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DISEASE SEVERITY, ACTIVITIES OF DAILY LIVING AND EXERCISE CAPACITY IN PATIENTS WITH CHRONIC PULMONARY DISEASE

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ABSTRACT

Chronic Pulmonary Disease (CPD) often causes a reduction in physical activity and lower limb dysfunction. This study determined combined and individual contributions of measures of activity of daily living (type and volume) and FEV_1 *to arm and leg ergometry ability of CPD patients. The 44 patients with mild to very severe airflow obstruction (mean* FEV_1*% predicted=54.64±18.27) consisted of 16 males and 28 females (mean age=59.80±11.92yrs). All participants completed spirometry, International Physical Activity Questionnaire (IPAQ) and were graded for pulmonary disease severity using the Medical Research Council degree of breathlessness scale. Additional assessments included Physical Activity of Daily Living (PADL), body composition, sub-maximal arm and leg ergometry, grip strength and isokinetic quadriceps and hamstring strength and endurance. The t-test, ANOVA and partial correlations were conducted. Total upper body and lower body physical activity showed no statistically significant relationships with measures of peripheral muscle strength and cardiovascular fitness. Leg strength contributed more to arm and leg ergometry ability than measures of physical activity. This study highlights the importance of assessing upper and lower limb strength in patients with CPD and endorses the incorporation of specified lower limb strength training in rehabilitation programmes, especially for those with reduced strength and physical activity levels.*

Key words: Chronic pulmonary disease; Activities of daily living; Arm and leg strength; Arm and leg ergometry.

INTRODUCTION

Chronic respiratory disease (CRD) is a common medical term used to describe respiratory conditions characterised by progressive airflow limitation that is not fully reversible (WHO, 2013). Chronic respiratory disease most commonly includes chronic bronchitis, emphysema, chronic obstructive pulmonary disease (COPD), bronchiectasis, asthma, interstitial lung disease, pulmonary hypertension and obstructive sleep apnoea syndrome. The symptoms of these respiratory conditions have a significant impact on the physical wellbeing of individuals. Exercise tolerance becomes limited as these diseases increase in severity due to increased dyspnoea and peripheral muscle fatigue when performing exercise and physical activities of daily living (Stendardi *et al*., 2005).

The general trend is that aerobic capacity and muscular strength decline across the stages of CRD progression. This reduction might be related to individuals reducing their level of Physical Activities of Daily Living (PADL), due to dyspnoea and/or increased leg/arm fatigue.

The reasons why persons with CRD adopt a more sedentary lifestyle are complex and could be dependent on the individual. Novel insights into the specific limitations of exercise are needed to develop effective exercise training modalities and ways to maintain physical activity levels in CRD patients.

There is scientific evidence indicating that frequency of muscle recruitment and activation in CRD patients largely determines the degree of dysfunction in a given muscle. Lower extremity muscles are chronically under-loaded due to inactivity and disuse, while upper extremity muscles are less under-loaded (Kim *et al*., 2008). This under-loading of the lower extremity muscles contributes to lower extremity muscle dysfunction. In this regard, researchers have demonstrated that the degree of skeletal muscle dysfunction in COPD patients is not homogeneous between various muscle groups. For example, Franssen *et al*. (2005) identified that COPD patients with skeletal muscle dysfunction had a higher dysfunction in leg strength than in arm strength, when compared to healthy individuals. Poor lower extremity functioning (as measured by the short performance physical battery) and poor exercise performance is related to a greater risk of COPD-related disability (Eisner *et al*., 2011). It was concluded by Eisner *et al*. (2011) that the management of COPD needs to be complimented with a comprehensive rehabilitation programme including exercise training to help prevent poor lower extremity function and COPD-related disability.

PURPOSE OF RESEARCH

It is unclear from scientific studies whether a relationship exists between peripheral muscle strength and PADL (type and volume), and whether there is an association between peripheral muscle strength and the exercise trainability across stages of disease progression. The aim of this study was to determine the combined and individual contributions of measures of physical activity of daily living (type and volume) and the degree of airflow obstruction as assessed by forced expiratory volume (FEV_1) to the arm and leg ergometry ability of patients with chronic pulmonary disease. It is hypothesised that individuals engaging in more PADL involving the arms and the legs will show better respective arm ergometry and leg ergometry functional abilities irrespective of degree of airflow obstruction (FEV_1).

METHODOLOGY

Study design and participants

A cross-sectional research design was used to investigate the within group relationships of respiratory, strength and physiological measures of patients with mild to very severe airflow obstruction. Forty-four (N=44) patients referred by the Palmerston North Hospital Respiratory Clinic to the U-Kinetics Exercise and Wellness Clinic, participated in a 12-week exercise-based rehabilitation programme. Written informed consent was obtained from all participants in the study. The participants had not been involved in structured exercise training for at least one year prior to participation in the study. All of the participants had been diagnosed with a chronic respiratory condition (or a combination) by a General Practitioner or Respiratory Physician including: chronic bronchitis, emphysema, COPD, bronchiectasis, asthma and obstructive sleep apnoea syndrome.

Data collection

Anthropometric measures

Stature was assessed with shoes removed using a wall mounted stadiometer (model 222, Seca, Hamburg, Germany). Body mass was measured on a calibrated electronic scale (Tanita, Cloverdale, Western Australia 6985) with shoes and as much clothing removed as possible. Body mass index (BMI) was calculated by dividing body mass (kg) by stature (m) squared.

Ergometry testing

All participants completed a modified version of the YMCA sub-maximal leg ergometer test (ACSM, 2014) for estimation of VO_{2max}. Exercise capacity testing was performed on a cycle leg ergometer (ec3000e, Custo-med, Germany). Participants sat upright on the cycle ergometer while undertaking the leg ergometry test. The saddle height allowed the legs to be almost straight when their feet reached the lowest part of the cycling arch. The test comprised an unloaded one-minute warm-up, followed by three 4-minute stages. Power output was increased at the end of the 4th minute of each stage if the 3rd and 4th minute heart rates were within a steady state (±6bpm) and no symptom limitations were present.

The aim was to reach either 70% of the age adjusted maximum heart rate using Karvonen's Formula [(220 – age – resting heart rate) x 0.7 + resting heart rate], or any symptom limitation according to the ACSM absolute and relative contra-indications for terminating exercise testing (ACSM, 2014). The following equation was used to calculate VO_{2max} [VO_2 = ((10.8 x work rate in watt) / body mass) + 7] (ACSM, 2014).

All participants performed an incremental multi-stage sub-maximal arm ergometry test (ACSM, 2014). Testing was performed on a Technogym Arm Ergometer (Top Excite 700, Technogym, Cesena, Italy). Participants sat upright with both feet on the ground and at a distance that their arms were slightly flexed while undertaking the arm ergometry test. Participants performed a one-minute warm-up of unloaded arm cycling, before completing 3 stages of 3 minutes. Participants started on 20 to 30 Watt for the first stage and then power output was gradually increased with each stage depending on rating of perceived exertion (RPE), pain and dyspnoea scores, and heart rate and blood pressure responses, and if the 3rd and 4th minute heart rates were within a steady state (±6bpm) and no symptom limitations were present.

The aim was to either reach 70% of age-adjusted maximal heart rates (using Karvonen's formula as above), a RPE score of higher than 14 or a power output equal to or greater than 42% as obtained during the last stage on the leg ergometry assessment, according to Carter *et al*. (2003). If peak power output beyond 42% of leg ergometry were required for subjects to reach the same maximum heart rates, the test continued beyond 3 stages until they reached the required heart rate, or at patient's request to stop. Test termination indications included the presence of signs and symptoms (ACSM, 2014) based on the ACSM's (2014) guidelines for early termination. The following equation was used to calculate VO_{2max} [VO_2=((10.8 x work rate in watt) / body mass) + 7] (ACSM, 2014).

Dyspnoea and rating of perceived exertion

Dyspnoea and Rating of Perceived Exertion (RPE) were measured at the end of each stage during arm and leg ergometry testing using the Borg dyspnoea scale and the Borg RPE scale (Borg, 1998).

Disease severity

Spirometry was performed in order to quantify/assess the degree of airway obstruction, based on the calculated ratio FEV_1/FVC. Participants were classified into mild ($FEV_1 \geq 80\%$ predicted), moderate (predicted $50\% \leq FEV_1 < 80\%$), severe (predicted $30\% \leq FEV_1 < 50\%$) and very severe (predicted $FEV_1 < 30\%$) obstruction categories (GOLD, 2014). Spirometry was performed using a hand-held spirometer (EasyOne and Medizintechnik AG, 8005 Zurich, Switzerland), which was calibrated prior to each test with a 3L syringe. The FEV_1 is the volume exhaled during the first second of a forced exhalation, and the forced vital capacity (FVC) the total amount of air exhaled during the FEV test. Participants performed the FEV_1 and FVC manoeuvre according to the American Thoracic Society guidelines (ATS, 2005). The participants sat in an upright position with both feet on the floor wearing a nose peg when performing the test, and were instructed to breathe in as deeply as they could, seal their lips around the mouthpiece, and blow out as hard, fast and as long as possible. Subjects performed 3 attempts and the best attempt was recorded. All subjects completed the MRC degree of breathlessness scale (Fletcher *et al*., 1959) for the purpose of determining severity of dyspnoea and stage of disease.

Physical Activity of Daily Living (PADL)

Current PADL was assessed using the International Physical Activity Questionnaire (IPAQ), Long Form. The IPAQ has 4 distinct PADL groupings, distinguishing between job-related, transport, domestic and recreational (sport and leisure) PADL. The IPAQ captures participation according to days and minutes of activity and segregates between walking, moderate and vigorous activity by multiplying the various activity minutes with a metabolic equivalent of task (MET) factor (8 METs for vigorous activity; 4 METs for moderate activity and 3.3 METs for walking). The questionnaire provides a total activity METs per minute score as well as individual METs per minute scores for each of the 4 PADL groups. A comprehensive and detailed interview was used in conjunction with the IPAQ to determine the amount of upper and lower body PADL participants performed on a daily basis. This was done in order to compare the impact of daily upper and lower body physical activities on aerobic capacity (arm and leg ergometry) and measures of arm and leg strength.

Peripheral muscle strength testing

Upper limb strength was measured by grip strength using a Jamar J00105 Baseline Hydraulic Hand Dynamometer (Irvington New York, 10533 U.S.A). The Jamar® dynamometer measures grip force isometrically and can be adjusted for hand size in 5 half-inch increments. The dual-scale readout displays isometric grip force from 0 to 200 pounds (90kg), with a "peak-hold" needle that remains in place once grip is released. The dynamometer was calibrated with the gradual application of factual loads (washers) in the centre of their handles, as recommended by Fess (1987) and the owner's manual (Rolyan, 2003) on a monthly basis. The washers (average mass of 4.97±0.05kgf) were added one by one until they reached the final load of 90kgf, which coincidentally is the limit load of the Jamar® dynamometer. The main researcher checked the Jamar hand dynamometer at the start of each day by measuring her own grip strength, observing that the needles rise round the dial together and that the red peak-hold needle remains stable and can be read when grip is released. A calibration record was maintained. Subjects performed two attempts on each side for familiarisation and the highest reading was recorded. The grip strength test started with the arm abducted 90 degrees at the shoulder, with the elbow in full extension (0° of flexion). The subject was instructed to grip the hand dynamometer as hard as possible, then lower the arm down to the side of the body squeezing the tool with maximum effort. The dynamometer was reset to zero prior to each reading.

Lower limb strength and endurance was measured by knee flexion and extension using an Isokinetic muscle dynamometer (HUMAC norm, model 502140, Computer Sports Medicine, Inc., Stoughton, MA 02072, USA). The dynamometer was calibrated according to standard settings outlined by the user manual with the axis of rotation in line with subject's femoral epicondyles. The dynamometer was corrected for gravity. Range of motion was set to at least 90°. Subjects completed one trial set of 5 repetitions at 60 and $180°.s^{-1}$ for familiarisation and then one set of 5 repetitions at $60°.s^{-1}$ and one set of 15 repetitions as fast as possible at $180°.s^{-1}$. Each set was separated by a 60-second rest interval, which has been found to be an adequate rest period during isokinetic testing to avoid fatigue (Parcell *et al*., 2002). Subjects were instructed to flex and extend their knee as hard and as fast as they could for the full duration of the test. This quadriceps/hamstring strength and endurance testing protocol has been used on healthy, inactive and elderly individuals (Malliou *et al*., 2003).

Statistical analysis

Statistical analyses were performed using STATISTICA (Version 7.0) and SPSS (Version 22). Descriptive statistics (anthropometric, PADL, aerobic capacity and strength values and disease severity) are presented as means, standard deviations and normal distribution for sex groups and the total group. For the purpose of the statistical analysis, disease severity categories were merged to form 2 groups, due to the low number of respondents in the mild (n=4) and very severe categories (n=5). Participants with mild to moderate airflow obstruction (GOLD 1-2) were combined to form the "Mild-Mod" group (n=28) and severe and very severe airflow obstruction (GOLD 3-4) were combined to form the "Severe" group (n=16). The Mild-Mod group included 10 males (35.7%) and 18 females (64.3%); and the Severe group included 6 males (37.5%) and 10 females (62.5%).

A factorial ANOVA was conducted to explore the independent relationships of PADL and disease severity (GOLD stage) with measures of arm and leg aerobic capacity and strength. Wilks Lambda and Eta^2 analyses was used to determine the combined and individual contributions of measures of PADL (type and volume) and FEV_1 to arm and leg ergometry capacity of patients with CRD. Partial correlations were performed - controlling for age, gender and body fat (BF%) - to assess relationships between measures of aerobic capacity (upper and lower body arm ergometry capacity), measures of strength (grip and isokinetic quadriceps and hamstrings), pulmonary function and physical activity (total activity and upper and lower body activity). The aim of the partial correlations was to determine whether the ANOVA finding, that physical activity negates the detrimental effect of disease development on certain measures of strength and arm aerobic capacity, will sustain after statistical control for the influence of external variables such as BF%, gender and age. For the purpose of the ANOVA analyses, the respondents were grouped as "high" or "low" regarding FEV_1% and participation in total PADLs. For total PADL level, participants were split at the 50th percentile and FEV_1% was split according to GOLD groups at 50% predicted (Mild-moderate=low; severe-very severe=high). The physical activity levels of the participants were generally low and there were only 16 respondents with severe and very severe COPD (FEV_1<50%). The 50th percentile of the group distribution was henceforth selected for PADLs and FEV_1 to ensure enough participants in the groups.

RESULTS

The descriptive and disease severity characteristics of the participants are displayed in Table 1. The study participants included 44 CRD patients, 16 males and 28 females, with a mean age of 59.8±11.9 years. The mean FEV_1% predicted was 54.6±18.3, indicating GOLD stage 2 (moderate CPD). Participants' FEV_1% predicted airflow obstruction ranged from 89-22% (mild to very severe).

Table 1. **DESCRIPTIVE DATA OF ALL PARTICIPANTS AND GENDER GROUPS**

Variables	**Total group** (n=44) M±SD	**Male** (n=16) M±SD	**Female** (n=28) M±SD	p-Value
Age	59.80±11.92	63.50±9.18	57.68±12.91	0.12
Weight	87.28±20.58	89.45±13.89	86.04±23.72	0.60
BMI	33.15±10.98	29.69±4.06	35.13±13.10	0.11
BF%	30.56±13.08	20.41±7.71	36.36±11.98	<0.001
FVC%	70.64±13.22	71.13±13.03	70.36±13.55	0.86
FEV_1%	54.64±18.27	50.63±19.71	55.21±17.75	0.78
VO_{2peak} (leg)	21.84±5.86	24.34±6.73	20.42±4.88	0.03
$Power_{peak}$ (leg)	49.32±19.13	57.81±20.16	44.46±17.02	0.02
$Pain_{peak}$ (leg)	3.31±1.82	2.81±1.61	3.61±1.89	0.17
VO_{2peak} (arm)	21.59±6.29	21.67±6.64	21.54±6.20	0.95
$Power_{peak}$ (arm)	38.86±11.71	45.00±12.78	35.36±9.62	0.01
$Pain_{peak}$ (arm)	3.29±1.52	3.34±1.62	3.26±1.49	0.86
Grip strength	30.92±10.39	41.13±8.64	25.09±5.79	<0.001
Quad strength	103.67±34.99	129.38±24.62	88.98±31.59	<0.001
Ham strength	53.10±19.47	66.94±15.96	45.20±16.85	<0.001
Quad endurance	88.42±14.11	88.88±12.31	88.16±15.26	0.87
Ham endurance	98.71±30.94	90.09±16.83	103.63±36.03	0.17
Overall activity	3074.03±3319.62	3341.75±4585.76	2921.05±2408.43	0.69
Vigorous activity	313.01±1042.20	798.13±1643.23	35.80±102.94	0.02
Moderate activity	2242.34±2282.45	1742.69±2268.97	2527.86±2281.25	0.28
Walking activity	524.25±761.58	814.69±1149.41	358.29±333.46	0.05

$Power_{peak}$=peak ergometry wattage; $Pain_{peak}$=peak pain during ergometry; VO_{2peak}=estimated peak VO_2 (ml/kg/min); RPE_{peak}=peak rating of perceived exertion; $Dysp_{peak}$=peak dyspnoea

Results of a factorial ANOVA, where the dependent and independent relationships of disease severity and total PADL participation were compared with peripheral muscle strength measures, are reported in Table 2.

Table 2. **FACTORIAL ANOVA: RELATIONSHIPS OF CPD STAGE AND TOTAL PADL WITH PERIPHERAL MUSCLE STRENGTH MEASURES**

Dependent variables	ANOVA groups	F-ratio	p-Value	Eta^2	Wilks Lambda
Grip strength	CPD stage	0.441	0.511	10.2	94.1
	Total PADL	1.957	0.170	21.5	
	Combined	0.841	0.479	5.94	
Quad strength	CPD stage	3.514	0.068	27.7	87.5
	Total PADL	1.779	0.190	19.7	
	Combined	1.906	0.144	12.5	
Hamstring strength	CPD stage	3.753	0.059	28.6	87.1
	Total PADL	0.405	0.528	9.39	
	Combined	1.978	0.133	12.9	
Quad endurance	CPD stage	0.658	0.422	12.5	94.5
	Total PADL	1.745	0.194	20.3	
	Combined	0.770	0.518	5.46	
Hamstring endurance	CPD stage	0.430	0.516	9.74	88.1
	Total PADL	2.321	0.135	22.6	
	Combined	1.795	0.164	11.9	

No statistically significant differences were found between any of the physical activity and disease severity groups for the peripheral muscle strength data. The Eta^2 calculations indicated that CPD disease stage showed larger (non-significant) independent contributions than total PADL minutes to the variances of quadriceps strength and hamstring strength. Total activity showed larger (non-significant) independent contributions than CPD stage to the variances of grip strength and quadriceps and hamstring endurance. The Wilks Lambda scores (reported in Table 2) indicated that the 2 independent variables in combination (CPD stage and total activity minutes) explains small portions of the variances in grip strength (5.9%), quadriceps strength (12.5%), hamstring strength (12.9%), quadriceps endurance (5.5%) and hamstring endurance (11.9%).

Results of a factorial ANOVA, where the dependent and independent relationships of disease severity and physical activity volume were compared with arm and leg ergometry outcome measures, are reported in Table 3. No statistically significant differences were found between the physical activity and disease severity groups for any of the arm and leg ergometry outcome measures. The F-ratio, p-values, Wilks Lambda scores and the Eta^2 calculations indicate that CPD disease stage displayed larger (non-significant) contributions than overall physical activity minutes to the variances of peak leg ergometry power, peak leg ergometry VO_2, peak leg pain, peak arm ergometry power and peak arm pain. Total activity displayed larger (non-significant) independent contributions than CPD stage to the variances of peak leg ergometry RPE score, peak arm ergometry VO_2, peak arm ergometry RPE and dyspnoea scores. The

Wilks Lambda scores indicated that the 2 independent variables in combination (CPD stage and total activity minutes) explained the small portions of variances of peak leg ergometry power (16.7%) and peak arm ergometry RPE (12.3%) and less than 10% of the variances of the other arm and leg ergometry variables.

Table 3. **FACTORIAL ANOVA: RELATIONSHIPS OF CPD STAGE AND TOTAL PADL WITH ARM AND LEG ERGOMETRY CAPACITY IN CPD PATIENTS**

Dependent variables	**ANOVA groups**	**F-ratio**	**p-Values**	**Eta^2**	**Wilks Lambda**
Leg Power$_{peak}$	CPD stage	4.725	0.035	31.4	83.6
	Overall Act	1.242	0.272	16.1	
	Combined	2.622	0.064	16.4	
Leg VO$_{2peak}$	CPD stage	2.247	0.142	22.9	94.0
	Total PADL	0.395	0.533	9.63	
	Combined	0.852	0.474	6.01	
Leg RPE$_{peak}$	CPD stage	0.131	0.719	5.57	98.3
	Total PADL	0.444	0.509	10.4	
	Combined	0.228	0.877	1.68	
Leg Dysp$_{peak}$	CPD stage	1.888	0.177	20.7	90.9
	Total PADL	1.888	0.177	20.7	
	Combined	1.339	0.275	9.13	
Leg Pain$_{peak}$	CPD stage	2.973	0.092	26.3	92.7
	Total PADL	0.019	0.891	2.08	
	Combined	1.044	0.384	7.26	
Arm Power$_{peak}$	CPD stage	3.015	0.090	26.1	90.7
	Total PADL	0.005	0.943	1.08	
	Combined	1.424	0.250	9.65	
Arm VO$_{2peak}$	CPD stage	1.524	0.224	18.5	90.0
	Total PADL	2.882	0.097	25.5	
	Combined	1.485	0.233	10.0	
Arm RPE$_{peak}$	CPD stage	0.495	0.486	10.4	87.9
	Total PADL	3.543	0.067	27.9	
	Combined	1.838	0.156	12.1	
Arm Dysp$_{peak}$	CPD stage	0.022	0.896	0.62	99.2
	Total PADL	0.299	0.632	7.61	
	Combined	0.110	0.954	0.82	
Arm Pain$_{peak}$	CPD stage	2.195	0.146	22.5	92.2
	Total PADL	1.000	0.323	15.2	
	Combined	1.126	0.350	7.79	

Power$_{peak}$=peak ergometry wattage, VO$_{2peak}$=estimated peak VO$_2$ (ml/kg/min), RPE$_{peak}$=peak rating of perceived exertion, Dysp$_{peak}$=peak dyspnoea, Pain$_{peak}$=peak pain during ergometry.

Partial correlations were conducted to examine the relationships between measures of pulmonary function, ergometry capacity (arm and leg), strength (quadriceps and grip), and physical activity levels (overall, lower body and upper body), while controlling for age, gender, and BF% (Table 4). Total activity and the amount of upper and lower body activity showed no statistically significant relationships ($p>0.05$) with measures of strength and aerobic capacity. Predicted FEV_1% displayed a weak non-significant correlation with quadriceps strength ($r=0.30$) and significant ($p<0.05$) moderate correlations with peak leg watt ($r=0.42$), peak arm watt ($r=0.33$) and hamstring strength ($r=0.41$).

Table 4. **PARTIAL CORRELATIONS OF TOTAL GROUP (N=44) BETWEEN VARIABLES CONTROLLING FOR AGE, GENDER AND BODY FAT PERCENTAGE**

Variables	**Leg $\text{Power}_{\text{peak}}$**	**Leg $\text{Pain}_{\text{peak}}$**	**Arm $\text{Power}_{\text{peak}}$**	**Arm $\text{Pain}_{\text{peak}}$**	**Grip Strength**	**Quad Strength**	**Ham Strength**
FVC%	0.29	-0.03	0.22	0.08	0.28	0.16	0.19
FEV_1%	0.42*	0.12	0.33*	0.22	0.17	0.30	0.41*
Leg $\text{Power}_{\text{peak}}$	—	-0.02	0.81*	0.23	-0.13	0.51*	0.47*
Leg $\text{Pain}_{\text{peak}}$	-0.02	—	-0.08	0.62*	-0.34*	0.13	0.13
Arm $\text{Power}_{\text{peak}}$	0.81*	-0.08	—	0.04	-0.02	0.58*	0.51*
Arm $\text{Pain}_{\text{peak}}$	0.23	0.62*	0.04	—	-0.28	0.16	0.10
Grip Strength	-0.13	-0.34*	-0.02	-0.28	—	0.28	0.13
Quad Strength	0.51*	0.13	0.58*	0.16	0.28	—	0.75*
Ham Strength	0.47*	0.13	0.51*	0.10	0.13	0.75*	—
Quad Endur.	0.10	-0.29	0.05	-0.19	-0.13	-0.13	-0.17
Ham Endur.	0.01	-0.09	-0.03	-0.01	-0.08	0.11	0.02
Total activity	0.02	-0.09	0.15	-0.14	0.02	-0.11	-0.06
UB activity	0.14	-0.01	0.29	-0.02	-0.12	0.11	0.18
LB activity	0.30	0.01	0.16	0.24	-0.14	0.08	0.13

VO_{2peak}=estimated peak VO_2 (ml/kg/min); $\text{Power}_{\text{peak}}$=peak ergometry wattage; $\text{Pain}_{\text{peak}}$=peak pain during ergometry; Ham=Hamstring; Quad=Quadriceps; Endur.=Endurance; UB=upper body; LB=lower body.
* Significance at $p<0.05$.

Peak arm ergometry power presented a strong positive association with peak leg ergometry power ($r=0.81$; $p<0.05$). Peak leg power demonstrated a moderate positive correlation with quadriceps strength ($r=0.51$; $p<0.05$) and hamstring strength ($r=0.47$; $p<0.05$). Peak arm power correlated moderately with quadriceps strength ($r=0.58$; $p<0.05$) and hamstring strength ($r=0.51$; $p<0.05$). No correlation was found between peak arm power and grip strength ($r=-0.02$). Grip strength demonstrated a significant negative correlation with peak pain during leg ergometry ($r=-0.34$; $p<0.05$). Arm pain and leg pain during ergometry correlated moderately ($r=0.62$; $p<0.05$), while quadriceps and hamstring strength evidenced a more pronounced correlation ($r=0.75$; $p<0.05$). Perceived pain (arm and leg) during ergometry did not correlate with maximum power during the 3rd stage of both the arm ergometry (arm pain $r=0.04$; leg pain $r=-0.08$) and leg ergometry (arm pain $r=0.23$; leg pain $r=-0.02$) tests. In contrast, leg strength measures correlated moderately with arm and leg ergometry power (arm power r=0.58; leg power r=0.51; p<0.05).

DISCUSSION

The primary aim of this study was to investigate the combined and individual contributions of physical activities of daily living (type and volume) and FEV_1 to arm and leg ergometry capacity of patients with CPD. The main findings of the study were that the volume of PADL performed with the upper and lower body did not correlate with the respective upper and lower body strength or ergometry capacity measures. Hence, the hypothesis that individuals engaging in more PADL involving the arms and the legs will show better respective arm ergometry capacity and leg ergometry capacity, can be rejected.

Disease severity (FEV_1) was moderately associated with measures of upper (r=0.33; p<0.05) and lower body (r=0.42; p<0.05) aerobic capacity and lower limb strength (r=0.41; p<0.05), suggesting that as CPD severity increases, both arm and leg functional capacity decreases. Similar findings have been reported for patients with chronic airflow obstruction by Carter *et al*. (2003), who found moderate associations between FEV_1 and peak arm ergometry power (r=0.59; p<0.0001) and peak leg ergometry power (r=0.53; p<0.0001). Previous studies have demonstrated moderate to high associations between FEV_1 and max/peak leg ergometry power (Haccoun *et al*., 2002), and VO_{2max} (Gosselink *et al*., 1996). Due to the cross-sectional construction of this study no causal conclusions can be made. However, the data does show moderate relationships between FEV_1 (stage of disease) and arm and leg ergometry capacity.

Arm ergometry power was strongly associated with peak leg ergometry (r=0.81; p<0.05). In terms of peripheral muscle strength, however, comparison of CPD groups revealed that leg strength was more reduced in the severe CPD group than arm strength. There was less of a difference between the two GOLD groups for grip strength (7%; p=0.47) than quadriceps (19%; p=0.05) and hamstring strength (21%; p=0.04), when combining the low and high PADL levels. A similar pattern was observed by Franssen *et al*. (2002), who observed a preserved upper limb exercise capacity compared to the lower limbs. The authors found that arm and leg peak power obtained during ergometry testing were similar (50±3 vs 61±4W, respectively), but the upper limbs were deemed less affected than the lower limb, as the maximum power output of healthy controls for leg ergometry was approximately double that of the arms (205±13 vs 108±7W). Overall the upper limbs had less of a reduction than the controls, but similar functional values were found when the researchers compared arms and legs in COPD patients (Franssen *et al*., 2002).

Peak leg ergometry power was associated with higher quadriceps strength (*r*=0.51; p<0.05) and hamstring strength (*r*=0.47; p<0.05), which is in line with previous studies where associations between leg ergometry capacity and quadriceps strength (Hamilton *et al*., 1995; Gosselink *et al*., 1996; Hillman *et al*., 2012) were found. Interestingly, an association was found between peak arm power output and lower limb strength (quadriceps r=0.58; p<0.05 and hamstrings r=0.51; p<0.05).

Total PADL (minutes/week) and GOLD stage, as a combination, did not explain major parts of the variability within any of the strength or ergometry capacity measures (Tables 2 and 3).

It is important to note that overall physical activity contributed more to the variances of peak RPE during leg ergometry (10.4 versus 5.57), arm ergometry VO_{2peak} (25.5 versus 18.5), peak RPE during arm ergometry (27.9 versus 10.4) and peak arm ergometry dyspnoea (7.61 versus 0.62) than CPD stage (Table 3). Total PADL also evidenced larger contributions to the variances of grip strength (21.5 versus 10.2), quadriceps endurance (20.3 versus 12.5) and hamstring endurance (22.6 versus 9.74) (Table 2).

These results confirm that activities of daily living do impact positively on perceived exertion (RPE) and dyspnoea symptoms across the stages of disease during exercise testing. This is in line with Andersson *et al*. (2013), who found lung function, walking speed and muscle strength to be important correlates of physical activity in COPD patients. The strength of the relationships, between overall participation in physical activity and the mentioned measures of strength and aerobic capacity in the current study, is probably influenced by the fact that the participants in this study generally exhibited quite low levels of participation in physical activity. Only 11 participants met the recommended requirements for adequate/sufficient physical activity according to the IPAQ guidelines (IPAQ Research Committee, 2005), while none of the participants met the ASCM recommendations.

The Wilks Lambda scores reported for the ANOVAs (Tables 2 and 3) suggested that total PADL does not contribute much (individually or in combination with CRD stage) to the variances of muscle strength and ergometry capacity. Additionally, the volume of total PADL performed with the upper and lower body correlates poorly ($p>0.05$) with the respective measures of upper and lower body strength or ergometry determined aerobic capacity (Table 4). Hence the hypothesis that individuals engaging in more PADL involving the arms and the legs will show better respective arm ergometry capacity and leg ergometry capacity, can be rejected. The hypothesis is rejected with acknowledgement that the data may be influenced by the low levels of physical activity in the group.

The findings of Katajisto *et al*. (2012) may explain the small contribution of physical activity to strength and aerobic capacity in the present study. The authors reported that sensation of dyspnoea, pain, and discomfort felt during strenuous exercise contributed to the physical inactivity of patients with COPD. Discomfort or fear might have prevented the participants in the present study from performing PADLs at an intensity high enough to maintain or improve their peripheral muscle strength and/or exercise capacity, which emphasises the importance of specified exercise training in this population.

LIMITATIONS AND RECOMMENDATIONS

It is acknowledged that there are some limitations to the present study that may impact on the reliability of the results and their interpretations. These primarily include limitations to physiological measurements and the sample size/study population. An indirect sub-maximal arm ergometry and leg ergometry method was used to estimate VO_{2max}. Direct gas exchange measures were not used in this study due to inaccessibility and safety of the participants, but it is acknowledged that cardiopulmonary exercise testing would have improved the accuracy of peak oxygen uptake measurement. In defence, the extrapolation method used to predict VO_{2peak} from the YMCA submaximal leg ergometer test has been shown to provide accurate predictions values (Beekley *et al*., 2004).

A convenience sample (N=44) of CRD patients was used for the study, which was limited by the number of referrals to U-kinetics. It was not possible to control the number of participants, or the number of participants in the various GOLD stages. Accordingly, participants with severe and very severe CRD were grouped together, as were participants with mild and moderate CRD. The limitation with this approach was that the impact of disease severity could not be tracked as effectively as was intended. It may be useful to complete a study with a larger sample size and enough participants in the separate GOLD stage groups to compare outcomes.

In the present study, lower limb dysfunction (low quadriceps strength) was associated with a reduced upper and lower body exercise capacity. Further investigation into the mechanisms behind the reduction in lower limb strength in patients with CPD is needed. Lower limb muscle dysfunction can be amendable through exercise rehabilitation strategies (Debigaré & Maltais, 2008). However, investigation into the specific components of strength training in CPD needs more attention.

Alternative testing methods to determine the severity of CPD are needed, especially for patients who are unable to perform spirometry due to contra-indications caused by co-morbidities. It would be interesting to investigate whether measures of grip strength, quadriceps strength or cardiovascular capacity may be used to identify disease severity in individuals where pulmonary function measures are unavailable. Grip strength and leg strength may pose an alternative method of assessing severity of disease if it is unsafe to perform spirometry, and to assess a patient's need for a funded pulmonary rehabilitation intervention. Leg and grip strength may be useful to identify those who will not perform well in cycle ergometry testing and may be helpful in estimating starting wattage when administrating a cycle ergometer test.

CLINICAL IMPLICATIONS

The findings of this study demonstrate the importance of maintaining and/or improving upper and lower body strength, in order to maintain arm and leg functional capacity. Upper and lower body strength measures were more important contributors to the physical functioning of the participants than their weekly volume of PADLs. The high association of leg strength to both arm and leg cardiovascular function, emphasise the need for improving and maintaining leg strength. Attention needs to be given to gaining maximum improvements in leg strength during exercise training interventions. In addition, the inclusion of leg strength testing before an exercise training intervention is justified in this study, to identify those who have reduced leg strength. A goal of amending this will be a key objective of the individual's specific exercise programme. It also justifies the need to test leg strength after rehabilitation interventions to monitor the effectiveness of exercise programmes on improving leg strength.

CONCLUSION

The findings of this study highlight the importance of assessing upper and lower limb strength in patients with CPD. This study endorses the incorporation of specified lower limb strength training in pulmonary rehabilitation programmes, especially for those with reduced strength and physical activity levels. There needs to be a continuation in the shift from the predominant cardiovascular exercise focus, to placing more emphasis on progressive lower limb strength training in the exercise rehabilitation of CPD patients.

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