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ORIGINAL

Comparison of Dynamic Muscle Activation during *Fente* Execution in Fencing Between Wearing Weighted and Waterbag Vests

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Objective: This study aimed to compare the activity of the trunk and leg muscles while performing *fente* (in fencing) wearing weighted and waterbag vests.

Method: The electromyography test was used to measure and analyze the activation of the trunk and leg muscles. Eight active fencers from B University (age: 19.5 ± 0.66 years, height: 179.75 ± 5.93 cm, weight: 72 ± 6.32 kg) were selected for this study.

Results: According to the EMG analysis results of the 4 muscles measured in this study, left-right differences were observed for rectus abdominis and external oblique abdominis, but left-right differences between the groups were not significant. The gluteus medius muscle was not significantly different from the adductor muscle, but there were significant differences between the groups.

Conclusion: The electromyographic analysis of the four muscles measured in this study revealed no significant difference between the left and right recti abdominis and external obliques depending on the vests. However, significant differences were observed between the left and right gluteus medius and adductor longus. Our results can be interpreted as the effects of the inherent movements involved in the *fente*. Furthermore, our results indicate that the weight transfer while wearing a waterbag vest, which provides an unstable environment, increased the activity of leg muscles.

Keywords: Electromyography, Instability, Waterbag vest, Fencing athletes

INTRODUCTION

Fencing matches are played on pistes of 1.8 and 2 m wide and 14 m long. Strength, power, agility, speed, and reaction time are the fitness factors associated with fencing performance, as the first fencer to touch the other scores (Barth & Beck, 2007; Roi & Bianchedi, 2008). Due to its unique asymmetrical movements, fencing places high physiological demands on neuromuscular control, strength, and the musculoskeletal system (Murgu, 2006). In addition, the rapid offensive and defensive movements to score points against the opponent expose fencers to varying degrees of impact and force distributed asymmetrically throughout their bodies (Sinclair, Bottoms, Taylor & Greenhalgh, 2010). Accordingly, it is believed that training in sport-specific methods is more necessary given the asymmetrical characteristics of fencing.

Resistance training improves the ability to generate muscle strength under specific conditions (Aspenes & Karlsen, 2012) and increases the speed at which strength is enhanced by increasing maximum strength (Suchomel, Nimphius & Stone, 2016). Athletes gained over 10% of their athletic ability in a study of an unconventional training method of wearing a weighted vest during training (Khlifa et al., 2010). Additionally, Khlifa et al. (2010) reported that adult male basketball players who performed plyometric exercises while wearing a weighted vest over 10 weeks of training improved vertical jump ability more than those who performed plyometric exercises without wearing a weighted vest.

Instability-based resistance training has been proposed as a method for neuromuscular stress adaptation than traditional resistance training (Behm & Anderson, 2006). Performing resistance exercises in unstable conditions promoted the activation of stabilizing muscles, thereby amplifying the effectiveness of training (Nairn, Sutherland & Drake, 2017). Furthermore, using instability tools in functional strength training improved neuromuscular adaptation and strength enhancement (Saeterbakken & Fimland, 2013; Ditroilo et al., 2018). Additionally, neuromuscular training induced through training using agility and instability has been reported to improve core stability (Araujo, Cohen & Hayes, 2015). Training using instability tools (e.g., Swiss ball, BOSU, wobble board, air cushion, and slash pipe) has primarily been performed in therapeutic settings. However, this type of training improves the effects of training and is now primarily used in the training of athletes (Behm & Colado, 2013; Chance-Larsen, Littlewood & Garth, 2010; Fowles, 2010).

Several previous studies have investigated the effectiveness of neuromuscular training for muscle activation using instability tools, and these studies focused on the activation of the trunk muscles by rendering the support surface unstable using instability tools, such as a Swiss ball or BOSU. The activation of the leg and trunk muscles is substantially affected by the use of instability tools to maintain balance and stability during lifting (Kohler, Flanagan & Whiting, 2010; Li, Cao & Chen, 2013; McBride, Larkin, Dayne, Haines & Kirby, 2010). While there are several methods for using instability tools, studies on exercises on an unstable surface that are focused on athletic movement during the sport are insufficient. Training methods that include instability can strengthen the athlete's training system according to the principle of the specificity of the sport, and athletes are encouraged to practice athletic movements of the sport in the same environment where they will compete (Behm & Anderson, 2006).

A water bag has the structure of inflatable tubes resembling barbells with water and is mainly used for functional strength training (Wezenbeek et al., 2022). When using the water bag, the water in the tubes produces small but rapid vibrations, and these vibrations prompt the user to maintain their balance constantly (Nairn, Sutherland & Drake, 2015). Water bag developers and researchers state that training using this tool can activate the user's torso muscles.

Wezenbeek et al. (2022) investigated the effect of using water bags and wooden sticks during three functional exercises, squats, lunges, and step-ups, on the activities of the muscles of the trunk and lower extremities. The abdominal and gluteal muscle activities increased considerably during the three exercises. Additionally, Calatayud et al. (2015) analyzed the activity of the trunk muscles during clean and jerk movements using barbells, water bags, and sandbags, and reported that the activity of the trunk muscles was high when using water bags.

Core muscle stability in a sports environment is the ability to control the position and movement of the trunk to optimally generate, transmit, and control force and movement in an integrated exercise environment (Kiber, Press & Sciascia, 2006).

Muscle activation measured by electromyography (EMG) plays an important role in all motor activities because it is assumed to originate from postural activation mechanisms (Borysiuk, Blaszczyszyn, Piechota, Konieczny & Cynarski, 2022). Witkowski et al. (2018) reported on the importance of core muscles that maintain posture based on the finding that the back and abdominal muscles were activated first in a study on wheelchair fencers. Additionally, Borysiuk et al. (2020) and Kriventsove et al. (2017) reported that postural muscles that stabilize the trunk play a critical role due to the dynamism of attack techniques during fencing matches.

Electromyography (EMG) testing is useful in assessing muscle activation (Ghezelbash, El Ouaaid, Shirazi-Adl, Plamondon & Arjmand, 2018), and a positive relationship between muscle activation and performance in sports can be established (Lynn, Watkins, Wong, Balfany & Feeney 2018).

Research on resistance training has shown that if the goal is simply to increase core muscle activation, lifting heavy loads on a stable base of support may be sufficient (Anderson, Gaetz, Holzmann & Twist, 2013). However, this study aims to study the sport-specific aspects of fencing based on previous research showing that training through instability can contribute to neuromuscular improvement as well as increased strength (Cowley, Swensen & Sforzo, 2007). When comparing dynamic muscle activation during fencing movements using a weight vest and a water bag vest, it is believed that dynamic

Table 1. Characteristics of participants N = 8

	Age (yrs.)	Height (cm)	Weight (kg)	Career (yrs.)
Participants (n=8)	19.5±0.66	179.75±5.93	72±6.32	7.75±1.19

Values are Mean ± SD

muscle activation will be higher when using a water bag vest.

In Korea and overseas, research on specific movements in sports with asymmetric movements, such as fencing, is still insufficient. In addition to the paucity of studies on the effects of using water bags, there is a lack of studies on the sport-specific, instability-related characteristics that are unique to each sport.

Therefore, this study aimed to provide basic data that can aid the efficient performance of the *fente* movement in fencing by using weighted and waterbag vests. Our findings contribute to improving the fencers' performance.

METHODS

1. Participants

Eight active male athletes (height: 179.75±5.93, weight: 72±6.32) from the B University fencing team in B Metropolitan City participated in this study. Athletes with current musculoskeletal injuries and those who have not recovered were excluded from the competition.

For the number of subjects in this study, the G Power 3.0 program (Faul, Erdfelder, Lang & Buchner, 2007) was applied with an effect size of 0.5, power of 0.8, and significance level of 0.05. There were 10 subjects who voluntarily agreed to participate in the study, but 8, excluding 2 due to injuries, were selected as final research subjects.

(Table 1) shows the physical characteristics of the participants. The study was conducted after explaining the aim to all participants and obtaining their consent voluntarily.

2. EMG Measurement methods and instruments

1) Surface EMG device and attachment sites

Fencing is a unilateral exercise performed in an asymmetric position while holding a sword in one hand, resulting in strength imbalances in the legs due to the different roles of the front and back legs, and these changes can also be observed in the torso muscles (Guilhem, Giroux, Couturier, Chollet & Rabita, 2014). In this study, the activities of rectus abdominis, external oblique, gluteus medius, and adductor longus were measured to compare the activities of the trunk and leg muscles in relation to the exercise equipment used (Figure 1). The semi-wireless surface EMG device WEMG8 (Lextha, Korea, gain = 1,000, input impedance > 1012, CMRR > 100 dB) was used for the measurement. The sampling frequency was set to 1,024 Hz, and the Telescan (Laxtha, 2019) program was used. Before the electrode attachment, the attachment site was cleaned with an alcohol-based disinfectant using cotton wipes to minimize skin resistance. For the EMG analysis, the maximum voluntary isometric contraction (MVIC) was measured and set to the corresponding % MVIC value.

Maximal voluntary isometric contraction is measured for individual muscles when exerting maximum force against isometric resistance using the Manual Muscle Testing (MMT) method of Daniels and Worthingham's muscle testing (Brown, Hislop & Avers, 2013). Data were collected three times for 5 seconds each. Rectus abdominis was measured by applying resistance to the flexor muscles in a supine position, with the lower limbs fixed, and the trunk flexed until the scapula came off the floor. The External Oblique was measured by applying resistance with the trunk rotated in a position with the knees up and the trunk flexed. Gluteus Medius was measured in a lying position with the hips and knees placed to the side and the hips abducted 10°. The adductor longus was measured by applying resistance with the lower leg adducted while lying down with the hips and knees placed to the side. Active and reference electrodes were attached to the most developed parts of the belly of the muscle, 1 cm away in parallel to the direction of the muscle fibers (Badier, Guillot, Lagier-Tessonnier, Burnet & Jammes, 1993). In addition, assistants moved the EMG device together to minimize participant discomfort and prevent motion artifacts during the movements (Figure 2). (Table 2) shows the experimental devices.

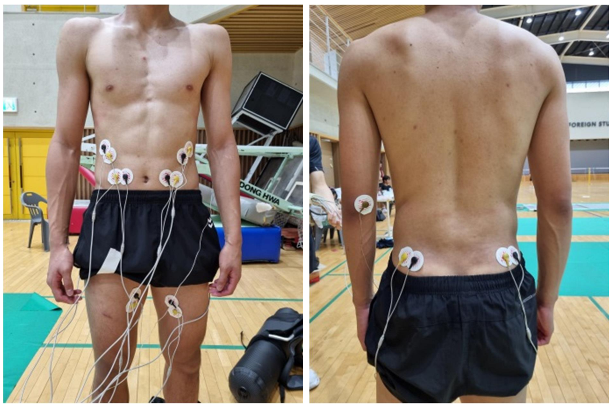

Figure 1. Electrode attachment sites for surface electromyography

Figure 2. Posture for the measurement of performing *fente*

Table 2. Electromyography (EMG) measurement device

Equipment	Model	Manufacture
EMG equipment	WEMG8	Laxtha. Korea
EMG analysis software	Telescan	Laxtha. korea
Surface electrode collar	AG/AgCl 2223	3M. Korea

AG : Silver
AgCl : Silver chloride
EMG : Electromyography

2) EMG Data collection interval

This study was conducted to verify the difference in muscle activities between the tools used to train the *fente* movement of fencers. The *fente* movement was performed three times on signal while wearing each tool. The movement was performed three times while wearing a weighted vest and three times with a waterbag vest, with a 3 min rest period between each set. The participants stopped all movements as soon as the *fente* foot touched the ground, and data was collected from the moment the foot touched the ground until 1 s after. All movements were synchronized to a 3-s interval, and the participants were instructed to perform the movements in time with the sound signal of the metronome in the computer program. After a sufficient explanation of the sound signal and timing, the participants were given multiple opportunities to adapt to the movement. The means of the measurements collected three times for each instrument were calculated.

3. Data analysis

All EMG data measured in this experiment were processed using a band-pass filter of 20 to 450 Hz, and the values converted into root mean square (RMS) were used. The MVICs of the muscles for measurement were measured before the start of the experiment, and the muscle activation during *fente* movement was normalized using the previously measured MVIC and the following equation.

$$muscle\ activation = \frac{EMG_{raw}}{EMG_{MVIC}} \times 100(\%)$$

where, EMG_{raw}: RMS value of muscular activation during the movement
EMG_{mvic} : Mean RMS of muscle activation at maximum voluntary isometric contraction

$$x_{rms} = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$$

4. Statistical analysis

All collected data are presented as means and standard deviations. These data were calculated using SPSS 28.0. The

Shapiro-Wilks test was used to analyze the normality of all general characteristics and variables. A paired *t*-test was performed to verify the difference between the left and right sides of a muscle group, and an independent-sample *t*-test was performed to confirm the differences between the left and right muscles between the experimental groups. $P < .05$ was considered to be statistically significant.

RESULTS

(Table 3) shows the differences in EMG results of the *fente* movement between muscle groups.

The activation of rectus abdominis was 10.85±5.14% and 7.32±6.21% for the right and left side, respectively, in the weighted-vest group; however, the difference between the two sides was non-significant. The right and left side of the waterbag vest group was calculated at 17.92±9.20%, and 13.65±11.64%, respectively, and the difference between the left and right was also non-significant. Significant differences were observed between groups regarding the right and left rectus abdominis. In addition, there was a difference between the left and right sides between the weight vest and the water bag vest group, but there was no significant difference.

The activation of external obliques was 12.15±8.93% and 9.02±2.50% for the right and left, respectively, in the weighted-vest group; however, the difference between the two sides was non-significant. For the waterbag-vest group, the muscle activation was 18.91±18.78% and 13.28±5.70% for the right and left side, respectively, with no significant difference between the two. Significant differences were observed between groups for the right and left external obliques. In addition, there was a difference between the left and right sides between the weight vest and the water bag vest group, but there was no significant difference.

The activation of gluteus medius was 12.18±5.40% and 13.11±5.44% for the right and left side, respectively, for the weighted-vest group, with no significant difference between the two sides. In the waterbag vest group, the muscle activation was 19.50±4.03% and 20.13±4.28% for the right and left side, respectively, with no significant difference between the two

Table 3. The result of EMG of left and right in each muscle between groups

Variable	Group	Right	Left	*t*	*p*
Rectus abdominis	Weight vest	10.85±5.14	7.32±6.21	1.487	0.181
	Waterbag vest	17.92±9.20	13.65±11.64	1.753	0.123
	t	-1.896	-1.357		
	p	0.079	0.203		
External oblique	Weight vest	12.15±8.93	9.02±2.50	1.015	0.344
	Waterbag vest	18.91±18.78	13.28±5.70	0.869	0.414
	t	-0.920	-1.939		
	p	0.379	0.082		
Gluteus medius	Weight vest	12.18±5.40	13.11±5.44	-1.998	0.086
	Waterbag vest	19.50±4.03	20.13±4.28	-1.138	0.292
	t	-3.074	-2.863		
	p	0.009*	0.013*		
Adductor longus	Weight vest	16.88±10.94	16.59±7.51	0.107	0.918
	Waterbag vest	32.80±17.40	35.51±11.96	-0.609	0.562
	t	-2.190	-3.789		
	p	0.049*	0.003*		

Values are Mean ± SD, *: $p < .05$

sides. However, there was a significant difference between the left and right sides of the weight vest and water bag vest groups (p < .05).

The activation of the adductor longus was 16.88±10.94% and 16.59±7.51% for the right and left side, respectively, in the weighted-vest group, with no significant difference between the two sides. In the waterbag-vest group, the muscle activation was 32.80±17.40% and 35.51±11.96% for the right and left side, respectively, with the difference being non-significant. However, there was a significant difference between the left and right sides of the weight vest and water bag vest groups (p < .05).

DISCUSSION

An important technical aspect of fencing is the *fente*, a fundamental movement in which the fencer thrusts to gain the upper hand in the attack. The scoring in fencing can be decided by a split of 1/25 s, and in the *fente*, an attack movement requires bold and quick judgment (Roi & Bianchedi, 2008). There are various approaches to training to improve such important *fente* movements, but the most effective way to improve the movement is by performing them. Herein, muscle activation during a *fente* movement while wearing weighted and waterbag vests was measured, and the extent to which these tools could activate the *fente*-specific muscle was examined. While a weighted vest is a tool that increases the body weight and increases movement load, a waterbag vest increases the load for the movement and induces the wearer to maintain balance through the rapid vibration of water in the tubes (Nairn et al., 2015).

Nairn et al. (2015) reported that training with water bags could activate the trunk muscles, and Calatayud et al. (2015) found high trunk muscle activity in the waterbag group while performing clean and jerk.

However, the results of this study were inconsistent with those of previous studies. The activation of the trunk muscles, the rectus abdominis, and external obliques, did not differ significantly between the left and right side depending on the tool used; however, there were significant differences between the left and right leg muscles, the gluteus medius and adductor longus, depending on the tool.

The above results are interpreted as the result of the unique movement characteristics of fencing and the various demands placed on the body during sports activities.

It is necessary to make an approach at high speed and spread the legs wide to thrust the opponent with a saber. The back leg needs to be extended, and the front knee needs to be bent to bring the saber closer to the opponent to execute the above (Thompson, Chang, Alaia, Jazrawi & Gonzalez-Lomas, 2022).

In other words, fencing is a dynamic movement that involves moving the body weight rather than a static movement of the legs in place, and in an actual fencing match, attack and defense techniques must be progressed according to the opponent's movements.

Core muscle activity was numerically different, but unlike the hypothesis, there was no statistically significant difference. McGill (2010) reported that core muscles play a role in maintaining posture during exercise, and lower limb muscles should be mainly used in movements that require speed or power. Based on these previous studies, it is believed that the leg muscles are more involved in the *fente* movement in fencing because it is dynamic and is a movement for speed and power. Additionally, because leg muscle activity increases in a dynamic posture compared to a static posture in an unstable environment (Park et al., 2015). It is judged that when using a water bag vest that provides an unstable environment, leg muscle activity increased due to strong weight transfer.

The gluteus medius is a typical hip abductor muscle that is concentrically activated when legs are spread apart and eccentrically activated when a single leg is supported (Floyd & Thompson, 2009). The adductor longus provides an intense extensor moment during hip extension and is also active during hip flexion (Neumann, 2010). In this study, when executing the *fente* movement, the left and right sides of these two muscles were activated simultaneously.

To score against an opponent, fencers must rapidly thrust their weapon at the opponent, which requires explosive force in the back leg to perform a strong forward lunge (Sinclair et al., 2010). Therefore, it is believed the left and right gluteus medius and adductor longus are activated because the *fente* is an attack motion generated by extending the hind leg at a fast speed while supporting the force with the front leg. In addition, since the *fente* has the advantage of enabling a faster return to a stable position for defense than other attack methods (Borysiuk & Waskiewicz, 2008), both the left and right muscles are believed to be simultaneously activated as a strategy to prepare for the defense at the same time as the attack.

Fencers have high leg injury rates because fencing requires dynamic and repetitive movements, and the most common injury site is reported to be the knees (19.6%), followed by the thighs (15.2%) and ankles (13.0%) (Wild et al., 2001).

Fencing matches require the ability to respond quickly and appropriately to an opponent's actions and the ability to repeatedly attack and defend (Turner et al., 2014). In particular, the most frequently used attack movements in fencing, such as lunges, are achieved through coordination of the kinetic chain of the ankle, knee, and hip joints (Bottoms, Greenhalgh & Sinclair, 2013). Therefore, it is known that activating lower extremity muscles is helpful for quick transition from offensive movements such as lunges to defensive movements and for preventing leg injuries (Turner et al., 2014).

Accordingly, wearing a waterbag vest when performing *fente* movements will help improve leg strength and prevent leg injuries.

CONCLUSION

The purpose of this study was to compare and analyze the activity of the torso and leg muscles according to the weight vest and the water bag vest during fencing fant movements to find out how the torso and leg muscles affect stability during specific movements depending on the tool. The same conclusion was obtained. The results were as follows. Among the four muscles observed, no difference was observed between the left and right sides of the gluteus medius and adductor longus when using a single tool; however, there were significant differences between the left and right sides of the muscles between the tools. Different results from previous studies were obtained due to the unique movement characteristics of fencing. However, as the leg muscle activity was high when wearing a water bag vest, It was also found to contribute to improvement training through instability such as a water bag vest not only increases muscle strength but also increases nerve muscle activity.

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