a CODS test that replicates bout performance will be used, involving changes in direction required over shorter distances, coupled with a shorter overall distance and thus time to completion. Both test scores will be compared to anthropometric measures and dynamic measures of lower body power. Given the significance of front leg strength and lower-limb muscle imbalance, these will also be measured. On the basis of these previous investigations, it is hypothesized that both front and rear leg power would correlate to lunge and CODS performance, as would stature, arm-span and flexibility. Furthermore, it is predicted that the high impact forces during the landing phase of a lunge, would generate a lower-limb strength imbalance favouring the front leg.

METHODS

Experimental Approach to the Problem

Lunging and CODS (dependent variables) are considered critical to performance in fencing and have previously been associated with anthropometry and assessments of lower body power and reactive strength (independent variables). Previously however,

these have been measured in tests that lacked ecologically validity. The lunge therefore will be measured using a force plate system that allows fencers to travel their “optimal” distance. The CODS test is designed to better replicate bout performance, requiring changes in direction over shorter distances, coupled with a shorter overall distance and thus time to completion. Through linear regression analysis, any association between one or more of the independent variables may be considered indicative of relevant exercise training prescription. To ensure a sample size large enough to utilise multiple regression analysis, academy fencers were used.

Participants

Seventy male ($n = 49$) and female ($n = 21$) fencers from the British Fencing National Academy took part in this study. Fencers from each sword, i.e., epee ($n = 30$), foil ($n = 21$) and sabre ($n = 19$) were tested, and on average (\pm SD) were 16.83 ± 1.72 years of age, 178.13 ± 8.91 cm tall, 68.20 ± 9.64 kg in mass and had 6.25 ± 2.23 years fencing experience. The Middlesex University Ethics Committee approved the study and each participant (or parent/guardian where relevant) provided written informed consent before taking part in the research. All participants were familiar with the testing protocol as it was regularly completed throughout their season at training camps. Given the age range of the fencers, it was possible that some athletes may be late matures and thus undergoing a “growth spurt”. Where this was detected (using calculations described below), the fencer’s data was not included in the final analysis.

Testing

Tests were selected to measure lower-body power and reactive strength. In addition to height and weight, anthropometric data included sitting height (and thus leg-length), arm span and flexibility. The inclusion of leg length also enabled the estimation of peak height velocity as described by Mirwald *et al.*, (2002); a measure used to control for variations in maturation, ensuring all fencers could be classed as adolescent and thus performance not affected by the neuromuscular and stature related alterations consequent to the growth spurt (Mirwald & Bailey, 2002). All tests were conducted on the same day, in the build up to a European competition, and all athletes were healthy and in good fitness. Athletes were residing at the training camp and thus hydration and nutrition was well maintained and monitored by staff.

Anthropometric data

Body mass was measured to the nearest 0.1 kg with an accurately pre-calibrated electronic weighing scale (Seca Alpha 770, Birmingham, UK). Participants were instructed to stand in the centre of the weighing scale's platform, barefoot and with minimum clothes (Eston & Reilly, 2009). Stature was measured to the nearest 0.1 cm with a stadiometer (Seca 220, Birmingham, UK). Participants were asked to stand barefoot in an erect position with heels together, arms hanging relaxed at sides and their upper back, buttocks and cranium against the stadiometer. They were also instructed to fully inhale, stretch up and orientate their head in the Frankfort plane upon measurement (Eston & Reilly, 2009). The measurement was taken as the maximum distance from the floor to the highest point (vertex) on the skull. Sitting

height was also measured with the only difference to standing height being that participants sat on a box, with their thighs parallel to the ground to ensure their spine was in a neutral position. This value provided an approximated peak height velocity using the regression equation devised by Mirwald *et al.*, (2002) as identified in equations one (for boys) and two (for girls).

Equation one.

*Maturity offset (boys) = -9.236 + (0.0002708*Leg length and sitting height interaction) – (0.001663*age and leg length interaction) + (0.007216*age and sitting height interaction) + (0.02292*weight by height ratio).*

Equation two.

*Maturity offset (girls) = -9.376 + (0.0001882*Leg Length and Sitting Height interaction) + (0.0022*Age and Leg Length interaction) + (0.005841*Age and Sitting Height interaction) – (0.002658*Age and Weight interaction) + (0.07693*Weight by Height ratio).*

Flexibility was measured as the linear distance between the lateral malleolus of each leg during a split in the frontal plane (Cronin, McNair, & Marshall, 2003) and arm span was measured as the linear distance between the middle finger tips, with the arms out to the side and parallel to the ground. All scores were recorded to the nearest 0.1 cm, using flexible tape.

Lower-body Power

Jump height was measured in the countermovement jump (CMJ) and single leg-countermovement jump (SLCMJ) for both front (or lead) and back legs. SLCMJ scores were used to identify any asymmetries between legs. Reactive strength index (RSI) was measured following a drop jump from a box height of 30cm. Typically this is measured at multiple heights (also 45, and 60 cm) (Flanagan & Comyns, 2008) but without appropriate technique, higher boxes can yield unreliable results and can be an injury risk. During the test, fencers were instructed to minimize ground contact time and then jump as high as possible. The RSI was calculated as flight time in milliseconds divided by ground contact time in milliseconds. For all jumps (drop jump, CMJ, SLCMJ), fencers were instructed to keep their hands in contact with their hips for the duration of the test. Any movement of the hands away from the hips would have resulted in the jump being disqualified. Following take-off, fencers were also instructed to maintain full extension until contact had been made with the floor upon landing. All scores were measured using an optical measurement system (Optijump, Microgate, Italy) and recorded to the nearest 0.01cm (or to two decimal places in the case of RSI). The standing broad jump was measured using a flexible tape measure, placed along the ground. Fencers had to jump as far forward as possible, keeping their hands on their hips as per other jump tests. If the fencers fell forward at landing, causing their feet to change position, the jump was disqualified. Scores were recorded to the nearest 0.1 cm, and in line with the heel of the foot furthest back. For all tests of lower-body power, three trials were conducted for reliability analysis, with the highest score used for analysis.

Change of Direction Speed

The CODS was measured using a 4-2-2-4 m shuttle. For this, fencers started behind one set of timing gates (Brower timing systems, Utah) set at hip height. Using fencing footwork, they travelled as fast as they could up to a 4 m line, ensuring their front foot crossed the line, they then travelled backwards ensuring the front foot crossed the 2 m line. Again they travelled forward to the 4 m-line, before moving backwards past the start line. The test was carried out on a metal, competition fencing piste to increase validity. The test was immediately stopped if the athlete used footwork deemed by the fencing coach to be unrepresentative of proper form, if the beam was broken at the start or finish line with any part of their body other than their hips, or if the athlete failed to pass either line with their toes or lunged in order to reach the line. Three trials were performed with the best score used in the analysis. During pilot testing, two other CODS tests were initially used. The first involved a shuttle sequence of 3-3-3-3-3 m (i.e., 3 m out to a line, 3 m back and repeat three times) and the second a shuttle sequence of 2-4-2 m. However, it was found that because fencers continually return to the start position where the beam of the light gate is broken, reliability was affected, resulting in intraclass correlations of $r < 0.6$. For this reason, the 4-2-2-4 m shuttle, where the beam was only broken at the start and finish of the test was developed and used for investigation.

Lunge performance

Fencers were instructed to lunge and strike a target as fast as they could, but from what they deemed to be their optimal distance. Fencers were aware that there may be a compromise between distance and time and that to favour one may disadvantage the other. The target was a round pad with a diameter of 24 cm; the fencer could adjust

the height of the target. The fencer was filmed in the sagittal plane using a Casio EX-ZR1000, recording at 480 fps. Data was then analysed using Kinovea software (<http://www.kinovea.org/>) to determine lunge distance (LD) and time. Lunge velocity was calculated as *distance/time*. The start of the lunge (and start of timing) was considered as the first forward movement of the front knee that was not immediately followed by a backward movement; this definition accounts for the fencer's tendency to "bounce" in preparation for attack. Time was stopped once contact had been made with the target.

Fencers also lunged to and from a surface mounted force plate (type 92866AA, Kistler Instruments Ltd., Hook, United Kingdom), enabling the quantification of lunge forces at push-off and landing. Push-off peak force (POPF), impulse (using time to hit) and rate of force development (RFD) measured at 30, 100, 200, 300 ms and time to peak force, were measured in the back leg. Peak landing forces and rate of loading were measured in the front leg. POPF was reported relative to body mass and expressed as N/kg and peak landing forces (PLF) were expressed relative to body weight in line with previous studies (West, et al., 2011). To improve the reliability of force-time data, athletes were asked to "freeze" in the start position prior to each lunge. To determine reliability, fencers performed 3 lunges, with the best scores used in the analysis. To calculate the ground reaction force derivatives described above, the resultant of the anterior-posterior and vertical forces was calculated and then filtered using a fourth-order zero-lag Butterworth low-pass filter with a 50 Hz cut-off for the back foot (push-off forces) and 44 Hz cut-off for the front foot (landing forces). Filter settings were determined by plotting the residual between the filtered and unfiltered signal as a function of cut-off frequency as described by Winter (2009).

Statistical Analysis

Measures of normality were assessed using the Kolmogorov-Smirnov statistic. To determine the reliability of each assessment, single measures intraclass correlations (two-way random with absolute agreement) between trials were conducted. Pearson's Product Moment Correlation analysis was used to identify relationships between variables and a stepwise multiple linear regression was used to identify the best predictors of lunge velocity and CODS. All statistical analysis was conducted using Statistical Package for Social Sciences (SPSS) version 21 with the level of significance set as $p < 0.05$. Due to the large sample size, it would be possible to identify significant correlations above 0.23, which, according to Cohen (1988), represents a "small" effect size. However, only significant correlations > 0.3 , which are considered "moderate", were reported.

RESULTS

All data was normally distributed and intraclass correlations demonstrated a high level of reliability between trials of CMJ ($r = 0.96$), SLCMJ lead-leg ($r = 0.92$) and back-leg ($r = 0.91$), SBJ ($r = 0.94$), RSI ($r = 0.86$), lunge distance ($r = 0.94$), time ($r = 0.87$), velocity ($r = 0.78$), POPF ($r = 0.9$), PLF ($r = 0.88$) and CODS ($r = 0.95$). Measures of RFD, at all time intervals (30, 100, 200, 300 ms and time to peak force), along with impulse and rate of loading, were all found to be unreliable ($r < 0.7$) and thus not used within the subsequent analysis. Results for all tests are illustrated in Table 1 and correlations are illustrated in Table 2. To avoid multicollinearity within the lunge regression model, CMJ was removed as it was highly correlated with SBJ (r

= 0.87); SBJ had a higher correlation with lunge velocity and also enabled SLCMJ back leg to be included in the analysis (for CMJ and SLCMJ back-leg, $r = 0.84$). SLCMJ lead-leg was not included as it was highly correlated with SLCMJ back-leg ($r = 0.87$) and the latter was deemed to contribute to lunge velocity more. Therefore, only three variables (CMJ, SLCMJ back-leg and POPF) were entered (noting that no anthropometric data correlated with lunge velocity) into the regression model, which given the sample size ($n = 70$), was deemed acceptable (Field, 2013). The best predictor of lunge velocity was a one variable model using SBJ (Table 3). For the CODS regression model, height, flexibility, SBJ, SLCMJ back-leg and RSI were entered. Again, the best predictor of lunge velocity was a one variable model using SBJ (Table 4).

**** Tables 1 – 4 here ****

DISCUSSION

Anthropometric measures of height, arm-span and flexibility showed no correlation with lunge velocity (LV). While most measures of lower-body power did, SBJ had the highest correlation ($r = 0.51$) and was also the only variable to be used in the multiple regression model, which accounted for 26% of the variability in the score. Height and flexibility did however, correlate with lunge distance (see Table 3). Based on previous research, flexibility was expected to show some relationship (Cronin, McNair, & Marshall, 2003), as enhanced mobility within the adductor complex would likely allow fencers to lunge further. Longer legs (again allowing a greater stride), coupled

with a longer torso (and thus a greater lean towards the target) would also enable fencers to do the same.

The CODS test was completed in 5.45 ± 0.65 s and thus better replicates the approximated work duration of a fencing point. While epee and foil have longer “work” times, much of this is at a sub-maximal intensity; also sabre’s work duration is averaged at half of this but it is expected that using a CODS that would take less than 3 s would negatively affect test reliability. The CODS was correlated with all variables (except flexibility where stride length was presumably not great enough to affect this) and similar to LV, SBJ had the highest correlation ($r = -0.65$). It was also the only variable to be used in the regression model, accounting for 43% of the variability in the score. Like LV, CODS is correlated to lower-body power, but also leg-length, which may in part dictate stride length. RSI is correlated, which given the need for “fast feet” and thus reduced ground contact times, is not a surprising finding. This is the first study to identify scores for CODS over sprint-based distances in fencing, so a comparison with other studies is not possible.

The lack of any correlation with lunge time across all variables may suggest that the ability to generate lower-body power, cancels out the assumed greater time expected for taller fencers (who travel a larger distance) to hit the target. That is, enhanced lower-body power also enables fencers (of smaller stature) to take up their *en guard* position further away from their opponent. It may also suggest that fencers tend to opt for standing a greater distance from the target (and staying out of range), rather than reducing time to contact. In essence, fencers used their perceived propulsive forces to

move further away from the target (beyond that dictated by their anthropometrics), rather than maintain distance and hit the target in a shorter time. This inference is supported by the consistent significant correlations between measures of lower-body power and lunge distance. Equally, it is measures of lower-body power, rather than anthropometric characteristics, which better relate to LV. Anecdotally, coaches also generally teach their athletes to maintain an “out of range” distance from their opponent. These observations fit the theories of body- and action-scaled affordances (Fajen, Riley, & Turvey, 2009), whereby athletes self optimises for a particular task based on anthropometry e.g., leg - length (body – scaled) or on capabilities such as strength (action – scaled). Results may suggest that the “optimal”, self-selected lunge, is a technique not only standardized by anthropometric measures, but also the ability to generate force and propel ones self forward.

A higher correlation between POPF (N/kg) and LV was expected, especially given the correlations with lower-body power including single-leg jumps. Also, Guilhem *et al.*, (2014) through electromyography analysis, showed that the activation of rear leg extensor muscles i.e., gluteus maximus, vastis lateralis and soleus, was correlated to LV ($r = 0.70, 0.59$ and 0.44 , respectively). On re-examination of the video footage, it is clear that some fencers initiate the lunge with extension of the legs, while others (correctly for the purpose of “priority” scoring) with extension of the lead arm; a discrepancy in technique noted elsewhere (Gholipour, Tabrizi, & Farahmand, 2008; Gutierrez-Davila, 2011). If the latter is performed incorrectly, it may have the effect of shifting the athlete’s centre of mass forward and thus reducing the ability of the athlete to generate force at the back leg due to its reduced active state, see Bobbert and Casius (2005) for further details. If coupled with torso lean, this could also result

in changes to the length-tension relationship across various muscle groups, including the hip extensor complex. If such assertions were true, they would warn of the negative consequences of a lead arm that does not move independent of the body; fencers should not feel that this movement shifts their weight forward favouring the front leg, or causes the torso to lean towards the target.

The average lunge distance was 148.28 ± 25.06 cm. This was further than that noted by Gholipour *et al.*, (2008), but similar to Gutierrez-Davila *et al.*, (2011) (117 and 140 cm respectively). Compared to Guilhem *et al.*, (2014), and acknowledging their lunge was preceded by a (small) step but our fencers were taller (~8 cm), distance travelled appears similar. The average lunge time (from initiation to sword contact with target) was 400 ± 8 ms. This was quicker than Gholipour *et al.*, (2008), Gutierrez-Davila *et al.*, (2011) and Guilhem *et al.*, (2014) (1082, 601 and 1430 ms respectively). In the study of Gholipour *et al.*, (2008), fencers were asked to lunge with no target to aim at, with time stopped at completion of the lunge, which can often follow the sword contact with the target as this may occur with the front foot still airborne. Also, data was recorded at 50 Hz, creating a probable error of ± 20 ms. In the study of Gutierrez-Davila *et al.*, (2011) lunge distance was set at 1.5-fold the height of the fencer. While time was stopped when the sword made contact with the target, fencers first had to respond to a visual cue, thus including a reactive element. In the Guilhem *et al.*, (2014) study, the lunge was preceded by a step as well as measured until the front foot made contact with the floor, rather than the sword with the target. Only Tsolakis and Vagenas (2010) have found quicker lunge times. They reported scores of 180 ± 30 ms and 210 ± 40 ms in elite and sub-elite Greek Fencers respectively. As aforementioned, they used a different protocol (four photocells placed at a lunge

distance of 2/3-leg length, with the height of the photocells adjusted to be interrupted by the chest) making comparisons difficult.

Like Tsolakis and Vagenas (2010) and Tsolakis *et al.*, (2010) correlations were found between lead leg power and lunge performance, which given the landing forces experienced (~ 3 times body weight) and thus the need to demonstrate and develop high eccentric (braking) strength (Guilhem, Giroux, Chollet, & Rabita, 2014), is not a surprising outcome. Also, given its correlation with LD, it appears that this will continually develop with increases in stature and the ability for rear leg propulsion. The association is of course indirect, as the measurement of lower-limb muscle activation has revealed the lunge is performed via rear leg propulsion (Guilhem, Giroux, Chollet, & Rabita, 2014). The high landing forces also explain the asymmetries noted here and previously (Guilhem, Giroux, Chollet, & Rabita, 2014) and although these fencers are ~ 17 years, they are already close to the threshold (> 15%) for which the likelihood for injury is high (Impellizzeri, Rampinni, & Marcora, 2007) and performance may be compromised (on average, fencers had asymmetry of 9.3%). Although not measured here, it is likely that the force required to return to the *en guard* position following the competition of the lunge, will add to this asymmetrical issue.

The results herein add to the growing evidence that strength and power characteristics positively correlate to lunge and CODS performance. We would also add stature and flexibility in the adductors as having beneficial effects. We also highlight the concerns of others regarding lower-limb asymmetries in favour of the front leg on

account of high landing forces (and probably the need to recover from this position). This will increase the risk of injury and compromise performance and is an issue already apparent in many of these adolescent fencers. Unfortunately, time based derivatives of force (i.e., RFD and impulse) were too unreliable to be used for analysis. Future investigations should look to standardize the lunge position better, requiring static poses in the start position in excess of 3 s to reduce active state (Bobbert & Casius, 2005).

CONCLUSIONS AND PRACTICAL APPLICATIONS

Training the lunge. Based on these results, fencers of smaller stature (and thus reduced attacking range) can compensate for this by working on the ability to generate force, especially in the horizontal direction. Training programmes should look to include horizontal jumping, bi-lateral and unilateral. Of note, the SLCMJ lead-leg was also correlated with distance and velocity and, despite not being as responsible for propelling the body forward while lunging, had higher jump scores than the back-leg (18.86 ± 4.65 cm vs. 17.1 ± 4.62 cm). It may be that this is an outcome of the high landing forces generated from the lunge, as well as the push-off force then required to quickly recover back to the *en guard* position; both are likely to translate to strength gains. These may reveal the benefits of exposing the back-leg to higher landing/eccentric forces as part of training, as well as high concentric forces from a relatively deep squat position (thighs at least parallel to the floor). Finally, despite the relatively young age of the fencers (16.83 years), the 6.25 years experience in fencing has already generated a lower-limb asymmetry between the front leg and back leg of 9.3%. Given that a 15% difference is a probable indication

of impeding injury (Impellizzeri, Rampinni, & Marcora, 2007), this needs to be addressed. As well as more single-leg work on the weaker leg (generally the back leg), switching the stance during warm-ups may be one way of addressing this.

Training CODS. Exercises that develop lower-body power, especially with horizontal propulsion, may be beneficial. These should also be supplemented with exercises that develop reactive strength such as drop jumps and hurdle jumps; perhaps the latter will have a greater carry-over given its horizontal displacement, as SBJ (horizontal displacement) showed a stronger correlation than CMJ (vertical displacement). Finally, taller athletes tend to be at an advantage; perhaps due to an ability to maximize stride length.

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Table 1 Descriptive statistics for anthropometric and strength and power variables in British Fencing National Academy Fencers (*n* = 70)

Variable	Mean (SD)	Standard deviation
APHV	1.63	1.21
Leg-length (cm)	92.50	7.01
Arm-span (cm)	171.91	10.56
Flexibility (cm)	147.75	17.49
SBJ (cm)	177.7	0.32
CMJ (cm)	34.33	7.33
SLCMJB (cm)	17.1	4.64
SLCMJF (cm)	18.86	4.65
Asymmetry (%)	9.3	8
RSI	2.27	0.56
Peak push-off force (N/kg)	14.61	2.47
Peak landing forces (BW)	2.83	1.16
Lunge distance (cm)	148.28	25.06
Lunge time (s)	0.40	0.08
Lunge velocity (m/s)	3.35	0.70
Change of direction speed (s)	5.45	0.65

APHV = approximated peak height velocity; SBJ = standing broad jump; CMJ = countermovement jump; SLCMJ = single leg-countermovement jump, both back (B) and front (F); RSI = reactive strength index; BW = body weight

Table 2 Correlations for anthropometric and strength and power tests with lunge distance, time and velocity.

	Lunge distance	Lunge time	Lunge velocity	CODS
Height	.45	-	-	-.37
Arm-span	.37	-	-	/
Flexibility	.38	-	-	-
CMJ	.44	-	.49	-.49
SBJ	.43	-	.51	-.65
SLCMJB	.43	-	.38	-.46
SLCMJF	.37	-	.45	-.45
RSI	.38	-	-	-.41
Peak push-off force	.32	-	.38	/
Peak landing forces	.38	-	/	/

All correlations significant at $p < 0.001$. CODS = change of direction speed; SBJ = standing broad jump; CMJ = countermovement jump; SLCMJ = single leg-countermovement jump, both back (B) and front (F); RSI = reactive strength index; / = not tested; - = no correlation.

Table 3 Multiple Regression model to predict lunge velocity

Model	B	SE B	β
Constant	1.766	0.350	
SBJ	0.923	0.198	0.507*

Note. $R^2 = .257$. * $p < .001$

Table 4 Multiple Regression model to predict change of direction speed

Model	B	SE B	β
Constant	7.660	0.320	
SBJ	-1.279	0.180	-0.652*

Note. $R^2 = .425$. * $p < .001$