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Official Title:

Facemask use during high intensity interval exercise in temperate and hot environments.

Objectives, Methods and Protocol

Objective: The purpose of this study was to investigate the effects of surgical mask use during high intensity interval exercise (HIIE) on physiological and perceptual responses in hot and temperate environments.

Methods, Protocol, and Statistical Analysis

Participants

Ten recreationally trained participants (5 males; 5 females) were recruited for this study (Table 1). Participants were free from known cardiovascular, renal, metabolic, or chronic respiratory disease (i.e., asthma) as determined from a health history questionnaire. Participants were excluded if in the last 6 months they smoked and performed less than 150 minutes of moderate-intensity exercise per week, had a VO_2max below the 50th percentile for age and sex according to the ACSM guidelines for aerobic fitness [18], or reported no experience performing HIIE. A pregnancy test was completed for female participants to include only non-pregnant participants.

Prior to any exercise and data collection, the study protocol was explained, all participant concerns were addressed, and written consent was obtained. This study was registered at Clincialtrials.gov (NCT05143801), approved by the university's Institutional Review Board, and was in compliance with the Declaration of Helsinki [19].

Prior to each visit the participant was screened through Zoom™ (Zoom Video Communications, Inc, Version 5.4.9), email, or by phone for possible exposure to, and symptoms of COVID-19 using a screening checklist. Additionally, they were instructed to avoid eating a filling meal 1-hour, consuming caffeine 4 hours, and vigorous exercise 24 hours before the first visit.

Procedures

Anthropometrics and maximal Oxygen uptake measurements

Before the experimental trials, participants visited the Exercise Physiology laboratories for anthropometrics and VO_2max measurement. Body height was measured using a stadiometer (SECA, seca 216, Chino, CA, USA) and weight was measured using a digital scale (Cardinal DETECTO 758C, Webb City, MO). Then, participants completed a 5-minute warm-up at a self-selected exercise intensity prior to the VO_2max test on an electrically braked cycle ergometer

(Lode, Excalibur Sport, Groningen, The Netherlands). During the VO_2max test, HR was measured using a Polar HR monitor (Polar, Polar H10, USA) with each test designed to last between 10 and 12 minutes. The starting resistance and the continuous increase in resistance (between 20-40 watts) throughout the test was based on the participants' self-reported fitness. Termination of the VO_2max test occurred at volitional fatigue or when the participant could no longer maintain a cycling cadence of 60 revolutions per minute or higher. Gas-exchange was measured using a metabolic analyzer (Parvo Medics Inc, TrueOne 2400, Salt Lake City, UT) and data were analyzed using an 11-breath rolling average[20]. Primary criteria for a VO_2max was categorized as an observed plateau that varied by less than 150 mlO_2/min[21]. To determine a plateau using primary criteria, the mean of the absolute difference from each neighboring data point in the last 30 seconds of the 11-breath rolling average VO_2 was compared against 150 mlO_2/min[21]; if the average value was smaller, the test was categorized as a VO_2max. In the absence of a plateau, a VO_2max was confirmed if two of the three secondary criteria were met: 1) an RPE ≥17, 2) a respiratory exchange ratio (RER) of 1.1 or greater, and 3) a HR within 10 beats of estimated heart rate max using the Jones et al.[22] equation (202 - 0.72 x age). The highest power output recorded from the VO_2max test was used to calculate the high intensity and active recovery bouts for the HIIE sessions.

Environmental control

All trials were performed indoors within the University of New Mexico exercise physiology lab. The environmental conditions for all trials were monitored using the same wet bulb globe temperature (WBGT) device (Metrosonics, hs-3600 Portable Heat Stress Monitor, QUEST TECHNOLOGIES INC., GA, USA). Dry and wet bulb temperatures were recorded at the end of each active rest and HIIE bout for each trial.

A heat chamber with two electric heaters connected to a thermostat set to 36°C was used for both HIIE-HOT/CON and HIIE-HOT/MASK trials. This room was ventilated with the use of a ceiling fan set to low and by having the door slightly open. To control for any deviations in room temperature additional heaters were placed in the room and manually controlled to keep the room temperature stable. Humidity buildup in the heat chamber was prevented by having the door slightly open to allow humidity to escape the room.

Both HIIE-TEMP/CON and HIIE-TEMP/MASK trials were performed in a well-ventilated room. The room temperature was controlled for using the same methods for the HIIE-HOT/CON and HIIE-HOT/MASK trials.

High Intensity Interval Exercise Trials

Before all HIIE sessions participant's hydration status was assessed measuring urine specific gravity (USG) using a handheld refractometer (Cole-Parmer, RSA-BR90A, Vernon Hills, IL). A USG measurement lower than 1.020 g/cc allowed participants to proceed to the HIIE sessions. If USG was greater than 1.020 g/cc, then participants consumed 500 ml of water, and were reassessed after 30 minutes. This water provision was only repeated twice if USG remained above 1.020 g/cc.

A randomized non-counterbalanced crossover repeated measures design was used to compare cardiovascular, thermoregulatory, metabolic, and perceived responses before and during HIIE across four experimental trials performed during two visits. For each visit, which was separated by a minimum of 72 hours, the participants completed two HIIE sessions separated by 3 hours of rest. Each HIIE bout consisted of 10 bouts lasting 30 seconds performed at 85% P_{max} followed by 90 seconds of active recovery at 30% P_{max}. The HIIE sessions were performed in a temperate environment (23°C, 25% relative humidity) with (TEMP/MASK) and without a surgical mask (TEMP/CON), and in a hot environment (36°C, 14% relative humidity) with (HOT/MASK) and without a surgical mask (HOT/CON). During the exercise protocol participants were allowed to drink water. Although most participants chose not drink water during all HIIE sessions, one participant chose to ingest water during two of the four HIIE sessions while another participant chose to ingest water during one of the four HIIE sessions.

During HIIE sessions with a mask, all participants were instructed to wear the surgical mask snuggly over their nose and mouth. The participants fitted the flexible metal plate within the surgical mask over the bridge of the nose and had the bottom of the mask cover underneath the chin. During the 3-hour rest period participants were provided a 350-calorie meal (7g of Fat; 64g Carbohydrate; 9g Protein) and water *ad libitum*.

Cardiovascular Measurements

Before every HIIE trial and after 5-minutes of seated rest, resting blood pressure was measured using a sphygmomanometer, and stethoscope. A cardiac impedance device (PhysioFlow®, NeuMeDex, Bristol, PA) calibrated per manufacturer guidelines was used to indirectly measure cardiac output (CO), stroke volume (SV), and HR. These measurements were taken continuously using 10-second averaging provided by the PhysioFlow® software during each HIIE session.

Metabolic Measurements

A near infra-red spectroscopy (NIRS) device (Moxy, Moxy Monitor System, MN, USA) was used to measure muscle tissue oxygenation every second during each HIIE session. The highest muscle tissue oxygenation value from each active rest period (MTO active rest %) was averaged for each HIIE session. Additionally, the lowest muscle tissue oxygenation (MTO during HIIE %) value per high intensity bout was recorded and averaged from each HIIE session. The difference of the average MTO active rest % and MTO during HIIE % was used to calculate the muscle tissue oxygenation difference (MTO difference %). All MTO measurements were taken on the dominant leg at a marked location on the *vastus lateralis* that would allow movement without interference from the NIRS device. A pulse oximeter (Caretaker, Caretaker Medical, USA) was used to measure SpO_2 during HIIE. Blood lactate measurements (Lactate Plus, NOVA Biomedical, MA) were taken in duplicate at the ear lobe immediately before, and 5-minutes post HIIE.

Perceptual Measurement before and during HIIE

Borg's rating of perceived exertion (6 rest to 20 maximal effort) scale (RPE)[23] and thermal sensation (0 very cold to 8 very hot)[24,25] was measured immediately before and every four minutes into HIIE. A breathlessness scale (0 mm no breathlessness to 200 mm maximal breathlessness)[26] was used immediately before, at 10-minutes, and immediately after exercise to record subjective change in difficulty breathing. The highest measurements for both RPE (peak RPE) and thermal sensation (peak thermal sensation) were recorded per HIIE session performed. Additionally, RPE (RPE avg) and dyspnea scores were averaged over time for every HIIE session.

Thermal strain and hydration measurements

During each HIIE exercise session continuous core temperature measurements were taken using rectal thermistors (Level 1 esophageal/rectal temperature probe, Smiths Medical, Minneapolis, MN, USA) connected to a thermometer (Precision 4000, YSI Incorporated, Yellow Springs, OH, USA) and monitored to ensure participant safety. Additionally, Δ core temperature (i.e., the difference between peak core temperature and core temperature prior to starting exercise) and peak core temperature were recorded for each HIIE session. Sweat rate and dehydration were calculated from pre-exercise nude weight, post-exercise nude weight, water ingestion, and post-exercise urine output measurements[27]. Participants were asked to measure and report their pre-exercise and post-exercise nude weight using a digital scale (Cardinal DETECTO 758C, Webb City, MO) in a private room.

Statistical Analysis

Female and male descriptive data in terms of mean and standard deviation (SD) were compared using an independent t-test. If normality was violated, a non-parametric Mann-Whitney U test was performed. A 2x2 repeated measures ANOVA was performed to investigate statistical differences for all variables across TEMP/CON, TEMP/MASK, HOT/MASK, HOT/CON conditions except for a 2x2x3 repeated measures ANOVA being performed for perceived dyspnea data where time was an additional independent variable. Both main and interaction effects were calculated along with effect size, reported as partial η^2. Effect size benchmarks were defined as small (partial η^2 =0.01), medium (η^2 =0.06), and large (η^2 =0.14)[28]. A Bonferroni post-hoc test was used to determine specific differences with significant interaction effects. All statistical tests were performed using JASP (version 0.14.1.0); statistical significance was set at $p < 0.05$.