

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**PERFORMANCE, PHYSIOLOGICAL, AND PERCEPTUAL EFFECTS OF
WEARING GRADUATED COMPRESSION STOCKINGS DURING RUNNING**

A thesis presented in partial fulfilment of the requirements for a degree of Master of
Science in Sport and Exercise Science at Massey University, Auckland, New Zealand.

ROBERT CREASY

2008

PERFORMANCE, PHYSIOLOGICAL, AND PERCEPTUAL EFFECTS OF
WEARING GRADUATED COMPRESSION STOCKINGS DURING RUNNING

Purpose: The aims of these studies were to examine the effects of wearing different grades of graduated compression stockings (GCS) on performance, physiological, and perceptual measures before, during, and after exercise in well-trained runners. **Method:** Two separate running studies were conducted where participants wore different grades of GCS compared with a placebo control stocking in random, counter-balanced order: (1) a field study focussed on a series of 10-km running performances on a 400m track; (2) a laboratory study that examined the effects of 40-min treadmill running on physiological, perceptual, and muscle function responses. Changes in muscle function and damage were determined pre- and post-run by measuring creatine kinase (CK) and myoglobin (Mb) concentrations, counter-movement jump (CMJ) height, muscle soreness, and pressure sensitivity. Physiological measurements of heart rate (HR), oxygen uptake ($\dot{V}O_2$), blood lactate concentration [La], and ratings of perceived exertion (RPE) were measured during running. Pre- and post-run perceptual scales assessed comfort, tightness and pain associated with wearing GCS. **Results:** There were no significant differences in 10-km run time, mean HR, $\dot{V}O_2$, [La], and RPE for participants wearing different GCS in (1) and (2) ($P < 0.05$). Con and Low were rated most comfortable ($P < 0.05$) and Hi were tightest ($P < 0.05$) and induced more pain ($P < 0.05$) when GCS were compared in both studies. CMJ was better in participants wearing Low and Med GCS post-run compared with Con in (1) and for Con and all GCS at 0 h post-exercise in (2). CK and Mb levels were higher ($P < 0.05$) and pressure sensitivity was more pronounced ($P < 0.05$) at 0 h post-run for Con and all GCS (2). Few participants (4/10) reported muscle soreness at any one location in (2). **Conclusions:** Well-trained runners did not experience improved performance, physiological, or perceptual responses when wearing different grades of GCS during 10-km track or 40 min treadmill running compared with a control garment. 40 min treadmill running at 80% $\dot{V}O_2$ max may not be strenuous enough to elicit a loss of muscle function in well-trained runners. Runners felt more comfortable wearing GCS that had less compression.

ACKNOWLEDGEMENTS

Thank you so much to all the athletes who participated in these two studies. Your blood, sweat, energy and time have written these pages. It has been a pleasure to work with all of you.

Thank you very much to Dr Ajmol Ali; initially for offering me the scholarship to study at Massey University, and more importantly for his advice, wisdom and patience in taking me on and leading me through the learning process to complete this research. Without his efforts none of this would have happened.

Thank you to Dr Johann Edge for his advice and assistance during all parts of the study. I have greatly appreciated your opinions and help.

Thank you also to all those who offered their time as research assistants in the lab: Helen Ryan, Stuart Mitchley, Simon Bennetts, and Jasmine Thompson. I enjoyed the time and learning experiences I spent with you all.

Rob Creasy

December 2008

CONTENTS

PERFORMANCE, PHYSIOLOGICAL, AND PERCEPTUAL EFFECTS OF WEARING GRADUATED COMPRESSION STOCKINGS DURING RUNNING	2
ACKNOWLEDGEMENTS	3
LIST OF TABLES	10
LIST OF FIGURES	12
1.0 GENERAL INTRODUCTION.....	1
2.0 REVIEW OF LITERATURE	5
2.1 Graduated Compression Stockings.....	5
History.....	6
2.2 Running Performance	12
Endurance Running.....	12
Leg Power	13
2.3 Mechanisms of Action	14
Muscle Soreness and Damage	15
Muscle Fatigue.....	24
Venous Return	26

Blood Lactate Clearance	28
Thermoregulation.....	31
$\dot{V}O_2$ Kinetics.....	31
Perception	34
2.4 Types of Sport.....	35
Endurance Sports	35
Jumping and Sprinting Sports.....	36
Team Sports	37
2.5 User Groups	38
Elderly.....	38
Untrained.....	39
2.6 Summary	40
3.0 GENERAL METHODS.....	42
Preliminary Procedures.....	42
Graduated Compression Stockings.....	42
Muscle Function.....	46

Physiological Measures	51
Perceptual Measures	56
10-km Time Trial Running.....	57
Treadmill Running.....	58
Concurrent $\dot{V}O_2$, max and Lactate Test	58
Statistical Analysis.....	59
4.0 THE EFFECTS OF GRADUATED COMPRESSION STOCKINGS ON RUNNING PERFORMANCE.....	61
4.1 Abstract.....	61
4.2 Introduction.....	62
4.3 Methods.....	65
Participants.....	65
Preliminary Procedures.....	66
Experimental Procedures	68
Statistical Analyses	71
4.4 Results.....	72
Performance Data.....	73

Physiological Data	75
Perceptual Data	75
4.5 Discussion.....	80
Conclusion	85
5.0 THE PHYSIOLOGICAL AND PERCEPTUAL EFFECTS OF WEARING GRADUATED COMPRESSION STOCKINGS DURING RUNNING	86
5.1 Abstract.....	86
5.2 Introduction.....	87
5.3 Methods.....	91
Participants.....	91
Experimental Measurements.....	92
Preliminary Procedures	95
Experimental Procedures	95
Blood sampling and analyses.....	97
Statistical Analyses	97
5.4 Results.....	100
Muscle Function.....	101

Physiological Data	107
Blood Analyses	110
Perceptual Data	112
5.5 Discussion.....	116
6.0 GENERAL DISCUSSION	123
7.0 REFERENCES	130
8.0 APPENDICES	153
Appendix 1.....	154
Appendix 2.....	156
Appendix 3.....	157
Appendix 4.....	158
Appendix 5.....	159
Appendix 6.....	160
Appendix 7.....	161
Appendix 8.....	162
Appendix 9.....	164
Appendix 10.....	167

Appendix 11.....	169
Appendix 12.....	174
Appendix 13.....	178
Appendix 14.....	180
Appendix 15.....	182
Appendix 16.....	183

LIST OF TABLES

Table 3.1: Compression applied by GCS at the ankle and below the knee according to manufacturers guidelines when fitted correctly from sizing chart.

Table 4.1: Anthropometric measures and performance characteristics of participants determined by a concurrent $\dot{V}O_2$ max and lactate test.

Table 4.2: Maximum counter-movement jump height (mean \pm SD) achieved over three attempts before and after 10-km time trial running wearing different GCS.

Table 4.3: Changes in blood lactate concentration ($\text{mmol}\cdot\text{L}^{-1}$) from pre- to post- 10-km run and heart rate at each 2-km mark of the time trial run for participants wearing GCS (mean \pm SD).

Table 4.4: Subjective perceptions of exertion (RPE), pleasure-displeasure (Feeling Scale), and activation (Felt Arousal Scale) experienced by participants wearing GCS (mean \pm SD).

Table 5.1: Anthropometric measures and performance characteristics of participants determined by a concurrent $\dot{V}O_2$ max and lactate test.

Table 5.2: Compression applied by GCS at the ankle and below the knee according to manufacturer's guidelines when fitted correctly from sizing chart.

Table 5.3: Subjective perceptions of pleasure/displeasure (Feeling Scale), and perceived activation (Felt Arousal Scale) experienced by participants during each trial (mean \pm SD).

LIST OF FIGURES

Figure 3.1: GCS correctly fitted over legs flush under the knee and smoothed to avoid bunching.

Figure 3.2: Compression level measured at the ankle using a pressure bladder connected to a digital meter.

Figure 3.3: Pressure sensitivity measured at the lateral head of the left gastrocnemius muscle using a pressure algometer.

Figure 3.4: Venous blood sampled from the right antecubital vein for creatine kinase and myoglobin analysis.

Figure 4.1: Experimental protocol for each 10-km time trial run.

Figure 4.2: Performance time for participants completing 10-km time trials wearing different GCS (mean \pm 95% CI).

Figure 4.3: Change in counter-movement jump height (cm) from pre- to post-10-km time trial runs for participants wearing GCS (mean \pm 95% CI).

Figure 4.4: Perceived GCS comfort recorded pre- and post-10-km running time trials for participants wearing different GCS (mean \pm 95% CI).

Figure 4.5: Perceived GCS tightness recorded pre- and post-10-km running time trials for participants wearing different GCS (mean \pm 95% CI).

Figure 4.6: Perceived pain for participants wearing GCS pre- and post-10-km running time trials (mean \pm 95% CI).

Figure 5.1: Breath-by-breath gas analysis and heart rate recorded during 40-min treadmill running wearing GCS.

Figure 5.2: Experimental protocol for 40-min treadmill running

Figure 5.3: Counter-movement jump height measured at pre-, 0 h post-, 24 h post-, and 48 h post-run for each GCS intervention (mean \pm 95% CI).

Figure 5.4: Peak leg power calculated from jump height at pre-exercise and 0, 24, and 48 h post-run for each GCS intervention (mean \pm 95% CI).

Figure 5.5a: Location and frequency of muscle soreness during the Con trial only

Figure 5.5b: Location and frequency of muscle soreness during the Low GCS trial only

Figure 5.5c: Location and frequency of muscle soreness during the Hi GCS trial only

Figure 5.6: Mean pressure sensitivity as measured by pressure algometer during each trial (left and right legs combined for each trial; mean \pm 95% CI).

Figure 5.7: Oxygen uptake ($\dot{V}O_2$) for each 5-min block of treadmill running during each trial (mean \pm 95% CI).

Figure 5.8: Heart rate for each 5-min block of treadmill running during each trial (mean \pm 95% CI)

Figure 5.9: Blood lactate concentration ($\text{mmol}\cdot\text{L}^{-1}$) at rest, during treadmill running at each 5-min block and immediately post-exercise (mean \pm 95% CI).

Figure 5.10: Mean (\pm 95% CI) Creatine Kinase levels during each trial; ⁺main effect of time, significantly higher than pre-run $P<0.001$).

Figure 5.11: Mean (\pm 95% CI) Myoglobin levels during each trial; *main effect of time, significantly higher than all time points $P<0.05$).

Figure 5.12: RPE at each 5-min block of treadmill running for participants wearing different GCS interventions (mean \pm 95% CI)

Figure 5.13: Ratings of perceived comfort pre- and post-run for participants wearing different GCS (mean \pm 95% CI).

Figure 5.14: Ratings of perceived tightness pre- and post-run for participants wearing different GCS (mean \pm 95% CI).

Figure 5.15: Ratings of perceived pain pre- and post-run for participants wearing different GCS (mean \pm 95% CI).