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Exploring Lower Body Asymmetry in Female Fencers: Implications for Enhanced Legging Design and Performance

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ABSTRACT

Fencing is a sport that places unique demands on the body due to its asymmetrical movements. As a result of long-term training, the body shapes of female fencers can differ from those of non-athlete women, leading to specific requirements for sportswear design. However, there is a lack of research focusing on the anthropometry of female fencers and their lower limb asymmetry, particularly in comparison with non-athlete females. This study aims to fill this research gap by examining and analyzing the body shapes of female fencers and non-athlete women using three-dimensional scanning technology. To achieve this goal, seven professional fencers and eight non-athlete women were invited to participate in a scanning experiment in a standard "A" pose. Cross-sectional circumferences of the lower body at eight separate positions were computed and compared between the left and right side, as well as between fencers and non-athletes. In addition, the performances of three commercial leggings were evaluated for fencers. The results revealed a clear asymmetry in the fencers' bodies. This finding could provide valuable insights into the physical attributes that contribute to the unique requirements for legging design, potentially enhancing the performance of fencers. Further research in this area could lead to the development of more effective and comfortable sportswear for fencers, ultimately improving their performance and reducing the risk of injury.

Keywords: Fencing, Body asymmetry, 3D body scanning, Legging design

INTRODUCTION

As one of the few sports that have been featured in every modern Olympic Games, fencing has gotten widespread international attention (Turner et al., 2014). It is characterized by its asymmetrical movements presenting unique physical demands on its athletes (Chen et al., 2017). While performing this exercise, the movement of the upper limb is followed by a robust extension of the dominant front leg and a vigorous lengthening of the non-dominant back leg during lunges. The non-dominant leg primarily generates power and

force, while the dominant leg is responsible for braking and stabilization. This leads to significant bilateral asymmetry between the two legs (Drakoulaki et al., 2021). Therefore, the long-term training involved in this sport often results in distinctive body shapes among female fencers, differing significantly from those of non-athlete women (Roi & Bianchedi, 2008; Tsolaks, Bogdanis & Vagenas, 2006). This divergence in body shape necessitates specific considerations in the design of sportswear to accommodate the unique physical requirements of female fencers. Despite this, there is a notable lack of research focusing on the anthropometry of female fencers (Chen et al., 2017), particularly in relation to lower body asymmetry, when compared to non-athlete females.

This study seeks to address this research gap by analysis of the lower body shapes of female fencers and non-athlete women. Utilizing three-dimensional scanning technology, this research aims to provide a comprehensive understanding of the physical attributes and asymmetries that characterize female fencers. This understanding is crucial in informing the design of leggings that cater to the specific needs of these athletes, potentially enhancing their performance and comfort during competition. The findings of this research could pave the way for the development of more effective and comfortable sportswear for female fencers.

PARTICIPANTS

The participants of this study were two groups of women (n = 15). The first group consisted of 7 female fencers, aged 20–27 years old (average age: 23.7 years old, SD: 2.87); And the second group included 8 non-athlete women, aged 26–42 years old (average age: 30.5 years old, SD: 5.29). The basic characteristics of the participants are listed in Table 1. All participants did not have physical injuries or other diseases that may affect body shape. The details of the research work were explained to all the participants, and they gave written informed consent prior to the start of the experiment. The research was given ethical approval by the Hong Kong Polytechnic University (Reference number HSEARS20231102003).

Table 1. Characteristics of the participants.

Group	Fencers							Non-Athlete Women							
Subject No.	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	S15
Age/ years	27	22	22	26	20	27	22	31	31	26	42	30	26	26	32
Height/ cm	167	164	162	158	173	162	169	162	172	162	160	163	170	171	174
Weight/ kg	57	52	53	51	59	62	67	69	60	46	54	50	60	56	60
BMI	20.4	19.3	20.2	20.4	19.7	23.6	23.4	26.3	20.3	17.5	21.1	18.8	20.7	19.2	19.8
Dominant side	R	R	R	R	L	R	L	R	R	R	R	R	R	R	R

EXPERIMENTAL PROCEDURE

The participants underwent scanning with a three-dimensional (3D) laser body scanner (Vitus, Human Solutions, Germany) which was set to scan at a high resolution of 300 pixels/cm^2. 3D scanning technology ensured consistent positioning when comparing the left and right legs and avoided

human errors, such as the issue of varying tension when using a tape measure. They were asked to stand straight in the standard "A" pose without any leggings or pants, with their arms open and feet apart at shoulder-width distance. The requirements during scanning were to hold still, look straightforward, breathe steadily, and relax.

RESULTS AND DISCUSSIONS

After 3D scanning experiments, the circumference of thirteen body positions (Figure 1) were measured using reverse engineering software (Geomagic Studio 12, USA). For the Body Mass Index (BMI) from Table 1, all of the fencers' BMI were within the healthy range, while among the non-athletes, two were not within the healthy range, one being too high and the other too low. In addition, fencers had more uniform BMI values than non-athletes. The standard deviation (SD) for the fencers' BMI was 1.75, while for the non-athletes' BMI, it was 2.62. However, BMI is a simple healthy indicator, which cannot distinguish between body fat and muscle, and it does not consider variations in body composition (Nemeth, Park & Mendle, 2020). Therefore, waist circumference and waist/hip ratio were also measured in this study (Table 2). Based on the previous research, waist circumference of 77cm was the optimal cutoff value to detect multiple risk components for females (Miyawaki et al., 2005). According to this standard, one fencer and one non-athlete each fall outside the healthy range. Moreover, the waist/hip ratio below 0.85 is considered another healthy indicator for women (Circumference & Ratio, 2008). Surprisingly, most of the fencers had higher waist/hip ratio. It may be because long-term training has altered the body shape. This speculation is due to the fact that the average waist circumference of fencers was larger than that of non-athletes, but the hip circumference was smaller than that of non-athletes, resulting in a high waist/hip ratio. This difference should be considered when designing a legging pattern for fencing to ensure a closer fit.

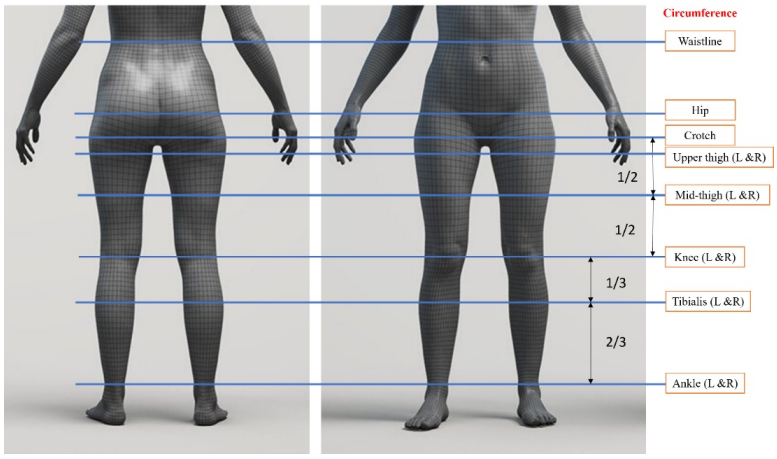

Figure 1: The measured body positions.

Table 2. Waist circumference and waist/hip ratio.

Group	Subject No.	Waist Circumference/cm	Hip Circumference/cm	Waist/Hip Ratio
Fencers	S01	71	80	0.89
	S02	64	73	0.88
	S03	92	96	0.96
	S04	70	78	0.90
	S05	66	76	0.87
	S06	76	91	0.84
	S07	76	91	0.84
Average Value ±	SD	73.6 ± 9.3	83.6 ± 8.9	0.88 ± 0.04
Non-athlete Women	S08	80	99	0.81
	S09	69	86	0.80
	S10	60	88	0.69
	S11	67	88	0.77
	S12	64	88	0.73
	S13	70	96	0.73
	S14	70	96	0.72
	S15	69	95	0.72
Average Value ±	SD	68.6 ± 5.8	92.0 ± 5.0	0.75 ± 0.04

To evaluate the asymmetry of the two legs for female fencers, the average differences between right and left thigh, knee, tibialis and ankle are shown in Figure 2 and Table 3. It is quite evident from the comparison that the asymmetry in the fencer's thighs is quite noticeable, while there is no significant difference in the lower leg portion compared to non-athletes. Even in terms of knee and ankle dimensions, the asymmetry is slightly more obvious in non-athletes. Therefore, when designing leggings, a unique asymmetrical design can be considered for the thigh portion, making it slightly looser on the side of the dominant leg.

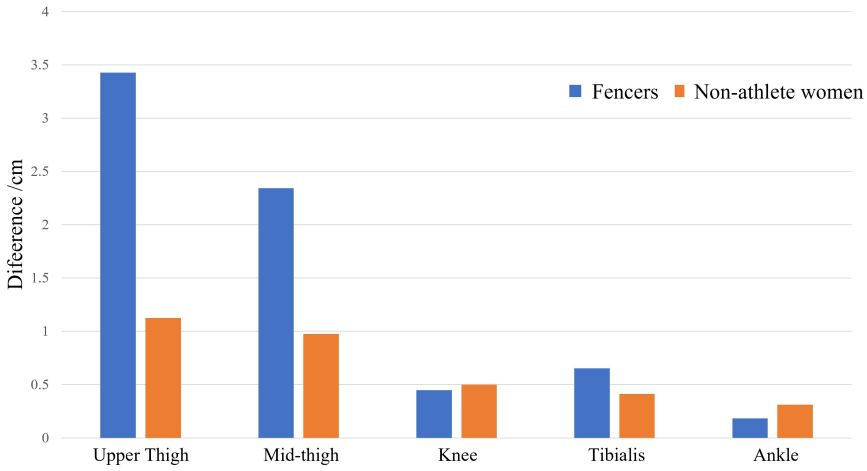

Figure 2: The comparison of left and right lower body.

Table 3. The measurements of the lower body.

Measurements	Group	
	Fencers (Average Value ± SD)/cm	Non-Athlete Women (Average Value ± SD)/cm
Left upper thigh	58.35 ± 4.75	55.56 ± 4.50
Right upper thigh	59.43 ± 3.17	56.29 ± 5.01
Left mid-thigh	48.72 ± 3.66	47.80 ± 4.46
Right mid-thigh	49.15 ± 3.25	48.35 ± 4.73
Left knee	33.48 ± 1.45	35.80 ± 2.23
Right knee	33.56 ± 1.48	36.28 ± 2.42
Left tibialis	35.33 ± 2.22	35.18 ± 2.96
Right tibialis	35.69 ± 2.55	35.21 ± 2.81
Left ankle	21.29 ± 1.18	21.78 ± 0.95
Right ankle	21.44 ± 1.23	21.89 ± 0.80

This study has a limitation in that the overall age of the non-athletes is higher than that of the fencers. Age can also affect body shape, which may result in inaccurate comparisons. Additionally, the small number of participants may make the suggestions less convincing. Future research should recruit more participants to obtain more reliable conclusions.

CONCLUSION

This study has provided valuable insights into the unique physical attributes and asymmetries of female fencers, particularly in comparison to non-athlete women. The results clearly indicate a significant asymmetry in the body shapes of fencers, especially in the thigh region. This asymmetry is likely a result of the unique demands of fencing, which involves asymmetrical movements and places different demands on the dominant and non-dominant legs. The findings of this study have important implications for the design of sportswear for female fencers. Specifically, the observed asymmetry in the thigh region suggests that leggings designed for fencers should consider an asymmetrical design, with a slightly looser fit on the side of the dominant leg. This could potentially enhance the comfort and performance of fencers during competition.

However, it is important to note that this study involved a relatively small sample size, and further research with a larger sample size is needed to confirm these findings. Future research could also explore other aspects of sportswear design for fencers, such as the material and cut of the garments, to further improve their performance and reduce the risk of injury.

In conclusion, this study has made a significant contribution to the limited body of research on the anthropometry of female fencers, and has highlighted the need for sportswear that is specifically designed to accommodate their unique physical attributes and asymmetries.

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