A RANDOMIZED CONTROLLED TRIAL OF BRAIN ENDURANCE TRAINING (BET) TO REDUCE FATIGUE DURING ENDURANCE EXERCISE

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ABSTRACT

PURPOSE: Brain Endurance Training (BET) is a new training method that uses acute mental fatigue as a training stimulus to induce chronic reductions in fatigue during physical and/or cognitive tasks. The aim of this study was to test the efficacy of BET in alleviating fatigue during endurance exercise in healthy male adults. The hypotheses were that the combination of BET and standard endurance training increases endurance exercise performance and reduces rating of perceived exertion (RPE) more than standard endurance training alone. METHODS: 35 healthy male volunteers were randomly assigned to two different training groups: BET and control. Both groups trained on a cycle ergometer for 60 min at 65% VO_{2max}. Whilst cycling, the BET group performed a mentally fatiguing task on a computer. The control group was not involved in any mentally fatiguing task whilst cycling. Both groups trained three times a week for 12 weeks. VO_{2max} and endurance exercise performance (time to exhaustion [TTE] test at 75% of current VO_{2max}) were measured at baseline (pre-test), after six weeks of training (mid-test) and after 12 weeks of training (post-test). RPE was measured every minute during the TTE test. Data were analysed using mixed model ANOVAs. RESULTS: VO_{2max} increased similarly in both groups from 40 ± 5 ml/kg/min to 52 ± 6 ml/kg/min ($P < 0.01$). However, TTE increased significantly more in the BET group (pre-test 28 ± 9 min; mid-test 39 ± 11 min; post-test 55 ± 17 min) than in the control group (pre-test 18 ± 5 min; mid-test 23 ± 7 min; post-test 28 ± 12 min) ($p < 0.01$). Analysis of covariance to adjust for the pre-test difference in TTE also revealed a larger improvement in the BET group (+126%) compared to the control group (+42%) ($p < 0.01$). RPE during the TTE was significantly lower in the BET group compared to the control group ($p < 0.05$). CONCLUSION: The results of this study provide initial evidence that the combination of BET and standard endurance training is more effective than standard endurance training alone in alleviating fatigue during endurance exercise in healthy male adults.

RATIONALE

- **Perception of effort**, not muscle fatigue, **is the limiting factor for endurance performance** in highly-motivated individuals (Marcora et al., 2008; Marcora and Staiano, 2010)
- **Perception of effort is associated with activity of the anterior cingulate cortex (ACC)** (Williamson et al., 2001; 2002; Staiano et al. unpublished results), not afferent feedback from the body (Marcora, 2009)
- **Damage of the ACC** is associated with changes in effort-based decision-making (**rats become "lazy"**) (Walton et al., 2002)
- **Mentally fatiguing tasks** based on visual stimuli ("video games") **strongly activate the ACC** (Boksem and Tops, 2008)
- **The brain adapts** to various stimuli and stressors by changing its structure and function (brain plasticity) (Kolb, 1995)

HYPOTHESES

Systematic repetition of mentally fatiguing tasks:

- **increases training load on the brain**
- induces adaptations in the ACC or other relevant cortical areas
- **reduces perception of effort**
- **Increases endurance performance**

METHODS

Study Design

Exploratory randomized controlled trial to assess the efficacy of BET + aerobic exercise against traditional physical training (aerobic exercise only, Control). Participants were tested at baseline (pre-test), after six weeks of training (mid-test) and after 12 weeks of training (post-test). We randomly allocated 35 male subjects to either BET or control.

Training Procedures

- Participants allocated to the BET group cycled at moderate intensity (65% of VO_{2max}) whilst performing the AX-CPT task we used previously to induce significant fatigue in healthy subjects
- Participants allocated to the control group cycled at moderate intensity (65% of VO_{2max}) without performing any concurrent cognitive task (traditional physical training).

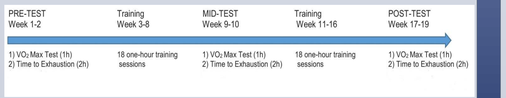
For both groups, the duration of each training session was fixed at 60 min, with RPE and HR measured throughout. Power output was adjusted in both groups after mid-test to accommodate for training-induced changes in VO_{2max}. Participants trained three times a week

-NASA-TLX Scale was used to measure the subjective workload of each of the 36 training sessions.

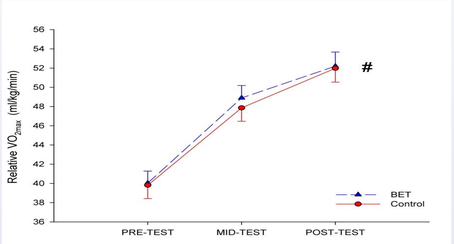
Testing Procedures

- ***Visit 1: VO_{2max} Test*** A standard incremental exercise test (2 min at 50 W + 50 W increments every 2 min) was performed until exhaustion.
- ***Visit 2: Time to Exhaustion Test*** After capillary blood analysis, participants sat on the cycle ergometer and performed a time to exhaustion test consisting of 3-min warm-up at 40% of peak power output followed by a rectangular workload corresponding to 75% of VO_{2max}. Pedal frequency was freely chosen between 60 and 100 RPM and was recorded every minute.

During the incremental exercise and the Time To Exhaustion test oxigen consumption (breath by breath), heart rate (continuously), RPE (every minute), mood and motivation (at the beginning of every test) were measured.

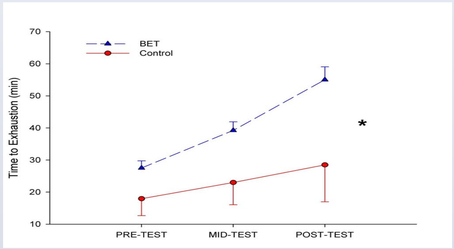


PHYSICAL PERFORMANCE RESULTS



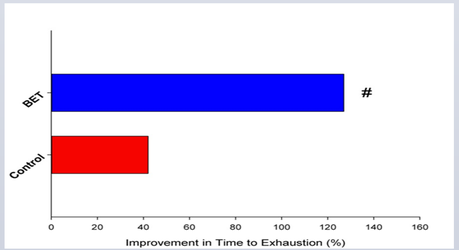
Changes in relative VO2max induced by BET and traditional physical training

Significant main effect of test ($P < 0.001$)



Absolute changes in physical endurance induced by BET and traditional physical training

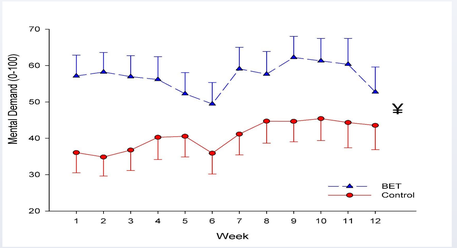
* Significant group x test interaction ($P < 0.001$)



Relative changes in physical endurance induced by BET and traditional physical training

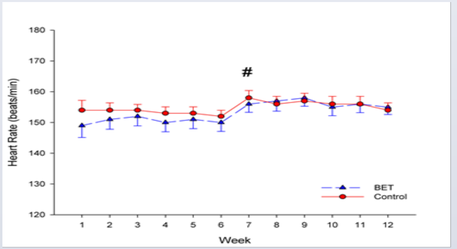
Significant main effect of group ($P < 0.001$)

COGNITIVE AND PERCEPTUAL RESULTS



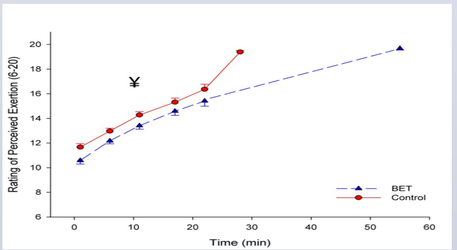
Average weekly ratings of mental demand of BET and traditional physical training

¥ Significant main effect of group ($P < 0.05$)



Average weekly heart rate recorded during BET and traditional physical training

Significant main effect of week ($P < 0.001$)



Perception of effort during time to exhaustion at post-test

¥ Significant main effect of group at isotime ($P < 0.01$)

CONCLUSIONS AND DIRECTIONS

BET seems **highly effective** in improving endurance performance when combined with traditional physical training in healthy active males

BET could provide **new training stimuli** to elite endurance athletes

BET could be used to **increase training load** in elite endurance athletes **without overloading the musculoskeletal system** (injury prevention)

BET could be used in **injured athletes that cannot perform physical training**

Beware **overtraining** (increased load on the brain)

Future studies:
BET in females and elite endurance athletes
Optimisation of BET (volume, intensity, frequency, duration etcetera)
Neurobiological mechanisms underlying positive effects of BET on perception of effort and endurance performance

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ACKNOLEDGMENTS

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