The BASES Expert Statement on Upper Body Exercise
Produced on behalf of the British Association of Sport and Exercise Sciences by Dr. Lindsay Bottoms,
Dr. Paul Smith, Dr. Garry Tew and Dr. Mike Price FBASES.

Introduction:
Lower-limb exercise is more commonly studied and prescribed than upper-body exercise (UBX).
However, UBX has many important applications This expert statement outlines the potential
benefits of UBX, particularly arm crank ergometry (ACE), in specific populations, though more
detailed testing guidelines are published elsewhere (Smith & Price, 2007).

Background and evidence:
Important points regarding the acute responses and chronic adaptations to UBX are as follows:
- In healthy individuals, peak oxygen consumption ($\dot{V}O_2$peak) for incremental UBX is
  approximately 30% lower than that measured during incremental lower-limb exercise,
  largely due to the smaller extent of muscle mass engaged.
- During sub-maximal exercise of the same absolute intensity, UBX evokes a lower stroke
  volume, a higher heart rate and increased blood pressure response compared with lower-
  body exercise.
- Adaptations to upper body endurance training typically depend on initial fitness, with
  greater gains for sedentary individuals .
- Finally, cross-transfer effects of ACE training are evident, especially for sedentary individuals.

ACE training in the elderly
Few studies have investigated the effects of ACE training in older adults. The most relevant study is
that of Pogliaghi *et al*. (2006), compared the training adaptations of two groups of elderly men, who
performed 12 weeks of either ACE or leg cycle training to that of a control group. At baseline and
following the intervention, participants performed cardiopulmonary exercise tests to maximum
volitional exertion on both arm-crank and cycle ergometers. This allowed the specific and cross-
transfer effects of both modes of training to be assessed. Physiological responses during exercise
testing did not change markedly in the control group from baseline to follow-up. A summary of the
results for the two training groups is provided in Table 1.

These data indicate that both training modalities evoked physiologically meaningful improvements
in both sub-maximal and maximal measures of cardiorespiratory fitness. Furthermore, mode-specific
and cross-transfer adaptations were observed following both training programmes, with the cross-
transfer effects being approximately 50% of the specific effects. The "transferability" of training
benefits has been classically interpreted as indirect evidence of the central nature of the adaptation.

Table 1. Changes in key physiological outcomes following 12 weeks of ACE or cycle ergometer
training in older adults (reproduced from Pogliaghi *et al*., 2006).

Group	Variable	Change on cycle ergometer test	Change on ACE test
ACE training	Peak power (W)	↑12 (8%)	↑19 (22%)
	$\dot{V}O_2$peak (L·min^{-1})	↑0.21 (9%)	↑0.37 (23%)
	Peak O_2pulse (mL·beat^{-1})	↑1.5 (10%)	↑2.4 (22%)
	Power at VT (W)	↑ 5 (5%)	↑10 (17%)
	$\dot{V}O_2$ at VT (L·min^{-1})	↑0.09 (5%)	↑0.19 (18%)
Cycle training	Peak power (W)	↑26 (18%)	↑4 (5%)
	$\dot{V}O_2$peak (L·min^{-1})	↑0.39 (18%)	↑0.16 (9%)

	Peak O_2pulse (mL·beat^{-1})	↑2.4 (17%)	↑1.2 (10%)
	Power at VT (W)	↑19 (19%)	↑3 (5%)
	$\dot{V}O_2$ at VT (L·min^{-1})	↑0.21 (13%)	↑0.07 (6%)

Data shown are absolute changes in the mean with relative changes in parentheses.
Specific effects shaded in grey, cross-transfer effects not shaded.

Clinical populations

In light of the work of Pogliaghi *et al.* (2006), many clinical applications of UBX become apparent. For example, ACE cardiopulmonary testing is useful to evaluate the physical capacity of people with lower extremity impairments caused by vascular, orthopaedic or neurological conditions. Thus, UBX may also form an important part of clinical rehabilitation programmes in conditions such as spinal cord injury, chronic obstructive pulmonary disease (COPD), peripheral arterial disease (PAD), stroke and chronic heart failure.

Example 1 – UBX training in COPD
A common lung disease, COPD is characterised by airflow obstruction that is not fully reversible. Associated with breathing difficulty (dyspnoea), exercise intolerance and impaired quality of life, pulmonary rehabilitation plays an important role in the management of COPD. Pulmonary rehabilitation using UBX is recommended as part of the exercise training component as it has a positive impact on exercise capacity, arm strength and reduced symptoms of dyspnoea (Ries *et al*., 2007). Typical arm training exercises for people with COPD include ACE, upper-body resistance training and overhead tasks. These activities are simple to incorporate into pulmonary rehabilitation programmes, and may be very relevant to people who frequently experience dyspnoea.

Example 2 – UBX training in PAD
Lower-limb PAD is a medical condition characterised by atherosclerotic narrowing of the arteries supplying the legs. A common symptom of PAD is intermittent claudication, which is a cramp-like leg pain that occurs during walking due to insufficient muscular blood flow. Intermittent claudication impairs quality of life by limiting ambulation and activities of daily living. Regular walking exercise improves functional outcomes in people with intermittent claudication; however, since walking can be painful, the desire and ability of these patients to perform such activity might be limited. Three small-to-moderate sized clinical trials have demonstrated that arm cranking is a well-tolerated alternative training modality, which can induce similar improvements in pain-free and maximum walking distances as compared with lower-limb exercise modalities (Tompra *et al.,* 2015). These studies used an interval training approach of 2 minutes of moderate-to-hard exercise at 50-60 rev·min^{-1}, followed by 2 minutes of passive recovery, for duration of 40-60 minutes. Interval training was favoured to continuous training primarily because it allowed for a higher-intensity of exercise to be performed, thus maximising the potential for a cross-transfer effect to walking ability. Training was 2-3 times per week for 12-24 weeks.

Handcycling

The most specific application of ACE is to the sport of handcycling. Since its introduction to the Paralympic Games as a demonstration event in 2004 its popularity has soared, both competitively and recreationally. Individuals are able to use specifically constructed handbikes, or clip-on devices that attach to any rigid wheelchair. Propulsion technique is typically achieved using a synchronous pattern. Importantly this liberating exercise mode assures inclusion even for profoundly disabled athletes.

As with able-bodied endurance events there are a range of physiological variables that help us to understand performance. For example, Janssen *et al*. (2001) tested handcyclists in both a 10-km road race and a range of variables from incremental treadmill tests. They reported race intensities of 80 and 88% heart rate reserve for those racers with upper-limb dysfunction and those without, respectively. Peak aerobic power output, $\dot{V}O_2$peak and gross efficiency were important determinants of race performance. Furthermore, the extent of physiological strain suggested this exercise mode was well suited to aerobic training.

Conclusions and recommendations:
Upper body exercise has several useful applications. Basic guidelines for arm-crank exercise testing and training are provided below. Guidelines for other UBX modes exist and should be considered wherever relevant.

Example ACE testing protocols for older adults and clinical populations
- 5-minute warm-up at 40 W, followed by step increases of 5 W·min^{-1} until maximum volitional exertion (Pogliaghi *et al*., 2006)

or
- 1 minute of resting measurements, followed by 2 minutes of unloaded arm cranking at 60-70 rev·min^{-1}, and then a ramp of 5-15 W·min^{-1} until maximum volitional exertion (Janaudis-Ferreira *et al*., 2012)

Example ACE training protocols for older adults and clinical populations
- Interval training: Accumulate 10-20 minutes of "hard" exercise, using a 1:1 work-rest ratio, and intervals lasting 1-3 minutes. A practical starting point for "work" intervals is the power output associated with VT, with progression occurring to heart rate and perceived exertion responses recorded towards the end of each interval.
- Continuous training: Start at power associated with 90% VT or 50% peak power determined on an initial ramp cardiopulmonary exercise test, and complete a session of 20 to 30 minutes duration.

Handcycling
- Guidelines for novice handcyclists are very similar to those presented for ACE above. The main difference is in body position: during ACE individuals typically adopt an upright seated posture, while a handcyclist will either sit in a recumbent position or kneel, depending on the nature and extent of disability. For highly trained, competitive individuals it is likely that stated work rates could easily be doubled compared to those reported herein for clinical and/or elderly individuals.

References:

Janaudis-Ferreira, T. *et al*. (2012). How should we measure arm exercise capacity in patients with COPD? A systematic review. Chest, 141, 111–120.

Janssen T.W., **Dallmeijer, A.J**. **& van der Woude, L.H. (2001).** Physical capacity and race performance of handcycle users. Journal of Rehabilitation Research & Development, 38, 33-40.

Pogliaghi, S. *et al*. (2006). Adaptations to endurance training in the healthy elderly: arm craning versus leg cycling. European Journal of Applied Physiology, 97, 723-731.

Ries, A.L. *et al*. **(2007).** Pulmonary Rehabilitation: Joint ACCP/AACVPR Evidence-Based Clinical Practice Guidelines. Chest, 131, 4S-42S.

Tompra, N. *et al.* **(2015).** Upper versus lower limb exercise training in patients with intermittent claudication: A systematic review. Atherosclerosis, 239, 599-606.

Smith, P.M. & Price, M.J. (2007). Upper body Exercise, in Sport and Exercise Physiology Testing Guidelines, The British Association of Sport and Exercise Sciences Guide. Volume Two, Exercise and Clinical Testing. Winter E.M., Jones, A.M., Davison, R.C.R., Bromley, P.D., Mercer, T.H. pp138 – 144.

Contributors:

Dr. Lindsay Bottoms

Lindsay is a Senior Lecturer at the University of Hertfordshire.

Dr. Paul Smith

Paul is a Senior Lecturer at Cardiff Metropolitan University.

Dr. Garry Tew

Garry is a BASES accredited sport and exercise scientist and a Research Fellow in York Trials Unit at the University of York.

Dr. Mike Price

Mike is a Reader in Exercise Physiology at Coventry University.