Effects of a long term exercise program on lower limb mobility in peripheral arterial disease patients

Thesis submitted by

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Declaration of ethics

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National Statement on Ethics Conduct in Research Involving Human (1999)*, the *Joint NHMRC/AVCC Statement and Guidelines on Research Practice (1997)*, the *James Cook University Statement and Guidelines on Research Practice (2001)*. The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (approval number H2395).

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Signature Date

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Abstract

Peripheral arterial disease (PAD) is a chronic arterial occlusive disease of the lower extremities caused by atherosclerosis. The most common presenting symptom of PAD is intermittent claudication (IC) with exercise induced pain experienced in the calves, thighs or buttocks that is relieved with rest. Research investigating the effects of PAD-IC on lower limb mobility is limited to five studies on the temporal-spatial gait parameters (e.g. stride length, cadence, support times, speed) in PAD-IC populations that produced conflicting results. Gardner et al. (2001) speculated that the temporal-spatial gait parameters of individuals with PAD-IC could be improved by participation in exercise programs. To date there has been no attempt to determine the validity of this proposition. There has also been no research on the underlying mechanism of these temporal-spatial gait parameters namely gait kinematics (angular joint displacement, velocity and acceleration). Observed limitations in temporal-spatial gait parameters may be explained by the effects of musculoskeletal abnormalities on lower limb joint kinematics during the gait cycle. Understanding of the relationships between temporal-spatial gait parameters and gait kinematics in PAD-IC allows more precise identification of gait abnormality and its effects on lower limb mobility in this population. Analysis of variability in gait kinematics is becoming more commonly used as a clinical tool for evaluation of lower limb mobility in the elderly, lower limb disease populations and individual responses to exercise programs. Increased movement variability in lower limb kinematics has been traditionally associated with decreased movement performance due to disease and aging. However, more recent research from a dynamical systems perspective has indicated that movement variability may be of functional importance in motor control and may provide flexibility when adjusting to movement constraints imposed by disease.

Therefore, for the purposes of this thesis, a series of studies were undertaken to investigate 1) the temporal-spatial gait parameters, gait kinematics, lower limb movement variability, walking performance, physiological responses to exercise and physical activity levels of individuals with and without PAD-IC and 2) the effects of a long term exercise program on these same variables in individuals with PAD-IC compared to individuals with and without PAD-IC.

Study 1 (Chapter 3) examined the lower limb mobility characteristics (temporal-spatial gait parameters and gait kinematics) of individuals with PAD-IC and the relationships between lower limb mobility, walking performance, physiological responses to exercise and physical activity levels in this population. Study 2 (Chapters 4 & 5) assessed intralimb joint coordination and single joint movement variability in patients with PAD-IC and without PAD-IC (CON). Lower limb mobility characteristics were determined via 2D motion analysis. A graded treadmill test was used to assess walking performance (pain free walking distance/time (PFWD/T) and maximal walking distance/time (MWD/T) and peak physiological responses to exercise (VO_{2peak}, HR_{peak}, RER_{peak} and VE_{peak}). Physical activity levels were measured via a 7 d pedometer recording following motion analysis. Intralimb coordination variability was measured using parameterization, vector coding and normalized root mean square techniques applied to relative motion plots of various joint couplings. Single joint movement variability was measured using spanning set and coefficient of variation. Study 3 (Chapter 6) examined the effects of a 12 mth exercise program on the lower limb mobility of individuals with PAD-IC. A further aim was to examine the extent to which lower limb mobility contributes to long term exercise induced changes in walking performance, peak physiological responses to exercise and physical activity levels in PAD-IC patients.

Finally study 4 (Chapter 7) investigated the effects of a 12 mth exercise program on walking performance and lower limb movement variability using intralimb joint coordination and single joint assessment techniques in individuals with and without PAD-IC.

Compared to CON, PAD-IC temporal-spatial gait parameters were significantly lower ($P < .05$), except for single support ipsilateral limb time. PAD-IC participants spent a greater percentage of time in gait support phases, took longer to complete a stride and had reduced stride length and walking speeds during the gait cycle. Participants with PAD-IC joint angular kinematics showed significantly reduced displacement of ankle plantar flexion ($P = .017$), knee ROM ($P = .021$) and hip extension ($P = .016$) compared to the CON participants during the gait cycle. All joint minimum and maximum angular velocities and accelerations, physiological responses to exercise (walking) and physical activity levels were significantly lower for PAD-IC compared to the CON participants. The PAD-IC participants displayed significantly higher levels of lower limb movement variability in all joints when assessed using the intralimb joint coordination and single joint movement variability techniques.

The 12 mth exercise program had no significant effect on lower limb mobility, peak physiological responses to exercise or physical activity levels in PAD-IC patients who received normal medical therapy treatment and a 12 mth exercise program (TPAD-IC) compared to PAD-IC patients who received normal medical therapy (CPAD-IC) . However, the TPAD-IC participants demonstrated significantly greater walking performance (171% improvement in PFWT and 120% improvement in MWT) compared with baseline. The 12 mth supervised exercise program made no significant

impact on the lower limb movement variability of the TPAD-IC group as determined by either intralimb joint coordination or single joint analysis techniques.

The results of these studies show that patients with PAD-IC have reduced lower limb mobility (temporal-spatial gait parameters and gait kinematics) and increased lower limb movement variability. The derived gait kinematics highlighted that the push-off (or toe-off) of the gait cycle in PAD-IC patients is significantly reduced compared to healthy age matched controls. The increased level of lower limb movement variability may be an adaptation to the gradual onset of claudication pain in this population. Patients with PAD-IC also demonstrated reduced walking performance, peak physiological responses to exercise and physical activity levels compared to healthy age matched controls. PAD-IC patients involved in a 12 mth supervised exercise program exhibited no change in lower limb mobility characteristics, physiological responses to exercise or physical activity levels. Gardner et al.'s (2001) speculation that the reduced temporal-spatial gait parameters of PAD-IC patients could be modified to resemble that of age matched controls through the use of an exercise program was not supported by the data. However, a 12 mth supervised exercise program did cause a significant improvement in walking performance in this population sample. It is suggested that the improvement in walking performance may be due at least in part, to adaptation of peripheral physiological mechanisms.

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