**Title:** Acute psycho-physiological responses to perceptually regulated hypoxic and normoxic interval walks in overweight-to-obese adults

**Abstract**

***Objectives:*** We investigated psycho-physiological responses to perceptually regulated interval walks in hypoxia *versus* normoxia in obese individuals.

***Design:*** Within-participants repeated measures.

***Methods*:** Ten obese adults (BMI = 32 ± 3 kg/m-2) completed a 60-min interval session (15 × 2 min walking at a rating of perceived exertion of 14 on the 6-20 Borg scale with 2 min of rest) either in hypoxia (FiO2 = 13.0%, HYP) or normoxia (NOR). A third trial replicating the HYPspeed pattern was carried out in normoxia as a control (CON). Exercise responses were analysed comparing the average of 1st to 3rd exercise bouts to those of the 4th–6th, 7th–9th, 10th–12th and 13th–15th exercise bouts (block 1 *vs*. 2, 3, 4 and 5).

***Results*:** Treadmill speed was slower during block 4 (6.14 ± 0.67 *versus* 6.24 ± 0.73 km/h-1) and block 5 (6.12 ± 0.64 *versus* 6.25 ± 0.75 km/h-1) in HYP compared to NOR or CON (p = 0.009). Compared to NOR and CON, heart rate was +6–10% higher (*p* = 0.001), whilst arterial oxygen saturation (−12–13%) was lower (*p* < 0.001) in HYP. Perceived limb discomfort was lower in HYP and CON *versus* NOR(−21 ± 4% and −34 ± 6%; *p* = 0.004).

***Conclusions*:** In overweight-to-obese adults, perceptually regulated interval walks in hypoxia *versus* normoxia leads to progressively slower speeds along with lower limb discomfort and larger physiological stress than normoxia. Walking at the speed adopted in hypoxia produces similar psycho-physiological responses at the same absolute intensity in normoxia.

**Key words:** Hypoxia, perceptually regulated exercise, interval training, obesity.

**Practical applications**

* When controlling exercise intensity perceptually (RPE = 14) during interval walks, slower walking speed occurs in hypoxia than normoxia.
* Perceptually regulated interval walking in hypoxia at a lower external workload (i.e., walking speed) achieves less discomfort and a higher physiological stress compared to normoxia.
* Walking at the speed adopted in hypoxia produces similar psycho-physiological responses at the same absolute intensity in normoxia.

**1. Introduction**

Obesity is typically caused by a positive energy balance, often accompanied by elevated blood pressure and metabolic deficiencies, which eventually leads to excess fat accumulation.1 Co-morbidities such as cardiovascular disease, hypertension and Type 2 Diabetes are therefore at greater risk of development in obese populations resulting in the likelihood of higher mortality rates.2 Walking is an effective strategy to increase the energy expenditure of physical activity and exercise in unhealthy individuals, including adults with obesity.3 Walking at a fixed-intensity (60% of maximal oxygen uptake [VO2MAX]) for 45–60 min, 1–5 times per week for at least six weeks, leads to a plethora of health improvements in obese individuals.4,5 A study of one hundred seventy-five sedentary, overweight men and women with mild to moderate dyslipidaemia over 8 months indicated a clear dose-response relationship between increase in exercise amount and decreases in visceral, subcutaneous and total abdominal fat, without changes in caloric intake.6

Exercise-related sensations (i.e., perceived recovery, motivation, breathlessness, limb discomfort and pleasure), either measured during or following exercise, likely have a significant influence on adherence to training. This is especially true in obese individuals who are typically facing higher-than-normal exercise-induced physiological and perceptual responses.7,8 In obese individuals, Ekkekakis and Lind9 showed that an acute bout of self-paced, continuous walking (20 min) increases post-exercise enjoyment above baseline, whereas imposing a 10% higher exercise intensity decreased enjoyment levels. Therefore, perceptually regulated walking that consists of matching a rating of perceived exertion [RPE] target, as opposed to a pre-determined fixed-intensity, may be a more effective approach to prescribing exercise in this population.10

Exercise with the addition of hypoxia provides a unique challenge to the cardiovascular system, due to immediate changes in convective oxygen delivery as a result of modifications from arterial oxygen content.11 This represents a promising exercise modality to increase the cardiovascular intensity of the session, without a corresponding elevation in the mechanical load imposed on the musculoskeletal system.12 In healthy individuals, acute muscle oxygenation responses didn’t differ during constant-load exercise (75% maximal heart rate [HRMAX] for 30 min) or high-intensity interval (15 × 1-min exercise with 1-min rest) cycling exercise performed in hypoxia (inspired fraction of oxygen or FiO2 = 13.5%) at the same relative intensity (similar hear rate) compared tonormoxia.13 However, fixed-intensity exercise does not permit the necessary adjustments to maintain a target exercise intensity that could potentially augment physiological stress levels in O2-deprived conditions.12,14 Our previous work demonstrated that trained runners carrying out perceptually regulated interval runs (4 × 4 min running at a RPE of 16 on the 6-20 Borg scale with 3 min of rest) adjusted to a slower speed in hypoxia than normoxia, with similar levels of physiological stress (i.e., HR and *vastus lateralis* muscle oxygenation) levels.14 Nonetheless, studies including a perceptually regulated interval protocol have not been carried out in an obese population, yet the potential findings could be promising for acute psycho-physiological responses when in hypoxia compared to normoxia.

Our intention was to compare, in overweight-to-obese individuals, the acute effects of a 60-min perceptually regulated (RPE = 14) interval walking (2 min of exercise interspersed with 2 min of rest) session in hypoxia and normoxia on psycho-physiological responses. We hypothesised that walking speed becomes progressively slower in hypoxia compared to normoxia when perceptually regulated, which results in similar adjustments in physiological and perceptual responses. In order to ascertain that these aforementioned changes are due to hypoxic exposure *per se*, and not a side effect of hypoxia-related expected reduction in walking speed, it was necessary to replicate the exercise pattern that participants self-selected in hypoxia but carried out in normoxia. Only then any potential psycho-physiological difference between O2-deprived and near sea level conditions could accurately be attributed to the stress of acute hypoxia. Therefore, a second aim was to investigate whether walking at the perceptually regulated speed adopted in hypoxia produces similar psycho-physiological responses at the same absolute intensity in normoxia. When the speed selected by participants in hypoxia is subsequently replicated in normoxia, we anticipated that a lower physiological/metabolic stress would accompany similar adjustments in exercise-related sensations and cognitive function.

**2. Methods**

Ten overweight-to-obese (7 males, 3 females; age: 38.2 ± 11.9 years; stature: 171 ± 10 cm; body weight: 93.8 ± 10.1 kg; body mass index: 32.1 ± 2.8 kg/m-2) individuals participated in this study after meeting the eligibility criteria and providing written informed consent. Eligible volunteers were those who had a body mass index of 27–35 kg/m-2, being normotensive (90–120 and 60–80 mmHg systolic and diastolic blood pressure, respectively), no known cardiovascular, metabolic or physiological illness/disease, sedentary (<1 h of moderate-intensity exercise/week), and no exposure to altitude (≥2500 m) for >48 h within six months. A sample size estimation was determined from a priori power analysis, using computer software G\*Power 3.1, to detect differences (effect size = 0.91, power of 0.80, alpha of 0.05) on treadmill speeds with effects sizes calculated from previous research assessing the effects of perceptually-regulated (RPE = 16) normoxic and hypoxic (FiO2 = 15%) interval runs on this variable.14 It was determined that 9 participants were required, with 10 allowing for a 10% attrition rate.This study received ethical approval from the School of Applied Science, London South Bank University (SAS1725) and was carried out in accordance with the Declaration of Helsinki (2013).

Participants attended the laboratory on four separate occasions. The first session consisted of eligibility determination, familiarisation with the measures and treadmill walking, and identification of preferred walking speed. Within 72 h, participants returned to the laboratory for the first of three experimental trials, each separated by seven days to enable a washout period. Participants completed a 60-min interval session (15 × 2 min walking, 2 min resting) during each experimental trial. The first and second experimental trials included exposure to either hypoxia (HYP, FiO2 = 13.0% / ~3750 m simulated altitude) or normoxia (NOR), with the order of intervention randomised, whilst the interval walking intensity was perceptually regulated (RPE = 14). The final experimental trial was the control (CON), where participants were exposed to normoxia and the intensity self-selected during HYP was imposed. The interval duration (work:rest ratio; 2:2 min) selected in the current study was based upon our previous findings.15 Each interval session was followed by a 60-min recovery period in normoxia.

At the preliminary visit to the laboratory, the preferred walking speed associated with an RPE of 14 (between ‘somewhat hard’ and ‘hard’) was determined for each participant in normoxia using a modified version of Martin and colleagues,16 as described previously.14 After a standardised 5-min warm up at 3.0 km/h-1, participants completed four ramped treadmill walks with increasing and decreasing speeds. After every 15 s per ramp, participants rated their RPE of the current speed (controlled by the investigator and out of sight of the participant) in accordance with Borg's 6 (“no exertion at all”) – 20 (“maximal exertion”) numeric scale. Ramp one started at km/h-1, increasing by 0.5 km/h-1 every 20 s until the speed was considered as RPE ≥16; ramp two started at +0.5 km/h-1 the previous end speed, decreasing by 0.5 km/h-1 until the speed was considered as RPE ≤10; ramp three started at the speed considered as an RPE of 12 in ramp two, increasing by 0.5 km/h-1 until the speed was considered as RPE ≥16; and ramp four started at +0.5 km/h-1 the previous end speed, decreasing by 0.5 km/h-1 until the speed was considered as RPE ≤10.

After a standardised 5-min warm up at 3.0 km/h-1, a facemask connected to a portable hypoxic generator was attached to the participants (*described further below*). Participants completed 15 × 2-min walking intervals, each separated by 2 min of passive recovery (quiet standing). The first 30 s of each 2-min interval began at participants’ preferred walking speed associated with an RPE of 14 during all sessions. During the HYP and NOR trials, participants were free to decide if and how treadmill speed needed to be altered every 30 s (i.e., self-paced and adjusted manually by the investigator) to ensure maintenance of RPE = 14, whilst walking. Participants hand-signalled in response to the current speed (finger up to increase, finger down to decrease, and circle using index finger and thumb to maintain); and signalled again to inform how much of an increase/decrease in speed is required [1, 2 or 3 fingers up (faster) or down (slower) for 0.2, 0.4 or 0.6 km/h-1 changes, respectively]. Signals were trialled during familiarisation. Participants were not required to make any adjustments during CON.

Participants wore a facemask connected to a hypoxic generator (Everest Training Summit II, Hypoxico Altitude Training Systems, USA). When breathing ‘normal air’ during normoxic conditions, the hypoxic generator was set at a simulated altitude of 100 m to increase the strength of blinding of the intervention. The study was designed as a single-blind fashion protocol in which participants, but not investigators, were blinded toward the environmental conditions. Total hypoxic exposure corresponded to exactly 60 min during HYP with the facemask remaining attached across all interval walking sessions.

Treadmill speed was manually recorded. A chest strap (H10, Polar, Finland) connected *via* Bluetooth to a watch (M400, Polar, Finland) permitted HR recording. Arterial oxygen saturation (SpO2) was assessed *via* finger pulse oximetry (iHealth Air, iHealthLabs, USA). Both HR watch and oximeter receiver were attached on the handrails on the sides of the treadmill in a manner to not allow participants to view any data. These measures were assessed every 30 s during each 2-min interval.

Perceived recovery was assessed by answering ‘*how recovered do you feel currently?*’ *via* a numeric scale, ranging from 0 (‘*very poorly recovered’*) to 10 (‘*very well recovered*’).17 Recovery was assessed before interval one to determine perceptions following the warm-up. Perceived motivation to exercise was assessed via a 20-cm visual analog scale.18 Participants were asked ‘*how motivated do you feel to exercise right now?*’ and answered by adjusting the level on the scale between 0 (‘*extremely low*’, white colored) and 20 (‘*extremely high*’, black colored). Perceived recovery and motivation to exercise were assessed 30 s before each interval.

Perceived breathlessness was assessed by answering ‘*how does your breathing feel currently?*’ via a numeric scale, ranging from 0 (‘*nothing at all’*) to 10 (‘*very, very severe*’).19 Using the same scale, perceived limb discomfort was assessed by answering ‘*how do your legs feel currently?*’. A 20 cm visual analog scale (the same as motivation above) was used to assess ‘*how pleasant was that run?*’ ranging from 0 (“*extremely unpleasant*”) and 20 (“*extremely pleasant*”). Ratings of perceived breathlessness, limb discomfort and pleasure were assessed immediately after each interval.

Perceived mood state, positive and negative affects (PANAS) and exercise self-efficacy were assessed at baseline and immediately (Post0), 30 (Post30) and 60 (Post60) min after the interval walking session. Participants were asked ‘*how are you feeling right now?’* and instructed to verbally specify a number on an 11-point scale anchored ‘*very bad*’ (-5) up to ‘*very good*’ (+5) for perceived mood state.20 PANAS were assessed *via* a 20-item 5-point Likert scale. Participants were instructed to answer how they feel towards 20 emotions including ‘*interested’*, ‘*distressed’* and ‘*excited’*, ranging from ‘*very slightly or not at all*’ (1) to ‘*extremely*’ (5). Items were totaled for positive and negative responses.21 Exercise self-efficacy was assessed *via* a six item 11-point Likert scale. Participants were instructed to answer how confident they feel in ‘*carrying out exercise* *3 times per week at a moderate-intensity for 40+ minutes without quitting*’ for 1–6 months from ‘*not at all confident*’ (0) up to ‘*highly confident*’.22 This Likert scale was in reference to exercise generally, and not the exercise employed in this study.

Treadmill speed, HR and SpO2 values were averaged across each 2-min interval. Treadmill speed, HR, SpO2, and perceptual measures assessed during the interval walking sessions were condensed by averaging intervals into five blocks of three (i.e., block 1: 1–3, block 2: 4–6, block 3: 7–9, block 4: 10–12 and block 5: 13–15). All perceptual data are expressed as raw values due to there being no significant differences at baseline.

Data distribution was assessed via a Shapiro-Wilk test. A parametric within-subject two-way analysis of variance was used to investigate the main effect of condition (HYP *versus* NOR and CON), time (baseline *versus* Post0, Post30 and Post60 or block 1 *versus* 2, 3, 4 and 5) and the condition × time interaction for normally distributed data. Partial eta-squared (η²) was calculated as a measure of effect size. Values of 0.01, 0.06 and above 0.14 were considered as small, medium and large, respectively. Bonferroni post-hoc pairwise comparisons were used to identify locations of significant effects. Statistical testing was carried out in SPSS (v21, IBM Corp., Armonk, NY, USA). Data was considered significant if *p* ≤ 0.05. All data are presented as group means ± SD.

**3. Results**

Treadmill speed was slower during blocks 4 and 5 (−1.7 ± 0.1% and −2.2 ± 0.2%, respectively; *p* < 0.05) in HYP *versus* NOR or CON (Figure 1A). HR increased progressively from block 1 to 5 in all conditions (+5.0 ± 0.5%, *p* = 0.011, Figure 1B). HR was higher overall during HYP compared to NOR and CON (+5.7 ± 1.0% and +10.0 ± 2.3%, respectively; *p* = 0.001). SpO2 was lower throughout HYP (84.6 ± 0.8%) *versus* NOR and CON (97.3 ± 0.2% and 97.7 ± 0.3%, respectively; *p* = 0.001, Figure 1C). Compared to block 1, SpO2 was also lower during blocks 2-5 in HYP only (*p* = 0.015).

Perceived recovery decreased progressively from block 1 to 5 (−11 ± 1%; *p* = 0.006, Figure 2A), irrespective of condition (*p* = 0.133). Perceived breathlessness increased progressively from block 1 to 5 (+9 ± 1%; *p* = 0.009, Figure 2C), irrespective of condition (*P* = 0.323). Perceived limb discomfort was lower overall during HYP (−18 ± 3%; *p* = 0.003) compared to NOR, irrespective of time (*p* = 0.268), while failing to reach statistical significance during CON (−21 ± 6%, *p* = 0.060) (Figure 2D). Perceived motivation and pleasure did not change throughout the protocol (all *p* > 0.05; Figure 2B and E).

Positive affect was lower at Post0 (−7 ± 1%), Post30 (−1 ± 0%) and Post60 (−4 ± 2%) compared to baseline (*p* = 0.020, Figure 3A). Positive affect was lower in HYPcompared to NOR(−11 ± 6% and -6 ± 0%, respectively) and CON (−10 ± 1% and −1 ± 2%, respectively) at Post0 and Post30 time points (*p* = 0.004, Figure 3A). Negative affect decreased over time (−7 ± 2%; *p* = 0.038, Figure 3B). Perceived mood state improved over time (+26 ± 7%; *p* = 0.020, Figure 3C). Exercise self-efficacy was lower at Post0 after HYP*versus* NOR (−25 ± 5%; *p* = 0.044, Figure 3D).

\*\*\* Figures 1, 2 and 3 about here \*\*\*

**4. Discussion**

Our novel findings show that a slower walking speed is adopted, along with lower limb discomfort and greater physiological stress (i.e., higher HR, lower SpO2) in HYPcompared with NOR. During CON − i.e., when the (hypoxic) speed is performed in normoxia − the level of physiological stress was lower than in HYP. Additionally, limb discomfort was lower in CON than in NOR. In overweight-to-obese individuals, perceptually regulated interval walking in hypoxia at a lower external workload (i.e., walking speed) achieves a higher physiological stress compared to normoxia, yet with a lower perceived load (i.e., limb discomfort). Walking at the speed adopted in hypoxia produces similar psycho-physiological responses at the same absolute intensity in normoxia.

Throughout HYP (FiO2 = 13.0%), greater physiological stress (i.e., higher HR, lower SpO2) occurred compared to NORand CON. These findings obtained in obese individuals are somewhat different to our previous work in trained runners, whereby HR did not differ between hypoxia (FiO2 = 15.0%) and normoxia during perceptually regulated interval running (4 × 4 min running at RPE = 16, 3-min recoveries).14 This may partly be due to larger hypoxia-related adjustments in workload (i.e., decreased treadmill speed) found in the previous (−6%) compared to the current study (−2%). In adults with obesity, Fernández Menéndez et al.10 showed that preferred walking speed increased each week during a 3-wks program, yet the treadmill speed selected by the hypoxic *versus* normoxic group only became significant lower by ~9% in the last week of training. Pending confirmatory research, during a longitudinal training program using perceptually-regulated intervals, this walking gap between the two conditions could increase over time. Both Wiesner and colleagues,23 during 60-min continuous running/walking, and Chacaroun and colleagues13, during interval cycling (15 × 1:1-min), have shown that lower hypoxia-induced absolute exercise level (i.e., speed/power) for a given exercise intensity (i.e., RPE or HR target) may preserve levels of physiological stress. In our study, in normoxia at a matched walking speed self-selected in hypoxia (CON), physiological stress level was reduced (i.e., lower HR, higher SpO2), reinforcing the impact of hypoxia on increased physiological markers of stress observed in the current study.

Perceptions of limb discomfort were globally lower throughout HYP compared with NOR. This is unlike the findings of Christian and colleagues,25 who found greater perceived limb discomfort during 5 min continuous, sub-maximal perceptually regulated cycling (RPE 3 on CR10 Borg scale) in hypoxia (FiO2 = 13.5%) *versus* normoxia. Remarkably, during HYP, this decrement also occurred prior to participants lowering the treadmill speed to maintain a preferred walking speed associated with an RPE of 14 as they walked intermittently. The current data suggests that, when walking in hypoxia (FiO2 = 13.0%) at a perceptually regulated intensity, there may be a potential disconnection between overall RPE and the contribution of perceived limb discomfort to an RPE target of 14, that is not present when in normoxia.24 Interestingly, in the current study, the time-dependent changes in perceived recovery (decrease) and breathlessness (increase) did not differ between conditions, whilst perceived motivation and pleasure were maintained during perceptually regulated interval walking. Except for limb discomfort, which was also lower in CON than in NOR, there were no other significant differences between these conditions. This is important because slower walking speed in HYP but also in CON is perceived as more comfortable than in NOR and, thus, both conditions can limit joint mechanical stress and eventually reduce the risk of orthopaedic injury.However, only in HYP, slower walking speed is associated with increased physiological stress.

Positive affect and exercise self-efficacy were lower for up to 30 min after HYPcompared with NORand CON. This is in disagreement with the proposed hypothesis. It was postulated there would be matched exercise-related sensations between perceptually regulated interval walks at a slower speed in hypoxia *versus* normoxia, whilst exercise-related sensations would be greater in CON. Lower ratings of positive affect and exercise self-efficacy following HYP may be explained through the larger physiological stress experienced during interval walking compared to NOR and CON. Obese individuals are considered to be more perceptually sensitive to exercise-induced physiological stress than healthy individuals.7 Therefore, it could be argued that greater speed adjustments (i.e., decreases) in HYP*versus* NOR,potentiating matched exercise-induced physiological stress, may have preserved exercise-related sensations after interval walking in the current study. However, time-dependent increases in perceived mood change and decreased negative affect occurred despite the effect of interval walking speed or hypoxic exposure. This is likely due to the positive effect of acute exercise on mood change, irrespective of intensity.26 Despite the decreases in interval walking speed during HYP, exercise-related sensations are negatively impacted for up to 30 min post-exercise compared with NORand CON.

The present study has several limitations. A single hypoxic dose (FiO2 = 13.0%) was implemented during hypoxic sessions based on current literature recommendations.27 It is, however, unknown if this FiO2 represents the threshold to induce a sufficient physiological stress, compared to normoxia, without negatively impacting performance of interval walking. Whether a lower FiO2 permits performance aligned with greater expected physiological stress is also unclear. Perhaps a clamped SpO2 compared to FiO2 would be more beneficial in decreasing the inter-subject variability in psycho-physiological responses to the hypoxic stimulus. In doing so, two instruments – Physical Activity Enjoyment Scale (i.e., after the exercise session) and the Exercise Enjoyment Scale (i.e., during the exercise session) – should be considered for measuring the enjoyment responses.28 The work:rest ratio employed in this study build on previous works,13 recommending shorter over longer interval walking cycles to maximise the psycho-physiological responses in obese individuals during hypoxic exposure. Further work should determine whether varying the hypoxic dose (i.e., severity and duration), interval exercise (i.e., duration) and intensity (i.e., perceptually regulated target RPE) leads to more favourable acute psycho-physiological responses when carried out in hypoxia compared to normoxia.

**5. Conclusion**

Overweight individuals, or those with obesity, achieved a higher physiological stress during perceptually regulated (RPE = 14) interval walking in hypoxia at a progressively slower speed compared to normoxia, which was also perceived as less uncomfortable in their legs. Although exercise-related sensations were negatively impacted after perceptually regulated interval walking in hypoxia compared to normoxia (i.e., perceived mood change and exercise self-efficacy), these findings add to the acute, therapeutic benefits of hypoxic training for obese individuals. Finally, walking at the speed adopted in hypoxia produces similar psycho-physiological responses at the same absolute intensity in normoxia.

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**7. Figure legends**

**Figure 1** - Treadmill speed (A), heart rate (B) and arterial oxygen saturation (SpO2; C) during the interval walking session.

*Data are condensed into five blocks for every three 2-min intervals and presented as mean ± SD. ANOVA main effects of condition, time and interaction are stated along with partial-eta squared for effect size into brackets with significant effects (P < 0.05) highlighted in bold. Black bars = self-paced hypoxic condition (HYP); white bars = self-paced normoxic condition (NOR); grey bars = normoxic condition imposed with speed selected in hypoxic condition (CON). 1 and 2 denotes a statistically significant difference (P < 0.05) between HYPversus NORand CON, respectively. a denotes a statistically significant difference (P < 0.05) compared to block 1.*

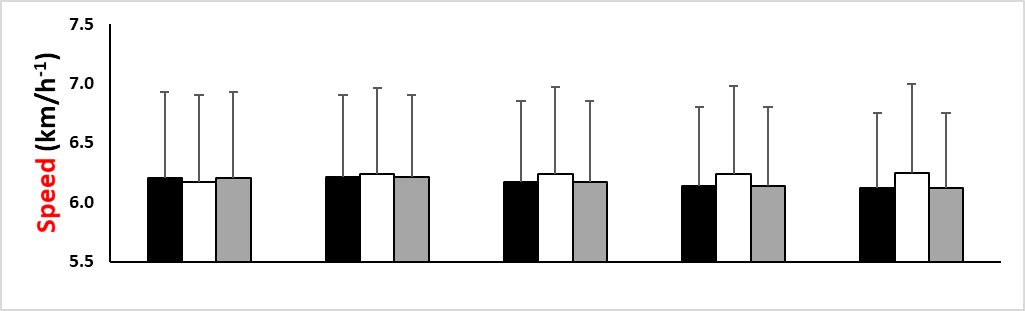
**Figure 2** - Perceived recovery (A), motivation (B), breathlessness (C), limb discomfort (D) and pleasure (E) during the interval walking session.

*Data are condensed into five blocks for every three 2-min intervals and rest periods, and presented as mean ± SD. ANOVA main effects of condition, time and interaction are stated along with partial-eta squared for effect size into brackets with significant effects (P < 0.05) highlighted in bold. Black bars = self-paced hypoxic condition (HYP); white bars = self-paced normoxic condition (NOR); grey bars = normoxic condition imposed with speed selected in hypoxic condition (CON). 1 and 3 denote a statistically significant difference (P < 0.05) for HYPversus NORand CON versus NOR, respectively. a denotes a statistically significant difference (P < 0.05) compared to block 1.*

**Figure 3** - Perceived mood change (A), positive affect (B), exercise self-efficacy (C) and negative affect (D) assessed at baseline and 0 (Post0), 30 (Post30) and 60 (Post60) min after the interval walking session.

*Data are presented as absolute change from baseline and as mean ± SD. ANOVA main effects of condition, time and interaction are stated along with partial-eta squared for effect size into brackets with significant effects (P < 0.05) highlighted in bold. Black bars = self-paced hypoxic condition (HYP); white bars = self-paced normoxic condition (NOR); grey bars = normoxic condition imposed with speed selected in hypoxic condition (CON). 1 and 2 denotes a statistically significant difference (P < 0.05) between HYPversus NORand CON, respectively. \* and \*\* denote a statistically significant difference (P < 0.05) compared to baseline and post0, respectively.*

*Figure 1.*

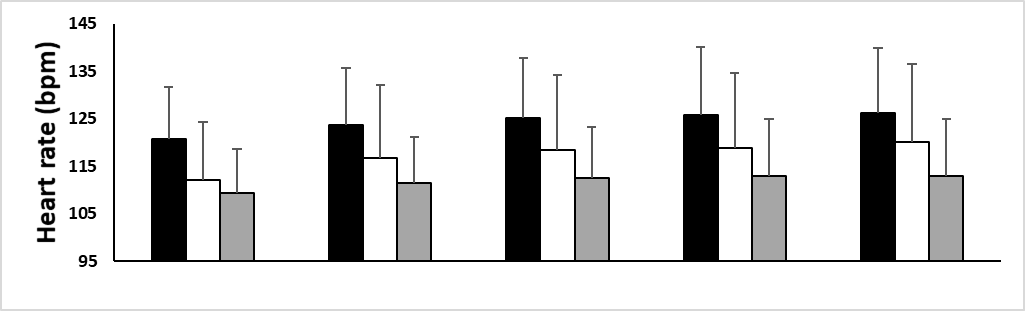


**A**

Condition: *p* = 0.344 (0.10)

Time: *p* = 0.678 (0.06)

**Interaction: *p* = 0.009 (0.30)**

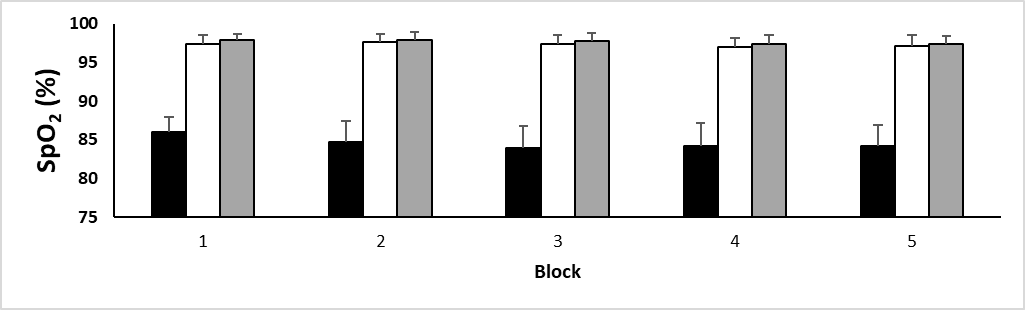


**B**

**Condition: *p* = 0.001 (0.60)**

**Time: *p* = 0.011 (0.48)**

Interaction: *p* = 0.406 (0.10)



**C**

**Condition: *p* < 0.001 (0.96)**

**Time: *p* = 0.015 (0.40)**

**Interaction: *p* = 0.007 (0.34)**

1

1

12

12a

12a

12a

12a

12

12a

12a

12a

12a

**HYP**

**NOR**

**CON**

*Figure 2*

**

*Figure 3*

**