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The effect of walking training on respiratory function and performance in older females

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Abstract

Background: Sarcopenia affects respiratory system function, potentially decreasing thoracic cavity pressure development and exercise performance. **Research question:** To investigate the role of walking training on reductions in respiratory muscle strength which are conceivably due to aging. **Type of study:** Randomised control study. **Methods:** Twenty-six older females (range: 60-69 yrs) were assessed for respiratory function, respiratory muscle strength and walking performance. Thirteen participants were then randomly assigned to a walking training group (WT) for eight weeks and were required to undertake three supervised walking sessions per week at 60% of the heart rate reserve value. Sessions ranged from 20 to 40 minutes duration. **Results:** Following the training, the amount of change in respiratory muscle strength was superior in the WT group in comparison to the control group (9% for inspiratory and expiratory strength, $p<0.05$). Further, the WT group demonstrated an improvement in treadmill walking performance of 11% ($p< 0.05$), whilst treadmill walking performance for the controls remained unchanged. Despite such improvements, there were no changes to respiratory variables measured at three submaximal velocities during the treadmill assessment. **Conclusions:** The improvement in respiratory muscle strength indicates the strong involvement of the respiratory system during walking training; however, the lack of change in respiratory variables during submaximal walking indicates that the respiratory system may not be an exercise limiting factor in 60-69 yr-old females during submaximal tasks. In contrast, at elevated walking intensities, the improved strength of the respiratory muscles may assist in a greater tolerance of the required workload. **Keywords:** elderly, respiratory muscle strength, quality of life, activities of daily living, women

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Introduction

Age-related sarcopenia has been shown to impair physical performance [1]. The evident loss of muscle strength may limit walking velocity [2,3] and hence, the performance of activities of daily living [4]. Furthermore, this reduction in walking ability may decrease the ability to perform training at intensities that stimulate physical fitness improvements, thus causing the individual to enter the vicious cycle of ageing [5]. Females are seemingly at a greater risk of such reductions, due to reduced exercise participation rates in comparison to males [6], and lower initial strength levels [7]. Numerous authors have examined the capacity for various training modalities to reduce the impact of sarcopenia, including strength training [8,9] and aerobic training [10]. Benefits for older individuals who participate in regular exercise include increased life satisfaction and increased quality of life in comparison to sedentary older individuals [11].

Walking training has been demonstrated as a viable modality to promote gains in cardiovascular fitness, primarily through an increase in leg strength, aerobic enzyme concentration, blood volume and stroke volume whilst decreasing vascular resistance [10,12,13]. Despite the documentation of these benefits, there remains a paucity of information regarding the function of the respiratory system and respiratory muscles (RM) following aerobic training. The increased respiratory demand during exercise provides a stimulus for the development of RM strength and endurance [14,15], which may have positive implications for exercise participation in the older population. Therefore, the aim of the current study was to elucidate if walking training at an intensity of 60%HRR for 20-40 minutes 3 times per week for 8-weeks was adequate to improve respiratory function and walking performance in older women. It was hypothesised that the elevated ventilatory requirement witnessed during walking training at 60% HRR would stimulate an increase in RM function and walking performance in the older population.

Methods

Twenty-six healthy females aged 60-69 yrs (64.7 ± 2.8 yr, 67.5 ± 8.6 kg, 162.4 ± 6.3 cm) were recruited via advertisements to the local community and gave their informed consent to participate in the research. The participants had a varied history of physical activity participation, with a mean of 2.5 sessions per week. The physical activity typically consisted of walking at a moderate intensity; however, several participants reported regular participation in cycling, running, resistance training and court sports, albeit at a recreational level. Participants were excluded from the study if they did not receive health clearance from their general practitioner or were not confident to continue with the testing following the familiarisation session in the laboratory. At the commencement of the research, several participants were taking medication for various conditions including hypertension (8 participants), hormone replacement therapy (3 participants) and arthritis (2 participants). However, following medical clearance, such conditions were deemed to be non-influential to the results of the study. The participants were required to perform four different tests on two occasions separated by a minimum of four days to ensure recovery. The physiological tests included spirometry (Day One), assessment of RM strength (Day Two), an inspiratory muscle endurance (IME) test (Day One) and an incremental treadmill test to a subjective intensity of "hard" (Day Two). During the treadmill test, walking economy was assessed at three speeds which were similar to those encountered during activities of daily living, 4.5, 5.0 and 5.5 $km{\cdot}h^{-1}$. All tests were implemented by one trained technician, who offered verbal encouragement throughout. Testing was conducted on all subjects prior to and after eight weeks of the walking training intervention. The research was approved by the Human Research Ethics Committee at the University of Technology, Sydney, Australia.

Spirometry

Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1) and maximum voluntary ventilation (MVV) were assessed on a spirometer (Spiro 501, Bosch, Germany). All spirometry procedures were conducted using standards set by the Thoracic Society of Australia and New Zealand. These procedures required the performance of at least three technically acceptable trials, with the final three values obtained being within ±5% of each other and the largest value used for analysis, thus ensuring reliability of the results [16].

Respiratory muscle strength

Maximal inspiratory pressure (P_{Imax}) and maximal expiratory pressure (P_{Emax}) at the mouth were measured as indicators of RM strength using a portable mouth pressure gauge (Spirovis, Cosmed, Italy). The Spirovis consists of an occluded airway which contains a 2mm diameter leak to prevent artificially elevated pressures being developed by the musculature of the mouth while the glottis is closed. P_{Imax} was performed from residual volume and P_{Emax} was performed from total lung capacity [17]. Participants remained in a seated position with a nose clip in place and were required to hold the sides of the mouth during P_{Emax} assessment to prevent air leaking out the side of the mouthpiece. Participants were required to breathe through the mouthpiece, attempting to "inhale/exhale the air as fast and hard as possible". The maximum pressure maintained for one second was recorded. All participants performed a minimum of three trials until several technically correct efforts were made, with the final three values obtained being within ±5% of each other and the largest value used for analysis. The reliability of this procedure has been published previously with healthy subjects [18].

Inspiratory muscle endurance

An indicator of the endurance of the inspiratory muscles was assessed using the Powerlung^{TM} respiratory muscle training device (Powerlung, USA). The Powerlung^{TM} is a threshold-loading device consisting of a rigid plastic tube housing two rubber plungers, each held in place by a spring. In order to produce significant airflow, the participant must generate respiratory pressures which overcome the threshold pressure (P_{TH}), causing the spring to compress and the plunger to lift off its port. While the Powerlung^{TM} is able to place a resistance on both the inspiratory and expiratory muscles, the expiratory port was sealed in order to conduct a more specific examination of IME. Adjusting the inspiratory resistance control of the Powerlung^{TM} places more tension on the spring, thereby increasing the P_{TH} that must be overcome with each inspiration. A U-tube manometer was constructed, and a vacuum pump used to calibrate the arbitrary resistance settings on the Powerlung^{TM} devices in cm of water (cmH_2O). A regression analysis performed on the relationship between these calibrated values and the arbitrary levels indicated that the levels on each device create a P_{TH} that increases in a linear fashion (r^2=0.99).

IME was measured using a two minute incremental threshold loading (ITL) test. The reliability and validity of this test has been documented, with strong test-retest reliability of 0.90 for maximal pressure maintained for a complete stage [19]. In a seated position with a nose-clip in place, each participant started the test at the same P_{TH} (13 cmH_2O). The participants were instructed to correctly place the mouthpiece in the mouth before beginning inspiration, and to make sure that this breath had completely finished before taking it out of the mouth for normal expiration. Breathing frequency (F_B) was not constrained as it has been demonstrated to be unnecessary during ITL [20]. After inspiring against this resistance for two minutes, the participant underwent two minutes rest involving normal breathing and the P_{TH} was then increased by 7 cmH_2O for all participants. Strong verbal encouragement was regularly given during the exercise periods. This process continued until the participant could no longer overcome the P_{TH} to generate a significant auditory signal to the researchers with the airflow. When three consecutive breaths failed to overcome the P_{TH}, the test was terminated. The maximum pressure sustained for a complete two minute stage was recorded for analysis (P_{END}).

Walking performance test

A submaximal, incremental walking test was undertaken on a motorised treadmill (Star Trac 4500 series, USA). To examine the physiological responses to increasing exercise intensity, oxygen consumption (VO_2), respiratory exchange ratio (RER), HR, rating of perceived exertion for walking (RPEW) (Borg 6-20)[21], rating of perceived exertion for breathing (RPEB) (Borg 6-20) and ventilatory variables were assessed. The participants performed a treadmill walking warm-up, consisting of ten minutes walking at various comfortable speeds. Following the warm-up, the participants received a detailed description of the treadmill walking test, including the measurement variables, the criteria for termination of the test, the rate of progression, and the intricacies of the treadmill and the testing protocol.

The test commenced at 4.5 km·h^{-1} and the participants were instructed to avoid using the handrails as much as possible. If they required the use of the handrails occasionally for balance purposes, the participants were instructed to press inwardly on the rails rather than hold the rails, as the support of body weight may affect energy expenditure. The participants walked at this speed for three minutes. During the final minute, HR, RPEW and RPEB were measured. The treadmill speed was then increased by 0.5 km·h^{-1} for a further three minutes, with the assessment variables measured in the final minute of each stage. The test continued in this fashion until the participant recorded a RPEW or RPEB of 15 (RPE15). This intensity of exercise related to a feeling of "hard" on the visual Borg scale and this time was recorded as the time-to-RPE15 (T_{RPE15}). The participants could volitionally terminate the test at any time. As an additional measure to ensure the exercise tolerance of the participant did not rapidly degrade without the opportunity to terminate the test, the RPE was monitored every 30 seconds once a RPEW or RPEB of 13 was recorded.

Throughout the test, the participants were required to respire through a Hans-Rudolph valve, permitting the assessment of expired gases. Expired gases were sampled breath-by-breath (Max-1, Physiodyne, USA), and averaged every 30 seconds during the final minute of each stage. The gas analysis equipment was calibrated immediately prior to and following each test, using gases of known composition. Measurement variables included VO_2, RER, minute ventilation (V_E) (L·min^{-1}), F_B (breaths·min^{-1}), tidal volume (V_T) (mL) and inspiratory time (T_I) (seconds). Furthermore, to provide an examination of the relative respiratory demand, the percentage of MVV (%MVV) used during each stage was recorded.

Training

Following the pre-testing, 13 participants were randomly assigned to a walking training group (WT), with the remainder acting as a non-exercising control group (CON) (Table 1). The WT group undertook three supervised walking sessions per week at 60% of the HR reserve (60%HRR) value. It has been reported that 12 weeks of training at this intensity resulted in high adherence rates and promoted improvements in physical fitness[22, 23]. In the current study, session duration was increased from 20 minutes to 30 minutes following Week Two and to 40 minutes following Week Six. Session duration was selected as the manipulated variable in the training design, as this variable has been reported as being more appropriate for the older population[24]. Post testing was undertaken within four days of the completion of the final training session.

Table 1: Participant characteristics for each group. Data is reported as mean ± 1SD, followed by range..

	Age (yr)	**Height (cm)**	**Body mass (kg)**	**Body mass index (kg/m^2)**
Walking Training	65.5 ± 2.6	162.8 ± 6.7	67.3 ± 8.3	25.5 ± 3.3
(n=13)	61-69	147.4-172.0	57.0-88.2	21.7-32.9
Controls	64.0 ± 2.9	161.9 ± 6.0	67.6 ± 9.3	25.7 ± 2.8
(n=13)	60-69	151.7-170.0	55.1-82.6	21.8-30.6

Statistical analyses

Data analysis was conducted using Statistical Package for the Social Sciences (SPSS) version 11.0. Descriptive statistics were calculated for all variables and reported as means ± 1 standard deviation (1SD). A one-way analysis of variance (ANOVA) was used to determine any differences between the two groups at the pre-test on the dependent measures. Further, the HR and subjective (RPEW and RPEB) data from the submaximal walking speeds was examined with repeated measures ANOVA to determine whether each speed elicited a significantly different physiological response. The post-test data was examined for normality of distribution and a one-way ANOVA was performed on the test data collected at each test occasion to examine any main effects following the training. Within-group effects were analysed using repeated measures ANOVA on the pre- and post-test results. Pearson's product-moment correlations also were determined for the differences between the pre- and post-testing (delta score, Δ) to examine the relationships between dependent variables. For all procedures, significance was accepted at an alpha level of 0.05.

Results

One-way ANOVA revealed that there were no significant differences between the groups at the pre-test occasion for P_{Imax}, P_{Emax}, P_{END} or any of the walking variables. Adherence to the walking programme was high, with a 98 ± 3% session completion rate for the WT group. There were no participant drop-outs over the course of the training. Furthermore, there were no changes to body mass following the training, or to any spirometry variables (Table 2). One-way ANOVA revealed main effect differences for the ΔRM strength variables (ΔP_{Imax} p=0.03; ΔP_{Emax} p=0.03) between the WT and CON groups following the eight week training period. Further, several interaction effects were identified following the within-group repeated measures analysis; the WT group demonstrated a 9% improvement in P_{Imax} (p=0.02) and P_{Emax} (p=0.04) following the training (Table 2). P_{END} displayed a 14% trend to increase following the training; however, this result failed to reach statistical significance (p=0.06).

The performance measure for the incremental treadmill test, T_{RPE15}, showed a significant within-group improvement (11%) in the WT group (p=0.01). Accordingly, the mean final treadmill speed increased by 4% in the WT group (p=0.01) (Table 3). When walking economy and physiological variables were assessed, the sole variable to display any improvement was a 5% reduction in HR at 5.5 km·h^{-1}. Despite several decreasing trends in HR, RPEW and RPEB for the WT group, there were no changes evident to other physiological or respiratory variables measured during the three walking economy velocities (Tables 4 and 5). Despite a lack of training-related changes, repeated measures ANOVA performed on the pre-test HR and subjective measures (RPEW and RPEB) assessed during submaximal stages of the treadmill test revealed that each stage required a greater exertion than the previous (4.5-5.0 km·h^{-1}, p<0.01 for HR, RPEW and RPEB; 5.0-5.5 km·h^{-1}, p<0.01 for HR, RPEW and RPEB). Furthermore, Pearson's correlations revealed several significant relationships between ΔRM strength and various physiological variables (Table 6).

Table 2: Spirometry results and maximum pressures developed for respiratory muscle strength and incremental threshold loading tests. Data is reported as mean ± 1SD, followed by the range of scores.

	FVC		**FEV_1**		**MVV**		**P_{Imax}**		**P_{Emax}**		**P_{END}**	
	PRE	**POST**	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**
Walking training (n=13)	3.30 ± 0.33	3.26 ± 0.33	2.45 ± 0.26	2.40 ± 0.26	71.5 ± 12.5	75.8 ± 20.1	68.9 ± 17.2	75.2 ± 21.7 $^{\#,*}$	83.4 ± 27.9	90.5 ± 27.2 $^{\#,*}$	56.4 ± 27.7	64.0 ± 25.7
	2.83-3.91	2.73-3.76	1.92-2.88	1.82-2.66	54.3-97.0	51.3-128.2	31.0-93.0	39.0-122.0	42.0-135.0	59.0-146.0	19.0-100.0	19.0-91.0
Controls (n=13)	3.08 ± 0.42	3.14 ± 0.40	2.27 ± 0.29	2.26 ± 0.32	68.9 ± 7.8	69.3 ± 7.1	74.5 ± 13.4	74.3 ± 10.8	88.0 ± 22.4	86.5 ± 20.9	60.5 ± 15.4	61.2 ± 13.4
	2.24-3.81	2.30-3.84	1.87-2.78	1.79-2.85	57.0-85.8	58.1-78.9	50.0-95.0	53.0-92.0	42.0-127.0	54.0-130.0	37.0-91.0	46.0-82.0

Key: FVC, forced vital capacity; FEV_1, forced expiratory volume in one second; MVV, maximum voluntary ventilation; P_{Imax}, maximum inspiratory pressure; P_{Emax}, maximum expiratory pressure; P_{END}, maximum pressure maintained for greatest complete two minute stage during IME test; cmH_2O, cm water pressure. $^{\#}$ Significantly greater change than CON group; * Significantly different to pre-test, $p<0.05$.

Table 3: Final stage results for incremental treadmill assessment. Data is reported as mean ± 1SD followed by the range of scores.

	Speed ($km \cdot h^{-1}$)		**%MVV**		**Total test time (s)**	
	PRE	**POST**	**PRE**	**POST**	**PRE**	**POST**
Walking training (n = 13)	6.42 ± 0.53	6.69 ± 0.56 *	43.0 ± 12.8	40.8 ± 11.8	819 ± 186	909 ± 164 *
	6.00-7.50	6.00-7.50	24.8-62.8	24.8-56.0	510-1020	600-1110
Controls (n = 13)	6.31 ± 0.56	6.32 ± 0.54	42.4 ± 10.3	42.0 ± 10.5	797 ± 220	827 ± 209
	6.00-7.50	6.00-7.50	19.0-61.2	20.3-60.2	450-1260	480-1260

Key: %MVV, percentage of maximum voluntary ventilation used during walking. * Significantly different to pre-test, $p<0.05$.

Table 4: Cardiovascular and perceived exertion results from incremental treadmill walking assessment. Data is reported as mean ± 1SD.

		HR (b·min^{-1})		**VO$_2$ (ml·kg^{-1}·min^{-1})**		**RER**		**RPEW (Borg units)**		**RPEB (Borg units)**	
		PRE	**POST**	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**
Walking training (n=13)	4.5 km·h^{-1}	107.3 ± 13.4	103.9 ± 14.4	15.1 ± 2.5	15.5 ± 3.8	0.79 ± 0.07	0.81 ± 0.08	9.5 ± 2.1	8.9 ± 2.1	9.2 ± 2.0	9.2 ± 1.9
	5.0 km·h^{-1}	110.8 ± 13.6	107.5 ± 14.7	15.7 ± 2.0	15.7 ± 2.6	0.81 ± 0.04	0.82 ± 0.03	11.2 ± 1.2	10.7 ± 1.9	11.2 ± 1.2	10.6 ± 2.1
	5.5 km·h^{-1}	117.5 ± 11.9	112.0 ± 13.4 *	16.7 ± 2.5	16.1 ± 2.3	0.83 ± 0.04	0.84 ± 0.03	12.9 ± 1.4	11.9 ± 1.4	12.5 ± 1.3	11.9 ± 1.4
Controls (n=13)	4.5 km·h^{-1}	103.4 ± 7.8	103.2 ± 8.1	14.2 ± 2.7	13.6 ± 2.8	0.83 ± 0.05	0.82 ± 0.06	10.3 ± 1.7	9.9 ± 1.8	10.7 ± 1.0	10.0 ± 1.5
	5.0 km·h^{-1}	109.2 ± 9.6	108.0 ± 8.6	14.9 ± 2.6	14.5 ± 2.6	0.82 ± 0.05	0.82 ± 0.06	11.7 ± 1.0	11.3 ± 1.0	11.6 ± 0.9	11.2 ± 1.2
	5.5 km·h^{-1}	116.7 ± 8.4	116.9 ± 8.0	15.5 ± 1.8	15.7 ± 1.8	0.84 ± 0.05	0.84 ± 0.06	12.5 ± 1.4	12.4 ± 1.3	12.6 ± 1.4	12.2 ± 1.2

Key: HR, heart rate; RER, respiratory exchange ratio; RPEW, rating of perceived exertion for walking; RPEB, rating of perceived exertion for breathing. * Significantly different to pre-test, $p<0.05$.

Table 5: Respiratory variables assessed during incremental treadmill test. Data is reported as mean ± 1SD.

		V_E (L·min^{-1})		%MVV		F_B (breaths·min^{-1})		V_T (mL)		T_I (s)	
		PRE	**POST**	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**
Walking training (n=13)	4.5 km·h^{-1}	21.8 ± 4.0	23.0 ± 5.6	31.4 ± 8.1	32.4 ± 13.0	22.9 ± 5.9	25.8 ± 6.0	1044 ± 261	976 ± 328	1.25 ± 0.38	1.13 ± 0.36
	5.0 km·h^{-1}	22.9 ± 4.3	23.3 ± 3.8	33.0 ± 8.6	32.6 ± 10.3	24.4 ± 5.7	26.0 ± 5.0	1016 ± 224	984 ± 298	1.18 ± 0.39	1.12 ± 0.35
	5.5 km·h^{-1}	24.9 ± 4.7	24.7 ± 4.3	35.9 ± 9.5	34.7 ± 11.0	25.8 ± 4.9	26.1 ± 4.2	1034 ± 268	987 ± 209	1.10 ± 0.32	1.04 ± 0.22
Controls (n=13)	4.5 km·h^{-1}	20.7 ± 5.7	20.0 ± 5.4	30.3 ± 8.3	29.1 ± 8.1	22.7 ± 5.2	23.7 ± 4.9	965 ± 265	959 ± 256	1.18 ± 0.29	1.12 ± 0.25
	5.0 km·h^{-1}	22.3 ± 6.4	21.4 ± 6.4	32.8 ± 10.6	31.4 ± 10.6	23.3 ± 6.1	22.4 ± 6.1	1021 ± 235	1021 ± 236	1.17 ± 0.29	1.18 ± 0.30
	5.5 km·h^{-1}	24.1 ± 5.9	24.5 ± 5.9	35.5 ± 12.6	36.0 ± 10.6	25.1 ± 6.7	26.2 ± 7.0	1028 ± 165	985 ± 190	1.08 ± 0.22	1.04 ± 0.31

Key: V_E, minute ventilation; %MVV, percentage of maximum voluntary ventilation used during walking; F_B, breathing frequency; V_T, tidal volume; T_I, inspiratory time.

Table 6: Pearson's product-moment correlations for all participants (n=26).

	ΔP_{Imax}	ΔP_{Emax}	ΔP_{END}	ΔT_{RPE15}
ΔFVC	-0.21	-0.16	0.03	0.06
ΔFEV_1	-0.27	-0.35	-0.01	-0.19
ΔPEF	-0.30	-0.01	-0.10	0.18
ΔMVV	0.56	-0.03	0.01	0.10
ΔP_{Imax}	1.00	0.44 *	0.03	0.19
ΔP_{Emax}	0.44 *	1.00	0.26	0.49 *
ΔP_{END}	0.03	0.26	1.00	0.05
ΔT_{RPE15}	0.19	0.49 *	0.05	1.00
ΔHR @ 4.5 km·h^{-1}	-0.43 *	-0.31	-0.33	-0.29
ΔHR @ 5.0 km·h^{-1}	-0.53 *	-0.17	-0.09	-0.36
ΔHR @ 5.5 km·h^{-1}	-0.44 *	-0.23	-0.12	-0.35
ΔRPEW @ 4.5 km·h^{-1}	0.04	0.19	-0.01	-0.21
ΔRPEW @ 5.0 km·h^{-1}	0.08	0.01	-0.16	-0.49 *
ΔRPEW @ 5.5 km·h^{-1}	0.06	-0.22	-0.11	-0.49 *
ΔRPEB @ 4.5 km·h^{-1}	-0.01	0.20	0.21	-0.21
ΔRPEB @ 5.0 km·h^{-1}	-0.24	-0.04	-0.07	-0.44 *
ΔRPEB @ 5.5 km·h^{-1}	0.16	-0.01	-0.08	-0.30

Key: Δ, amount of change pre- vs. post-test; FVC, forced vital capacity; FEV_1, forced expiratory volume in one second; MVV, maximal voluntary ventilation; P_{Imax}, maximal inspiratory pressure; P_{Emax}, maximal expiratory pressure; P_{END}, greatest pressure sustained for two minutes during incremental inspiratory muscle endurance test; HR, heart rate; RPEW, rating of perceived exertion for walking during incremental treadmill test; RPEB, rating of perceived exertion for breathing during incremental treadmill test. * Significant correlation, $p<0.05$.

Discussion

In the current study, it was hypothesised that the elevated ventilation during walking training at 60%HRR would stimulate an increase in RM function and walking performance in older females. The evident main effect and within-group improvements in P_{Imax} and P_{Emax} reflects the involvement and the adaptation of the respiratory system during walking training (Table 2). Further, the improvement in T_{RPE15} in the WT group provides evidence of an improvement in performance following the training period. These results support the hypothesis proposed in the current investigation.

Similar results have been previously reported following various forms of cardiovascular training [14, 15] however, these studies used near maximal training intensities with younger participants. It is unlikely that the older population could maintain or reach such intensities without risk; however, the lower intensity training performed in the current study was clearly sufficient to elicit a moderate training effect. In the absence of direct measurement, it is hypothesised that the elevated ventilatory drive from an increase in blood PCO_2 during the training sessions led to an elevated requirement for inspiratory pressure development from the RM and the ensuing training effect. Interestingly, the RM strength results for the WT group (which were slightly lower at the pre-test) appeared to approach those of the CON group following the training. One practical implication from this finding is that perhaps walking training has a greater effect on individuals with lower initial strength levels, allowing them to return to levels considered as 'normal'. However, such an implication remains to be confirmed as the results of one study can neither confirm nor dispel such an issue. These results show that there is scope for further research in this area.

Submaximal walking performance

Despite the improvements in RM strength characteristics, walking training at 60%HRR did not impact upon physiological or respiratory parameters during submaximal walking. With the exception of HR at 5.5 $km \cdot h^{-1}$, there were no significant changes to any of the measured variables (Tables 4 and 5). A reduced HR following walking training has been reported previously [12, 25], however, this finding is difficult to explain using the measured variables in this study, as there were no significant changes to VO_2, F_B, RPEW or RPEB. Despite the absence of explanatory variables, significant negative correlations between ΔP_{Imax} and ΔHR were evident at the submaximal walking velocities, indicating that as P_{Imax} increased, HR tended to decrease. In fact, up to 25% of the variance in the reduction in HR at these submaximal walking speeds was related to the change in P_{Imax} (Table 6). Whilst there is a distinct lack of evidence proclaiming the relationship between an increase in RM strength and a reduction in submaximal HR within the literature, these results give support to the theorised relationship [26, 27].

The 8-week training period did not have an effect on low intensity walking performance. Potentially, the duration of the training period in the current study was insufficient to elicit a specific training response, with previous researchers using durations of up to 40 minutes per session for 12 weeks to cause improvements in aerobic fitness [23]. In spite of such issues, the session and program durations selected for the current study were based upon standard training durations performed by community dwelling older adults, therefore representing typical training patterns of the older population.

The lack of changes to submaximal performance in the current study indicate that whilst walking training has the capacity to alter the strength of the RM, the respiratory system does not appear to be a limiting factor to submaximal exercise performance in healthy 60-69 yr old females. Accordingly, it appears that the small within-group improvement in RM performance would have minimal implications for the performance of activities of daily living for this age group, which are usually performed at submaximal intensities. This result is somewhat surprising, as improved RM function has been linked to exertional dyspnoea [28] and a decrease in dyspnoea would potentially enhance exercise capacity. Despite having minimal implications for walking economy, there were several anecdotal reports from the participants of improved mobility and walking capacity following the training. Participants in the WT group described a greater ability to walk up flights of stairs, concentrate during activities requiring physical exertion such as golf and tennis and perform various tasks around the home including gardening and cleaning. It was reported by Larson et al. [29], that the sensations of dyspnoea associated with physical exertion does not always relate to dyspnoea in the performance of activities of daily living. Therefore, in the current study, the age group assessed may not be limited by respiratory variables during such activities even if they exhibit dyspnoea at the higher workloads in excess of 5.5 $km \cdot h^{-1}$.

To improve the physiological and respiratory response during low intensity walking in the older population, it appears that training at an intensity or duration above that used in the current study is required. This has clear implications for exercise guidelines for the older population, with the selection of an appropriate intensity crucial if improvements in physical condition are desired. Furthermore, despite the evident differences in intensity between stages (as shown by differences in group mean scores for HR, RPEW and RPEB between speeds 1-2 and speeds 2-3) and the requirement of a ventilatory output greater than that witnessed at rest, the intensity of activity during the walking economy assessment velocities was perhaps of insufficient magnitude to determine an altered respiratory response following the training. This limitation, however, was not controllable in the current study, as the assessment velocities used in the analysis were the only speeds that all 26 participants completed during the assessment. The analysis of respiratory demand and walking economy at greater velocities (say 6.0 or 6.5 $km \cdot h^{-1}$) would exclude many participants as this was beyond their T_{RPE15}, therefore adding bias to the results.

"Hard" intensity walking performance

When moderate-hard intensity exercise was examined (up to RPE15), it appeared that walking training provided an adequate stimulus for improvement in walking performance. This finding was not unexpected, as there is a wealth of literature available detailing the benefits of walking training for walking performance, especially in the older population [23, 30-34]. The reasons for such an improvement consist of potentially improved leg strength and a more efficient cardiovascular response following the training. The improved cardiovascular response consists of a greater mitochondrion content, elevated aerobic enzyme concentration, type I muscle fiber hypertrophy, improved cardiac dimensions and the ability to tolerate blood lactate associated with a greater chemical buffer capacity [12, 25, 35, 36]. Such results probably account for the anecdotal remarks in the current study. However, due to the respiratory focus of the current study, these variables were not measured.

A further mechanism for the improvement in T_{RPE15} following the training period may be related to the increase in RM performance. The enhanced RM strength may improve the dynamics of the respiratory pump, thus reducing the competition for blood flow between the central and peripheral sections of the body. Accordingly, it was assumed that following the walking training, such an effect was evident, permitting a greater work output for the same physiological demand [26, 27]. This mechanism for performance enhancement has been described in the non-healthy population, with an improvement in RM function assisting to enhance walking performance in patients with chronic obstructive pulmonary disease [37, 38] and heart disease [39, 40]. Such improvements signify potential benefits for improved completion of daily tasks for members of the older population. ΔP_{Emax} was significantly correlated with ΔT_{RPE15} (Table 6), indicating the presence of such a relationship. Interestingly, ΔP_{Imax} was not correlated to ΔT_{RPE15}, which tends to suggest that expiratory muscle strength may play more of a role in moderate-hard intensity activities in the older population. Such improvements in physical performance are based upon a reduced competition for blood flow between the RM and the periphery, along with reduced exertional dyspnoea. Such positive implications may also play a role in the more intense activities of daily living, thus impacting upon quality of life. The evident relationship between expiratory muscle strength and walking performance indicates that specific training to this musculature may assist moderate-hard walking performance in the older population. Further research examining this phenomenon is required.

The relatively small sample size may have affected the apparent lack of improvement in physical performance following the training period. Even though RM function has been demonstrated to display a moderate-large effect size following training, physiological parameters, such as VO_2, HR, F_B, V_E and T_I, display greater biological variability and hence require larger sample sizes to detect meaningful changes. It has been proposed that a sample size of 11 per group is sufficient to detect changes in RM function following training; however, it appears that outcomes with small-moderate effect sizes (~0.40) would require approximately 45 participants to detect changes at the 80% power level at an alpha level of 0.05 [41]. Such participant numbers (n=90) were deemed unfeasible in the current study due to constraints on laboratory resources.

The results of the current study suggest that RM capacity in healthy, older females is not a determinant of submaximal exercise performance. In contrast, at intensities associated with an RPE of "hard", the improved strength and endurance of the RM may assist in a greater tolerance of the required workload. Therefore, one potential mechanism for the improved T_{RPE15} may be the improvement in RM strength. Although ΔP_{Emax} was correlated to ΔT_{RPE15} in the current study, ΔP_{Imax} and ΔP_{END} were not (Table 6). Whilst there is an argument suggesting that the performance of walking training at 60%HRR may improve moderate intensity walking performance, the role of RM function during maximal exercise remains undetermined in this population. Whilst members of the older population rarely approach intensities close to maximal energy expenditure, submaximal performance is highly reliant upon maximum capacity; therefore, further research is required to determine the role of improved RM strength and endurance at VO_{2max} intensity.

Conclusion

Three walking sessions per week at 60%HRR for an 8-week period appear to positively affect RM strength in older females aged 60-69 yrs. Such improvements appear to have concomitant effects on walking performance at "hard" walking intensities. However, they do not appear to be of benefit for submaximal intensities such as those witnessed during the performance of some activities of daily living. This study demonstrates the potential for the positive effects of a walking programme on RM function and functional performance in older adults, and hence the potential benefits for more intense types of daily activities. However, the mechanisms for such changes were not confirmed in the current study, despite the improvement in RM strength being significantly superior to the CON group. The current results assist in the derivation of a clear set of guidelines for exercise in the older population, with the intensity of the walking undertaken being insufficient to result in main effect improvements. Future research is required to examine the effects of training programmes involving greater walking intensities, the role of the RM in tasks of maximal intensity in the older population, and the relationship between walking performance and respiratory function in individuals aged in excess of 70 years.

List of non-standard characters

Δ (Greek symbol) – delta. This symbol has been used in the article to signify the amount of change between the pre- and post-test scores

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