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The Effect of Non-Leading Foot Placement on Power in the Fencing Lunge

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Carolyn Gresham-Fiegel

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The Effect of Non-Leading Foot Placement on Power in the Fencing Lunge

A THESIS

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By

Paul D. House
Paul House, PhD

Donna Cobb
Donna Cobb, EdD

Larry A. Lucas
Larry Lucas, PhD

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Carolyn Gresham-Fiegel

Dedication

I dedicate this thesis to Bob, who helped me see a sport as science and science as a sport.

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Abstract

Fencing success does not depend on specific morphological or physiological attributes. Nevertheless, the muscular demands are very specific and development of effective movement takes time and practice. Being able to lunge appropriately and with adequate power is an essential ability for fencers. But while the pattern of muscular activation is known, the effect of foot placement has not been investigated. Using a TENDO weightlifting analyzer to assess velocity and power, the impact of foot placement angle on lunge power is studied.

The Effect of Non-Leading Foot Placement on Power in the Fencing Lunge

The sport of fencing developed over hundreds of years from the combat use of swords. Modern fencing involves three weapons (the foil, epee, and sabre), each with its own history, rules of engagement, and target area. Each requires slightly different movements, but all three have the same goal: to touch the opponent on the valid target area without being touched (United States Fencing Association [USFA], 2002).

The basic stance of fencing, the guard position, is relatively wide, with feet spaced shoulder-width apart. The leading foot aims directly toward the opposing fencer. The non-leading foot is placed at an angle of approximately 90 degrees from the line of the front foot. This angle, however, varies greatly among fencers, from acute (both feet facing forward) to obtuse (feet facing in slightly opposite directions). To score, a fencer lunges from guard position, quickly closing the distance to the opponent, and touches the opponent with his weapon (Szabó, 1998). Unlike the forward lunge common in many other sports, the fencing lunge maintains the perpendicular orientation of the feet, the sole of the non-leading foot remains planted on the ground, and the non-leading leg extends forcefully and almost completely. In fencing, a powerful lunge is key to a successful touch (score).

Fencing requires an athlete to have "the reflexes of a boxer, the legs of a high jumper, and the concentration of a tournament chess player" (USFA, 2002, p. 2). Because of this multifaceted aspect, many previous studies of fencing have focused on the morphological and physiological attributes (Nystrom et al., 1990; Vander et al., 1984), the development of power through interval training techniques (Rippetoe, 2000), and stimulus discrimination within the motor program (Di Russo, Taddei, Apnile, & Spinelli, 2006; Guizani et al., 2006; Williams & Walmsley, 2000a; Yiou & Do, 2000).

The lunge itself has been the focus of fewer studies. In an early investigation of lunge performance, Klinger and Adrian (1987) studied the power produced in the lunges of nine fencers in reaction to different starting cues. Power means ranged from 2105 Watts to 1988 Watts, with no standard deviations reported. Using video technology with four participants, Zhang, Chu, and Hong (1999) analyzed the velocity of the center of mass and time to reach target during a lunge, as well as joint angles and stride length of the end lunge position. Maximum horizontal center of gravity (CG) velocity ranged from 304.7 ± 61.2 CG/s to 345.0 ± 44.2 CG/s (the investigators' units). In a more recent study of 31 male athletes from a variety of predominantly lower body sports, Cronin, McNair, and Marshall (2003) studied the relationship between a measure of explosive strength and forward lunge performance. Using a squat machine to measure strength and a linear transducer to measure lunge velocity, the mean maximum concentric velocity was found to be 1.64 ± 0.247 m/s and mean maximum eccentric velocity was 1.68 ± 0.144 m/s. The researchers concluded that time to peak force was the single best predictor of lunge performance, when performing non-fencing specific lunges. A complete discussion of these and other studies can be found in Appendix A.

Purpose

The present study was designed to expand previous research by determining more specifically how placement of the non-leading foot affects lunge power. Participants performed a series of fencing lunges, with the non-leading foot placed at specific angles.

Power and velocity were measured for lunges performed at each foot placement. Power has traditionally been defined as the rate at which mechanical work can be done and is the product of force and velocity (Cronin et al., 2003). Thus, power is a function of the body's mass and its velocity, as reflected in the time taken to move that mass a given distance. In order to allow the comparison of a participant's power production between foot angles, it was necessary to keep lunge distance constant for each participant. Lunge power was determined by the TENDO Weightlifting Analyzer (Slovak Republic), a linear transducer which uses displacement and velocity measurements to determine peak and average power.

Assumptions

Although the fencing lunge is affected by other biomechanical aspects of movement, i.e., non-weapon hand use and torso angle, it was assumed that each participant's movement was the same through all test lunges, so that the only variable was non-leading foot placement. Any anticipatory or preparatory movements were considered to be constant among test lunges for each individual. In addition, all lunges were presumed to be performed at maximum effort. Since peak velocity and highest average velocity did not always occur in a single lunge at each foot placement, the three trails at each foot placement were averaged before statistical analysis. Cronin et al. (2003) suggest that three repetitions are sufficient to accurately measure peak power and exhibit strong intraclass correlation.

Delimitations and Limitations

Defining foot placement as the angle of the non-leading foot measured from the leading foot, foot placement was delimited here to three specific angles: 45º, 90º, and 135º. For comparison purposes, the angle of natural stance was also determined for each participant.

A limitation for this study arose in the availability of participants already skilled in the performance of fencing lunges. Due to the foot placement, a fencing lunge differs significantly from the more commonly known forward lunge. The production of a powerful fencing lunge takes practice as well as development of specific muscular control (Lukovich, 1986). Therefore, participants must be trained in competitive sport fencing, in order to produce adequate lunge power. In addition, a developed fencing ability is necessary to be able to produce a powerful lunge, while maintaining an unaccustomed position of the non-leading foot. Size of the study sample was also considered. Because sample size in previous fencing-specific studies has been very small and results are incomplete from research that focused specifically on different velocities of fencing lunges, an accurate estimate of sample size was not possible. However, the competitive team at the United States Air Force Academy (USAFA) in Colorado Springs, Colorado, had a large number of competitive fencers, who fit the requirements of participation. For these reasons, participants were recruited from the USAFA fencing team.

Research Hypothesis

The hypothesis in the present study was that the traditional foot position, with feet placed at a 90º angle, would result in the greatest peak and average power, followed in magnitude by the 45º and the 135º angles respectively. The determination of the optimal foot placement, and further delineation of the optimal foot placement range, may aid in the development of specific training techniques. This, in turn, would enhance lunge power and scoring success for competitive fencers.

Methodology

Participants

Data was collected at the fencing facility on the USAFA campus in Colorado Springs, CO. Institutional review board approval was obtained from both the University of Central Oklahoma (UCO) and from the USAFA. Through the distribution of flyers and the posting of a notice in the fencing facility, volunteers were recruited from the 20 female and 20 male members, aged 18-28 years, of the USAFA fencing team. In an informational meeting, participants received an explanation of the purpose of the study and informed consent forms from UCO and from the USAFA. Informed consent forms, and approval letters are included in Appendices B and C. After providing consent, each subject was tested individually.

Equipment and Design

Participants wore their fencing uniforms to the testing sessions. This included fencing jacket, fencing pants, socks, and their competitive fencing shoes. This ensured consistency in the testing situation and enabled attachment of the testing equipment. Every fencing jacket has a metal D-ring, used for connection during competition of the fencing body cord/reel interface and linking the fencer to the electric scoring system. This same D-ring was used to attach the power measurement device (TENDO Weightlifting Analyzer) to the participant.

The TENDO Weightlifting Analyzer is a microcomputer system used for measuring power and velocity. A velocity sensor unit in the device contains an optical sensor for displacement, a time measurement tool, and a DC motor for movement orientation (Tendo Sports, n.d.). Linear displacement is measured with a pulley and cable system. The system measures average and peak velocity (m/s); using known mass (kg), the computer calculates average and peak power (W) in the concentric phase of a movement. The TENDO was placed on the floor, directly behind the participant, with the digital readout and computer positioned to one side of the analyzer.

A testing platform was used for all testing (Figure 1). The wooden platform measures 3 feet by 8 feet, with lines for foot placement and a scale for foot angle measurement marked for both left- and right-handers. A raised knob extends above the platform surface by 1.5 cm (about 0.6 inch), giving the participant a specified location in which to place and keep the non-leading heel. In addition, the platform has a thin bar which is positioned against the medial edge of the non-leading foot. The bar can be attached to the platform by Velcro, is shallow enough in height to not interfere with the lunge process, yet gives a kinesthetic cue to maintain the foot position while lunging.

Procedures

Initial assessment included height, weight, age, sex, and fencing handedness. Determination of the natural stance necessitated consideration of the shape of different fencing shoes. Before testing began, each participant was asked to place his or her finger on the distal end of the second toe of the non-leading foot. This point was marked with narrow tape, attached to the participant's shoe. The second toe was selected as the toe most closely approximating the central axis of the foot. Measurement of the natural stance was accomplished through the following steps: (1) the participant aligned the foot marker with the 90° line; (2) the foot bar was placed along the medial surface of the shoe and the angle of the shoe measured, using the scale on the testing platform; (3) the difference in degrees was calculated between 90° and the angle of the shoe (shoe angle); (4) the participant stood in his or her natural stance; (5) the foot bar was aligned and the angle of the shoe measured as described above; and (6) the shoe angle was added to the measured angle to determine angle of natural stance. After natural stance measurement, the participant performed three practice lunges. The lengths of the longest and the shortest practice lunge were marked on the platform with tape. The area between the two marked lines was used as the target distance (Figure 2, Line 4) for all subsequent lunges for that participant. The TENDO was attached to the subject's fencing jacket, near the subject's center of gravity, using the pre-existing body cord D-ring on the jacket. The order of lunge testing was randomized among the subjects. During testing, the participant was asked to align the toe marker with the angle line on the testing platform, thereby allowing more consistent placement of the non-leading foot. Each subject stood on guard, with the non-leading foot on Line 1, 2, or 3 (90°, 45°, or 135° angle from line of front foot, respectively) or in the natural stance. The subject lunged as quickly as possible, and landed with the heel of the leading foot on Line 4. Three lunges were performed. After moving the non-leading foot to a second line, the process was repeated; the same procedure was then performed for the third and fourth positions. After testing, each subject was given a written report of the power production of his or her natural stance lunges. See Appendix D for supplemental forms and materials used in data collection.

Statistical Analyses

As a measure of trial reliability, repeated measures ANOVA and intraclass correlation coefficients were utilized to distinguish significant differences between individual lunge attempts at each foot placement angle. For each participant, the average of the three lunge trials for each dependent variable was then calculated. Using these calculated average values of peak power, peak velocity, average power, and average velocity from each of the four stances, repeated measures ANOVA analyses were run. Post hoc multiple comparisons among means (paired-sample t-tests) investigated the differences between the stance variables. Significance was set at $p < .05$ for all statistical tests.

Results

Descriptive Data

The mean age for participants was 20.28 years, with a range of 18-28 years. Thirteen subjects were female; twelve were male. The mean height and weight for the women were 1.67 ± .02 m and 66.95 ± 2.03 kg, respectively. The men's mean height was 1.79 ± .02 m and mean weight was 75.13 ± 2.32 kg. Two participants had natural stances at 68°; six had natural stances between 71° and 79.9°; seven between 80° and 89.9°; and nine were from 90° to 92°. One participant had a 100° natural stance.

Trial Reliability

Repeated measures ANOVA, comparing the three trials for each individual within each level of the independent variable, showed no significant differences between trials. Intraclass correlation coefficients for trials within each independent variable level were moderate to very strong (Table 1), suggesting that the trials were reliable measures of power and velocity at each foot placement.

Pooled Means Data

When data were pooled across participants ($n = 25$), the 90° foot placement resulted in highest values for average power and average velocity, followed in magnitude by the natural stance, the backward deviation, and finally the forward deviation of the non-leading leg (Table 2). The ordering for peak power and peak velocity placed the magnitude ranking as natural stance, followed by the 90° placement, backward deviation, and then forward deviation (Table 2).

Hypothesis Results

After application of a repeated measures ANOVA with foot placement as the independent variable, Mauchly's test indicated that the assumption of sphericity had been violated with respect to peak power ($W[5] = 0.305$, $p < .001$) and to peak velocity ($W[5] = .359$, $p < .001$); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .605$ and .661 for peak power and peak velocity, respectively). Based on the same tests, sphericity was assumed for average power and average velocity.

The results showed significant differences in peak power ($F[1.82, 41.74] = 14.729$, $p < .001$), average power ($F[3,69] = 15.198$, $p < .001$), peak velocity ($F[1.98, 45.59] = 16.907$, $p < .001$), and average velocity ($F[3,69] = 15.604$, $p < .001$). Pairwise comparisons, using the Bonferroni correction, indicated significant differences in average power and average velocity between the 45° angle and each of the other three angles (Table 3). Average power and average velocity also differed significantly between 90° and 135°; average velocity was significantly different between 90° and the natural stance. Similarly, peak power and peak velocity differed significantly (1) between 45° and each of the other three angles and (2) between 90° and 135° (Table 4). Additional results are included in Appendix E.

Discussion

Results indicated that the greatest average power and velocity were produced at 90 degrees. These values were significantly higher than values at 45° and at 135°. In addition, average velocity at 90° was higher than the natural stance. Average power at 90°, however, was not significantly greater than that produced at the natural stance. This disparity may result from the calculation of power, when the mass value is rounded by the TENDO before figuring power values. In general, participants were able to sustain higher velocity and power throughout the lunge movement, when the non-leading foot was held at the 90° foot placement. By contrast, the average values reached in the natural stance were significantly greater than only the 45° stance.

For peak values, a slightly different pattern emerged. The greatest peak power and peak velocity were attained in the natural stance, though the values were not significantly greater than those produced in the 90° foot placement. The natural stance resulted in values significantly greater than the 45° foot placement, but did not produce peak values significantly greater than the 135° stance.

In the present study, it was hypothesized that the traditional foot position, with feet placed at a 90º angle, would result in the greatest peak and average power, followed in magnitude by the 45º and the 135º angles respectively. Although it was hypothesized that the 135° placement would result in the smallest velocity and power measurements, the 45° stance consistently produced the lowest values for all dependent variables. When fencers stood in a natural on-guard position, the angle of the back foot varied from 68° to 100°. Sixty-eight percent of participants were within the range of 80 - 100°; eighty-eight percent were between 71° and 92° (Figure 3). It is obvious from results that a forward deviation of 45° decreases the power and velocity, both peak and average, that can be produced during a lunge. However, the majority of participants had natural stance angles within a 20° forward deviation of the perpendicular stance, and between the 90° and natural foot placement a significant difference was detected for average velocity. This implies that forward deviation of the foot begins to affect velocity and, as the angle of deviation moves toward 45°, power and velocity are increasingly influenced. Whether there is a "critical" angle, at which velocity and power are first affected, remains to be discovered.

When values for power were expressed relative to body weight, a similar pattern emerged. For average power, the 90° foot placement resulted in the highest value, followed in magnitude by the natural stance, the 135° stance, and finally the 45° foot placement. As was seen with the absolute measurements, all differences were significant, except between (1) the perpendicular and the natural stance and (2) between the natural and the 135° stance. The natural foot orientation again produced the greatest peak power, though not significantly more than the 90° stance nor the 135° placement (Tables 5 and

6). The forward deviation of the non-leading foot produced consistently lower values for average and peak power, whether considered as absolute or as relative values.

When a fencer lunges, the body mass is propelled forward through a rapid extension of the non-leading leg. Since power is the product of mass and velocity, lunge power can then be defined as the ability of the fencer to move his or her mass a given distance in a short amount of time. When the non-leading foot is held at or near perpendicular to the leading foot, the push is accomplished through the entirety of the non-leading sole. As the foot deviates forward, the push is shifted forward into the ball of the foot, and velocity and power decrease. The 45° foot placement exaggerated the forward deviation and necessitated the use of the ball and toes of the non-leading foot for body propulsion. Even in the natural stance, with forward deviations as small as 15°, average velocity was affected; thus, it can be suggested that using the entire sole for pushing in the lunge is a requirement for optimal muscular use.

A previous study (Nystrom et al., 1990) considered the percentage of Type I and Type II fibers in fencers' legs and showed lower concentrations of Type I fibers in the non-leading than in the leading leg. This would be expected, due to the role of the non-leading leg in producing a rapid contraction of ultrashort duration. The production of power results from the ability to exert maximum force in a minimum amount of time, by recruiting motor units quickly and synchronously in a muscle contraction. Sport-specific training increases power by targeting the muscles used and developing the best and most efficient muscular patterns (Rippetoe, 2000). In the present study, average velocity values were significantly greater at 90° than at all other stances, and average power greater at 90° than at 45° or at 135°. This suggests that the perpendicular foot placement aligns the musculature for the most efficient use of the non-leading leg and develops highest average velocity and power.

Maintaining high velocity and power throughout the lunge translates to the rapid delivery of a touch. While different tactics require some alteration in lunge technique, in general, lunges with high velocity and power are essential in fencing actions that are intended to reach target before a defensive response can be launched. Although it can be argued that forward deviation of the non-leading foot would permit greater mobility during maneuvering, lunging with the forward deviation reduces lunge velocity, and the reduction in velocity may be reflected in failure to touch. Maneuvering with a forward deviation and then shifting the non-leading foot to a more perpendicular orientation before the lunge may produce higher average lunge velocity and power and result in a rapid delivery of a touch. The advantage of the higher values would be tempered, however, by the telegraphing of intent which may come from a visible foot position shift.

Thus, the degree of forward deviation becomes an issue: a 45° deviation is clearly too much. Even deviations of 15 - 20° or less may reduce average velocity. Holding the non-leading foot nearly perpendicular appears to promote the most efficient use of the leg muscles and foot for sustained velocity and power.

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Tables

Table 1

Intraclass correlation coefficients for the three trials at each foot placement

	Variable			
	Average		Peak	
Trials	power	velocity	power	velocity
45°	0.746	0.570	0.946	0.916
90°	0.923	0.835	0.958	0.925
135°	0.953	0.900	0.947	0.917
natural	0.863	0.747	0.970	0.949

Table 2

Means and standard deviations for power and velocity measurements

Variable	Foot placement			
	45°	90°	135°	natural
Power, W				
average	346.2 ± 86.1	430.9 ± 123.1	385.8 ± 113.6	398.7 ± 99.9
peak	704.3 ± 237.1	849.0 ± 243.0	761.2 ± 220.6	861.4 ± 307.1
Velocity, m/s				
average	0.49 ± 0.09	0.61 ± 0.12	0.55 ± 0.11	0.57 ± 0.10
peak	1.00 ± 0.72	1.21 ± 0.25	1.09 ± 0.25	1.22 ± 0.34

Table 3

Pairwise comparisons between foot placements for average power and average velocity

	average power			average velocity		
Comparisons	*t*	*df* [a]	significance[b]	*t*	*df*	significance
45 - 90	-5.461	24	0.001*	-5.580	24	0.001*
45 - 135	-3.330	23	0.003*	-3.375	23	0.003*
45 - natural	-4.374	24	0.001*	-4.304	24	0.001*
90 - 135	3.535	23	0.002*	3.566	23	0.002*
90 - natural	2.861	24	0.009	2.876	24	0.008*
135 - natural	-0.946	23	0.354	-1.042	23	0.308

[a] *df* = degrees of freedom

[b] significance set at .05 level. Adjustment for multiple comparisons: Bonferroni.

* result is significant

Table 4

Pairwise comparisons between foot placements for peak power and peak velocity

	peak power			peak velocity		
Comparisons	*t*	*df* [a]	significance[b]	*t*	*df*	significance
45 - 90	-8.999	24	0.001*	-9.062	24	0.001*
45 - 135	-2.861	23	0.008*	-3.055	23	0.006*
45 - natural	-5.218	24	0.001*	-5.500	24	0.001*
90 - 135	3.814	23	0.001*	3.985	23	0.001*
90 - natural	-0.524	24	0.605	-0.546	24	0.590
135 - natural	-2.335	23	0.029	-2.502	23	0.020

[a] *df* = degrees of freedom

[b] significance set at .05 level. Adjustment for multiple comparisons: Bonferroni.

* result is significant

Table 5

Average power and peak power expressed relative to body weight, n = 25

	Power, in W/kg			
Angle	Minimum	Maximum	Mean	SD[a]
Average				
45°	3.46	7.04	4.92	0.95
90°	4.18	9.18	6.00	1.19
135°	3.57	8.04	5.42	1.11
natural	3.61	7.48	5.58	0.98
Peak				
45°	5.43	15.78	9.78	2.60
90°	7.41	17.41	11.82	2.41
135°	6.99	16.27	10.73	2.43
natural	7.39	22.21	11.98	3.30

[a] SD=Standard deviation of the mean

Table 6

Pairwise comparisons for average power and peak power, relative to body weight

	average power			peak power		
Comparisons	*t*	*df* [a]	significance[b]	*t*	*df*	significance
45 - 90	-5.098	24	0.001*	-9.047	24	0.001*
45 - 135	-3.247	23	0.004*	-3.005	23	0.006*
45 - natural	-3.558	24	0.002*	-5.475	24	0.001*
90 - 135	3.674	23	0.001*	4.048	23	0.001*
90 - natural	2.813	24	0.010	-0.506	24	0.62
135 - natural	-1.224	23	0.233	-2.510	23	0.020

[a] *df* = degrees of freedom

[b] significance set at .05 level. Adjustment for multiple comparisons: Bonferroni.

* result is significant

Figures

Figure 1. Testing platform for lunge testing. The bar acts as a kinesthetic reminder to maintain non-leading foot position.

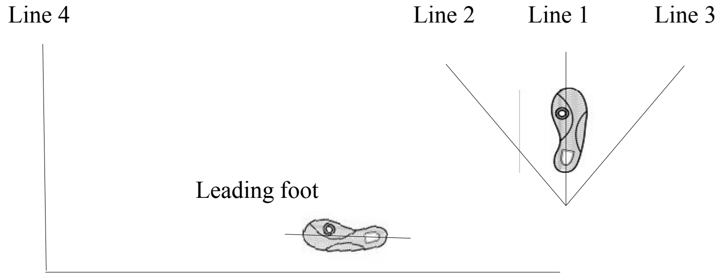


Figure 2. Stance outline for lunge testing. Line 1 is the placement of the non-leading foot at 90° from the line of the leading foot; Line 2 is the non-leading foot placement for 45° and Line 3 is non-leading foot placement for 135° from the line of the leading foot. Line 4 is the placement of leading heel, when landing at lunge completion.

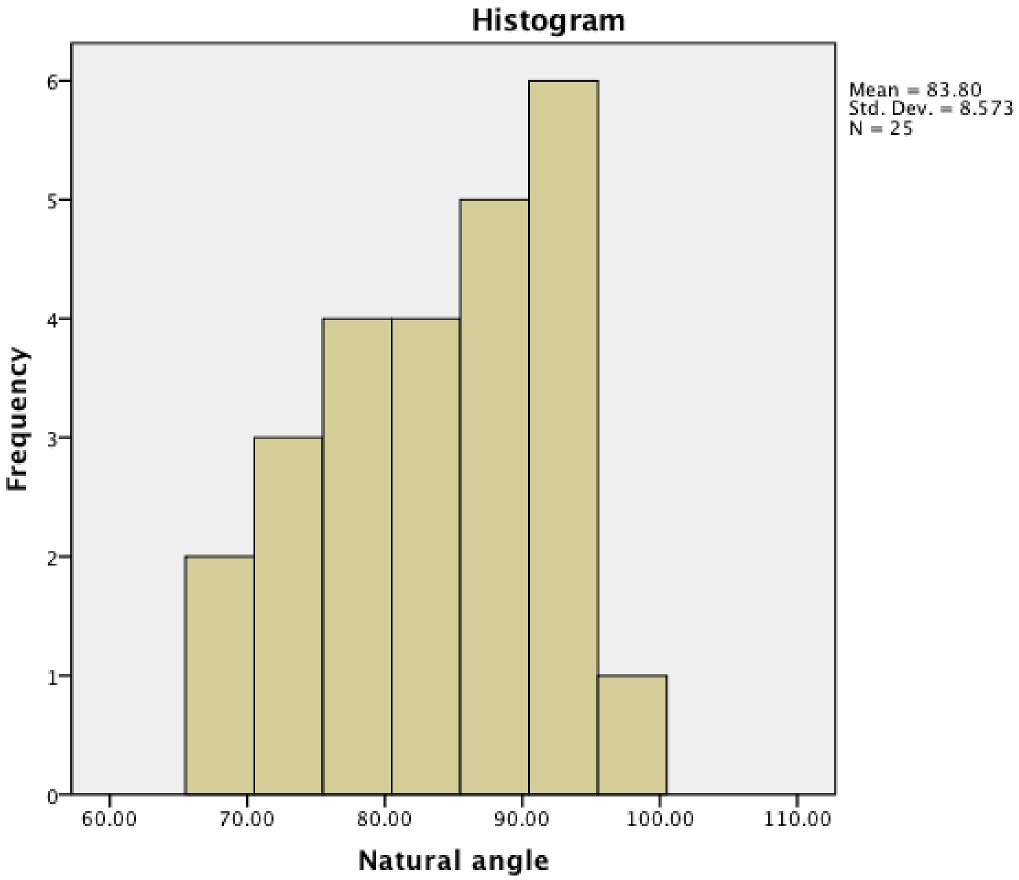


Figure 3. Histogram of natural stance angles.

Appendix A

Literature Review

Fencing is a unique sport in many ways. It can be pursued both recreationally and competitively. In competitions, a fencer can compete as an individual and as a member of a three-person team. Though originally an adult male sport, fencing has opened to all age groups and both sexes. Fencers can now compete in age groups from Youth-10 (7-10 years olds) to the Veteran-70 (70 years old and older), in Divisions I-III, at World Cups, as NCAA athletes, and as Olympians (USFA, 2002).

Though some aspects of the physique may be an advantage in some weapons, in general, there are no requirements for height, weight, age, or gender for fencing success. Vander et al. (1984) suggested that fencing success depends more on technique, speed, and agility than on body composition. Comparing seven national class fencers (1983 National Collegiate Athletic Association Division I champions) to non-athletes and to non-fencing athletes, maximal oxygen uptake (VO_2max) was measured during cycle ergometry. In addition, a 12-hour fasting blood lipid profile and pulmonary function test were performed; finally, body density, found through standard underwater weighing technique, was used to determine body fat percentage. Fencers were shorter (174.9 cm vs. 177 cm), lighter (68.7 kg vs. 75.6 kg), and had a lower body fat percentage (12.2% vs. 14.6%) than non-athletes; they were similar in height to and heavier (68.7 kg vs. 64.2 kg) than elite marathon runners, with a higher percentage of body fat (12.2% vs. 7.5%). The fencers' mean VO_2max of 50.2 ± 5.3 $\text{ml}\cdot \text{kg}^{1}\cdot\text{min}^{-1}$ was lower than distance runners and Nordic skiers (75 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and swimmers (60-70 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), though higher than basketball and volleyball players (45 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). Lipid profiles showed total cholesterol levels within normal range (187 ± 21 mg/dL), with elevated HDL-C (54.5 ± 10.4 mg/dL). In a later study, Krawczyk, Sklad, and Majle (1995) analyzed the anthropometric data from 20 male fencers, members of national and/or Olympic teams, and found body fat percentages (11.99 ± 3.39%) similar to those reported by Vander. Gathering information as well from 15 female fencers, Krawczyk et al. found body fat percentages of 21.89 ± 4.48%. Using the Heath-Carter method (Carter, 2002), Tsolakis, Bogdanis, and Vagenas (2004) assessed and reported somatotype in 84 male and 68 female fencers participating in the 2004 Greek national championships. The Heath-Carter method defines the somatotype as the "quantification of the present shape and composition of the human body" (Carter, 2002, p. 2). The somatotype is expressed in a three-number rating system; the numbers are always reported in the same order and represent endomorphy, mesomorphy, and ectomorphy components respectively. Endomorphy is a measure of relative fatness, mesomorphy of relative musculo-skeletal predominance, and ectomorphy of relative slenderness of a physique. The rating system gives a magnitude for each of the three components: ratings of 0.5 to 2.5 are considered low, 3 to 5 are moderate, 5.5 to 7 are high, and 7.5 and above are very high (Carter, 2002). Tsolakis et al. (2004) determined that male fencers exhibited a central type (mean endomorphy 3.1, mesomorphy 2.6, ectomorphy 3.2) and female fencers an endo-ectomorph type (mean endomorphy 3.8, mesomorphy 1.8, ectomorphy 3.3). In addition, male fencers showed a decrease in percent body fat with age (22.7 ± 1.2% at age 12 vs. 18.0 ± 0.1% at age 15 vs. 14.3 ± 1.4% at age 19); females showed an opposite trend (25.1

± 1.1% at age 12 vs. 26.7 ± 0.7% at age 15 vs. 27.3 ± 1.7% at age 19). On the basis of these studies, researchers concluded that fencing success does not rely on special morphological characteristics (Krawczyk et al., 1995; Tsolakis et al., 2004; Vander et al., 1984). Instead, success results from a combination of physical skill, stamina, speed and power to finish a movement, balance, and the mental ability to be at the right distance at the right time. As in any sport, this combination of physical and mental aspects takes time and practice to develop (Lukovich, 1986).

The fencing lunge is an essential skill in fencing. It is a full-body movement, coordinating arms and legs to shift the body forward forcefully and in balance. When investigating the fencing lunge and its ability to produce power, several factors must be examined and reviewed. Muscular demands and the sequence of muscular activation form the basis of biomechanical performance. How the lunge is initiated in response to stimuli, and the effect of those stimuli on lunge power, influence the methodological design of lunge studies. Finally, lunge power and specific methods of measurement warrant consideration.

Performance Considerations

The guard position, with perpendicular orientation of the feet, is the starting stance for fencers. Moving forward and backward, called advancing and retreating respectively, maintains the guard throughout the fencing encounter (the bout), as the fencers jockey for an advantageous position and time for scoring. When a fencer begins an aggressive action intended to score, he moves forward with advances and often ends his attack with a lunge. While the leading arm lifts and aims the weapon, it is the lunge that moves the tip forward in an explosive push and delivers the final touch (score).

The rules of the sport (USFA, 2010) allow the weapon to be held with only one hand and the weapon cannot be shifted between hands during a bout. In general, left-handers have the left foot and hand leading, right-handers lead with the right. The lunge begins when the weapon arm extends to raise the weapon and the leading toes lift. While the leading leg swings forward and the leading heel skims the floor, the non-leading leg pushes with a forceful extension of the knee and hip, shoving the body's mass forward; the torso remains upright and balanced over the hips. The leading foot lands heel first and, as the sole of the leading foot rolls onto the floor, the body's forward and downward movement stops. In the final lunge position, the leading knee is directly over the leading ankle, the torso is upright, and the non-leading leg is straight (Lukovich, 1986).

Muscular Demands

The asymmetry of fencing places an unequal demand on the left and right sides of the body. Nystrom et al. (1990) used an isokinetic dynamometer to measure isometric and dynamic strength in the hands and legs of six Swedish national team fencers. In addition, they performed computed tomography and muscular biopsies of the right and left quadriceps femoris of the subjects. On the basis of their results, they determined that hand strength in the weapon hand was significantly greater than in the non-weapon hand (636 ± 42 N vs. 550 ± 82 N, $p < .01$), while finger strength did not differ significantly. Though no differences were found in the legs' isometric strength, dynamic strength was significantly greater in the leading leg at 30 degrees/second (249 ± 18 Nm vs. 219 ± 15 Nm, $p < .01$), 60 degrees/second (234 ± 36 Nm vs. 210 ± 24 Nm, $p < .05$), and 180 degrees/second (181 ± 39 Nm vs. 160 ± 20 Nm, $p < .05$). The circumference of the leading leg thigh was significantly larger (60.2 ± 1.6 cm vs. 56.8 ± 3.3 cm, $p < .01$) with higher areas of the medial extensors (49.1 ± 4.8 cm^2 vs. 47.1 ± 3.5 cm^2, $p < .01$), lateral extensors (48.3 ± 9.6 cm^2 vs. 40.5 ± 3.5 cm^2, $p < .05$), and non-extensors (108.9 ± 9.1 cm^2 vs. 92.2 ± 7.1 cm^2, $p < .01$). The percentage of Type I fibers was 56 ± 12% in the leading leg and 48 ± 12% in the non-leading leg. The greater development of the leading leg in mass and dynamic strength, and of the weapon hand in isometric strength, is an inherent result of the specific muscular demands of the sport.

Lunge Muscular Sequencing

During the performance of a lunge, the weapon is displaced forward by extending the elbow and the body's center of gravity is propelled forward by an explosive extension of the non-leading knee and hip. How the upper and lower extremities interact to form an efficient lunge was the topic of a study by Williams and Walmsley (2000a). While their study focused primarily on differences in reaction time between elite ($n = 3$) and novice ($n = 3$) fencers, they gathered extensive EMG data from the anterior deltoid and the triceps muscles of the weapon arm and the biceps femoris and rectus femoris muscles of both legs of all participants. The mean EMG results provided a sequence of muscle activation for elite fencers, who exhibited early activation of the non-leading leg rectus femoris (178 ± 97 ms), followed by weapon arm anterior deltoid activation (226 ± 133 ms), then activation of the non-leading leg biceps femoris (248 ± 36 ms), weapon arm triceps (281 ± 86 ms), and finally rectus femoris (304 ± 91 ms) and biceps femoris (378 ± 156 ms) of the leading leg. Williams and Walmsley concluded that this pattern indicated a coordination of raising and extending the weapon arm with the extension of the non-leading knee and hip. Muscles of the leading leg were activated later in the sequence, to coordinate the forward step and lunge completion.

In their study of lunge biomechanics, Do and Yiou (1999) used (1) oscilloscopic tracings from surface EMG activity of the weapon arm anterior deltoid, (2) weapon arm and leading foot acceleration measured with accelerometers, and (3) center of foot pressure displacement as measured by a force platform to determine the relationship between the arm extension and the lunge. The researchers hypothesized that the lunge would be preceded by anticipatory postural adjustments (APA) and that, if the extension occurred during these APA, arm extension velocity would decrease. Five male non-fencers performed extensions alone, lunges alone, and lunge-extension sequences; the APA of the lunge was defined as the period between the initial shifting of the center of foot pressure toward the rear foot and the time of voluntary lunge evidenced by the lifting of the leading foot. The results indicated that, when participants performed a sequence of lunge then extension, the APA of the lunge movement did indeed slow the performance velocity of the extension (2.19 ± 0.52 m/s vs. 2.54 ± 0.44 m/s, $p < .01$).

In a subsequent study, Yiou and Do (2000) confined their focus to novice ($n = 5$) and elite ($n = 4$) fencers. Here, the emphasis was on the velocity of the extension, comparing the velocity when the extension was performed alone and when performed as a component of the global extension-lunge movement. By comparison of extension alone, lunge alone, and extension-lunge conditions, it was shown that novice fencers performed the global movement as if it were two distinct movements, extension and then lunge, with a latency period between the two parts of 330 ± 80 ms. In contrast, elite fencers exhibited a latency period of only 70 ± 40 ms, a difference significant at the $p < .01$ level, leading the researchers to conclude that elite fencers performed the extension during the APA of the lunge.

A third study by Yiou and Do (2001) examined the effect of the lunge APA on extension velocity among novice ($n = 6$) and elite ($n = 5$) fencers, investigating the difference in timing of submovement initiation. Holding the initiation time of the extension constant across the two groups, the researchers found that, when the touch was performed before the lunge APA, there was no significant difference in extension speed between novices and experts (186 ± 33 ms vs. 175 ± 25 ms, $p > .05$). Similarly, there were no significant differences between novices and experts in the onset of the lunge APA (175 ± 34 ms vs. 163 ± 27 ms, $p > .05$), duration of the APA (192 ± 40 ms vs. 205 ± 42 ms, $p > .05$), or initiation of the lunge (373 ± 33 ms vs. 367 ± 36 ms, $p > .05$). However, when the extension was initiated at 200 ms, 150 ms, 100 ms, 50 ms, and 0 ms before the leading foot lifted (i.e., during the development of the lunge APA), graphed results indicated that the extension velocity remained constant for the novice subjects and increased for elite fencers. Since extension initiation timing was held constant between novice and elite fencers, the increased velocity for experts was attributed to increased economy of motion and the passive forces of the APA enhancing the efficacy of the active muscular forces. It was suggested by the researchers that "with practice, [expert] subjects are able to control several movements with a single motor program, while novices and beginners control each movement of the sequence with separate motor programs" (Yiou & Do, 2001, p. 204).

The Stimulus:Lunge Relationship

The lunge is, by necessity, an explosive movement, designed to carry the weapon to the target, and takes practice to fully develop (Lukovich, 1986; Rippetoe, 2000; Yiou & Do, 2001). In order to adequately investigate how power is produced in a lunge, it is necessary to understand how the movement initiates. Similar to many other sport-specific explosive movements, the fencing lunge may be done in response to sport stimuli (competition or scrimmage situations) or in isolation (practice).

Reaction Time

In 1999, Zhang et al. used video profiling to capture and assess lunge speed, joint angle, and velocity of the center of gravity of four female epee fencers. Defining attack reaction time as the period between initiation of the center of gravity movement and its sudden increase in velocity as determined from individual velocity time graphs, the researchers found that, among these subjects, attack reaction time averaged 0.3 seconds.

Williams and Walmsley (2000a) reported significant differences in reaction time between elite and novice fencers. On the basis of their EMG readings taken from the triceps and anterior deltoid muscles of the weapon arm and of the biceps femoris and rectus femoris muscles of both legs, reaction time for elite fencers averaged 333 ± 128 ms, while novice fencers showed an average reaction time of 612 ± 62 ms ($F[1,24] = 49.58$, $p < .05$).

What this may mean at the level of brain activity was the subject of a study by Di Russo et al. (2006), which employed an EEG to track event-related potentials (ERPs) in the brain during response selection. Using a BrainVision^{TM} system with 64 electrodes, EEG was recorded and horizontal eye movements, blinks, and vertical eye movements were documented in response to simple reactions tasks (SRT) and discriminative reaction tasks (DRT). Comparing 12 fencers (mean age 25.2 ± 5.4 years) with 12 non-fencers/controls (mean age 24.9 ± 3.5 years), no differences were found between groups in the SRT (fencers 204 ms vs. controls 189 ms, $p > .05$). When the task was more complex (i.e., DRT), however, fencers exhibited faster overall reaction times than the non-fencers (386 vs. 435 ms; $p < .05$). Di Russo et al. attributed this result to sport-specific training that shapes brain activity for higher attention and quicker stimulus discrimination, leading to more efficient functioning during fencing encounters.

Because most choices in sports are made during periods of activity, a group of researchers led by Guizani investigated simple (SRT) and choice reaction time (CRT) in relation to physical load (Guizani et al., 2006). Comparing fencers ($n = 12$, mean age = 19.10 ± 2.99 years) to sedentary participants ($n = 12$, mean age = 20.83 ± 3.97 years), reaction time tests were performed with subjects on a cycle ergometer at different intensity levels: (1) without pedaling; and (2) at 20%, 40%, 60%, and 80% of individual VO_2max. Within the sedentary group, workload did not affect either simple or choice reaction time. In contrast, for fencers, while SRT remained relatively stable, a significant workload effect was seen in CRT, with CRT decreasing as workload increased ($F[4,28] = 4.30$, $p < .001$). All workloads were less than 85% of VO_2max, and could therefore be considered moderate in intensity, leading researchers to conclude that "moderate levels of physical activation resulted in enhanced performance" (Guizani et al., 2006, p. 350).

Stimulus Influences

Thus, reaction to a stimulus plays a significant role in fencing, influencing the initiation of the lunge, and the ability to react increases with intensity. What effect, if any, stimulus reaction may have on other aspects of the lunge was the focus of studies by Klinger and Adrian (1983, 1987) and Williams and Walmsley (2000b). In their 1983 study, Klinger and Adrian considered lunge velocity in relation to target material. Testing 20 fencers, participants lunged in a self-paced condition at targets made of different materials, specifically woody, padded, bony, and fleshy substances. Participants began with the leading foot on a make-break switch and lunged to land on a second switch; both switches were connected to a chronoscope which recorded the duration of the lunge. Lunge velocity was calculated by dividing the lunge distance by the duration of the lunge. Results showed average lunge velocities of 2.41 m/s with a range of 1.5 to 4.0 m/s; there were no differences in the speed or distance lunged due to target conditions. The interaction of reaction time and lunge distance was considered by Williams and Walmsley (2000b). In their study of response timing and muscular coordination in fencing, the researchers used EMG tracings from the triceps and anterior deltoid of the weapon arm and the biceps femoris and rectus femoris of both legs, measured for three lunge distances (short, medium, and long). The test distance was measured from the target to the big toe of the non-leading foot and was standardized to each participant's standing height by multiplying height by 1.0, 1.25, and 1.5 for the short, medium, and long distances respectively. The small group of participants was then allowed to adjust the distance to their personal preference. The novice group (*n* = 1) shortened the distances by 24.7 cm (short), 27.8 cm (medium), and 31.6 cm (long). The elite subjects (*n* = 2) lengthened the short distance by an average of 9 cm and the medium distance by an average of 7 cm; they shortened only the long distance (average 6 cm). In support of intuition, except for some differentiation between the short distance and the other two distances in total response time (F[2,8] = 5.67, *p* = .029), the effects of lunge distance were not marked. Differences in EMG onsets were not significant (*p* = .062) and individual differences in reaction time were not affected by lunge distance.

In 1987, researchers investigated the power production of lunges, performed in response to three specific stimulus situations (Klinger & Adrian, 1987). Measuring force with an AMTI force platform, nine male college fencers lunged (1) in a self-paced manner; (2) in response to an auditory stimulus ("ready-go"); and (3) in response to a visual stimulus (lowering of the researcher's forearm). The self-paced and the auditory conditions were considered to be typical practice situations, while the visual stimulus simulated a competitive condition. Variability in power among subjects was great, but no significant differences were found in mean power produced in response to the different stimulus situations (self-paced 1988 W vs. auditory 1992 W vs. visual 2105 W,*p* > .05). Based on these results, lunge power appears to be independent of the stimulus triggering the start of the lunge.

Power Measurement

By definition, power is the rate at which mechanical work can be done and is the product of force and velocity (Cronin et al., 2003). Rippetoe (2000) described power as the "application of force with respect to the time of application"; it is the ability to produce a maximal force in a minimal amount of time, to recruit motor units quickly and synchronously in a muscle contraction. Simplistically, power can be visualized as the ability of a fencer to move his or her mass a given distance (lunge) in a short amount of time. The development of power in a fencing lunge comes specifically from increasing absolute strength or from practicing explosive exercises that target power; the utilization of sport-specific movement (including lunging) is an integral part of power training (Rippetoe, 2000). Power is increased in sport-specific training by targeting the muscles used and developing the best and most efficient muscular patterns. However, the foot placement that results in highest power production in a fencing lunge is still not known; determining how the angle of the non-leading foot affects power production will allow fencing coaches to develop training methods, using an understanding of the foot placement and its effect on power.

Lunge Power

Some studies have begun the work of developing a methodology to determine power production in a lunge. Zhang et al. (1999) used videography to record four female fencers during competitive bouts; lunges to be studied were chosen by the fencers' coach. A Peak Performance System was used to calculate the velocity of the center of gravity (CG), the reaction time of attack, joint angles, and body displacement. Horizontal CG velocities ranged from 304.7 ± 61.2 CG/s to 345.0 ± 44.2 CG/s; interestingly, the participant with the lowest velocity showed the shortest time to target (.54 ± .08 s) and the fencer with the highest velocity showed the shortest lunge distance and the longest time to target (.70 ± .13 s). Researchers attributed this result to the latter fencer's slow blade velocity, as evidenced by arm extension and time to final landing of the blade.

In their extensive study of lunge performance and its determinants, Cronin et al. (2003) focused on strength qualities as predictors of lunge performance. The participants were 31 male athletes involved in a variety of sports emphasizing lower body use. Using a supine squat machine, each participant performed a unilateral 1-repetition maximum (1-RM) squat. At least two but no more than seven days later, each participant performed (1) three trials of a traditional forward lunge, while attached to a linear transducer, followed by (2) a unilateral jump squat at 50% 1-RM on the supine machine. Results were analyzed using a stepwise multiple regression, with lunge performance as the dependent variable and various strength, flexibility, and anthropometric measures as independent variables. Time to peak force was the best single predictor of lunge performance, accounting for 55% of the explained variance. The best three-predictor model of concentric velocity, including leg length, flexibility, and time to peak force, accounted for 85% of the common variance associated with lunge performance. When expressed relative to body mass, however, mean power and relative strength became important predictors, in conjunction with time to peak force, and accounted for 76% of the common variance.

Measurement Methods

Cronin and his associates (2003) considered the linear position transducer to be a satisfactory measurement method for average and peak power of the forward lunge. Various studies have considered the most suitable measurement methods for dynamic multi-joint exercise (Cormie, McBride, & McCaulley, 2007; Cronin, Hing, & McNair, 2004; Cronin, McNair, & Marshall, 2001; Cronin, McNair, & Marshall, 2002; Jidovtseff et al., 2006). While "current knowledge does not allow an unequivocal affirmation that one form of dynamometry is more suitable than another" (Jidovtseff et al., 2006, p. 53), studies have focused on the advantages and disadvantages of isometric and isokinetic methods. While isometric dynamometers measure strength in multi-joint static positions, isokinetics incorporate dynamic muscular action and assess power through a range of motion. Since many sports movements, including the forward lunge and the fencing lunge, involve the acceleration of a constant mass, measurement of the velocity and power of such movements is more specific than the measurement of torque produced at a constant velocity (Lidovtseff et al., 2006). Lidovtseff and his associates recommended the use of a cable extension position transducer in conjunction with an accelerometer or optical device to measure power and velocity at different loads. Their study used an accelerometer and a cable-extension position transducer to assess the bench press and squat ability of sixteen experienced male weightlifters. Lifting only in the concentric phase, trials were carried out at increasing loads, in the following manner: (1) three trials at lower weight (35% and 50% of 1-RM for bench press and 45% and 60% of 1-RM for squat) with 90 seconds of rest between trials and (2) two trials at higher loads (70% and 90% of 1-RM for bench press and 75% and 90% of 1-RM for squat) with three minutes of rest between trials. Results indicated good to excellent reproducibility for power and velocity measurements in both exercises, with coefficients of variability varying from 2.5 to 9.1% (mean *CV* = 5.27) in velocity and from 4.2 to 9.6% (mean *CV* = 7.13) in power measurements.

Cormie et al. (2007) used combinations of linear position transducers (LPT) and a force platform (FP) to investigate the validity of power measurement techniques during jump squats, squats, and power cleans. Ten male athletes were assessed for power output at various intensities (percentages of 1-RM), using six data collection systems: (1) one linear position transducer (1-LPT), (2) one linear position transducer plus a system mass representing force (1-LPT-MASS), (3) two linear position transducers (2-LPT), (4) a force platform (FP), (5) one linear position transducer plus a force platform (1-LPT-FP), and (6) two linear position transducers plus a force platform (2-LPT-FP). Force was measured directly with the FP; with the 1-LPT and 2-LPT systems, acceleration was calculated from velocity and multiplied by mass to determine force. The 1-LPT-MASS method used a constant force, determined as the product of system mass and acceleration due to gravity. Repeated-measured ANOVA was used to determine whether significant differences in velocity, force, and power existed between the methodologies. In the jump squat, peak power and average power measured by the 1-LPT-MASS and the average power measured by FP were significantly different, though test statistics were not reported. In the squat, peak power measured by the 1-LPT and 2-LPT methods differed significantly; peak power measured by the FP and the 1-LPT-MASS, as well as average power measured by the FP, the 2-LPT and the 1-LPT, differed significantly in the power clean. Researchers concluded that methodologies should incorporate both kinematic and kinetic measurements in order to accurately assess power production.

However, while force platforms have been considered the gold standard of force measurement, and combinations of methods may improve accuracy of power assessment, cost-effective and portable equipment that is also reliable and valid would have great advantage in field testing. Cronin et al. (2004) used a linear position transducer and a force platform to measure mean force, peak force, and time-to-peak force of squat jumps, countermovement jumps, and drop jumps with 25 volunteer male athletes from a variety of sports backgrounds. Measurements were made by both instruments simultaneously, in order to compare results. Pearson correlation coefficients across the three jumps for mean force (r = 0.952-0.962), peak force (r = 0.861-0.934), and time-to-peak force (r = 0.924-0.995) were high, indicating that the transducer was a valid measurement technique. The intraclass correlation coefficients (0.924-0.975 for mean force, 0.977-0.982 for peak force, and 0.721-0.964 for time-to-peak force) and the correlations of variance (2.1-4.5% for mean force, 2.5-8.4% for peak force, and 4.1-11.8% for time-to-peak force) indicated that the transducer was also reliable. Paired sample Student *t*-tests found no statistical differences between the trials for any of the variables measured, indicating factors such as learning effects, motivation, and protocol inconsistencies did not influence the assessment.

Concentric and Eccentric Movement

Determination of lunge power in relation to non-leading foot placement does not require the specific quantification of peak and average power, but rather depends on the detection of a difference in power produced among the foot positions. In this case, as long as the instrument used is consistent in its measurement, power data will be comparable. One consideration, however, is the effect of eccentric movements on power production and the ability of the instrumentation to measure concentric movement specifically. Using a linear position transducer, Cronin et al. (2001) investigated the influence of contraction type and movement type on power output. Twenty-seven males, with athletic backgrounds but no weightlifting experience, were tested with a bench press in four specific movements: (1) concentric bench press (CBP), in which the barbell started in a position 5 cm above the chest and was projected up and held at the end of the movement; (2) concentric bench press with throw (CBPT), in which movement followed that of the CBP, but the bar was thrown at the end of the movement; (3) eccentric-concentric bench press or rebound bench press (RBP), in which the barbell was held at arm's length, then lowered as quickly as possible to just above the chest, and pushed upward immediately; and (4) rebound bench press with throw (RBPT), with the barbell lowered and then raised, with a throw at the end of the movement. Results showed that the rebound conditions, whether held or thrown, produced higher mean power outputs (11.7% - mean across loads). In a similar study of concentric and rebound bench press, Cronin et al. (2002) investigated the important predictors of power production during large-amplitude slow motion of the stretch-shorten cycle (SSC). Using 27 male and 27 female athletes, lifts were performed at 40% and at 80% of 1-RM, with the lower percentage associated with power development (high velocity, low force) and the higher percentage with maximal strength development (low velocity, high force). Similar to the results of their previous study, rebound improved mean power output by 11.9% and 15.1% for males and 11.0% and 3.0% for females, for the 40% and 80% of 1-RM loads respectively. Although the fencing lunge is predominantly a concentric movement, some eccentric anticipatory movements may occur. While it is assumed that each participant will perform his or her lunges with consistent anticipatory movements, and therefore power outcomes will be comparable, limiting measurement to the concentric phase of the lunge would be a preferred method.

TENDO Weightlifting Analyzer

The TENDO Weightlifting Analyzer and the TENDO Fitrodyne Powerlyzer are linear position transducers that use velocity to calculate power in the concentric phase of a movement. The Weightlifting Analyzer has the added ability that it can be interfaced with a laptop computer (Tendo Sports, n.d.). In both transducers, a pulley and cable system measures linear displacement; an optical sensor measures movement orientation and time. Mass is entered into the system manually. During concentric movement, the analyzer measures distance of displacement and time of displacement to calculate velocity. Force is calculated as the product of the entered mass and the acceleration of gravity. Peak and average power are then computed from the force and velocity figures (TENDO, n.d.).

The reliability of the TENDO Fitrodyne was the focus of a study by Jennings, Viljoen, Durandt, and Lambert (2005). Thirty volunteers performed six squat jumps and six biceps curls at increasing loads with conventional resistance-training equipment on three separate occasions. Biceps curls were done with the upper arm flat against a curl bench; the weight was lowered and held for approximately one second before the contraction. In the squat jump, the subject supported the barbell on his back, held the bottom position for approximately one second, then jumped straight up from this position. In both lifts, the TENDO Fitrodyne was positioned on the floor and the nylon cord attached so that the cord was as close to the vertical plane of the lift as possible. The analyzer determined the peak upward velocity of contraction for each lift; this was defined as the peak speed of contraction for each load. Force was calculated as the product of gravity and the lifted mass which equaled (1) the weight lifted during the biceps curl or (2) the combined body weight and supported load during the squat jump. The relationship of force vs. speed of contraction was determined for each exercise, and maximum power predicted from the relationship. The intraclass correlation for both squat jumps and biceps curls was high, with R = 0.97 (95% CI, 0.95-0.98) and R = 0.97 (95% CI, 0.95-0.98) respectively. The researchers concluded that the Fitrodyne was reliable for measuring muscle power; in addition, it was fairly inexpensive and portable and could be used to test a variety of muscles and movement patterns.

Several recent studies have employed the TENDO Fitrodyne to measure and compare power production of movement. Rhea, Peterson, Oliverson, Ayllón, and Potenziano (2008) used the TENDO Fitrodyne to assess the effectiveness of the VertiMax resisted jump trainer in improving lower body reactive power. Two groups of collegiate athletes completed a 12-week mixed-methods training program. Both groups performed the same resistance and strength training regimens; the control group (n = 20) performed traditional plyometric exercises, while the experimental group (n = 20) used the VertiMax resisted jump trainer. Results showed a significant difference in power development between the two groups ($p < .05$), with the VertiMax eliciting a greater treatment effect (effect size = .54) than the plyometric training (effect size = .09). Similarly, Rhea and Kenn (2009) used the TENDO Fitrodyne to measure peak power in a study of the efficacy of whole-body vibration training. Two groups of male college athletes performed two sets of back squats, with each set composed of three repetitions at 75% of individual 1-RM, completed as quickly as possible. The control group ($n = 8$) rested passively in a chair for 3 minutes between sets; the experimental group ($n = 8$) rested passively in a chair for 2 minutes, then performed 30 seconds of dynamic squats on an iTonic vibration platform between sets. The TENDO Fitrodyne measured peak power during the concentric phase of each repetition and statistical analyses determined a significantly greater improvement in power (5.2% vs. 0.55%, $p < .05$) in the experimental group than in the control group.

It should be noted that both of these studies utilized the TENDO analyzer to measure vertical power. Measuring power of a fencing lunge shifts the measured displacement to a horizontal plane. As discussed previously, Cronin et al. (2003) used a linear position transducer to measure horizontal power in a forward lunge; it is believed that the TENDO can be used in a similar manner. The one consideration of the horizontal orientation lies in the calculation of force, both in the mass and the acceleration figures used. Since the TENDO is designed specifically for vertical weightlifting, it automatically calculates force by multiplying the weight lifted (mass) by the acceleration of gravity. When lunging, the fencer moves his body mass forward, but some portion of the body mass remains unmoved, that is, the non-leading foot and leg remain in place. In addition, horizontal acceleration will differ from that of gravity. Thus, the calculated force, and therefore power, will differ from true force and true power. However, when assessing the power of fencing lunges by this method, the body mass moved and the horizontal acceleration can be assumed to be similar for each lunge performed by the same participant. In the present study, the ultimate goal is not to determine a specific value for power produced; instead, the aim is to distinguish differences, if any, in the power produced from each of several non-leading foot placements.

Summary

Previous studies of fencing have shown that the ability to function well in the sport does not depend on unique morphological characteristics (Krawczyk et al., 1995; Tsolakis et al., 2004; Vander et al., 1984). However, the muscular demands of a fencing lunge are very specific and the integration of the muscles into a smooth and efficient lunge movement is complex (Do & Yiou, 1999; Nystrom et al., 1990; Williams & Walmsley, 2000a; Yiou & Do, 2000; Yiou & Do, 2001). Being able to lunge appropriately, i.e., with an organized muscular pattern and at the proper time in relation to a stimulus, is a hallmark of experienced fencers. As fencers progress from novice to elite levels, their reaction time decreases and this ability is enhanced by moderate levels of physical activity (Guizani et al., 2006; Williams & Walmsley, 2000a).

Power in a lunge comes from practice, from increasing leg strength, and from repeating specific movements to improve muscular response and recruitment (Rippetoe, 2000). Lunge power is not affected by stimulus type; however, because of the relationship between distance, velocity, and power, lunge length may affect lunge power.

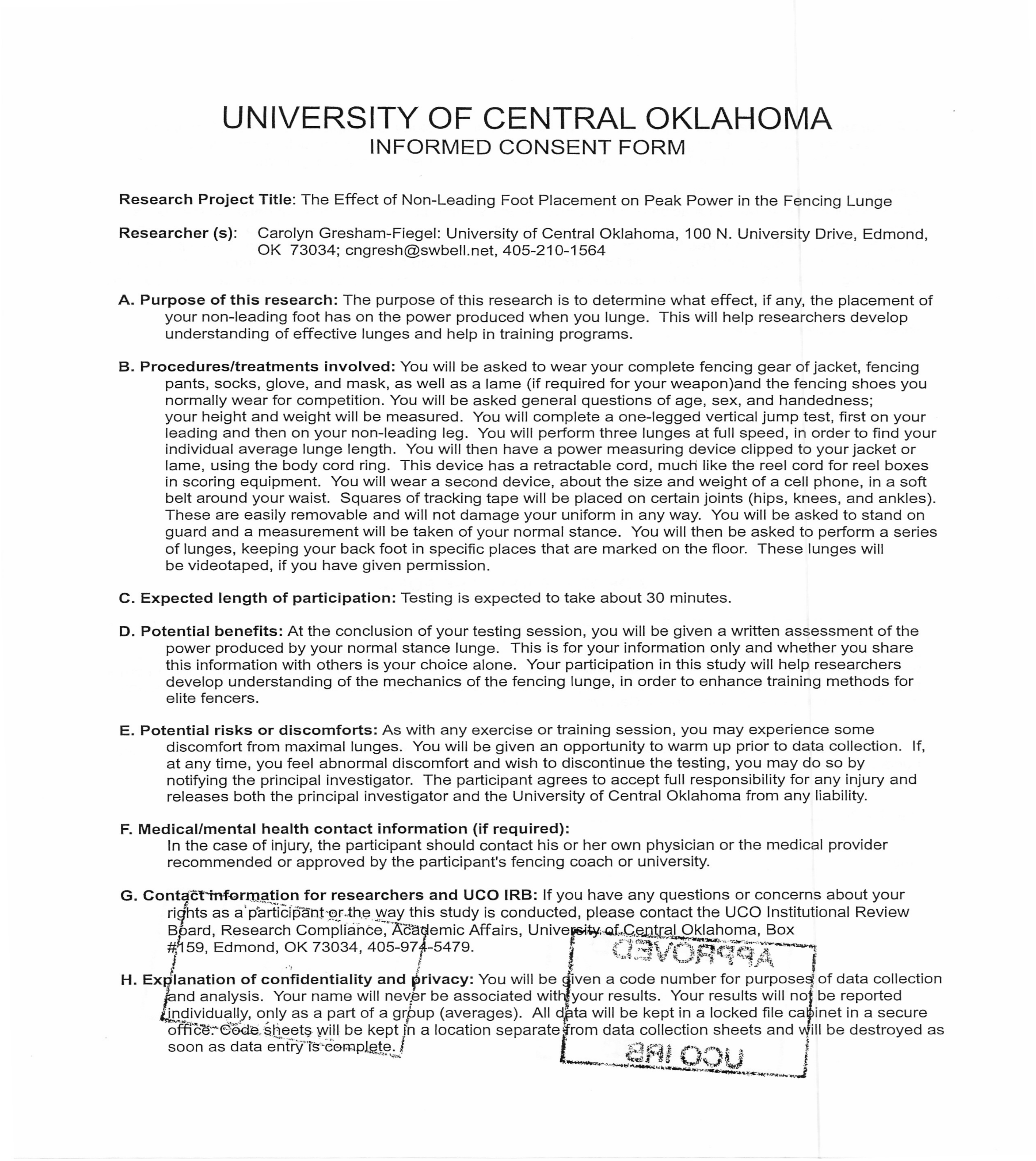
While a multitude of power measurement methods exist (Cormie et al., 2007; Cronin et al., 2003; Jennings et al., 2005; Jidovtseff et al., 2006), use of a linear transducer that is portable, assesses concentric dynamic multi-joint movements, and can be readily adapted for use with a horizontal lunge movement is preferred.

The present study incorporates the use of the TENDO to measure the concentric phase of the fencing lunge. Due to the horizontal movement, a difference between the power actually produced and the power measured is expected; however, this difference will be equal across all trials for the same participant. Similarly, preparatory eccentric movements, while perhaps increasing the power produced, are assumed to be similar for all lunges by a given individual. Lunge length, however, while apparently not affecting reaction time or muscular activation, affects power measurements, if lunge lengths are allowed to vary across trials for any subject. Therefore, specifying lunge distance and eliminating improperly executed lunges is a part of methodology.

Data collected from this study indicate that the position of the non-leading foot affects the power of a fencing lunge. Whether there is a critical forward deviation at which velocity and power are first affected is not yet determined. But the present information, as well as continued study of lunge biomechanics through various methods, may lead to a greater understanding of the mechanics of the lunge and aid in the development of better training techniques. This, in turn, may lead to improved lunge power and scoring success for competitive fencers.

Appendix B

Informed Consent Forms



UNIVERSITY OF CENTRAL OKLAHOMA

INFORMED CONSENT FORM

Research Project Title: The Effect of Non-Leading Foot Placement on Peak Power in the Fencing Lunge

Researcher (s): Carolyn Gresham-Fiegel: University of Central Oklahoma, 100 N. University Drive, Edmond, OK 73034; cngresh@swbell.net, 405-210-1564

A. Purpose of this research: The purpose of this research is to determine what effect, if any, the placement of your non-leading foot has on the power produced when you lunge. This will help researchers develop understanding of effective lunges and help in training programs.

B. Procedures/treatments involved: You will be asked to wear your complete fencing gear of jacket, fencing pants, socks, glove, and mask, as well as a lame (if required for your weapon)and the fencing shoes you normally wear for competition. You will be asked general questions of age, sex, and handedness; your height and weight will be measured. You will complete a one-legged vertical jump test, first on your leading and then on your non-leading leg. You will perform three lunges at full speed, in order to find your individual average lunge length. You will then have a power measuring device clipped to your jacket or lame, using the body cord ring. This device has a retractable cord, much like the reel cord for reel boxes in scoring equipment. You will wear a second device, about the size and weight of a cell phone, in a soft belt around your waist. Squares of tracking tape will be placed on certain joints (hips, knees, and ankles). These are easily removable and will not damage your uniform in any way. You will be asked to stand on guard and a measurement will be taken of your normal stance. You will then be asked to perform a series of lunges, keeping your back foot in specific places that are marked on the floor. These lunges will be videotaped, if you have given permission.

C. Expected length of participation: Testing is expected to take about 30 minutes.

D. Potential benefits: At the conclusion of your testing session, you will be given a written assessment of the power produced by your normal stance lunge. This is for your information only and whether you share this information with others is your choice alone. Your participation in this study will help researchers develop understanding of the mechanics of the fencing lunge, in order to enhance training methods for elite fencers.

E. Potential risks or discomforts: As with any exercise or training session, you may experience some discomfort from maximal lunges. You will be given an opportunity to warm up prior to data collection. If, at any time, you feel abnormal discomfort and wish to discontinue the testing, you may do so by notifying the principal investigator. The participant agrees to accept full responsibility for any injury and releases both the principal investigator and the University of Central Oklahoma from any liability.

F. Medical/mental health contact information (if required): In the case of injury, the participant should contact his or her own physician or the medical provider recommended or approved by the participant's fencing coach or university.

G. Contact information for researchers and UCO IRB: If you have any questions or concerns about your rights as a participant or the way this study is conducted, please contact the UCO Institutional Review Board, Research Compliance, Academic Affairs, University of Central Oklahoma, Box #159, Edmond, OK 73034, 405-974-5479.

H. Explanation of confidentiality and privacy: You will be given a code number for purposes of data collection and analysis. Your name will never be associated with your results. Your results will not be reported individually, only as a part of a group (averages). All data will be kept in a locked file cabinet in a secure office. Code sheets will be kept in a location separate from data collection sheets and will be destroyed as soon as data entry is complete.

I. Assurance of voluntary participation: Your participation in this study is completely voluntary. There are no payments for participating. You are free to refuse to participate and to withdraw from this study at any time. Your decision to withdraw will bring no negative consequences or penalty to you.

AFFIRMATION BY RESEARCH SUBJECT
I hereby voluntarily agree to participate in the above listed research project and further understand the above listed explanations and descriptions of the research project. I also understand that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty. I acknowledge that I am at least 18 years old. I have read and fully understand this Informed Consent Form. I sign it freely and voluntarily. I acknowledge that a copy of this Informed Consent Form has been given to me to keep.

Research Subject's Name: ______________________________

Signature: ______________________________

Date: ____________________

VIDEOTAPE RELEASE FORM

The principal investigator (Carolyn Gresham Fiegel) requests permission to videotape your lunges during the testing. Videotapes will be used for analysis purposes. Videotape may be used in a variety of media, including slide shows, multimedia presentations, and display boards. Your identity will not be revealed in any way and any identifying names on clothing will be removed. You are not required to give this permission, in order to participate in the study. No compensation is paid to individuals or organizations for this use. If you have any questions or concerns, please contact Carolyn, 405-210-1564.

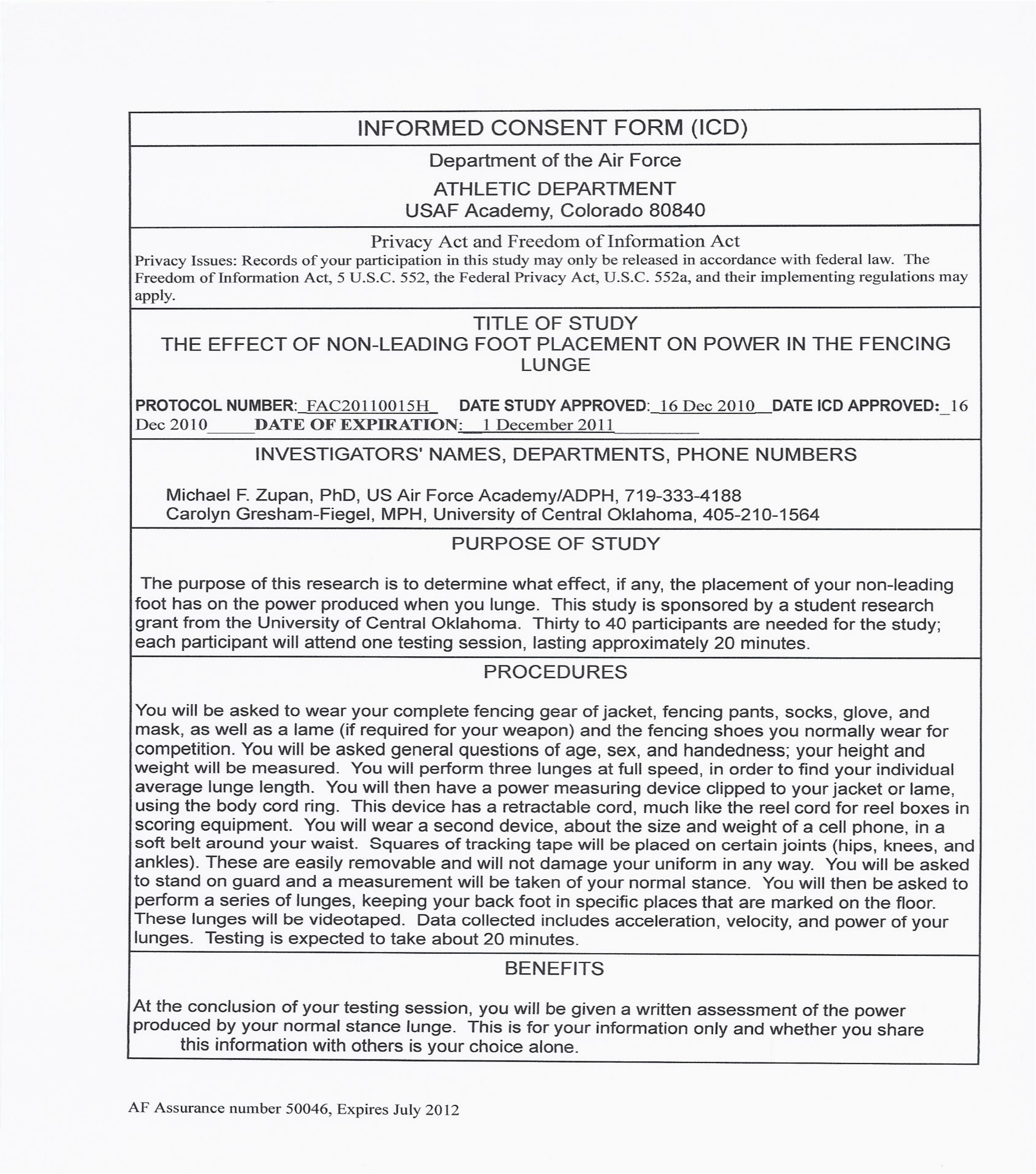
By signing below, I give permission for videotape to be taken of me during my participation in this project. I understand that these videotapes will be used for analysis purposes.

Signature:______________________________

Date: ____________________

APPROVED kp
OCT 19 2010
UCO IRB

APPROVAL kp
OCT 18 2011
EXPIRES



INFORMED CONSENT FORM (ICD)

Department of the Air Force

ATHLETIC DEPARTMENT
USAF Academy, Colorado 80840

Privacy Act and Freedom of Information Act

Privacy Issues: Records of your participation in this study may only be released in accordance with federal law. The Freedom of Information Act, 5 U.S.C. 552, the Federal Privacy Act, U.S.C. 552a, and their implementing regulations may apply.

TITLE OF STUDY

THE EFFECT OF NON-LEADING FOOT PLACEMENT ON POWER IN THE FENCING LUNGE

PROTOCOL NUMBER:_FAC20110015H_ **DATE STUDY APPROVED:**_16 Dec 2010__**DATE ICD APPROVED:**_16 Dec 2010_____**DATE OF EXPIRATION:**__1 December 2011_________

INVESTIGATORS' NAMES, DEPARTMENTS, PHONE NUMBERS

Michael F. Zupan, PhD, US Air Force Academy/ADPH, 719-333-4188
Carolyn Gresham-Fiegel, MPH, University of Central Oklahoma, 405-210-1564

PURPOSE OF STUDY

The purpose of this research is to determine what effect, if any, the placement of your non-leading foot has on the power produced when you lunge. This study is sponsored by a student research grant from the University of Central Oklahoma. Thirty to 40 participants are needed for the study; each participant will attend one testing session, lasting approximately 20 minutes.

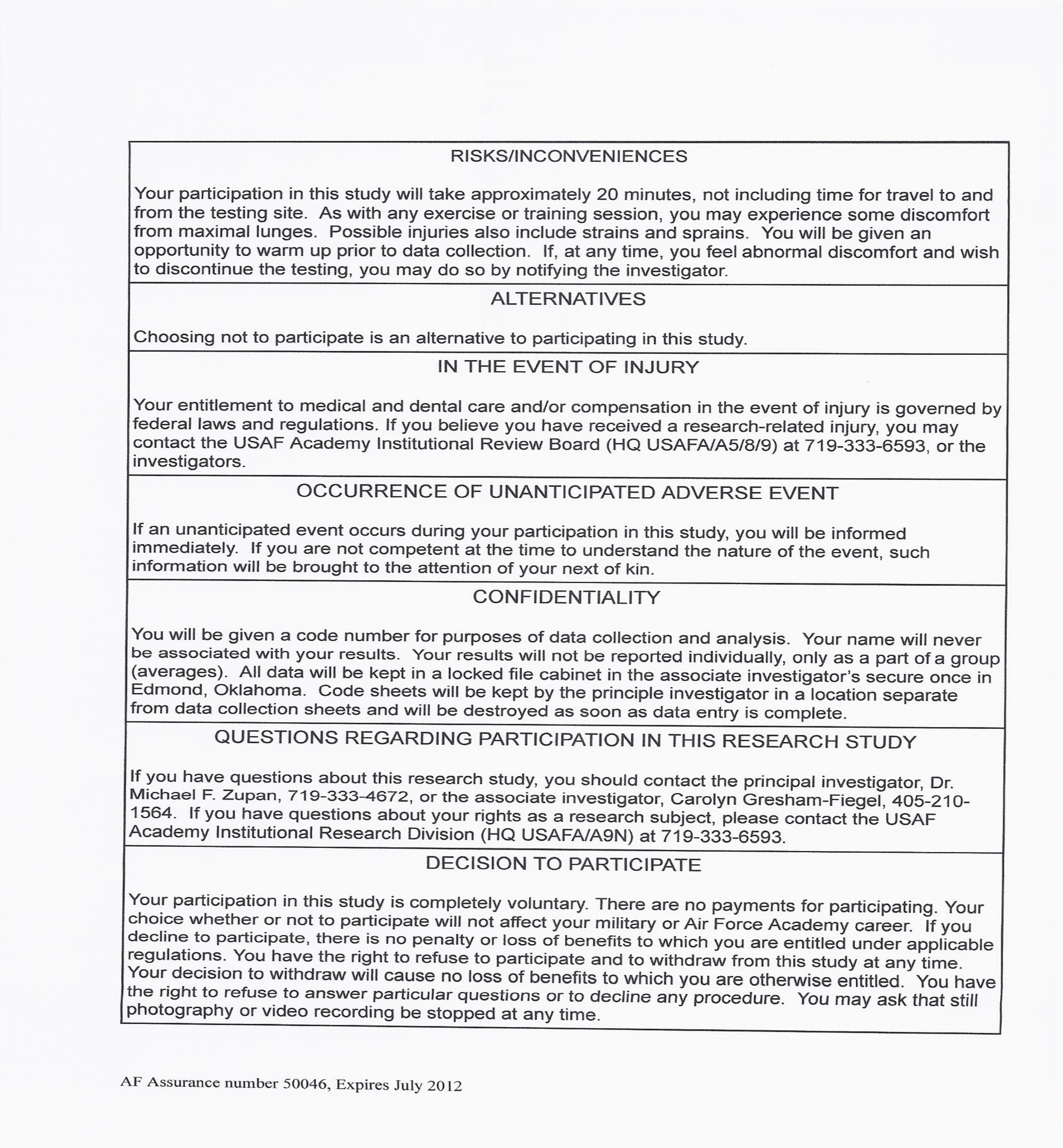
PROCEDURES

You will be asked to wear your complete fencing gear of jacket, fencing pants, socks, glove, and mask, as well as a lame (if required for your weapon) and the fencing shoes you normally wear for competition. You will be asked general questions of age, sex, and handedness; your height and weight will be measured. You will perform three lunges at full speed, in order to find your individual average lunge length. You will then have a power measuring device clipped to your jacket or lame, using the body cord ring. This device has a retractable cord, much like the reel cord for reel boxes in scoring equipment. You will wear a second device, about the size and weight of a cell phone, in a soft belt around your waist. Squares of tracking tape will be placed on certain joints (hips, knees, and ankles). These are easily removable and will not damage your uniform in any way. You will be asked to stand on guard and a measurement will be taken of your normal stance. You will then be asked to perform a series of lunges, keeping your back foot in specific places that are marked on the floor. These lunges will be videotaped. Data collected includes acceleration, velocity, and power of your lunges. Testing is expected to take about 20 minutes.

BENEFITS

At the conclusion of your testing session, you will be given a written assessment of the power produced by your normal stance lunge. This is for your information only and whether you share this information with others is your choice alone.

AF Assurance number 50046, Expires July 2012



RISKS/INCONVENIENCES

Your participation in this study will take approximately 20 minutes, not including time for travel to and from the testing site. As with any exercise or training session, you may experience some discomfort from maximal lunges. Possible injuries also include strains and sprains. You will be given an opportunity to warm up prior to data collection. If, at any time, you feel abnormal discomfort and wish to discontinue the testing, you may do so by notifying the investigator.

ALTERNATIVES

Choosing not to participate is an alternative to participating in this study.

IN THE EVENT OF INJURY

Your entitlement to medical and dental care and/or compensation in the event of injury is governed by federal laws and regulations. If you believe you have received a research-related injury, you may contact the USAF Academy Institutional Review Board (HQ USAFA/A5/8/9) at 719-333-6593, or the investigators.

OCCURRENCE OF UNANTICIPATED ADVERSE EVENT

If an unanticipated event occurs during your participation in this study, you will be informed immediately. If you are not competent at the time to understand the nature of the event, such information will be brought to the attention of your next of kin.

CONFIDENTIALITY

You will be given a code number for purposes of data collection and analysis. Your name will never be associated with your results. Your results will not be reported individually, only as a part of a group (averages). All data will be kept in a locked file cabinet in the associate investigator's secure once in Edmond, Oklahoma. Code sheets will be kept by the principle investigator in a location separate from data collection sheets and will be destroyed as soon as data entry is complete.

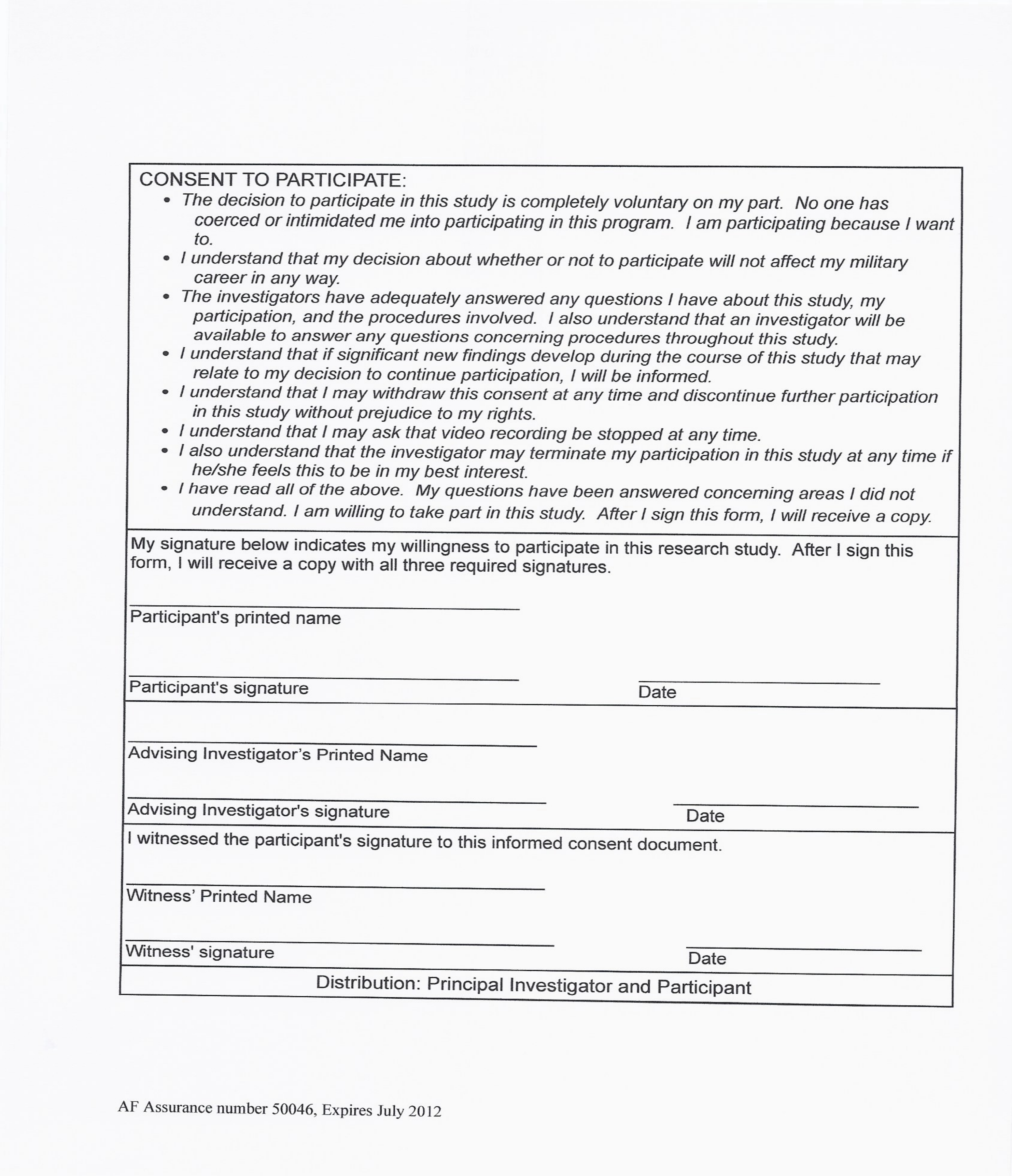
QUESTIONS REGARDING PARTICIPATION IN THIS RESEARCH STUDY

If you have questions about this research study, you should contact the principal investigator, Dr. Michael F. Zupan, 719-333-4672, or the associate investigator, Carolyn Gresham-Fiegel, 405-210-1564. If you have questions about your rights as a research subject, please contact the USAF Academy Institutional Research Division (HQ USAFA/A9N) at 719-333-6593.

DECISION TO PARTICIPATE

Your participation in this study is completely voluntary. There are no payments for participating. Your choice whether or not to participate will not affect your military or Air Force Academy career. If you decline to participate, there is no penalty or loss of benefits to which you are entitled under applicable regulations. You have the right to refuse to participate and to withdraw from this study at any time. Your decision to withdraw will cause no loss of benefits to which you are otherwise entitled. You have the right to refuse to answer particular questions or to decline any procedure. You may ask that still photography or video recording be stopped at any time.

AF Assurance number 50046, Expires July 2012



CONSENT TO PARTICIPATE:

- *The decision to participate in this study is completely voluntary on my part. No one has coerced or intimidated me into participating in this program. I am participating because I want to.*
- *I understand that my decision about whether or not to participate will not affect my military career in any way.*
- *The investigators have adequately answered any questions I have about this study, my participation, and the procedures involved. I also understand that an investigator will be available to answer any questions concerning procedures throughout this study.*
- *I understand that if significant new findings develop during the course of this study that may relate to my decision to continue participation, I will be informed.*
- *I understand that I may withdraw this consent at any time and discontinue further participation in this study without prejudice to my rights.*
- *I understand that I may ask that video recording be stopped at any time.*
- *I also understand that the investigator may terminate my participation in this study at any time if he/she feels this to be in my best interest.*
- *I have read all of the above. My questions have been answered concerning areas I did not understand. I am willing to take part in this study. After I sign this form, I will receive a copy.*

My signature below indicates my willingness to participate in this research study. After I sign this form, I will receive a copy with all three required signatures.

____
Participant's printed name

______________________________ ______________________
Participant's signature Date

____
Advising Investigator's Printed Name

______________________________ ______________________
Advising Investigator's signature Date

I witnessed the participant's signature to this informed consent document.

____
Witness' Printed Name

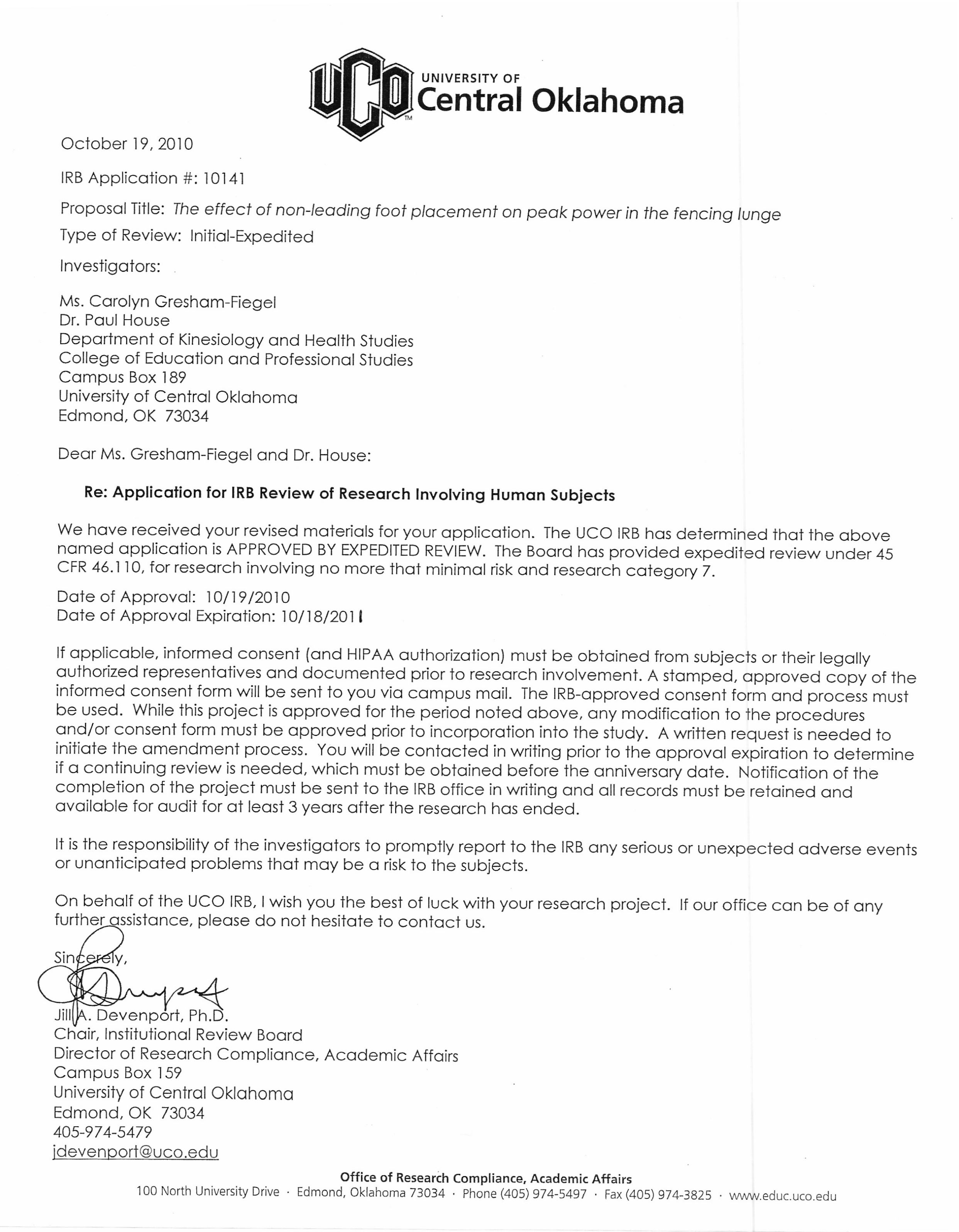
______________________________ ______________________
Witness' signature Date

Distribution: Principal Investigator and Participant

AF Assurance number 50046, Expires July 2012

Appendix C

IRB Approval Letters



UCO UNIVERSITY OF
Central Oklahoma

October 19, 2010

IRB Application #: 10141

Proposal Title: *The effect of non-leading foot placement on peak power in the fencing lunge*

Type of Review: Initial-Expedited

Investigators:

Ms. Carolyn Gresham-Fiegel
Dr. Paul House
Department of Kinesiology and Health Studies
College of Education and Professional Studies
Campus Box 189
University of Central Oklahoma
Edmond, OK 73034

Dear Ms. Gresham-Fiegel and Dr. House:

Re: Application for IRB Review of Research Involving Human Subjects

We have received your revised materials for your application. The UCO IRB has determined that the above named application is APPROVED BY EXPEDITED REVIEW. The Board has provided expedited review under 45 CFR 46.110, for research involving no more that minimal risk and research category 7.

Date of Approval: 10/19/2010
Date of Approval Expiration: 10/18/2011

If applicable, informed consent (and HIPAA authorization) must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. A stamped, approved copy of the informed consent form will be sent to you via campus mail. The IRB-approved consent form and process must be used. While this project is approved for the period noted above, any modification to the procedures and/or consent form must be approved prior to incorporation into the study. A written request is needed to initiate the amendment process. You will be contacted in writing prior to the approval expiration to determine if a continuing review is needed, which must be obtained before the anniversary date. Notification of the completion of the project must be sent to the IRB office in writing and all records must be retained and available for audit for at least 3 years after the research has ended.

It is the responsibility of the investigators to promptly report to the IRB any serious or unexpected adverse events or unanticipated problems that may be a risk to the subjects.

On behalf of the UCO IRB, I wish you the best of luck with your research project. If our office can be of any further assistance, please do not hesitate to contact us.

Sincerely,

Jill A. Devenport, Ph.D.
Chair, Institutional Review Board
Director of Research Compliance, Academic Affairs
Campus Box 159
University of Central Oklahoma
Edmond, OK 73034
405-974-5479
jdevenport@uco.edu

Office of Research Compliance, Academic Affairs
100 North University Drive · Edmond, Oklahoma 73034 · Phone (405) 974-5497 · Fax (405) 974-3825 · www.educ.uco.edu

HEADQUARTERS UNITED STATES AIR FORCE ACADEMY
DEPARTMENT OF THE AIR FORCE

MEMORANDUM FOR LT COL MICHAEL ZUPAN
18 January 2011

FROM: HQ USAFA/A9N

SUBJECT: Protocol FAC20110015H Approved

1. The HQ USAFA Institutional Review Board considered your protocol FAC20110015H – The Effect of Non-Leading Foot Placement on Power in the Fencing Lunge at its 16 December 2010 meeting. The study and any required changes were approved as minimal risk for a maximum of 40 subjects. The following statements at the bottom of your recruitment material: 'Approved: HQ USAFA IRB FAC20110015H.' 'Expiration date of this protocol is 1 December 2011.' This will inform potential subjects that your research has been reviewed and approved. Attached is a final ICD for you to use for this study. Please note that the USAFA Authorized Institutional Official, HQ USAFA/CV and the Surgeon General's Research Oversight & Compliance Division, AFMSA/SGE-C review all USAFA IRB actions and may amend this decision or identify additional requirements. The USAFA's DoD Assurance Number is 50046, expiration date 19 July 2012 our Federalwide Assurance number is IORG0006125, expiration date 14 October 2012. Carolyn Gresham-Fiegel, Individual Investigator Assurance with USAFA.

2. Reminder: The IRB must review and approve all human subjects research protocols at intervals appropriate to the degree of risk but not less than once per year. **There is no grace period beyond one year from the last IRB approval date.** In order to avoid lapses in approval of your research, please submit your continuation report at least six weeks before the protocol's expiration date. **It is ultimately your responsibility to submit your research protocol in time to allow for continuing review and approval by the IRB before your protocol's expiration date.** Please keep this letter in your protocol file as proof of IRB approval and as a helpful reminder of your expiration date. Failure to comply with this requirement may result in closure of your protocol and suspension of further research here at USAFA.

3. Any problems of a serious nature should be brought to the immediate attention of the IRB, and any proposed changes should be submitted for IRB approval **before** they are implemented. You **must coordinate** all cadet-wide emails through Cadet Wing Director of Staff.

4. When you submit an annual report for this research, all original informed consent documents (ICDs) collected to date **must** accompany the report. If the ICDs are not properly executed you will not be allowed to use the data. When data collection and analysis are complete please submit your final report in a timely manner. As the principal investigator for this study, you must contact the IRB prior to departing or transferring from USAFA.

5. If you have any questions or if I can be of further assistance, please don't hesitate to contact me at 333-6593 or the IRB Chair, Dr. Wilbur Scott at 333-6740.

Gail B. Rosado

GAIL B. ROSADO
HQ USAFA IRB Administrator

Appendix D

Supplemental Materials

DATA COLLECTION FORM

Participant ID No. _____

Age_____ Sex _____ Height_____ Weight_____ Handedness_____

Jump height, non-leading leg, cm ______ Jump height, leading leg, cm ______

Shoe angle ______°
Stance angle, measured_______°
Stance angle, actual _________°

The order of the following will be randomly assigned:

<u>Non-leading foot angle</u>

	trial 1				trial 2				trial 3			
Order	AP	AV	PP	PV	AP	AV	PP	PV	AP	AV	PP	PV
45 degrees												
90 degrees												
135 degrees												
natural												

Average values	AP	AV	PP	PV
45 degrees				
90 degrees				
135 degrees				
natural				

Got a good lunge? Like to know just how powerful it is?

I am looking for volunteer fencers interested in participating in a research project. Participants will perform a series of lunges with the back foot held in different positions.

Requirements:
Experienced fencer (one year or more)
Over 18 years old

If you are interested in participating and would like more information, please attend an informational meeting:

USAFA Fencing facility: Wednesday, Feb 9, 2011
(West gym) 3:00 pm

For more information, call Carolyn Gresham-Fiegel
405-210-1564
University of Central Oklahoma

Appendix E

Additional Results

Within Subject Effects

Variable	Mauchly's *W*	*df* [a]	Signif.[b]	Greenhouse-Geisser Epsilon
Average power	0.646	5	0.92	0.777
Peak power	0.305	5	0.00	0.605
Average velocity	0.669	5	0.12	0.791
Peak velocity	0.359	5	0.01	0.661

[a] *df* = degrees of freedom

[b] Signif.= significance set at .05 level

Variable	Test	Mean Squares	*df* [a]	*F*	Signif. [b]
Average power	Sphericity assumed	27260.57	3	15.198	0.001
Peak power	Greenhouse-Geisser	203602.82	1.815	14.729	0.001
Average velocity	Sphericity assumed	0.06	3	15.604	0.001
Peak velocity	Greenhouse-Geisser	0.39	1.982	16.907	0.001

[a] *df* = degrees of freedom

[b] Signif.= significance set at .05 level

Pairwise Comparisons

Measure: Average Power

Foot angle, in degrees		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference Lower Bound	95% Confidence Interval for Difference Upper Bound
45	90	-84.694	15.508	0.000	-116.700	-52.687
	135	-43.722	13.131	0.003	-70.886	-16.559
	nat	-52.467	11.995	0.000	-77.224	-27.710
90	45	84.694	15.508	0.000	52.687	116.700
	135	37.861	10.711	0.002	15.705	60.018
	nat	32.227	11.265	0.009	8.976	55.477
135	45	43.722	13.131	0.003	16.559	70.886
	90	-37.861	10.711	0.002	-60.018	-15.705
	nat	-7.972	8.429	0.354	-25.410	9.465
nat	45	52.467	11.995	0.000	27.710	77.224
	90	-32.227	11.265	0.009	-55.477	-8.976
	135	7.972	8.429	0.354	-9.465	25.410

[a] Sig. = significance set at .05 level.

Measure: Average velocity

		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference	
Foot angle, in degrees					Lower Bound	Upper Bound
45	90	-0.119	0.021	.000	-0.163	-0.075
	135	-0.062	0.018	.003	-0.100	-0.024
	nat	-0.075	0.017	.000	-0.111	-0.039
90	45	0.119	0.021	.000	0.075	0.163
	135	0.054	0.015	.002	0.023	0.086
	nat	0.044	0.015	.008	0.013	0.076
135	45	0.062	0.018	.000	0.024	0.100
	90	-0.054	0.015	.002	-0.086	-0.023
	nat	-0.013	0.012	.308	-0.037	0.012
nat	45	0.075	0.017	.000	0.039	0.111
	90	-0.044	0.015	.008	-0.076	-0.013
	135	0.013	0.012	.308	-0.012	0.037

[a] Sig. = significance set at .05 level.

Measure: Peak Power

Foot angle, in degrees		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
45	90	-144.759	16.086	0.000	-177.959	-111.559
	135	-66.195	23.139	0.009	-114.061	-18.328
	nat	-157.133	30.112	0.000	-219.282	-94.985
90	45	144.759	16.086	0.000	111.559	177.959
	135	75.596	19.823	0.001	34.588	116.603
	nat	-12.374	23.633	0.605	-61.151	36.402
135	45	66.195	23.139	0.009	18.328	114.061
	90	-75.596	19.823	0.001	-116.603	-34.588
	nat	-87.417	37.443	0.029	-164.873	-9.960
nat	45	157.133	30.112	0.000	94.985	219.282
	90	12.374	23.633	0.605	-36.402	61.151
	135	87.417	37.443	0.029	9.960	164.873

[a] Sig. = significance set at .05 level

Measure: Peak Velocity

Foot angle, in degrees		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval of the Difference	
					Lower Bound	Upper Bound
45	90	-0.208	0.023	0.000	-0.256	-0.161
	135	-0.102	0.033	0.006	-0.171	-0.033
	nat	-0.226	0.041	0.000	-0.310	-0.141
90	45	0.208	0.023	0.000	0.161	0.256
	135	0.105	0.026	0.001	0.050	0.159
	nat	-0.017	0.031	0.590	-0.082	0.048
135	45	0.102	0.033	0.006	0.033	0.171
	90	-0.105	0.026	0.001	-0.159	-0.050
	nat	-0.121	0.048	0.020	-0.222	-0.021
nat	45	0.226	0.041	0.000	0.141	0.310
	90	0.017	0.031	0.590	-0.048	0.082
	135	0.121	0.048	0.020	0.021	0.222

[a] Sig. = significance set at .05 level.

Appendix F

Thesis Summary

Statement of the Problem

Fencers depend on the fencing lunge movement to deliver a touch onto the opponent's target area, thereby scoring a point. In general, a fencer must cover the distance forward to the opponent faster than the opponent can retreat away. A powerful lunge, evidenced by the ability to move the body forward quickly, is an essential skill in fencing. The fencing lunge is a specific whole-body movement and the feet retain a perpendicular orientation relative to one another throughout the lunge, with the leading foot facing toward the opponent. This foot orientation, however, often varies among fencers. How the angle of the non-leading foot affects lunge power is the focus of this study.

Summary of the Literature

Most previous studies on fencing have dealt with morphological and physiological characteristics of fencers ((Nystrom et al., 1990; Vander et al., 1984), the development of power through interval training techniques (Rippetoe, 2000), and stimulus discrimination within the motor program (Di Russo, Taddei, Apnile, & Spinelli, 2006; Guizani et al., 2006; Williams & Walmsley, 2000a; Yiou & Do, 2000). Two studies have focused on the lunge itself. In 1987, Klinger and Adrian studied the power produced in the lunges of nine fencers in reaction to different starting cues. Power means ranged from 2105 Watts to 1988 Watts, with no standard deviations reported. Using video technology with four participants, Zhang, Chu, and Hong (1999) analyzed the velocity of the center of mass and time to reach target during a lunge, as well as joint angles and stride length of the end lunge position. Maximum horizontal center of gravity (CG) velocity ranged from 304.7 ± 61.2 CG/s to 345.0 ± 44.2 CG/s (the investigators' units). Neither study investigated variations in the biomechanical aspects of the lunge.

Thesis Statement and Methodology

The present study was designed to expand previous research by determining more specifically how placement of the non-leading foot affects lunge power. The hypothesis was that the traditional foot position, with feet placed at a 90º angle, would result in the greatest peak and average power, followed in magnitude by the 45º and the 135º angles respectively. Participants performed a series of fencing lunges, with the non-leading foot placed at specific angles. Defining foot placement as the angle of the non-leading foot measured from the leading foot, foot placement was delimited here to three specific angles: 45º, 90º, and 135º. Power and velocity were measured for lunges performed at each foot placement. Lunge power was determined by the TENDO Weightlifting Analyzer (Slovak Republic), a linear transducer which uses displacement and velocity measurements to determine peak and average power.

Findings

Results indicated that the greatest average power and velocity were produced at 90º. These values were significantly higher than values at 45° and at 135°. Additionally, average velocity at 90° was higher than the natural stance. In general, participants were able to sustain higher velocity and power throughout the lunge movement, when the non-leading foot was held at the 90° foot placement. By contrast, the average values reached in the natural stance were significantly greater than only the 45° stance.

For peak values, a slightly different pattern emerged. The greatest peak power and peak velocity were attained in the natural stance, though the values were not significantly greater than those produced in the 90° foot placement. The natural stance resulted in values significantly greater than the 45° foot placement, but did not produce peak values significantly greater than the 135° stance.

Thesis Results

Although it was hypothesized that the 135° placement would result in the lowest velocity and power measurements, the 45° stance consistently produced the lowest values for all dependent variables.

Significance of the Findings

Maintaining high velocity and power throughout the lunge translates to the rapid delivery of a touch. While different tactics require some alteration in lunge technique, in general, lunges with high velocity and power are essential in fencing actions that are intended to reach target before a defensive response can be launched. Although it can be argued that forward deviation of the non-leading foot would permit greater mobility during maneuvering, lunging with the forward deviation reduces lunge velocity, and the reduction in velocity may be reflected in failure to touch. Maneuvering with a forward deviation and then shifting the non-leading foot to a more perpendicular orientation before the lunge may produce higher average lunge velocity and power and result in a rapid delivery of a touch. The advantage of the higher values would be tempered, however, by the telegraphing of intent which may come from a visible foot position shift.

Holding the non-leading foot nearly perpendicular appears to promote the most efficient use of the leg muscles and foot for sustained velocity and power.