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นิพนธ์ต้นฉบับ (Original article)
สรีรวิทยาการออกกำลังกายและกีฬา (Sports and Exercise Physiology)

ผลของการใส่ถุงน่องแบบผ้ายืดต่อการตอบสนองของระบบหัวใจ การไหลเวียนเลือด และการรับรู้ความเหนื่อยขณะเดินและฟื้นตัว

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บทคัดย่อ

วัตถุประสงค์ของการศึกษาครั้งนี้คือการค้นหาผลของการใส่ถุงน่องแบบผ้ายืดที่มีผลต่อการตอบสนองต่อระบบหัวใจและการไหลเวียนเลือดและการรับรู้ความเหนื่อยในผู้ใหญ่เพศชาย ตัวแปรประกอบด้วย อัตราการเต้นของหัวใจ , ปริมาณเลือดที่สูบฉีดต่อ 1 ครั้ง, ปริมาณเลือดที่สูบฉีดในเวลา 1 นาที, ปริมาณเลือดก่อนหัวใจบีบตัว, สัดส่วนของปริมาณเลือดที่บีบออกต่อปริมาณเลือดที่มี และระดับการรับรู้ความเหนื่อยเมื่อออกกำลัง ชายสุขภาพดีจำนวน 16 คน ซึ่งถูกสุ่มให้ใส่หรือไม่ใส่ถุงน่องแบบผ้ายืดเป็นผู้เข้าร่วมวิจัยครั้งนี้ ผู้เข้าร่วมวิจัยทุกคนจะเข้าร่วมทำการทดลอง 2 ครั้ง การทดลองแต่ละครั้งประกอบด้วยนั่งพัก 10 นาที แล้วเดินบนลู่วิ่งไฟฟ้าด้วยความเร็ว 3.5 ไมล์ต่อชั่วโมง ที่ความชัน 10% คงที่ เป็นเวลา 45 นาที และนั่งพักในระยะฟื้นตัวอีก 15 นาทีทำการทดลองอย่างต่อเนื่องและการทดลองแต่ละครั้งห่าง 1 สัปดาห์ ทำการเปรียบเทียบตัวแปรทั้งหมดระหว่างการทดลองทั้งสองในช่วงเวลาทุก 5 นาทีอย่างต่อเนื่องติดต่อกัน วิเคราะห์ด้วยสถิติความแปรปรวนสองทางแบบวัดซ้ำไม่พบความแตกต่างทางสถิติระหว่างสองเงื่อนไขและแต่ละช่วงเวลาในอัตรา การเต้นของหัวใจ , ปริมาณเลือดที่สูบฉีดต่อ 1 ครั้ง, ปริมาณเลือดที่สูบฉีดในเวลา 1 นาที, ปริมาณเลือดก่อนหัวใจบีบตัว, สัดส่วนของปริมาณเลือดที่บีบออกต่อปริมาณเลือดที่มี อย่างไรก็ตามพบว่าขณะเดินระดับการรับรู้ความเหนื่อยเมื่อใส่ถุงน่องมีค่าน้อยกว่าเมื่อเปรียบเทียบกับไม่ใส่ถุงน่องอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) จึงสรุปได้ว่าการใส่ถุงน่องแบบผ้ายืดอาจจะส่งผลในเรื่องความรู้สึกซึ่งแสดงให้เห็นด้วยค่าระดับการรับรู้ความเหนื่อยที่ลดลงในกลุ่มที่ใส่ถุงน่อง นอกจากนี้เพื่อจะอธิบายว่าการใส่ถุงน่องนั้นส่งผลอย่างไรต่อสมรรถนะทางกาย การศึกษาผลของการใส่ผ้ายืดที่มีต่อการเปลี่ยนของระบบหัวใจและการไหลเวียนหรือการเปลี่ยนทางด้านสรีรวิทยาจำเป็นที่จะต้องมีการศึกษาต่อไป

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นิพนธ์ต้นฉบับ (Original article)
สรีรวิทยาการออกกำลังกายและกีฬา (Sports and Exercise Physiology)

EFFECT OF ELASTIC COMPRESSION STOCKING ON CARDIOVASCULAR RESPONSES AND PERCEIVED EXERTION DURING WALKING AND RECOVERY

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ABSTRACT

The purpose of this study was to investigate the effects of elastic compression stocking (ECS) on cardiovascular responses and perceived exertion in adult male including heart rate (HR), stroke volume (SV), cardiac output (CO), end diastolic volume (EDV), ejection fraction (EF) and rating of perceived exertion (RPE). Sixteen male healthy persons who randomly selected to wear the ECS or not wear the ECS condition participated in this study. All subjects performed 2 trials, with and without wearing the ECS. Each trial consists of resting for 10 minutes, walking on treadmill at 3.5 mph with 10% of incline for 45 minutes and recovery for 15 minutes continuously with a week apart. All parameters between trials were compared at every 5 minutes consecutively. Two-way repeated-measure ANOVA did not reveal any statistically significant differences among HR, SV, CO, EDV and EF between two conditions and any time sequences. However, the RPE during walking with the ECS condition was significantly lower ($p<0.05$) than without the ECS condition. In conclusion, the results suggest that the ECS wearing may affect the subjective feeling response which represent by the lower RPE score. Additionally, to explain how compression stockings/garments affect the physical performance, investigation in the topic how does the effects of ECS on cardiovascular or physiological responses need to be determined in further study.

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KEY WORDS: leg compression stocking, cardiac output monitoring device, rating of perceived exertion

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INTRODUCTION

External compressions produced by bandage, compression stocking, elastic tight or pneumatic compression have been clinically used for prevention and treatment of diseases or problems with varicose veins. Pressure from the external compression that exerted to the skin inhibits venous blood stasis and drive blood from extremity back to the heart. With the mechanism of compression pressure, there were many studies to investigate the effects of external compression while doing various activities in general population and adult athletes. Bringard, *et al*. investigated the effects of leg compression garment on calf muscle oxygenation and venous pooling during 5 minutes of quiet resting and standing. They found the significantly increasing of the amount of muscle oxygenation as a result of the decreasing of venous pooling when compared without leg compression, in both supine and standing positions[1]. Ibegbuna, *et al*. reported that compression stocking affect venous return during the 1.0 to 2.5 km/h of walking on treadmill[2]. Previous studies had reported the effects of the external compression garment such an increase in forearm blood perfusion during repeated handgrip[3], a reduction in muscle soreness after 30 minutes of downhill walking[4], an improvement of performance in time to exhaustion while incremented treadmill test[5]. Additionally, wearing compression garment during running to exhaustion may affect the subjective feeling by the lower rating of perceived exertion then compared to that without[6]. In contrast, there were some studies reported an ineffectiveness of wearing compression garment such as no effects of wearing compression stocking on heart rate and blood lactate during 3 repeated running test[7]. No effects of wearing compression stocking on hear rate, blood pressure and rating of perceived exertion during incremental cycling test[8]. No effects of wearing leg compression on subjective sensation responses during submaximal running test was also observed, but found the lower energy cost compared to wearing conventional sport short[9]. Additionally, no effects of wearing compression stocking on blood lactate and heart rate after running to exhaustion on treadmill, and this studied suggest that wearing the high grade of compression stocking was perceived as tighter and discomfort than wearing the low grade compression stocking[10]. Although previous studies have reported the positive effect of wearing compression garment that affects venous function, hemodynamic and performance, the positive effect of compressive garments was often reported from the studies with the short duration task and/or high intensity exercise[3,4,5,6]. To our knowledge, only the study of Ibegbuna that investigate the effect of compression garment on systemic responses that claimed to explain how the vouse hemodynamic change during walking on treadmill. However, no previous studies were conducted on the cardiovascular changes especially the central circulation that explain how does wearing compression stocking/garments affect systemic responses lead to an improvement of the performance. It could have been caused by the lack of appropriate tools for testing. Therefore, the purpose of this study was to investigate the effect of wearing elastic compression stocking (ECS) on cardiovascular responses during walking and recovery, and investigate the effect of ECS on perceived of exertion throughout experiment.

METHODS

Experimental Approach to the Problem

A randomized repeated measures experimental design was used to test the hypothesis that wearing elastic compression stocking (ECS) affect cardiovascular and sensation responses differently. The independent variables were wearing ECS and without ECS conditions whereas the dependent variables were cardiovascular variables and rating of perceived exertion (RPE).

Subjects

Sixteen healthy male persons; age 22.0 ± 0.6 years, weight 65.7 ± 2.1 kg, height 171.5 ± 1.4 cm, body mass index 22.2 ± 0.5 kg.m^{-2}, volunteered to participate in this study. They were interviewed about their physical activity by a questionair[11]. There were 20.6 ± 0.2 of physical activity score and subjects were in the range of moderate activity person. Inclusion criteria were as follows; no participation in other vigorous sports or physical activities during the period of experiment, no cardiovascular disease and no musculoskeletal injuries. Before the testing day, all subjects were prohibited to do vigorous exercise, drink alcohol beverage and sleep less than 6 hours. On the experimental day, subjects had no smoking, no coffee/tea intake before arrival at the laboratory room.

Testing Procedures

The testing protocol in this study consisted of resting by sitting on the chair for 10 minutes, walking on the treadmill at the speed of 2.0 mph for 2 minutes, then walking at the speed 3.5 mph with 10% of incline until 45 minutes and recovery for 15 minutes, respectively. Subjects were randomly selected to either walk with or without the ECS conditions. They performed 2 trial tests with at least a week apart for each condition in the air conditioned room at 25.3 ± 0.1 degree Celsius with relative humidity of 42.7 ± 0.9%. Cardiovascular variables were recorded by cardiac output monitoring device (Physioflow Enduro, France) whereas rating of perceived exertion (RPE) were measured by a Borg 6-20 scale (Borg 1982), recorded all parameters every 5 minutes throughout the experiment.

Instrument

The ECS was fabricated by a manufacturer (Thai Parfun, Japan), specifically designed with the same garment for each subject. The lower leg length and the circumferences of the smallest of the ankle, the largest part of the calf, and the part around head of fibula were measured. And then, the percentages of those circumferences were used to design the size and the pressure of the ECS. All of ECS were in the form of 60%-65%-70% for ankle, calf and below knee circumferences, respectively. The highest pressure was exerted at ankle and degressive pressure upward into the knee. The pressure of garment was assessed by applied technique of Maton, *et al*[12]. The average pressures of the ECSs from sixteen participants before starting the experimental protocol were 4.4 ± 0.4 and 4.4 ± 0.3 mmHg in the right and the left legs, respectively.

Statistical analysis

Statistical analysis was performed by using SPSS-16. Data were expressed as a mean and standard errors of the mean (SEM). Kolmogorov-Smirnov test was used for testing normality of distribution. A two-way repeated-measures analysis of variance was performed to compare the differences between conditions. Significance was accepted at $p< 0.05$.

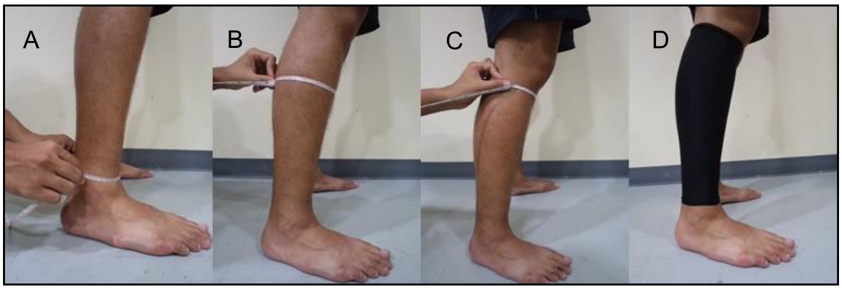


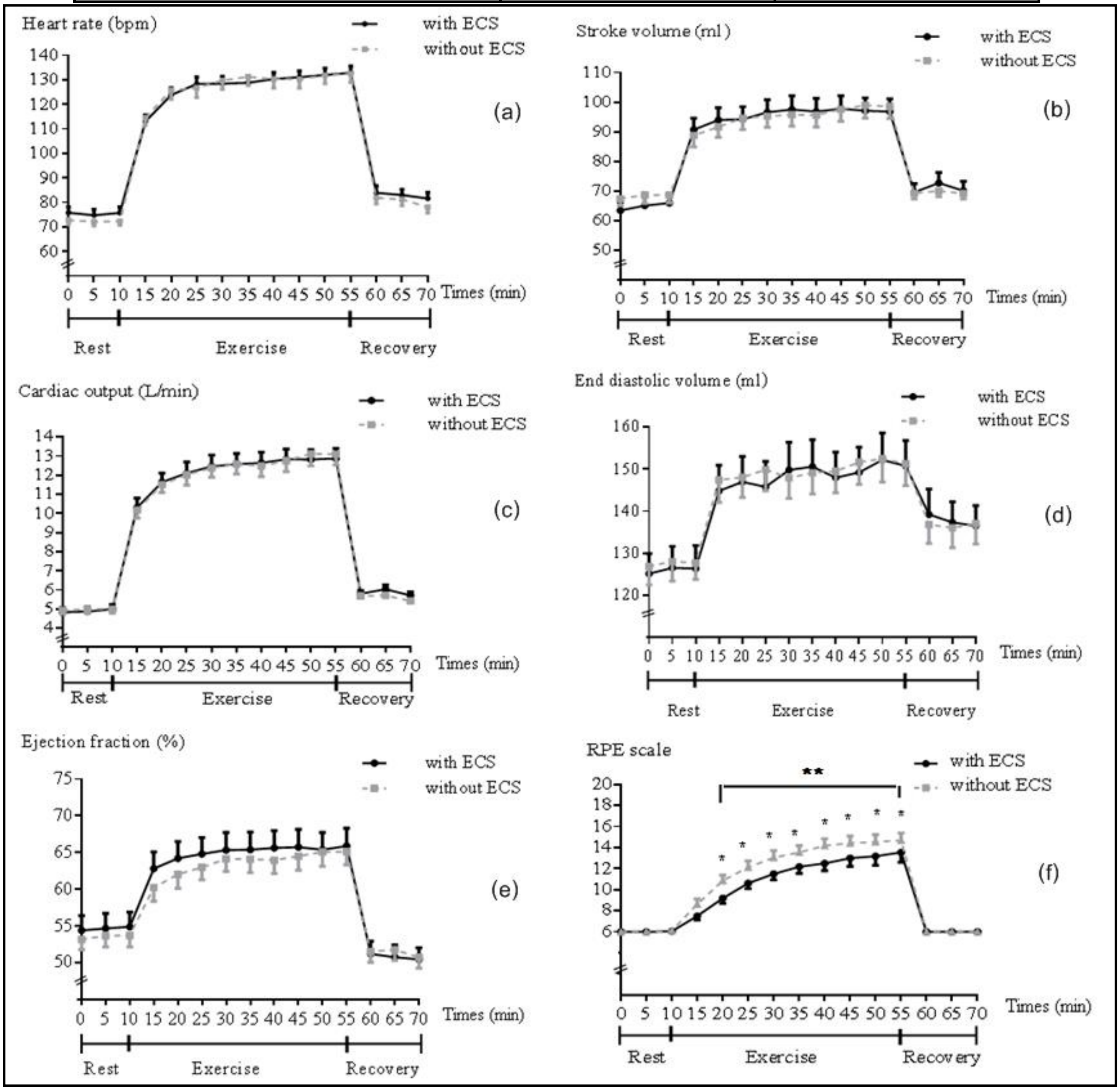
Figure 1 Position of the leg circumferences and leg length measurement; A = the smallest-circumference part of the ankle, B = the largest-circumference part of the calf, C = the circumference measured at the head of fibula, D = wearing the ECS (leg length from a lateral malleolus to a head of fibula)

RESULTS

The resting cardiovascular variables and the oral temperature were shown in Table 1. The data showed that there were no significant differences between the two conditions in resting period. While various parameters in the experimental testing protocol were shown in Figure 1. No significant differences between with and without the ECS conditions in cardiovascular variables including heart rate (HR), stroke volume (SV), cardiac output (CO), end diastolic volume (EDV), ejection fraction (EF) at rest, during exercise and recovery. However, the RPE scores during walking with ECS condition was significantly lower than that without ECS condition ($p<0.05$). The significant difference between two conditions were observed at the 20th, 25th, 30th, 35th, 40th, 45th, 50th and 55th minutes of the total time, respectively. Additionally, the RPE within each condition at the 20th, 25th, 30th, 35th, 40th, 45th, 50th and 55th minutes were significantly higher than the 10th minutes. This may be due to a main effect of exercise and time.

Table 1 Resting physiological variables between conditions.

Variables	With ECS (n=16)	Without ECS (n=16)
Resting HR/min	72.9 ± 2.4	70.5 ± 1.8
Systolic blood pressure (mmHg)	113.9 ± 1.5	113.5 ± 2.1
Diastolic blood pressure (mmHg)	66.2 ± 1.2	67.2 ± 1.5
Mean arterial pressure (mmHg)	82.1 ± 1.0	82.6 ± 1.4
Oral temperature (degree Celsius)	36.7 ± 0.1	36.6 ± 0.1



* Significant diffrence compared between with and without ECS conditions at p < 0.05.

** Significant different compared with initial exercise within each conditions at p < 0.05.

Figure 2 Cardiovascular variables and rating of percieved exertion (RPE) between conditions.

DISCUSSION

The purpose of this study was to investigate the effects of wearing elastic compression stocking on cardiovascular responses and perceived exertion during walking and recovery. Unfortunately, we did not find any effects of the ECS on HR, SV, CO, EDV, and EF except the RPE. The effect of ECS on the subjective parameters represent by the lower RPE was similar to Goh, *et al*[6]. Subjects probably know the use of compression garment which may predispose them to believe that their performance would benefit from using the garment[13]. It related with the previous studies, 93% of subjects believed that compression garment were supportive with regard to physical activity, despite no improvement in sprint, agility or maximal aerobic capacity running performance[14]. Additionally, no differences in comfort sensations, RPE and thermal sensation during cycling and submaximal running with compression garments compared with elastic tights and compression control[8,9]. Although the RPE is subjective psychophysiological variable that varies any factors such as the learning effect, but randomly assigned was used in this study. Moreover, the activity in this study was in the range of moderate intensity exercise which represent by the 132 beat/min of HR during walking protocol, it was different when compared to exhaustion test or submaximal to maximal test[15]. Therefore the learning effect was minimal. The ECS may provide positive psychological effect that affect subjective feeling improved. In contrast, the effects of ECS on HR, SV, CO, EDV and EF were not found. This means that the ECS was insufficiency to improve performance because the ECS did not act as an ergogenic aids to induce the physiological changes[8]. There were 2 main reasons that explain why the ECS in this study is ineffectiveness. Firstly, the posture of assignment in this study is upright position. Because of the gravity effect, the upright position induces a blood pooling in the lower extremity as a result increasing of vascular resistance. Well known that upright position has a greater of vascular resistance when compared with the supine position. So, the positive effects of wearing compression garments are often found in supine position[16,17]. Second is the pressure of compression garment. Previous studies reported the recommendation for optimal pressure of the ECS was 20-40 mmHg[18]. Additionally, Perry[19] recommended the optimal pressure were 18 mmHg at the ankle, 14 mm Hg at the calf, 8 mmHg at the knee, 10 mmHg at the lower thigh and 8 mmHg at the upper thigh. The Effectiveness of compressive garment with 20-14-10 mmHg was found by Ibegbuna, *et al*[2]. They explained that appropriate pressure of compression garment acts as ergogenics aids to improve a muscle pump resulting in an improvement of venous return and a reduction of residual volume during walking according to Norris *et al*. They found a lower-blood lactate concentration when wearing compression stocking with 15 mmHg at calf muscle[8]. In other hand, Mayrovitz[20] found the negative effect of 40 mmHg-compression garment (highest pressure at the ankle). Mayrovitz reported that the high pressure applied of compressive garment affect the reduction of skin blood flow. Interestingly, the recommended pressure in range of 20-40 mmHg could induce in either positive and negative effects on systemic responses.

Therefore, the optimal pressure of compression garment would be identified if you selected the pressure of compression garment was improper resulting in no effects of treatments. And the optimal pressures of this application remain no answer.

"A custom made ECS" in this study which designed in the form of 60-65-70% of lower leg circumferences. It is the "low pressure" profiles when compared that to the recommendation. We selected the lower pressure-ECS because from the pilot trial, we selected various the pressure profiles of ECS and found that high-pressure compressive garments including the commercials sleeve/stocking and a custom made ECS with "55-60-65% profiles" were difficult to put on and off into the leg, it related with Carpentier, *et al*[21]. Moreover, the ECS with 60-65-70% profiles were shown cardiovascular changes; it is the reason why select this low-pressure ECS. Therefore, result from this experiment was referring to effect of wearing a "specific ECS with 60-65-70%" profiles. Because of the assessment of ECS profiles is different when compared that to the standardization. We applied the assessment of ECS profiles according Maton's techniqe[12]. The pressure profiles of ECS was assessed at the calf, used a thin plastic sleeve with an air pump, covered around the leg on a target point. The sleeve was inflated with the air pressure of approximately 20 mmHg and then covered this sleeve by the ECS. The pressure exerted by the ECS was equal to pressure after wearing the stocking minus 20 mmHg. On other hand, the standardized practice which evaluation the compressive pressure of garments is usually done by standard equipment. Stocking or compressive garment is placed on the "hard-cylinder" and then the sensors/transducers identify the pressure that exert on the cylineder[22]. Although the ECS in this study is "low-pressure ECS, the effect of ECS on the subjective responses were found which represent by the lower RPE. While the ECS was insufficiency exert an effect on cardiovascular responses. It confirm that ECS not acts as ergogenics aids to encourage myogenic response process resulting in stimulating vasodilation or improvement of muscle pump during exercise when compared that to previous studies that claimed the effectiveness of compressive garments when they selected the pressure profiles according the recommendation for optimal pressure[2,3,5,8,9].

CONCLUSION

The ECS could be affecting the feeling of the subject to be less fatigue than without the ECS during walking but no effect on cardiovascular responses. These mean that the ECS may insufficient to improve performance. Although our results confirm the absence of the effectiveness under wearing ECS condition on cardiovascular responses during walking and recovery except the RPE, an understanding the effect of wearing ECS on physiological responses is important to answer the question, how does it work on performance?

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