nt J Sports Med
DOI: 10.1055/s-0042-121261

Physiology & Biochemistry

Effects of Resistance Band Exercise on Vascular Activity and Fitness in Older Adults

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Abstract

This study investigated the effects of a low to moderately intense resistance-band exercise intervention on cutaneous microvascular function in an older population. 18 sedentary healthy participants (age: 58±5) were assessed for their upper and lower-limb endothelial cutaneous vascular conductance using laser Doppler fluximetry with endothelial-dependent (80 µl acetylcholine chloride), and -independent vasodilation (80 µl sodium nitroprusside). In addition, participants underwent a range of functional assessments (cardiopulmonary fitness, strength, flexibility), and completed a perceived quality of life questionnaire. Participants were randomised into 2 groups: Exercise (EX) and Control (CON), and followed either an 8-week self-supervised home-based resistance-band intervention or maintained their habitual lifestyle. Following post-intervention assessment (n=16; EX=7, CON=9), EX improved acetylcholine-chloride-mediated endothelial-dependent vasodilation within the lower limb (cutaneous vascular conductance at 2 000 µCb; P<0.01), but without associated changes in the upper limb. Exercise, compared to CON, significantly affected sodium-nitroprusside-mediated independent vasodilation in the upper limb (P<0.01) at 2 000 µCb, but without associated changes in the lower limb. Of functional assessments, only lower limb strength and flexibility improved for EX (P<0.05). EX experienced positive changes within global measures of General Health, Bodily Pain and Energy/Fatigue (P<0.05). An 8-week home-based resistance-band exercise programme improves age-provoked microcirculatory endothelial vasodilation, but without concomitant changes in cardiopulmonary and anthropometric measures.

Key words

microcirculation - fitness assessment - resistance training - endothelium - ageing

Introduction

It has been well documented that the structural and functional integrity of the microcirculation to maintain blood flow, tissue oxygenation, and nutrient delivery appear to be among the factors that affect tissue viability and susceptibility in a range of diseases and conditions [18]. Endothelial dysfunction, an attenuated vasodilator response in the vasculature [13], is considered an early and important promoter for atherosclerosis and thrombosis, and thus contributes to the occurrence of cardiovascular events [22]. In addition, skin microvessel vasodilator dysfunction might also render the aged more vulnerable to heat-related illness and injury during exposure to elevated environmental temperatures.

It therefore appears necessary to identify strategies that can attenuate these mechanisms and improve long-term health. Exercise appears to provide an effective response to the problem – for example 2 recent studies investigating the effects of aerobic exercise training (brisk walking) on lower-limb cutaneous microvascular function in post-surgical varicose-vein patients, found that the short-term [30] and long-term [31] effects of walking exercise improved microvascular endothelial function (ACh responsiveness). This adaptation might be clinically meaningful with respect to the risk of venous ulceration, whereas other studies have shown that exercise improves age-related decline in microvascular function in older populations [4] [40]. We have also identified that aerobic exercise alone, and in combination with a Mediterranean-based nutritional strategy, attenuates microvascular dysfunction and promotes functional integrity [28].

Given the global health benefits of resistance training to the ageing adult population [24], it has become an integral component of exercise recommendations endorsed by a number of national organisations [1]. Resistance training has beneficial effects on the musculoskeletal system, thereby contributing to the maintenance of functional capacity and prevention of sarcopenia and osteoporosis. Previous research has noted improvement in endothelial responsiveness following a period of resistance-based exercise [5] [37], whereas others have noted that such changes are dependent on volume, frequency and intensity level [7] [26] [35] [42].

However, resistance training interventions have been associated with reduced compliance and increased arterial stiffness in the central elastic artery [26], with increased arterial stiffness and reduced arterial compliance being associated with endothelial dysfunction [8] [36]. Indeed, impaired endothelial function and arterial stiffening are induced with advancing age and in the presence of cardiovascular diseases [35]. Such deleterious effects of vascular architecture and structure however are typically seen in resistance programmes high in volume, frequency and/or intensity, as well as those that have undertaken moderate to high resistance training over sustained periods (≥6 months) [35]. Contrary to this analysis, less is known regarding microcirculatory endothelial function during lower intensity short-term whole-body resistance exercise that incorporates a degree of cardiovascular (aerobic) strain.

It may be hypothesised therefore that selecting whole-body resistance regimes at intensities previously shown not to induce arterial non-compliance [7] [26], but which incorporate a degree of cardiovascular stress that has been shown to attenuate endothelial dysfunction [28] may have a positive impact on microcirculatory integrity. Few studies to date have implemented such lower-intensity whole-body resistance interventions in otherwise healthy ageing groups (>50 years) with respect to impact on endothelial function. In addition to possible positive effects on vascular activity, such regimes, delivered in a safe and accessible environment [14] [27], may also act to reduce age-related sarcopenia through improved functional physical capacity and positively impact overall quality of life [1].

This being the case, the study aim was to investigate the short-term effects of a low to moderately intense resistance-band-based intervention that combined whole body activity on lower- and upper-limb cutaneous microvascular function, functional fitness capacity, and quality of life in a healthy sedentary older adult population.

Materials and Methods

Participants

18 healthy participants were recruited via electronic posters, radio announcements and word of mouth. All participants were required to be over 50 years of age, normotensive, non-smokers, sedentary and not taking any regular medications. Sedentary status was defined as participants not being engaged in purposeful physical activity with the intention of improving physical fitness for at least 6 months. Participants with past venous ulceration, lower-limb arterial disease, hypercholesterolemia, peripheral oedema or cardiac failure, and those with major skin changes in the gaiter area were excluded as well as those who were engaged in any form of regular exercise. Participants were asked to refrain from any regular or structured exercise activities outside the requirements of the study for the duration of their involvement.

The study was approved by the School of Sport and Exercise Science ethics committee in line with the Helsinki Declarations for research with human volunteers and all participants gave their written, informed consent to participate. This study meets the ethical standards of the Journal [20]. Baseline outcome measures where then assessed (see below). Sample size calculations using the equation proposed by Hopkins [23] were based on the 8-week exercise training response in cutaneous vascular conductance (CVC at 2 000 µCb) for ACh and SNP [28]. Outcome measures were assessed at baseline and following the 8-week intervention period. Participants were fully habituated with all assessment protocols prior to baseline data collection. Participants were instructed not to perform any exercise in the 24 h before an assessment and to abstain from caffeine for at least 2 h before an assessment. Participant characteristics are shown in[Table 1]. There were no significant differences at baseline between the groups with respect to demographics, anthropometrics, and measures of functional fitness.

Table 1 Participant demographics at the commencement of the study (values are presented in mean±SD).

Variable	Exercise Group	Control
Gender (n) (Female/male)	7/0	7/2
Age (year)	56.1±4.5	59.0±5.9
Body mass (kg)	69.5±23.6	75.9±8.2
Stature (m)	1.63±0.09	1.63±0.04
MAP (mean arterial pressure) (mmHg)	94.3±3.3	97.0±6.3
Systolic pressure (mmHg)	132.4±7.6	131.9±10.0
Diastolic pressure (mmHg)	75.3±2.6	80.1±7.2

Procedures

Cutaneous microvascular assessment

All microvascular assessments were performed in a temperature-controlled room (range 22–24°C) following an acclimatisation period ≥10 min. With the participant lying supine, the gaiter area of the left leg was cleaned with an alcohol wipe and allowed to dry before applying 2 Perspex iontophoresis chambers to the skin surface 4–8 cm proximal to the medial malleolus. The chambers were positioned approximately 4 cm apart, with one containing 80 µl of the endothelium-dependent vasodilator, acetylcholine chloride (ACh; Miochol-E, Novartis, Stein, Switzerland), and the other 80 µl of the endothelium-independent vasodilator, sodium nitroprusside (SNP; Rottapharm, S.L., Barcelona, Spain). Drug concentrations of 10 g^{-1} were used with deionised water as the solvent. The laser Doppler probe was positioned through the centre of each chamber. Laser Doppler fluximetry (LDF) measurements were made using the moorVMS-LDF2 (Moor Instruments, Axminster, UK) system and included skin temperature, flux, and microvascular dose-response curves for each of the 4 iontophoretic challenges obtained. A battery-powered iontophoresis controller (MIC2; Moor Instruments) was used to provide the charge needed for ACh and SNP delivery. The anodal (positive) current was used to transfer ACh, with the cathodal (negative) current used to transfer SNP.

After achieving a stable recording of baseline flux, LDF responses to ACh and SNP were measured using an incremental-dose iontophoresis protocol as previously described [29]. In brief, dose-response curves for ACh- and SNP-induced vasodilation were characterised using the following procedure to apply incremental charge-stimuli: 25 µA applied for 10 s (i. e., 250 µCb), 50 µA for 10 s (500 µCb), 100 µA for 10 s (1000 µCb), and 100 µA for 20 s (2 000 µCb), with a 4-min recording period between each dose. This protocol was chosen because it is sufficient to provide effective ACh and SNP delivery while largely avoiding the non-specific vasodilation observed with higher electrical charges with satisfactory reproducibility both in patient and healthy populations.

Thereafter, following a 10-min recovery period, the protocol was repeated with the probes attached on the ventral surface of the right forearm of each participant to establish a baseline for the upper-limb cutaneous microvascular function. The protocol was repeated on the participants' following visit. Skin temperatures were continuously recorded using temperature sensors that are part of the laser Doppler probes to ensure stability in measurement conditions. Additionally, the laser Doppler probes used for each drug were alternated at each test. Heart rate and blood pressure (contralateral arm to avoid occlusion-related alterations in skin blood flow for the experimental arm (Dash 2500, GE Healthcare, USA) were recorded throughout the protocol. There were no adverse effects in any of the assessment trials.

Anthropometric assessment

For the measurements of mass (kg) and stature (cm), standardised procedures were deployed [17]. Following the acclimatisation period (≥10 min) and before the commencement of the microvascular assessment, body composition was recorded in the supine position by way of the bioelectrical impedance method adhering to procedures previously described [17].

Functional capacity assessment

Cardiopulmonary exercise assessment

All participants were assessed for their cardiopulmonary response during a submaximal incremental exercise test on a treadmill (Cosmos HP Mercury 5.0, Nussdorf-Traunstein, Germany). Participants' responses (i. e., oxygen uptake $\dot{V}O_2$, carbon dioxide production $\dot{V}CO_2$, and respiratory exchange ratio (RER)) were continuously measured breath by breath using an online gas analyzer (Metalyzer Cortex 3B, Leipzig, Germany). Flow sensor and gas analyzers using gases of known concentration (16% for O_2, and 5% for CO_2), and a 3 L gas volume syringe were calibrated prior to each test. The incremental test protocol started with 3.0 $km.h^{-1}$, and was increased by 1.0 $km.h^{-1}$ every 3 min until reaching the test termination criteria defined as reaching RER=1.0 and 85% of age-predicted maximal heart rate, to avoid any presence of low peak RER [3]. Further, the rating of perceived exertion (RPE) Borg Scale was used to ensure subjective perception of exercise exertion was monitored throughout.

Maximal strength assessment

Maximal grip strength of the dominant hand was measured in kg using a standard adjustable digital hand-grip dynamometer (Takei Scientific Instruments Co. Ltd, Japan). Participants held the dynamometer at a standing position with the shoulder adducted and neutrally rotated and the elbow in full extension. The participants were instructed to apply maximum force to the dynamometer whilst moving the arm down to the waist. 3 attempts separated by 30 s rest were performed with the highest being used for subsequent data analysis.

Strength endurance assessment

The knee push-up test and squat test were performed to assess strength endurance. For both, test procedures outlined by Colado and Triplett [10] were adhered to, which involved maximal obtainable repetitions on the push-up test and maximal repetitions within 1 min for the squat test.

Functional balance, mobility and flexibility

Conducted in a standing position, the functional reach test was performed using procedures described by Capodaglio et al. [6]. The sit-and-reach test was performed by participants whilst sitting upright on the floor with their legs extended and feet dorsi-flexed and placed against a measurement box. Participants' then reached forward with their arms extended past their feet as far as possible and the distance in cm from or past the participants' feet was measured. For both tests, the longest of 3 reaches was used for data analysis.

Quality of Life (SF-36) assessment

To assess Quality of Life (QOL), a RAND 36-Item Short Form Health Survey (SF-36) was administered to each participant pre- and post-intervention [21]. The SF-36 has 8 scored dimensions: Physical

Functioning (10 items), Role Limitations Due to Physical Health (4 items), Bodily Pain (2 items), General Health (5 items), Emotional Well-being (5 items), Role Limitations Due to Emotional Problems (3 items), Social Functioning (2 items) and Energy/Fatigue (4 items). High scores (0–100) in each dimension suggest a better perceived health status. [RAND Health. The RAND 36-Item Short Form Health Survey. (2015). On Internet: rand.org/health/surveys_tools/mos/36-item-short-form/survey-instrument.html (accessed 21 July 2015)].

Resistance exercise intervention

Upon completion of all baseline assessments, participants were randomly assigned into one of 2 groups: i) exercise (8-week home-based resistance-exercise programme (24-session)), or ii) control (maintenance of normal sedentary habitual lifestyle). All activity within both groups across the 8-week period was self-recorded using pre-structured activity diaries. This was to ensure that i) the exercise intervention was completed, and ii) the control group activity remained sedentary and unchanged from their previous habitual patterns of activity.

The programme consisted of 3 resistance-band training sessions per week. 2 separate exercise sessions, each consisting of 6 carefully selected exercises targeting the major muscle groups of the body, were rotated on a session-by-session basis throughout the intervention period. Session A exercises consisted of: 1) squat (hip-width stance), 2) stiff leg deadlift, 3) reverse flies, 4) chest press, 5) side lateral raise, and 6) biceps curl. Session B exercises consisted of: 1) wide-stance squat (double of hip-width stance), 2) hip abduction, 3) bent-over row, 4) chest flies, 5) overhead press, and 6) elbow kick-back. Each session was approximately 30 min in duration excluding periods for warm-up and cool-down. Resistance was achieved using a range of latex elastic bands (Therabands™, The Hygenic Corporation, USA) where resistance level was determined from band colour (resistance level: yellow>red>green>blue>black [38]) and symmetrical marked numbers at 5-cm intervals (1–10) on each band. The outermost section of each band was given a rating of '1' indicating the lowest resistance level of the band. Corresponding numbers toward the centre of the band were marked at 5-cm intervals up to a rating of '10', which indicated the highest resistance level of the band. During the familiarisation session, a band colour and grip rating (1–10) for each exercise was chosen which allowed participants to perform 20 repetitions that corresponded with low to moderate intensity. To achieve this, an OMNI-Resistance Exercise Scale (OMNI-RES) was used, which provides the means of gauging perceived exertion/intensity and establishing progression throughout the programme [9]. During the course of the 8-week programme, participants were encouraged to increase band resistance in order to stay at this required intensity level of exertion for the required repetition range (15–20) for each set of exercises. During the first 4 weeks of the programme, participants were instructed to perform 2 sets of exercise at an exertion level of 6, 'somewhat hard'. Whereas for the final 4 weeks participants were asked to perform 3 sets at an OMNI-RES rating of 8 'hard' (moderate), thereby ensuring progression of both intensity and volume. A 30-s rest period was advised between each set of exercises.

Prior to intervention initiation all participants within the exercise group attended a familiarisation session where the programme structure and objectives were discussed, instruction was provided for all featured exercises and appropriate band resistances were assigned. A 3-min warm-up and cool-down protocol featuring various callisthenic exercises was demonstrated which was to be performed by participants before and after each training session. At the end of the session, each participant received an exercise demonstration and instruction DVD, a printed handbook, and a full set of resistance bands. Those in the exercise group were also contacted via email on 3 occasions (after 1 week, 4 weeks and 7 weeks) to discuss programme progression and adherence. The exercise prescription was deemed effective for all participants within the exercising group. This was evidenced through diary entries as self-recorded monitoring of band resistance progression. For example, the normal-stance squat that provides a representation of lower-body resistance exercise improved on average from a green-coloured band (grip rating 4) to a black-coloured band (grip rating 2). Representing upper-body resistance exercise, the bent-over-row improved on average from a red-coloured band (grip rating 6) to a blue-coloured band (grip rating 3). Participants did not report any adverse events associated with the performance of the exercise intervention. Upon completion of the intervention period, all baseline assessments were repeated in accordance with procedures previously described. During the course of the intervention, 2 participants were unable to complete the exercise programme due to non-research-related personal circumstances, therefore a total of 7 participants were analyzed for the exercise group.

Data recording and analysis

Peak cutaneous flux responses to ACh and SNP, recorded in conventional perfusion units (PU), were used as measures of microvascular endothelial smooth muscle response profiles. These were endothelial-dependent and -independent function, respectively as described previously by Deanfield et al. [11]. These were expressed as cutaneous blood flux data (CVC) and calculated by dividing PU by mean arterial pressure. Time (s) to reach maximum perfusion (T_{max}) was also measured according to the literature. The breath-by-breath cardiopulmonary data were averaged for the final minute of each stage. Ventilatory threshold (VT) was determined individually for each test using the methods previously described by Wasserman et al. [43]. Detection of each threshold point was determined visually by an experienced researcher and verified by 2 further experienced researchers.

Data are expressed as mean±SD unless otherwise stated and the significance level was set at $P<0.05$ for all analyses. The software IBM SPSS Statistics version 22.0 was used for data analysis (SPSS Statistics, IBM Corporation, Armonk, NY, USA). All outcome measures were first assessed for normal distribution using the Shapiro-Wilk goodness-of-fit test and homogeneity of variance was established. 2-way mixed analysis of variance (ANOVA) (group x trial) tests were performed to detect any between-group pre-post changes within assessments across the intervention period. In addition, 3-way (group×trial×dose) ANOVA tests were conducted to assess any dose-dependent effects respective to the administration of ACh and SNP. For any observed interaction effect, an independent t-test was performed to assess between-group changes in microcirculatory responses as a consequence of the intervention period. In addition to between-group analysis, within-group pre- to post-intervention differences were assessed for anthropometric assessment and functional capacity assessment via paired sample t-tests. For further interpretation of effect magnitudes, effect size was calculated for any observed significant differences both within- and between-group from baseline to post-intervention trials in accordance with procedures suggested by Hopkins WG. [A spreadsheet for analysis of straightforward controlled trials. (2003). On Internet: sportsci.org/jour/03/wghtrials.htm. (accessed: 5 September 2016)]. In accordance with these procedures, interpretation of observed effect sizes is as follows: trivial<0.2, small 0.2–0.6, moderate 0.6–1.2, large 1.2–2.0, very large>2.0.

Results

Cutaneous microvascular assessment

Perfusion in Lower Limbs

A dose-dependent main effect was observed for both ACh (F=37.15; P<0.001) and SNP in the lower limbs regardless of group (F=40.25; P<0.001). Analysis revealed a significant group x trial x dose interaction effect for only ACh-mediated dependent vasodilation (F=5.06, P=0.001), highlighting a between-group difference following the intervention. Further analysis considering the pre- to post-intervention change revealed a difference between the exercise group and control group at 2 000 µCb (EX Δ1.23±0.48 vs. CON Δ0.11±0.11, P<0.01, effect size=2.60; very large effect) ([Fig. 1]).

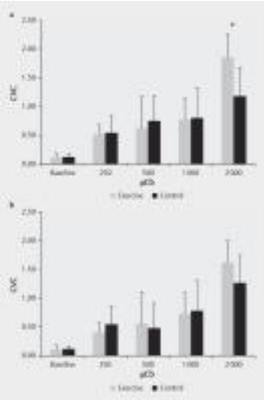

Fig. 1 Lower-limb cutaneous vascular condutance (CVC) at each charge-stimuli (µCb) following an 8-week intevention period for ACh **a** and SNP **b** (between-group difference, pre- to post-intervention change value; *p<0.05).
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Perfusion in Upper Limbs

A dose-dependent main effect was observed for both ACh (F=27.37, P<0.001) and SNP in the upper limbs (F=56.07, P<0.001). Analysis revealed a significant group x trial x dose interaction effect for only SNP-mediated dependent vasodilation (F=2.73, P=0.038) suggesting a between-group difference following the intervention. Further analysis considering the pre- to post-intervention change, revealed a difference between the exercise group and control group at 2 000 µCb (EX Δ0.88±0.31 vs. CON Δ0.01±0.01, P<0.01, effect size=1.38; large effect) ([Fig. 2]).

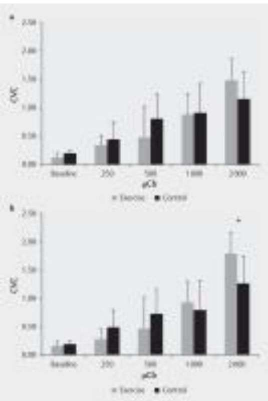

Fig. 2 Upper-limb cutaneous vascular condutance (CVC) at each charge-stimuli (µCb) following an 8-week intevention period for ACh **a** and SNP **b** (between-group difference, pre- to post-intervention

change value; *p<0.05).

Time to reach maximum perfusion (Tmax)

In agreement with our previous findings, where it was noted that exercise did not significantly affect the time to reach maximum perfusion, no statistically significant differences were observed for both upper- and lower-limb T_{max} between groups across each charge-stimuli for either ACh-mediated dependent vasodilation (as an illustration T_{max} at 2 000 µCb for upper limb post-intervention: EX 115±22 vs. CON 133±38, P=0.29) or SNP-mediated independent vasodilation (as an illustration T_{max} at 2 000 µCb for upper limb post=intervention: EX 189±54 vs. CON 176±30, P=0.56). Similarly no interactions were observed between time period and charge-stimuli for the agents ACh and SNP (P>0.05).

Anthropometric assessment

No significant main effects across the time period or between groups were found for all body composition measurements (P>0.05) ([Table 2a]).

Table 2 Changes in physical measurements for body composition (A); functional capacity (strength, balance, and mobility) (B); and cardiopulmonary fitness measures at ventilatory threshold (C) (within-group difference, pre to post; *P<0.05).

(A)				
Variable	**Exercise Group**		**Control Group**	
	Pre	**Post**	**Pre**	**Post**
Fat Percentage (%)	35.0±9.5	34.2±9.8	37.8±11.0	39.2±11.9
Fat Mass (kg)	25.8±17.0	25.2±17.3	28.7±9.9	30.4±10.9
Lean Percent (%)	65.0±9.5	65.8±9.8	59.5 ±12.3	59.7±13.0
Lean Mass (kg)	43.7±9.1	44.1±9.7	47.2±8.8	46.5±9.6
Dry Lean Mass (kg)	9.6±3.5	9.5±3.4	10.9±3.3	10.6±3.2
Water Percent (%)	51.2±8.3	52.0±8.3	47.3±7.8	47.0±9.1

Table 2 Changes in physical measurements for body composition (A); functional capacity (strength, balance, and mobility) (B); and cardiopulmonary fitness measures at ventilatory threshold (C) (within-group difference, pre to post; *P<0.05).

(A)				
Variable	**Exercise Group**		**Control Group**	
	Pre	**Post**	**Pre**	**Post**
Total Water Content (l)	34.8 ±7.2	34.6±6.6	35.3±6.1	36.3±7.7
(B)				
Variable	**Exercise Group**		**Control Group**	
	Pre	**Post**	**Pre**	**Post**
Grip Strength	29.9±5.4	27.6±5.6	31.3±9.2	31.1±9.7
Assisted Push-up	20±16	25±17	16±14	19±18
Seated Squat	33±7	38±9*	27±20	30±18
Standing Reach (cm)	38±6	40±3	37±5	34±4
Seated Reach (cm)	15±11	22±13*	17±8	18±8
(C)				
Variable	**Exercise Group**		**Control Group**	
	Pre	**Post**	**Pre**	**Post**
VE ($l \cdot min^{-1}$)	24.7±5.9	27.5±8.6	27.8±9.9	31.4±11.4

Table 2 Changes in physical measurements for body composition (A); functional capacity (strength, balance, and mobility) (B); and cardiopulmonary fitness measures at ventilatory threshold (C) (within-group difference, pre to post; *P<0.05).

(A)				
Variable	**Exercise Group**		**Control Group**	
	Pre	**Post**	**Pre**	**Post**
VO_2 ($l{\cdot}min^{-1}$)	1.02±0.3	1.03±0.3	1.05±0.4	1.09±0.5
VO_2 ($ml{\cdot}kg{\cdot}min^{-1}$)	14.9±3.0	15.1±3.6	14.5±5.9	15.5±5.5
VCO_2 ($l{\cdot}min^{-1}$)	0.88±0.3	0.93±0.3	0.92±0.4	1.1±0.5
RER ($VCO_2{\cdot}VO_2^{-1}$)	0.84±0.06	0.88±0.03	0.83±0.08	0.86±0.07
HR ($b{\cdot}min^{-1}$)	100±6	102±9	107±21	108±26
RPE (6–20 scale)	11.1±1.1	12.3±0.5	11.7±1.9	11.6±1.7

Functional capacity assessment

No significant main effects were found for grip strength (F=2.95, P=0.108) or standing reach test (F=0.49, P=0.494) across the intervention period ([Table 2b]). However, irrespective of group, assisted push-up (F=4.90, P=0.044), seated squat (F=5.92, P=0.029) and seated reach test (F=8.06, P=0.013) significantly improved across the intervention period. Paired t-tests were performed on pre- and post-intervention data for each group. No significant improvements existed for the control group; however, there were significant increases in the number of squats performed (pre: 33±7, post: 38±9, P=0.039, effect size=0.60; moderate effect) and sit-and-reach score (pre: 15±11, post: 22±13, P=0.021, effect size=0.57; moderate effect) within the exercise group.

Central cardiopulmonary fitness was determined by way of physiologic markers at ventilatory threshold (VT). As a consequence of the exercise intervention, no significant changes were observed for all measures at VT (P>0.05) ([Table 2c]). Furthermore, there were no interactions for all variables measured (P>0.05).

Quality of Life assessment

There were significantly greater improvements in 3 of the 8 SF-36 health status subscales (Bodily Pain: EX Δ14.7±0.01 vs. CON Δ–12.7±5.6, P=0.02, effect size=1.06, moderate effect; General Health: EX Δ7.4±4.5 vs. CON Δ–1.4±2.5, P=0.03, effect size=0.69, moderate effect; and Energy/Fatigue: EX Δ24.8±4.1 vs. CON Δ8.3±5.5, P=0.02, effect size=0.99, moderate effect) in the exercise group compared with the control group following the intervention ([Table 3]).

Table 3 Within- and between-group comparisons of RAND Health SF-36 subscales before and after the 8-week intervention period (between-group difference, pre to post change value; *P<0.05).

SF-36 Subscales	Exercise Group		Control	
	Pre	Post	Pre	Post
Physical Functioning	88.9±11.5	92.1±7.6	85.6±12.4	78.9±19.3
Limitations due to Physical Health	100±0.0	100±0.0	72.2±44.1	77.8±34.1
Limitations due to Emotional Health	71.4±23.7	80.6±11.4	69.8±13.0	70.7±13.4
Bodily Pain	76.4±11.6	91.1±11.5*	86.9±19.1	74.2±13.5
Energy/Fatigue	62.1±16.3	86.9±12.2*	52.8±17.7	61.1±12.2
Emotional Well-being	71.4±23.7	80.6±11.4	69.8±13.0	70.7±13.4
Social Functioning	91.1±18.7	89.3±19.7	89.1±18.2	86.9±23.8
General Health	58.9±10.2	66.3±14.7*	59.7±15.0	58.3±12.5

Discussion

The current study presents the effects of resistance-band exercise training on measurements of vascular endothelial function, functional fitness capacity, and quality-of-life measures in sedentary older adults. Using a home-based strategy that engaged participants in a programme of whole-body exercise, the most relevant findings show that early changes in cutaneous microvascular integrity are detectable following a resistance intervention that is considered both suitable and safe for sedentary older populations. These results show that short-term (8-week) resistance band training in older adults can induce a change in endothelial microvascular integrity, which appears to represent an acute adaptation similar to what we have observed previously in lower-intensity aerobic exercise [28].

We believe that 2 main messages can be highlighted in the present study. First, the completion of a home-based exercise regime that is based on self-administration is a feasible vehicle to engage otherwise inactive older individuals in a short-term programme of activity. This is especially important because with the age of individuals in the western world increasing, it is crucial to provide effective structured programmes that can be built around individual work-life commitments to improve well-being and quality of life. Most recently, this approach has also been shown in adults to improve functional fitness in chronic obstructive pulmonary disease patients [39], to enhance manual dexterity in multiple sclerosis patients [25], and to improve contralateral lower joint instability [19]; it is also used effectively in type 2 diabetic management [2].

The choice to select a home-based approach within the present study was to ensure that participants were compliant with the programme; the approach was self-administrable using commercially available resistance bands, and comfort and familiarity to the exercise setting was maximised. Compliance was maintained by providing participants with a sense of control over progression (i. e., using the OMNI-RES scale), which has been suggested to improve exercise adherence, intrinsic motivation, greater perception of autonomy, and more pleasant experiences during activity [15] [16]. This notion is supported by the significant observed increases in perceived energy levels and general health in the current study. To further enhance adherence to the programme, a self-reporting diary was used in addition to an instructional DVD and email communication. Given that, over a similar period, unsupervised resistance-band training based within a home setting resulted in the same outcomes as supervised exercise [34] our approach was considered effective. Others have deployed telephone supervision as well as home visits by a healthcare professional; however given the cost-effectiveness of our strategy we deem it a viable means of eliciting a start-up activity programme in inactive older adults. Qualitatively, based on self-reported diary entries, all participants increased band resistance through the intervention period. Although limited change was identified in global functional fitness, the visible changes in band use across the 8-week period can offer an observable motivational tool for sedentary individuals undertaking such a planned activity regime.

Secondly, our results show that older previously sedentary and otherwise healthy people who adopt a safe resistance-band programme into their normal activity patterns significantly improve endothelium-dependent, vasodilatory function in lower limbs (assessed by Ach-induced vasodilation) when compared with those who maintained their normal sedentary lifestyle. Microcirculation was improved as shown by better responsiveness to the endothelial-independent factor, agreeing with our previous findings [28]. It has been postulated that nitric oxide (NOx) bioavailability results from lower-intensity aerobic exercise, which in turn modulates sympathetic activity [12]. The effects of low- to moderate-load exercise on microcirculatory function, as used within this study, has also highlighted such endothelial adaptation in the form of NOx synthesis [4] and alterations to neural vascular control [41].

Some evidence has suggested that sustained strenuous resistance training in younger, healthy adults fails to enhance vascular function [35], as assessed through flow-mediated dilation. The adverse effect is that it increases, rather than decreases, arterial stiffness. It still remains unclear as to the exact underlying physiological mechanisms that may lead to arterial stiffening associated with high-load resistance training, but strenuous exercise may promote endothelium release of reactive oxygen species that may mediate vascular injury and inflammation [12]. Furthermore, modes of sustained intense resistance training are known to be a strong stimulus to increase sympathetic nervous system activity, which may act to increase arterial stiffness by providing chronic restraint on the arterial wall via greater sympathetic adrenergic vasoconstrictor tone. During sustained resistance exercise that is deemed high in load (>85% one repetition maximum), arterial blood pressure can increase substantially [32], with such elevations resulting in vessel remodelling [12]. Given this association between blood pressure and arterial compliance, higher blood pressure may lead to lower arterial function. Within our study, although we did not measure either arterial compliance or blood pressure during exercise, we were explicit to ensure that each exercise was dynamic in nature (i. e., continually moving and never isometric), involved more than 2 major muscle groups at any one time and required a degree of cardiovascular reactivity.

Evidence has suggested that short-term acute resistance training of sufficient stimulus in older adults does produce beneficial effects on the vasculature without any unfavourable effects on arterial non-compliance [33] [35]. Previous work has highlighted that central arterial stiffness, as assessed by aortic pulse wave velocity, does not change with resistance training that involved lower-limb exercise. Maeda et al. [33] has shown that by undertaking a 12-week programme of isokinetic (concentric and eccentric) knee extension and flexion exercises in both legs, maximal (peak) power increased, as did plasma concentration of NOx following the resistance intervention. Within the present study, both volume and intensity (equivalent to ~50% one repetition max) were markedly lower than that previously reported. We therefore theorise that the resistance training stimulus is outside the magnitude that would cause any attenuated changes in arterial non-compliance. However further research is required to assess the extent to which arterial architecture changes at lower resistance levels. Within the present study, we selected a short-term training programme (8 weeks) and opted for a self-administered home-based intervention strategy. Such an approach was deployed to ensure that the setting facilitated greater compliance due to reduced travel and cost associated with the programme. The use of a short-term acute period of stimulus, similar to our previous approach, provides comparable findings given the time course of intervention and frequency of sessions [28].

Conclusions

The present study demonstrated that a low to moderate resistance-exercise intervention, delivered through a home-based strategy by adopting elastic bands improves some measures of microcirculatory, endothelial function of a healthy, but sedentary, group of adults. In addition, select functional fitness outcomes may provide a further risk reduction in a number of diseases and conditions associated with a loss of musculoskeletal function. In this context, improving age-related endothelial dysfunction in ageing people by resistance exercise via whole-body activity may be regarded as an applied strategy for modifying vascular risk. In light of these positive findings, some caution should be exercised until further work is undertaken that evaluates the effectiveness of this approach on larger populations. Given these functional and physiological benefits of a cheap and effective short-term low to moderate resistance programme on sedentary healthy older adults, we emphasise that the practice of safely managed resistance training should be encouraged.

Conflict of Interest

The author have no conflict of interest to declare.

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