Physiological Response and Comfort Sensory Perception towards Physical-Mechanical Performance of Compression Hosiery Textiles

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Abstract: The purpose of the present study is to determine the psycho-physiological effects of mechanical properties of compression hosieries (CHs) with different pressure levels and longitudinal gradient distribution profiles on the wearing comfort perception and blood circulation performance of the lower extremities in vivo. The mechanical properties of CHs (tensile, shearing, and bending) significantly influencing pressure level performances have been instrumentally estimated. Blood circulation as the main physiological parameter was investigated along the long and short saphenous veins and popliteal veins (PopV) of a total of 24 lower extremities of twelve female subjects by using Colour Doppler Ultrasound equipment in conjunction with four-hour subjective wear trials in a controlled environmental chamber. The study demonstrated that the mechanical properties of CHs fabric produced gradient variations along hosiery hose and among pressure levels. The skin pressures applied by CHs with four pressure levels significantly decreased the cross-sectional areas, and increased the mean flow velocities (VP mean) of the PopV by 15.70%, 29.80%, 31.30 % and 24.20%, respectively. Wearing comfort and acceptance degree significantly correlated with mechanical quality of CHs textiles. Light and mild compression by CHs provides the subjects more comfort sensory perception for long-term wearing period. The application of CHs textiles appears to be effective in preventing venous dilation and improving blood circulation in the lower extremities when wearers lack of physical activities. The fabrics with lower elasticity and higher bending rigidity properties produced higher pressure; while no significant differences in increasing blood circulation was found among mild, moderate, and strong pressure levels. An illustrative plot represents the integrative relationships between multiple materials mechanical properties, pressure performance, and resultant physiological responses and subjective comfort sensory perception, which provide a reference for product designer and physician in development and application of functional compression hosiery textiles.

Keywords: compression hosiery, mechanical properties, comfort perception, physiology, blood flow

1. Introduction

Compression hosiery (CH) with engineering designed gradient pressure and 3D fit construction has been one of important medical and healthcare textile products for prophylaxis and treatment of venous diseases in the lower extremities, such as fatigue, swelling, varicose veins, deep vein thrombosis (DVT), recurrent leg ulcerations, and lymphedema, etc [1-3]. During wear, the physical-mechanical stimuli induced by CH textiles trigger responses from various sensory receptors and induce resultant psycho-physiological variation, which affects the overall wearing comfort and health status of users. Immobilization, and prolonged standing and sitting may result in disruption of certain muscle fiber membranes, especially in the lower body musculature [4,5], thus reducing the effectiveness of the venous-muscle pump mechanisms and resulting in valvular incompetence, venous circulatory insufficiency and feelings of discomfort [6-8]. The most significant function of CHs is to provide gradient support and pressure on the cutaneous surface, underlying tissues and venous system of the lower extremities (e.g. the greatest pressure at the ankle, and then the thigh) by their limited and elastic stretch capability. However, to date the effects of compression hosiery

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with multiple material mechanical properties on pressure performances and corresponding physiological responses as well as wearing comfort perception have been not sufficiently studied, and relationships between different pressure levels and blood flow produced remain controversial. The compressive effects of hosiery on a lower limb were considered to depend largely upon the elastic tensile strength (stretch) of the garment and the circumference of the limb at different levels [9,10]. By conducting cylinder-elongation experiments and wear experiments, Morooka et al found that the compressive properties of different kinds of hosieries fabrics (compressive energy, compressive resilience, and fabric thickness) differ markedly according to the types and the sites of hose and posture while being worn [11]. The mechanical properties of hosiery fabrics directly influenced their pressure magnitudes and distributions as well as corresponding therapeutic efficiencies. The CHs with a compression force of 10-18 mmHg at the ankle, 2-8 mmHg at mid-thigh, are used in the prevention of deep vein thrombosis (DVT) [12-14]. Struckmann [15] examined the effects of CHs with low compression and high gradient, with the steepness of ankle/knee being 100:50 on the musculo-venous pump by using strain-gauge plethysmography (SGP), and stockings were found to elevate the maximal venous outflow by 27 %.

On the other hand, some researchers suggested that CHs with different pressure levels produced no significant differences in therapeutic effects. For instance, Mayberry et al [16] found that an exerted pressure of 30-50 mmHg at the ankle only produced a slight increase in venous flow in patients with deep venous insufficiency, and no significant improvement in ambulatory venous pressure in either the control or patient groups. Therefore, the present study is to elucidate the psycho-physiological effects of materials mechanical properties of CH textiles on blood circulation and subjective comfort perception during wear.

2. Materials and Methods

2.1 Subjects and Materials

Twelve healthy adult females were recruited with written consent to participate in this study, which has been approved by the university's ethics sub-committee for research on human subjects. All subjects were studied wearing all 4 pressure levels of CHs in random order following the control condition, as shown in Table 1.

2.2 Anthropometric Estimation

In order that individual subject wear the most fitting CHs for testing, the anthropometric parameters of the lower body were estimated and the measurement results are shown in Table 2.

2.3 Mechanical Properties Estimation

Systematic measurements and analysis in our correlative studies have shown that, among numerous mechanical properties, fabric tensile, shearing, and bending properties play more prominent roles in influencing the skin pressure functional performances of compression hosieries [5]. In that, tensile energy (WT), tensile strain, (EM), tensile resilience (RT), shearing stiffness (G), and bending rigidity (B) relating to three fundamental stress states (tensile, shearing, bending) became the primary parameters used for assessing mechanical behaviours of compression hosieries fabrics in this study. The fabric samples (swatches) with standard size of 20 cm × 20 cm were obtained directly from different regions of tested compression hoses and were assessed by Kawabata Standard Evaluation (KESF) (Kato-Tec Co., Japan) under an environmental controlled lab (temperature T: 20ºC ± 2 ºC, and relative humidity RH: 65 ±3%).