

## Effect of Compression Socks and Smooth Socks on $VO_{2max}$ and Blood Lactate Concentration of Experienced and Novice Runners

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### ABSTRACT

Novice and experienced runners consistently seek appropriate strategies that can maximise their performance which include wearing compression socks. The purpose of the present study was to observe the effects of compression socks (CS) and smooth socks (SS) on blood lactate (BLa) and maximal oxygen uptake ( $VO_{2max}$ ) in runners with different experience level. The result of this study may benefit the fitness industries and would promote new running strategy. A randomized cross-over design was used in this study. Accordingly, eight experienced and eight novice runners ( $23.56 \pm 1.41$  years) were selected for the study. In particular, the participants were required to run on a Bruce treadmill for both conditions with

random arrangement separated by seven days of the washout period. A mixed model ANOVA showed a significant difference ( $p < 0.05$ ) for  $VO_{2max}$  in novice runners instead of experienced runners. Moreover, it was revealed that the  $VO_{2max}$  ( $44.5 \text{ ml/min/kg} \pm 1.1 \text{ ml/min/kg}$ ) in novice runners was higher while wearing CS. However, no significant differences were found for BLa between the conditions (CS/SS) for both groups (Novice/Experienced). Therefore, the overall finding suggests that the use of

### ARTICLE INFO

#### Article history:

Received: 26 June 2019

Accepted: 18 October 2019

Published: 19 March 2020

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CS during running only increases the  $VO_{2max}$  among novice runners.

*Keywords:* Compression socks, experienced runners, novice runners, running performance

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## INTRODUCTION

Novice and experienced runners consistently seek a new method that can increase their running performance to the fullest potential. For example, the latest trend to hit the performance gear shelve is to wear compression garments (Rider et al., 2014). Moreover, it should be noted that compression garments come with different styles such as sleeves and socks (knee length, thigh length), upper body garments (covering the torso and upper limbs in full or part), lower-body garments (from waist to covering legs in full or part) that are worn with the aim of improving their running performance. In the case of the present study, it must be noted that compression socks (CS) were first introduced as a rehabilitation aid or treatment for patients with a venous disorder such as thrombosis, oedema, and phlebitis.

The CS operates by giving pressure to the surface veins, arteries, and muscles with the aim of forcing the blood to circulate through a narrower channel in order to improve blood flow. In return, this causes arterial pressure to increase and more blood to return to the heart from the limbs. According to Areces et al. (2015), this will enhance venous return blood flow and reduce leg swelling. On a similar note, the compression garments are able to increase

internal compression, which consequently enhances the extrastitial fluid return to the vascular system (Fletcher et al., 2014). More importantly, it is believed that the benefits of CS in the medical setting may produce the same ergogenic benefit in the sports setting. Accordingly, CS was later introduced as a mechanical ergogenic aid for sports, especially for endurance sport with several benefits which include improvement in muscular strength, muscular power, muscular endurance, proprioception, recovery, and injury management.

Regarding this matter, a previous study conducted by Ali et al. (2007) concluded the need to conduct future works that investigate the use of compression socks for other user groups, including untrained participants, females, and older athletes. Apart from that, research done by Struhár et al. (2018) discovered that running experience might be able to minimise the effect of CS. Hence, the objective of the present study was to investigate the effect of compression socks and smooth socks on  $VO_{2max}$  and blood lactate concentration of experienced and novice runners. Moreover, this suggestion was supported by Rider et al. (2014) who stated that the level of training had an influence on the possible effects of wearing CS.

## METHODS

### The Socks

Commercial over-the calf length type CS and SS were obtained from a local sport shop. Some properties of both socks were characterized in the preliminary stage. CS

outperforms SS in terms of total breaking strength with the value of 495.7 N and 399.1 N respectively. Nevertheless, in terms of abrasion resistance, CS were found lower than SS with the weight losses of 0.7 and 0.6 g respectively, after being abraded 10,000 cycles. In water vapour and air permeability tests, the results showed that CS ( $29 \text{ g m}^{-2} \text{ day}^{-1}$  and  $39 \text{ mm s}^{-1}$ ) has lower value than SS ( $57 \text{ g m}^{-2} \text{ day}^{-1}$  and  $77 \text{ mm s}^{-1}$ ) due to the tighter structure of CS.

### Participant Selection

A total of 16 participants that participated in the present study were in the age range of 20-25 ( $M=23.56$ ,  $SD=1.41$  years old). The number of participants was based on the sample size used in the previous study (Rider et al., 2014; Rivas et al., 2017; Struhár et al., 2018). In the case of the current research, the inclusion criteria for experienced runner are as follows: (1) a running history of at least four years, (2) a running volume between 25 and 70km per week during the previous year, and (3) a duration of more than 34 minutes for 10,000m. On the other hand, the followings are the inclusion criteria for novice runner: (1) an absolute beginner with a running volume of less than 5km per week, or (2) no prior running experience. More importantly, all of the participants were required to be free from any injuries within the past six months prior to the testing and healthy with no cardiovascular-related diseases. Other than that, it was also made compulsory for the participants to be free from any alcohol or drug consumption 24 hours before the test and procedure.

### Familiarisation Session

Every participant was required to attend a familiarization session. During the familiarization session, the participant signed the consent form and was familiarized with all the procedures. The height and body mass were also recorded. The diameter of the calf at the widest point and the size of the shoe was taken to determine the correct size of socks for precise compression socks fitting based on the socks manufactures guideline.

### Procedure

In the case of the present study, all participants were required to answer the Physical Activity Readiness Questionnaire (PAR-Q) (American College of Sports Medicine [ACSM], 2014) and pass the resting electrocardiogram (ECG) with no abnormality. In addition, written informed consent was signed by each of the participants prior to the conduct of the test. The study was approved and conducted based on the guidelines set by the board of ethics committee Universiti Teknologi MARA (600-IRMI(5/1/6)REC/228/18). Next, the participants were categorised randomly into two groups using the block list method in order to avoid any possible sequence effect. Furthermore, all participants were required to attend the sports laboratory on two occasions (2 sessions) separated by a gap of seven days in order to omit any carryover effects of fatigue as well as training effects. Accordingly, the participants were asked to refrain from vigorous exercise training sessions 48 hours before the test.

This study was a non-blind ability because the participant will be able to feel when compression socks are being worn and also the difference in effort to put on compression socks and smooth socks. Specifically, this study utilised the crossover design as follows: (1) Group 1 wear the CS for their first session and SS for their second session, and (2) Group 2 wear SS for first session and CS for second session. Other than that, all the participants were asked to eat a similar or identical meal 24 hours before each session as well as required to wear the same clothing and running shoes for each session.

### Testing Session

In the present study, a total of 10 stages were conducted for the Bruce treadmill test in which the first stage started with the walking rate of 2.74 km/h and a gradient set at 10%. Next, it should be noted that the gradient and speed were respectively increased at every level based on Bruce Protocol (Luong et al., 2016). Moreover, the participants were informed to grab onto the treadmill handrails if they need to stop for any reason during the test. Hence, this would serve as a volitional sign to end the test. In this case, the speed of the treadmill was reduced to 2.74 km/h if the participant achieved volitional fatigue or stop the exercise, while the gradient was lowered to 0% which indicates the end of the test. Next, the participants were required to walk for another five minutes for the cooling down process.

### Maximal Oxygen Uptake ( $VO_{2max}$ )

Each participant was fitted with a Polar heart

rate monitor (Polar USA, Lake Success, NY, USA), while an indirect method was adopted in the present study to predict the maximal oxygen uptake (validity  $r=0.96$ ). In addition, the reliability of the test was tested based on Hall-López et al. (2015) with high reproducibility between the two conservative trials ( $r=0.907$ ).

### Blood Lactate (BLa)

The BLa was measured by a qualified lab assistant using accutrend plus meter (Roche, Rotkreuz, Switzerland) with a standard finger-prick method. The blood lactate was taken four times, namely the pre-test, post-test, post 5 minutes, and posts 15 minutes throughout the test. Moreover, the device was considered as a valid ( $r=0.91$ ) and reliable ( $r=0.999$ ) method to measure blood lactate for the sports research field (Baldari et al., 2009).

## RESULTS

The present study conducted a mixed between-within subject analysis of variance with the aim of investigating the blood lactate concentration of the two different groups (novice and experienced) over a four-time period (pre, post, post-5 minutes, and post-15 minutes). However, no significant difference was found for socks condition and blood lactate concentration for both groups of novice runners ( $F(1)= 0.384$ ,  $p=0.545$ ,  $\eta_p^2 = 0.027$ ) and experienced runners, ( $F(1)= 0.136$ ,  $p=0.718$ ,  $\eta_p^2=0.010$ ). Nevertheless, it should be noted that the blood lactate concentration during the recovery period for novice runners was

higher for compression socks (9.9 mmol/L  $\pm$  0.758 mmol/L, CV=7.66%) compared to smooth socks (9.4 mmol/L  $\pm$  0.64 mmol/L, CV=6.81%). On the other hand, the blood lactate concentration during the recovery period for experienced runners was lower for compression socks (11.11 mmol/L  $\pm$  0.64 mmol/L, CV=5.76%) compared to smooth socks (10.8 mmol/L  $\pm$  0.76 mmol/L, CV=7.03%) (Figure 1).

On another note, an independent t-test was conducted to investigate the difference of maximal oxygen uptake between different conditions (CS/SS) of

both groups (Novice/Experience). The results showed a significant difference for socks condition and maximal oxygen uptake for novice runners ( $F(1)= 11.016, p=0.005, \eta_p^2 = 0.440$ ). Specifically, it was observed that the maximal oxygen uptake was higher when wearing a compression socks (44.5 ml/min/kg  $\pm$  1.1 ml/min/kg, CV=2.47%) compared to smooth socks (43.0 ml/min/kg  $\pm$  1.24 ml/min/kg, CV=2.88%). However, no significant difference was detected for the socks condition and maximal oxygen uptake among experienced runners ( $F(1)= 3.75, p=0.073, \eta_p^2 = 0.211$ ). Nevertheless, it

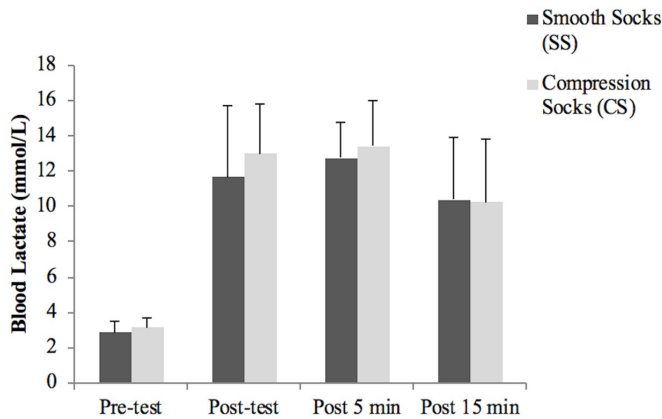


Figure 1. Mean (SD) blood lactate concentration (Novice)

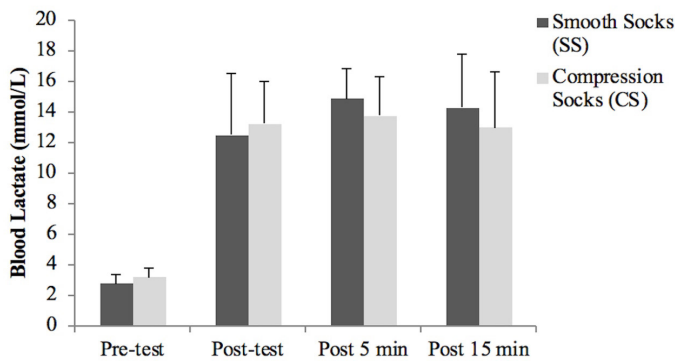


Figure 2. Mean (SD) blood lactate concentration (Experienced)

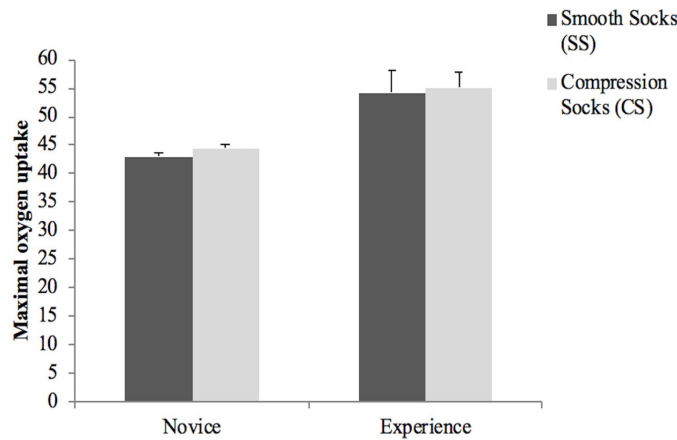


Figure 3. Mean (SD) maximal oxygen uptake by group

is important to note that the maximal oxygen uptake for compression socks (55.1 ml/min/kg  $\pm$  1.09 ml/min/kg, CV=1.98%) was higher than smooth socks (54.3 ml/min/kg  $\pm$  1.24 ml/min/kg, CV=2.28%) (Figure 2 & Figure 3).

## DISCUSSION

### Effect of CS on Blood Lactate Concentration

The ability to maintain adequate circulation plays an important part in the recovery phase which can be achieved by enhancing the elimination of built-up lactic acid. In addition, engineered compression can be applied to exert a controlled external pressure over specific body parts. Furthermore, the recoil force by the elastic fabric with limited stretch during sports is able to trigger an acceleration of venous blood flow which enhances the blood flow and venous return, thus consequently increasing oxygen delivery to working muscles and eliminating lactic acid and waste more rapidly (Liu & Little, 2009). However, no

significant difference was found between both conditions and groups.

The finding of this study is in agreement with a past study conducted by de Glanville and Hamlin (2012) who reported that compression tights were not able to improve blood lactate clearance after aerobic endurance activities (40 km cycling trial). Furthermore, the result of the present study was found to be consistent with the finding by Areces et al. (2015) which reported that compression socks did not prevent exercise-induced muscle damage. Meanwhile, a study was done by Lovell et al. (2011) supported the finding of the current research by revealing that no changes would occur on blood lactate immediately after treadmill running ( $\sim$ 85%  $VO_{2max}$ ) when wearing compression garments. Other than that, similar research on the effect of CS when running 40 min on a treadmill performed by Hsu et al. (2017) found no significant changes in blood lactate.

Furthermore, the results of the present study by the group showed that novice

runners had a higher value of blood lactate concentration when wearing compression socks compared to smooth socks. However, this finding was unexpected and one of the possible explanations that led to this result is that the participants were required to run until they were exhausted.

In other words, novice runners ran on the treadmill for a longer period of time while wearing compression socks, thus causing higher blood lactate due to the longer period spent on running. Most importantly, this finding was supported by Rider et al. (2014) who stated that lower blood lactate levels observed in the CS group condition were resulted from the decrease in time to fatigue (TTF). Hence, it should be understood that more time spent running would increase the blood lactate level. Apart from that, the placebo effect of wearing CS may have taken place because the novice runners ended up running for a longer period of time when wearing compression socks, thus producing a higher blood lactate concentration. In addition, the participants were fully aware of what socks they were wearing due to the compression level. However, the placebo effect still occurred even though a smooth sock was provided to minimise the compression level. Moreover, the use of placebo may have helped in eliminating any bias (consciously or subconsciously).

On the other hand, the findings of the present study showed that experienced runners had a higher value of blood lactate concentration when wearing smooth socks compared to compression socks which is in

addition, a trend of improvement managed to be detected even though the result was non-statistically significant. Nevertheless, several possible explanations may be able to describe the insignificant result. Blood lactate production in the muscle and lactate accumulation in the blood depends on the individual lactate threshold which was not measured in this study.

Besides that, a study on patients with chronic venous insufficiency conducted by Padberg et al. (2004) concluded that six-month structured exercise was able to enhance muscle pump function. Hence, the finding of this study is in agreement with the previous study because it stands to reason that training will result in improved muscle pump function in healthy participants. Therefore, it can be clearly understood that aerobically trained improvement in muscle pump function will leave little room for improvement when wearing CS. Accordingly, this may be the reason that led to no significant changes in their blood lactate due to their well-developed muscle pump function. Finally, the result also suggests that metabolic activity may not be affected by the conditions, while the changes in performance may not be pure as a result of the physiological changes.

### **Effect of CS on Maximal Oxygen Uptake**

Past research that investigated different pressure profile and lower-limbs haemodynamic found that the application of compression garments with light and mild compression profiles was effective

in reducing venous dilation and venous pooling, which also improved venous return in the lower extremities (Liu et al., 2008). Hence, this may also be the mechanism behind the improvement of maximal oxygen uptake in the present study. The finding of this research is consistent with the study conducted by Sperlich et al. (2010) which discovered no significant difference in maximal oxygen uptake in a well-trained athlete when wearing CS. Similarly, research done by Goh et al. (2011) on well-trained middle distance runners and triathlete found no significant difference when wearing various size lower-body compression garments. Meanwhile, research conducted on well-trained endurance athlete by Wahl et al. (2012) revealed no significant difference in maximal oxygen uptake when wearing CS. In addition, this finding is similar to the study of Ali et al. (2011) which found no significant difference in maximal oxygen uptake when wearing CS during a 40 min treadmill run on highly trained runners and triathlete.

Nevertheless, a significant difference in maximal oxygen uptake was found in novice runners when wearing CS. This preliminary finding suggests that the effectiveness of CS may be influenced by the experience level because CS only affected novice runners. A possible explanation for this may refer to the method used in predicting  $VO_{2max}$  which was based on time to exhaustion. Hence, it can be concluded that the placebo effect may have taken place on novice runners when running despite the randomised sequence of condition that was aimed to reduce the

sequence effect. Meanwhile, it is crucial to note that novice runners may be affected by psychological factors of wearing CS which caused the increase in the running time when wearing CS.

Apart from that, several physiological factors may have influenced the increased value of  $VO_{2max}$ . Specifically, the mechanism behind the improvement of  $VO_{2max}$  in novice runners when wearing compression socks may be caused by the increase of blood flow and stroke volume which led to higher cardiac output. Higher cardiac output is linearly related to  $VO_{2max}$ . This finding is supported by a study conducted by Mann et al. (2016) on the effects of compression socks on arterial blood flow and arterial reserves in amateur sportsmen.

Meanwhile, a study by Dascombe et al. (2011) suggested that the use of CS facilitated a small number of cardiorespiratory and peripheral physiological benefits which were mostly related to the improvement of venous flow. The present study employed an indirect method to predict the maximal oxygen uptake using a formula from the total running time. Nevertheless, a direct method (collecting expired air) may produce more precise data despite the fact that several past research agreed that the indirect method is a reliable technique that can predict maximal oxygen uptake.

On another note, no significant difference was discovered in the maximal oxygen uptake for experienced runners. However, the result of  $VO_{2max}$  for experienced runners showed a non-statistically trend of improvement. In the present study, the total



running time was utilised as a prediction formula for the maximal oxygen uptake. In this case, experienced runners may not be affected by the placebo effect because they ran until maximum exhaustion for both conditions. Hence, this explains why there was no significant difference in the maximal oxygen uptake due to the same total running time for both conditions. Apart from that, the number of participants in the present study was limited, thus restricting the statistical power. Hence, it should be understood that a larger sample size would produce greater statistical power. In addition, the findings from the current study also suggested that experience runners should employ the use of compression socks in order to gain a faster improvement in their running performance. Nevertheless, the trend of improvement indicates that the maximal oxygen uptake may be affected by CS even though the improvement was not statistically significant. A past study concluded that it is not harmful to wear CS and every runner would do anything to gain some slight advantage over their opponents. The findings of the current study suggest that runners should employ the use of compression socks in order to gain a faster running performance, especially in the cardiorespiratory component.

## CONCLUSION

The present study examined the effect of CS on runners while running. In addition, the effect of wearing compression socks while running on the running parameters in novice and experienced runners were

tested, particularly in terms of blood lactate concentration and maximal oxygen uptake. The statistical analysis of the current research concluded no significant changes in wearing compression socks on blood lactate concentration both on novice and experienced runners. However, a significant difference in maximal oxygen uptake was discovered in novice runners when wearing compression socks.

Furthermore, the present study was the first of its kind known by the author which made the author select two different levels of runners, namely novice and experienced runners because previous findings indicated that compression socks improved performance outcomes. In addition, it is possible for the outcomes to vary if the number of participants is larger, while the criteria of the novice runners should be more elaborated (not active in other sports). Regardless, the results of the present study emphasised on the increase of the maximal oxygen uptake among novice runners but it was counterproductive for the experienced runners when wearing compression socks during running. Overall, this suggests that there is a possibility of some positive changes in the cardiorespiratory components of novice runners.

## RECOMMENDATIONS

The current research was limited in several ways due to the numerous types of compression garments available in the market which include hand sleeve, shorts, calf sleeve and upper body garments. Hence, it is impossible to generalise the effect of

the compression garments considering the fact that a specific type of compression garment may produce a different result. Apart from that, it is important to note that these compression garments are made using different materials and various technical designs depending on the manufacturer itself. Therefore, future research should be carried out to investigate different types of garments and it is also important to consider the different types of material.

Furthermore, a further study can usefully explore different types of compression level because it may produce a different result. In addition, it would be interesting to understand the effect of a certain pressure on the running performance itself. Other than that, future study should also take consideration of the age and gender of the participant because there is a scarce number of studies that investigate the effect of CS on youth and women.

Future research will have to be conducted in order to determine different running protocol considering the existence of numerous running protocols which can either be outdoor or lab-based protocol. The present study employed the Bruce maximal treadmill run which was a lab-based protocol as the running protocol. However, this running environment may not simulate a real race environment which might pose different effects on the participants' performance. Hence, future work should also take into consideration the running time and recovery time. A new study on the effect of CS on a longer period of running time should be

proposed with an emphasis on the recovery time period.

Another possible area of future research would be to investigate the factors contributing to the improved performance by adopting more extensive physiological parameters such as venous return and inflammatory markers that were not investigated in the present study. Apart from that, further investigation should also be carried out on novice runners with more elaborated criteria (does not play other sport) in order to gain a greater understanding on the effect of compression on muscle pump function.

## ACKNOWLEDGEMENTS

Special thanks to Lestari Grant UiTM (600-IRMI/Dana KCM 5/3/LESTARI (112/2017) for funding this research and we are grateful to those participants who contributed their time and helped to make this research possible.

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