Institution: BRUNEL UNIVERSITY (H0113)

Unit of Assessment: 26 – Sport and Exercise Sciences, Leisure and Tourism

Title of case study: From laboratory to Amazon.com and the NHS – How breathing training joined the mainstream

1. Summary of the impact (indicative maximum 100 words)

Research by Alison McConnell and colleagues has underpinned the creation of a new category of exercise training and rehabilitation; "breathing training" improves exercise tolerance and reduces perceived exertion. McConnell invented the market-leading POWERbreathe® breathing trainer, and since joining Brunel (2000), has led further new product developments via Knowledge Transfer Partnerships (KTP) and consultancy. Research by McConnell and her team underpins marketing by POWERbreathe® and several "copycat" products serving UK and overseas markets. Impacts include: 1. physiological benefits to individual users globally, from elite athletes to patients; and 2. commercial benefits to POWERbreathe International Ltd., its supply chain, and to new international businesses serving the breathing training market created by POWERbreathe®.

2. Underpinning research (indicative maximum 500 words)

McConnell's research on inspiratory muscle training (IMT) began in the early 1990s, with the most influential outputs published since joining Brunel in 2000. Research took a sequential path: 1. describing physiological responses to inspiratory muscle training (IMT); 2. elucidating underlying mechanisms; 3. using insights gained in 2 to inform new product development. The research has underpinned the marketing and development of "breathing training" products by POWERbreathe® and by new entrants to the breathing training market. Fundamental to commercial success has been the group's leading contribution to: 1. evidence that IMT is ergogenic and 2. elucidation of underlying mechanisms. Two independent meta-analyses confirming the efficacy of IMT in healthy adults rely heavily upon the group's work. In the Illi et al. study (*Sports Med* **42**, 707-724, 2012), the group contributed half of the data that were meta-analysed. The following summarises the important research insights underpinning impact.

The rationale for IMT is underpinned by evidence of respiratory muscle overload during exercise, which manifests as respiratory muscle fatigue, and/or as respiratory muscle metaboreflex activation. Group members (McConnell, Romer, Volianitis, *Griffiths, Lomax, Ross, Taylor*) have each published evidence of post-exercise respiratory muscle fatigue in healthy adults (e.g., #1, 2, 5). Linked to this rationale is evidence that prior fatigue of respiratory muscles hastens exercise intolerance and limb fatigue (McConnell, Romer, *Lomax, Taylor*; e.g., #6). This evidence supports the marketing proposition that IMT solves a real-world problem.

The group has also provided evidence that IMT is ergogenic and reduces inspiratory muscle fatigue (McConnell, Romer, Volianitis, *Griffiths*; e.g.,#1, 2, 5), but that expiratory muscle training is not ergogenic (McConnell, *Griffiths*; e.g., #2). Descriptive insights are underpinned by the elucidation, and the exclusion, of underlying mechanisms; the group was the first to implicate the inspiratory muscle metaboreflex in ergogenicity (Romer, McConnell; #1), and the first to provide evidence supporting this mechanism (McConnell, *Lomax*; #4). Mechanistic clarity has also been provided by excluding involvement of maximal oxygen uptake and lactate threshold (McConnell, Romer). Evidence of efficacy is exploited to support marketing claims, whilst mechanistic insight enhances credibility. The group was also the first to show that acute, non-fatiguing inspiratory muscle loading ("warm-up") improves inspiratory muscle function (McConnell, Volianitis, *Lomax, Ross*; e.g., #3) via central and peripheral processes (McConnell, *Ross*; #3). Functionally, inspiratory "warm-up" enhances exercise performance and reduces breathing effort (McConnell, Volianitis), providing a further marketing proposition.

Most recently, McConnell has explored IMT in patients, demonstrating that: 1. IMT improves exercise tolerance and reduces dyspnoea, as well as reducing the oxygen cost of exercise in asthmatics (#5 and REF2); and 2. acute inspiratory loading attenuates bronchoconstriction after deep inhalation in asthmatics (see REF2). Novel applications of IMT to enhance postural balance are also supported (see REF2). Romer contributed to evidence that oxygen uptake kinetics are hastened by IMT. The group has also characterised (mechanically and physiologically) the training stimulus delivered during IMT, using these insights to inform development of new, improved

products (see section 4) (#6 and REF2).

Author status:

Brunel employees: McConnell (Reader & Professor; 2000>), Romer (Senior Lecturer and Reader; 2004>), Volianitis (Lecturer; 2004-07), Ross (Lecturer; 2005-08), Taylor (Research Associate; 2007-09)

PhD students (Awarded): *Griffiths* (2010), *How* (2010), *Lomax* (2007), *Ross* (2005), *Taylor* (2007)

3. References to the research (indicative maximum of six references)

1. Romer LM, McConnell AK & Jones DA. (2002). Effects of inspiratory muscle training on time-trial performance in trained cyclists. *J Sports Sci* **20**, 547-562.

   http://dx.doi.org/10.1080/026404102760000053

2. Griffiths LA & McConnell AK. (2007). The influence of inspiratory and expiratory muscle training upon rowing performance. *Eur J Appl Physiol* **99**, 457-466.

   http://dx.doi.org/10.1007/s00421-006-0367-6

3. Ross EZ, Nowicky AV & McConnell AK. (2007). Influence of acute inspiratory loading upon diaphragm motor-evoked potentials in healthy humans. *J Appl Physiol* **102**, 1883-1890.

   http://dx.doi.org/10.1152/japplphysiol.00694.2006

4. McConnell AK & Lomax M. (2006). The influence of inspiratory muscle work history and specific inspiratory muscle training upon human limb muscle fatigue. *J Physiol* **577**, 445-457.

   http://dx.doi.org/10.1113/jphysiol.2006.117614

5. Turner LA, Mickleborough TD, McConnell AK, et al. (2011). Effect of inspiratory muscle training on exercise tolerance in asthmatic individuals. *Med Sci Sports Exerc* **43**, 2031-2038.

   http://dx.doi.org/10.1249/MSS.0b013e31821f4090 (see REF2)

6. McConnell AK & Griffiths LA. (2010). Acute cardiorespiratory responses to inspiratory pressure threshold loading. *Med Sci Sports Exerc* **42**, 1696-1703.

   http://dx.doi.org/10.1249/MSS.0b013e3181d435cf (see REF2)

Research grants –

1. Knowledge Transfer Partnerships 12/09/05 to 31/10/07 - Project grant - £202,500

Title: Development of a computerised, electro-mechanical inspiratory muscle assessment and training system

2. Knowledge Transfer Partnerships 19/07/04 to 18/07/06 - Project grant - £100,770

Title: Development of a novel inspiratory muscle training device

3. HaB International Ltd. 09/04 to 08/07 PhD Bursary (Stephen How) - £42,000

Title: The effects of acute and chronic pressure-threshold inspiratory muscle loading upon upper and lower airway function.

4. Details of the impact (indicative maximum 750 words)

POWERbreathe® is an exercise product, patented by McConnell, which trains the breathing muscles. Prior to its commercial launch in 1997, no consumer breathing training products existed. Wide-ranging benefits include, ubiquitous improvements in exercise tolerance and breathlessness. The ground breaking status of POWERbreathe® has necessitated education of the market, relying heavily upon the group's body of research. This scientific heritage also allows marketing claims to comply with UK and international advertising standards. POWERbreathe® is the global market-leading brand of breathing training products, and sales have grown steeply since it was acquired by POWERbreathe International Ltd (PBI) in 2000 (data available directly from PBI); UK channels include household names such as Amazon, Boots and John Lewis. POWERbreathe® has received extensive media coverage and positive product reviews. The global reach of POWERbreathe® is

demonstrated by sales through PBI's overseas subsidiaries and distributors in 43 countries. It's also noteworthy that POWERbreathe®'s success has spawned a number of copycat products, brought to market by new companies, which also cite the group's research in their marketing. Whilst the group's research has become part of a larger body of knowledge, it has contributed key papers, providing the mainstay of marketing support for the breathing training product category. In May 2011, McConnell published a monograph on the IMT for sportspeople. The medical market is also supported by the group's outputs, especially its elucidation of underlying mechanisms. The significance of this body of literature to clinical practice is illustrated by a watershed event in 2006, when the POWERbreathe® *Medic* became the first exercise training equipment approved by the Prescription Pricing Authority for NHS prescription. Clinical collaborations have also resulted in outputs supporting novel clinical applications such as postural control (REF2) and low back pain (REF2), as well as more traditional applications such as asthma (REF2). In May 2013, McConnell published a monograph supporting the implementation of IMT in healthcare settings.

Insights provided by the group's research (section 3, #6) were exploited through two KTPs to extend the POWERbreathe® product range, and in 2010 the world's first electronic inspiratory muscle trainer was launched. The development resulted in a new patent (McConnell is an inventor) and a royalty bearing licence agreement. The product won the Plastic's Industry 2010 "Consumer Product Design of the Year" award, and was featured on the European Respiratory Society annual meeting Buyers' guide 2011. In July 2013, McConnell also began providing consultancy services to a global, market-leading respiratory medical company. The company wishes to develop a novel product, specifically for patients undergoing mechanical ventilation.

Reach

The reach of the impact created by the group's research has been maximised via: 1. peer-reviewed journal papers; 2. conference presentations; 3. articles in consumer publications; 4. presentations to opinion formers and the general public; 5. a book on "breathing training" for sports people (>6k sales in 24 mo); 6. a book on respiratory muscle training for clinicians; 7. a sports website [breathestrong.com] and a clinical website [physiobreathe.com]; 8. social media [Twitter, Facebook, Blog]; 9. iPhone Apps (>1k sales in 18 mo). The reach of breathing training, and its underpinning by the group's research is evidenced by metrics such as:

- 1.2 million hits from a Google search using "Powerbreathe"
- 115k hits from a Google search using "POWERbreathe Romer"
- 38k hits from a Google search using "POWERbreathe McConnell"
- 68k hits from a Google search using "IMT McConnell COPD"
- 53k hits from a Google search using McConnell's book title, "Breathe Strong, Perform Better"
- 1,500 new monthly visitors to McConnell's breathestrong.com website
- Google keyword search of the phrase "breathing training" yields over 51k hits, the top 3 rankings of which are occupied by breathestrong.com (1 and 2) and POWERbreathe.com (3)

Beneficiaries

POWERbreathe® has two principal markets: 1. sport, fitness and wellbeing; and 2. medical. Beneficiaries in the former group range from elite sportspeople, to older people. Recreationally active people use POWERbreathe® because it makes exercise feel easier. Athletes typically experience improvements in time trial performance of 2-5% within 6 weeks, making IMT an integral part of elite competition preparation. Publically-known Olympic and World Champions include the gold medal winning men's eight from the Athens Olympics and England's 2003 Rugby World Cup winners, as well as the current Rabobank cycling team. Dr Steve Ingham, Head of Technical Development at English Institute of Sport, included IMT as one of his "Top 10 applications of sports physiology" in his pre-Olympic Blog. In 2012, McConnell's work on breathing training was featured in The Wellcome Trust's "In the Zone" project. POWERbreathe® is also part of the curriculum of OCR Advanced Subsidiary GCE in Physical Education. Beneficiaries in a clinical setting include people with breathlessness and exercise intolerance (e.g., respiratory and cardiac patients). In 2012, the POWERbreathe® K-Series product (developed through KTP) was selected for use in a

six nation (Belgium, Holland, Germany, Austria, Switzerland, Canada) multi-centre randomised, controlled trial of IMT in patients with chronic obstructive pulmonary disease. Economic benefits accrue from sales by manufacturers of all breathing training products and their supply chains.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Evidence of the use of the group's research in promotion of breathing training products –

- The following commercial websites refer to research by McConnell and colleagues - www.powerbreath.com, www.powerlung.com, www.respibelt.com, www.ultrabreathe.com, www.easybreathe.co.uk

Evidence of the impact of the group's research and knowhow upon POWERbreathe International Ltd.'s business, and the reach and significance of POWERbreathe® -

- The Managing Director at POWERbreathe International Ltd.
- www.powerbreathe.com

Evidence of impact amongst the general public and in schools -

- McConnell AK. (2011). Breathe Strong: Perform Better. Human Kinetics, Champaign, IL. *Book on the application of respiratory muscle training to sport.*
- POWERbreathe® featured in Universities Week Report (2012) "Olympic and Paralympic Games: the impact of universities" (see pdf evidence file) www.universitiesuk.ac.uk/highereducation/Pages/OlympicAndParalympicGamesTheImpactOfUniversities.aspx#.Uk7htxaUZD0
- Wellcome Trust "In the Zone" project (2012) (see pdf evidence file) www.getinthezone.org.uk/media/24715/wellcometrust_11-14_introduction.pdf
- OCR Advanced Subsidiary GCE in Physical Education (see pdf evidence file) www.ocr.org.uk/images/80821-unit-g451-schemes-of-work-and-lesson-plans-booklet.doc

Evidence of impact in elite sport –

- Managing Director of POWERbreathe International Ltd.
- Head of Technical Development at English Institute of Sport http://steveingham.blogspot.co.uk/2012/06/top-10-applications-no-7-seeking.html
- Rabobank Cycling Team - http://www.youtube.com/watch?v=dpHsDr80Bxk

Evidence of impact in a clinical setting –

- Prescription Pricing Authority listing of POWERbreathe® Medic www.powerbreathe.com/media/wysiwyg/pdfs/PB_Med_Broch.pdf www.powerbreathe.com/powerbreathe-on-the-nhs
- Piepoli MF et al. (2011). *Eur J Heart Fail* **13,** 347-357. DOI 10.1093/eurjhf/hfr017 *This Position Statement recommends IMT and mentions POWERbreathe® specifically.*
- New POWERbreathe K-Series medical product featured on the front cover of European Respiratory Society Buyers' guide 2011 (see pdf evidence file).
- McConnell, AK. (2013) Inspiratory Muscle Training: Theory & Practice, Reed Elsevier. *Book on the application of respiratory muscle training to clinical practice.*
- Multi-centre trial of IMT in patients with COPD led by Prof. Rik Gosselink, KU Leuven. Charususin N et al. (2013). Inspiratory muscle training protocol for patients with chronic obstructive pulmonary disease (IMTCO study): a multicentre randomised controlled trial. *BMJ open* **3.** DOI 10.1136/bmjopen-2013-003101 *The new POWERbreathe® K-Series product was selected for use in this international trial.*

Patents –

- McConnell AK. (1994). Inspiratory muscle training device. GB19930008285 19930421
- Spurling DA, Lam DHY, Skelton A, McConnell AK, Cecelja F & Broomhead P. (2009). Dynamic inspiratory muscle training device. WO2010000439A1.