**Title:** The physiological and perceptual responses of stand-up paddle board exercise in a laboratory- and field-setting

**Running head:** Physiological responses to stand-up paddle boarding

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**Abstract**

This study quantified the physiological and perceptual responses of stand-up paddle boarding (SUP) during a range of stroke rates in a laboratory- and field-setting. Ten participants (eight male, two female; mean ± standard deviation [SD] age: 23±3 years; body mass: 70.5±9.1 kg; height: 170±9 cm; body mass index [BMI]: 24.3±1.5 kg.m2) completed a SUP V̇O2peak trial, and two SUP trials in both a laboratory- and field-setting (5-min at 10, 20 and 30 strokes.min-1 per stage). Energy expenditure (EE), metabolic equivalents (METs), heart rate (HR) and rating of perceived exertion (RPE) were recorded throughout.In the laboratory-setting, mean± SD EE and METs increased (*P*<0.001) linearly when SUP at 10 (3.3±1.0 kcal.min-1, 2.7±0.5), 20 (5.5±0.9 kcal.min-1, 4.4±0.7) and 30 strokes.min-1 (7.6±1.6 kcal.min-1, 6.1±1.2), respectively. During these efforts, mean± SD percentage of maximal HR were 56±5%, 69±6% and 84±8%, respectively. In the field-setting, mean± SD EE and METs also increased (*P*<0.001) linearly when SUP at 10 (3.6±0.9 kcal.min-1, 2.7±0.9), 20 (4.3±1.8 kcal.min-1, 3.5±1.0) and 30 strokes.min-1 (6.3±2.1 kcal.min-1, 4.6±1.4). During the three conditions mean± SD percentage of maximal HR were 58±8%, 65±7% and 73±9%.SUP at ≥20 strokes.min-1 in the laboratory- and field-setting meet the criteria for moderate-intensity exercise (3.0-5.9 METs). These findings may now be included in the latest Compendium of Physical Activities guidelines and offer potential to improve cardiorespiratory fitness if SUP is undertaken regularly by young, healthy adults.

**Keywords:** physical activity, aquatic exercise, stand-up paddle board, energy expenditure, cardiorespiratory health

**Introduction**

Stand-up paddle boarding (SUP) is an aquatic-based physical activity (PA), that has recently increased in popularity globally (Schram and Furness et al., 2017), likely due to its proposed short- and long-term health benefits (Hammer, 2011; Schram et al., 2016abc, 2017ab), with the majority of individuals commonly using SUP for enjoyment and fitness purposes (Furness et al., 2017). SUP is a low-impact, non-weight bearing PA and competitive sport, requiring users of all ages and abilities to stand-up and balance on the board, whilst simultaneously paddling bilaterally with a long single-bladed paddle to navigate (Schram et al., 2016a). Although SUP necessitates the predominant use of upper limb movements for paddling, trunk and lower limb muscles are also activated and utilized for balancing against the rotational forces produced by the act of paddling (Ruess et al., 2013ab). Whereby, aerobic and anaerobic capacity are key determinants of elite profiles (Schram et al., 2016a) and performance outcomes (Schram et al., 2017). Hence, SUP offers a whole-body exercise (Ruess et al., 2013ab), that can be performed on almost any body of water (sea, rivers and lakes) (Schram & Furness, 2017), and offers an enjoyable, somewhat easy to learn PA, that provides a plethora of physiological, musculoskeletal and psychological benefits for health and well-being (Schram et al., 2016b).

The readers are directed to the work of Schram and colleagues, who provide an excellent series of SUP research related to; demographic and participation data (Schram and Furness, 2017); recreational and elite athlete profiles (Schram et al., 2016a); differences between laboratory- and field-based maximal aerobic power in elite athletes (Schram et al., 2016c); performance analysis of a SUP marathon race (Schram et al., 2017a) and; short- (6 weeks [Schram et al., 2016b]), and long-term (1 year [Schram et al., 2017b]) adaptations following SUP training. However, there remains a dearth of research investigating the use of SUP as a form of PA for recreational users (Schram et al., 2016b) and that which provides informative data (exercise intensity and/or duration) to meet weekly exercise prescription guidelines (moderate-intensity: 150-min, vigorous-intensity: 75-min, or a combination thereof [O'Donovan et al., 2010; Department of Health, 2011]). As such, with SUP popularity increasing, recreational users may improve their cardiorespiratory fitness if SUP exercise intensity (stroke rate and/or power output) provide sufficient physiological stimulus (>65% of heart rate maximum [HRmax]) (Pollock et al., 1998), however, it is unknown what exercise intensity and/or time is required to induce favorable benefits (Schram et al., 2016b) for this increasingly popular and alternate form of aquatic PA.

Indeed, improvements in aerobic (maximal oxygen uptake [V̇O2max]: +23.6%) and anaerobic performance (maximal power output: +42.0%), alongside increased trunk muscle endurance (spine flexors via prone bridge time: +19.8%) and psychological status (self-rated quality of life: +10.0%, self-satisfaction: +28.1% and psychological health: +17.5%, as measured using the self-rated quality of life questionnaire [World Health Organisation, 1996]) were reported in sedentary individuals following a 6-week training program of low- and high-intensity SUP (Schram et al., 2016b). Given these favorable improvements to health and fitness, the increased and progressive SUP training volume (180 min.week-1) and sedentary population investigated, are likely contributing factors. Nonetheless, SUP may serve as an alternate form of PA for this population, although, further research is required to determine the correct exercise intensity and/or time to inform exercise prescription guidelines. This is of importance as population levels of sedentary behaviour are high (Loyen et al., 2016), with PA participation declining (Tremblay et al., 2014, 2016) and, high proportions of adolescents and adults failing to achieve daily recommended PA guidelines (Hallal et al., 2012), thus, contributing to the rise of non-communicable diseases (Stamatakis et al., 2019).

Consequently, understanding the physiological responses in recreational SUP users, specifically; quantifying the metabolic responses (energy expenditure [EE] and metabolic equivalents [METs]) across a range of representative and applicable stroke rates for recreational users, will allow for SUP exercise to be assessed as a form of PA, and subsequently determine if SUP conforms to current exercise guidelines (MET classification: *Light:* 1.6–2.9, *Moderate:* 3.0–5.9, and *Vigorous:* ≥6.0 [Jette et al., 1990; Ainsworth et al., 2000, 2011]). This information may benefit public healthcare professionals, guides/coaches and researchers, who may add SUP into the current Compendium of Physical Activities (Ainsworth et al., 2011) and/or PA guidelines (O'Donovan et al., 2010; Department of Health, 2011) due to its portability, simplicity and proposed physiological and psychological benefits.

Therefore, the aims of this study were to; 1) quantify the physiological (heart rate [HR], volume of oxygen uptake [V̇O2], metabolic equivalents [METs] and energy expenditure [EE]) and perceptual responses (ratings of perceived exertion [RPE] and feeling scales) at specific stroke rates of 10, 20 and 30 strokes.min-1 in both laboratory- and field-settings; 2) compare physiological and perceptual responses between laboratory- and field-settings, and; 3) quantify if SUP meets the criteria for ‘*Moderate’* intensity exercise (3.0-5.9 METS) to contribute to PA guidelines.

**Materials and methods:**

**Participants:**

Ten recreational SUP users (eight male, two female; mean ± standard deviation [SD] age: 23±3 years; body mass: 70.5±9.1 kg; height: 170±9 cm; body mass index [BMI]: 24.3±1.5 kg.m2) volunteered after providing written informed consent. This study was in accordance with the Declaration of Helsinki (World Medical Association, 2013) and approved by the Institution’s Research and Ethics Committee. Participants refrained from caffeine (2-h), alcohol and prolonged strenuous activity (both 24-h) prior to testing and arrived in a hydrated state (Sawka et al., 2007).

**Experimental design:**

Participants visited the laboratory on two occasions, 1) for a V̇O2peak SUP test and 2) for an incremental SUP trial in temperate conditions (22.9±1.5°C, 35.4±1.6 % relative humidity [RH]). The participants also completed the incremental SUP trial on a river within temperate conditions (15.4±0.3°C, 46.6±7.1% RH and 2.3±0.5 m.s-1 wind speed [“*Light-breeze*”]). Participants completed the incremental SUP trial, which involved paddling at three increasing, non-randomised stroke rates (10, 20 and 30 strokes.min-1) for 5-min per stage, in both the laboratory- and field-setting (Figure 1).

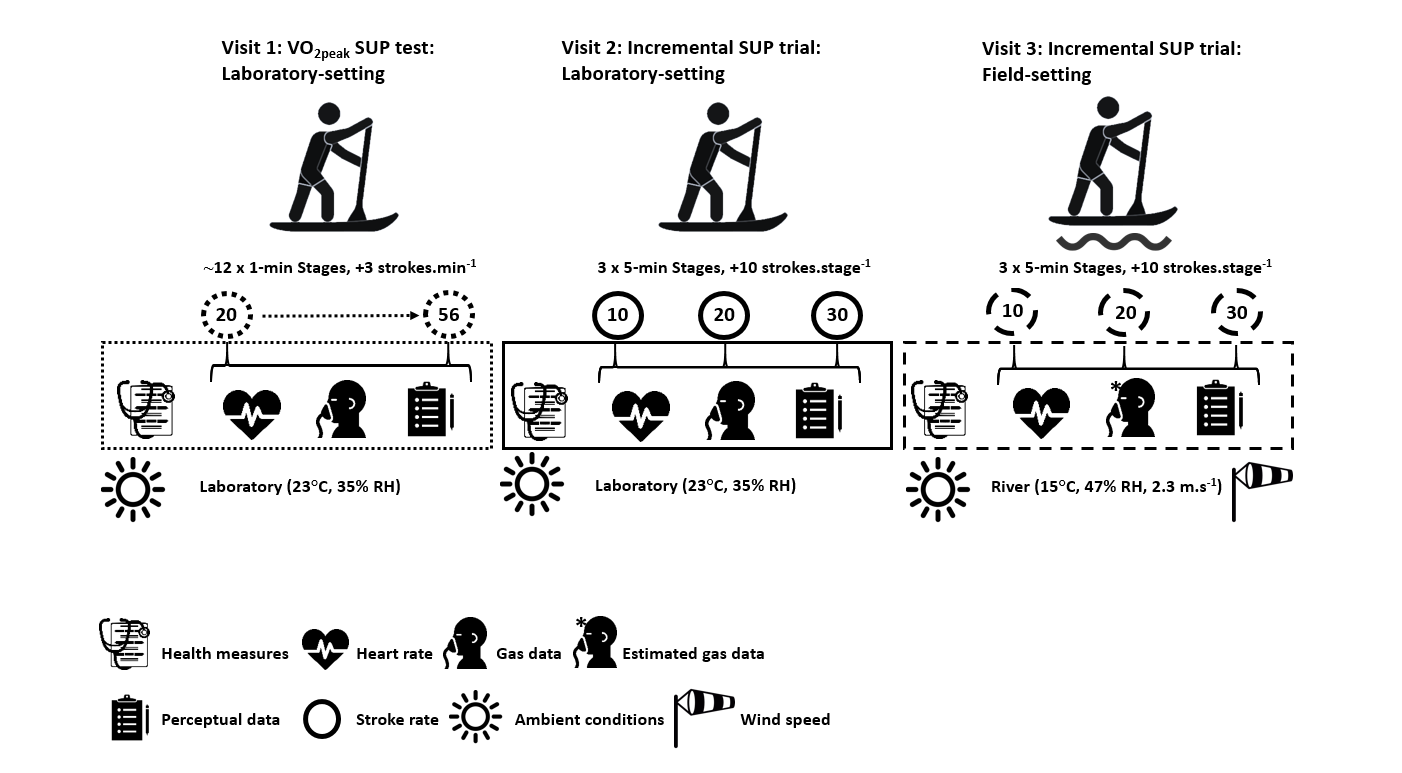


Figure 1. Schematic overview of the experimental protocol (Top), SUP in laboratory- (Bottom Left) and field-settings (Bottom Right).

**V̇O2peak SUP test:**

The V̇O2peak SUP tests were completed on a SUP ergometer (KayakPro SUPErgo, USA) starting at 20 strokes.min-1 and subsequently increasing 3 strokes.min-1 until volitional exhaustion. HR was measured during the final 15-s of each min stage. Gas data were collected during the stages where HR exceeded 180 beats.min-1. Final RPE was collected at the end of the test.

**Incremental SUP trials:**

**Laboratory-setting:** The laboratory incremental SUP trials were completed on an SUP ergometer (KayakPro SUPErgo, USA) (Figure 1). Participants paddled for 5-min at stroke rates of 10, 20 and 30 strokes.min-1, interspersed with 5-min active recovery of paddling at 8 strokes.min-1. HR, RPE and gas data were collected in the last min of each stage.

**Field-setting:** The field incremental SUP trials were completed on an inflatable paddle-board (Hiks, UK) (Figure 1), measuring 305 cm in length (10 foot), 71 cm in width and 10 cm in height, with a maximum user body mass of 100 kg. Before participants began the trial, they were informed of the testing procedures, safety measures (attaching a 2.3 m foot leash) and the height of the paddle was adjusted individually (range 1.7-2.2 m). Time and assistance was provided for SUP stroke rate familiarity and pacing adjustments. Participants were provided 15-min familiarisation at self- and experimenter-selected stroke rates, providing a warm-up and practice before starting the main trial at 10, 20 and 30 strokes.min-1 for 5-min per stage. No incidence of injuries occurred during SUP. During the trial, participants paddled along a river, matching the stroke rates, which were played aloud using wireless speakers (SoundLink® Mini-Bluetooth® speakers, Bose®, UK). Researchers followed participants along the river within a kayak to continuously record physiological (HR) and perceptual measures (RPE and feeling scales) in the last min of each stage. To keep consistency between participants and stages of the trial, participants paddle boarded along a river, with the direction of the wind (2.3±0.5 m.s-1 wind speed [“*Light breeze*”] in an easterly direction) for each 5-min stage. Upon completion of each stage, participants turned around and made their way back to the start line for the next stage (~5-min), this procedure was repeated twice.

**Physiological measures:**

Body mass (Adam Equipment Co Ltd., UK) and height were measured (Detecto Scale Company, USA), and used to calculate BMI (DuBois and DuBois, 1916). Adequate hydration status was determined on arrival to the laboratories from a fresh urine sample for; colour (<3 scale), osmolality <700 mOsmol.kgH2O-1 (Osmocheck, Vitech Scientific Ltd, Japan) and specific gravity <1.020 (Hand refractometer, Atago, Japan) (Sawka et al., 2007). HR was measured using a water-proof Polar H10 monitor (Polar Electro, Finland) attached to the participant’s chest, with data recorded by the experimenter and also stored for later analysis after each trial as an average over 30-s. Gas data was collected by indirect calorimetry via the Douglas bag method and subsequently analysed following the laboratory trials only. Oxygen (O2) and carbon dioxide (CO2) were sampled using a gas analyser (Servomex International Ltd., UK). A two-point calibration using nitrogen and known O2 and CO2 quantities (British Oxygen Company, UK) were completed prior to each test to prevent drift and ensure measurement reliability. EE and METs were estimated from a known volume of oxygenuptake (V̇O2)and respiratory exchange ratio (RER) during the last min of each stage of the V̇O2peak and laboratory-setting incremental SUP trial. EE (kcal.min-1) was calculated from the kcal equivalent for the known RER during the final min of each stage, this was then multiplied by the V̇O2 (i.e. 4.9 kcal per 1.00 L of O2 [McArdle, Katch, and Katch, 2009]). METs were calculated by dividing V̇O2 (mL.kg.min-1) by 3.5 mL.kg.min-1.

**Perceptual measures:**

The participants’ perceived exertion and mood were assessed using a RPE scale from 6-20 (*No exertion* to *Maximal exertion*) (Borg, 1992), and feeling scale from +5 (*Very good*), 0 (*Neutral*) to -5 (*Very bad*) (Hardy and Rejeski, 1989), respectively. Participants were familiarised to scales upon their first visit and were recorded at the end of each stage during the V̇O2peak, laboratory- and field-setting SUP trials.

**Environmental conditions:**

Ambient temperature and RH were recorded using a heat stress meter (HT30, Extech instruments, USA), while wind speed was recorded using an airflow anemometer (LCA 6600, UK).

**Statistical analyses:**

All data are presented as mean ± SD and conformed to normality and sphericity prior to statistical analyses. One-way repeated measure ANOVAs were used on the physiological and perceptual measures across each SUP stroke rate for laboratory- and field-setting SUP trials. Two-way repeated measure ANOVAs were also used on the physiological and perceptual measures across each SUP stroke rate between laboratory- and field-setting SUP trials (stroke rate\*trial). Where appropriate, Bonferroni-corrected pairwise comparisons were used to identify where significant differences occurred. Data were analysed using SPSS (v22.0) with significance set at *P*<0.05. Pearson's product moment correlation coefficient (*r*) and regression equations were used for SUP stroke rate and; EE, METs, HR and RPE. Regression equations were also used between HR and; V̇O2, EE and METs for the V̇O2peak test to estimate metabolic data within the field-setting trial, which were calculated from the measured HR. Relationships were interpreted as; <0.3=weak, 0.3-0.5=moderate, 0.5-0.7=strong, 0.7-0.9=very strong, 0.9-1.0 near perfect (Hopkins, 2002).

**Results:**

**V̇O2peak SUP test:**

All V̇O2peak SUP test data are displayed in Table 1.

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| **Table 1. Mean ± SD physiological and perceptual responses to the**  **V̇O2peak SUP test** | | | | | | |
| **Max stroke rate**  **(strokes.min-1)** | **Max HR**  **(beats.min-1)** | **Age predicted HRmax (%)** | **V̇O2peak**  **(L.min-1)** | **Max VE**  **(L.min-1)** | **End RER** | **End RPE** |
| 46 ± 3 | 186 ± 8 | 94 ± 5 | 1.94 ± 0.43 | 67.0 ± 18.2 | 1.09 ± 0.06 | 18 ± 1 |
| Note: HR: heart rate, V̇O2peak: peak oxygen uptake, VE: ventilation, RER: respiratory exchange ratio, RPE: rating of perceived exertion. | | | | | | |

**Incremental SUP trial:**

**Laboratory-setting:**

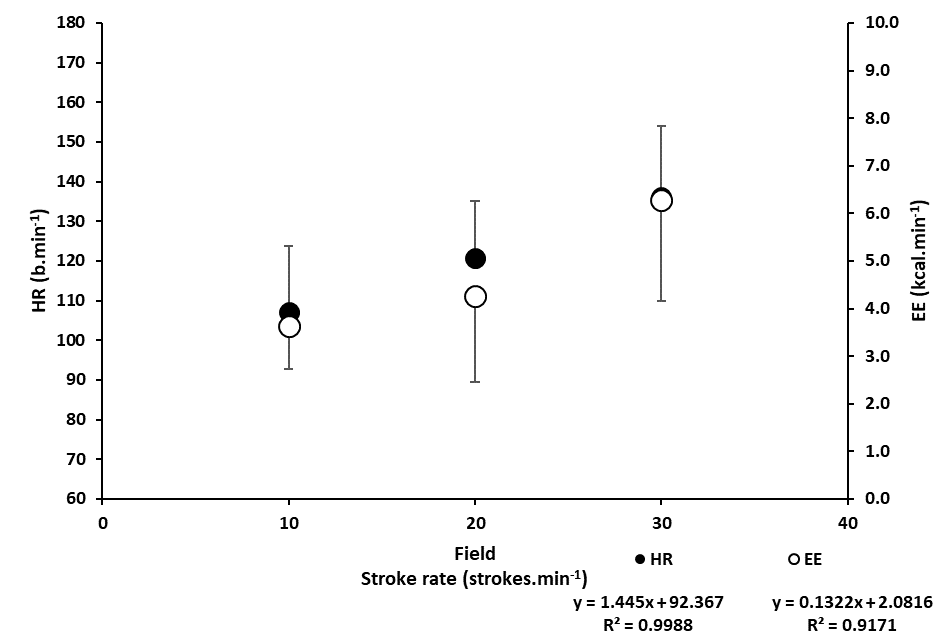
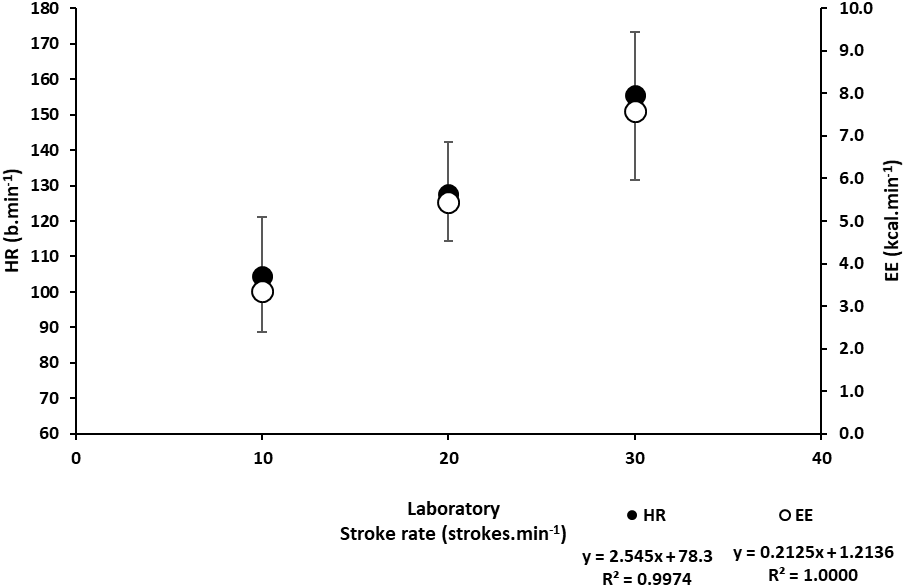
As SUP stroke rates increased during the laboratory trial, significant main effects were found for mean EE (F(2,18)=65.97, *P<*0.001, np2=0.880), METs (F(2,18)=58.79, *P*<0.001, np2=0.867), HR (F(2,18)=86.83, *P*<0.001, np2=0.906), V̇O2 (F(2,18)=66.43, *P*<0.001, np2=0.881), VE (F(2,18)=46.55, *P*<0.001, np2=0.838), and RPE (F(2,18)=75.52, *P*<0.001, np2=0.894), but not for feeling scale (F(2,20)=1.48, *P*=0.251, np2 =0.129).

EE, HR (Figure 2 - Top), METs, V̇O2, VE and RPE significantly increased (*P*<0.05) as SUP stroke rates progressed from 10 to 30 strokes.min-1 (Table 2). The percentage of HRmax (relative intensity) for SUP stroke rates also increased (F(2,18)=94.57, *P<0.001*, np2=0.913), from 10 (56±5%) to 20 (69±6%) and 30 strokes.min-1 (84±8%), respectively. The regression equations for SUP stroke rate (*X*, strokes.min-1) and: HR (*Y*, beats.min-1) and; EE (*Y*, kcal.min-1) were *Y*=2.545+78.3 (*r*=0.997) and; *Y*=0.2125*X*+1.2136 (*r*=1.000), respectively (Figure 2 - Top). RPE and stroke rate (*r*=0.997) and HR (*r*=0.992) were significantly (*P<0.001*) correlated.

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Figure 2. Mean ± SD HR and EE for SUP stroke rates for laboratory- (Top) and field-setting trials (Bottom) (\* denotes a significant difference between stroke rates [*P*<0.05] for 10, 20 and 30 strokes.min-1).

**Field-setting:**

Similarly in the field-setting SUP trial, as stroke rates increased main effects were found for mean HR (F(2,18)=32.84, *P*<0.001, np2=0.785) and RPE (F(2,18)=19.07, *P*<0.001, np2=0.679), but not for feeling scale (F(2,18)=2.67, *P*=0.097, np2=0.229). Likewise, main effects were observed for the estimated EE (F(2,18)=9.82, *P=*0.013, np2=0.766), METs (F(2,18)=22.83, *P*<0.001, np2=0.717) and V̇O2 (F(2,18)=20.52, *P*<0.001, np2=0.746).

EE, HR (Figure 2 - Bottom), METs, V̇O2 and RPE significantly increased (*P*<0.05) as SUP stroke rates progressed from 10 to 30 strokes.min-1 (Table 2). The percentage of HRmax (relative intensity) for SUP stroke rates also increased (F(2,18)=34.11, *P<0.001*, np2=0.791), from 10 (58±8%) to 20 (65±7%) and 30 strokes.min-1 (73±9%), respectively. The regression equations for SUP stroke rate (*X*, strokes.min-1) and: HR (*Y*, beats.min-1) and; EE (*Y*, kcal.min-1) were *Y*=1.445*X*+92.367 (*r*=0.999) and; *Y*=0.1322*X*+2.0816 (*r*=0.958), respectively (Figure 2 - Bottom). RPE and stroke rate (*r*=0.997) and HR (*r*=0.994) were significantly (*P<0.001*) correlated.

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| **Table 2. Mean ± SD physiological and perceptual responses to a range of SUP stroke rates in a laboratory- and field-setting.** | | | | | | | | | |
| **Setting** | **Time**  **(mins)** | **Stroke rate**  **(strokes.min-1)** | **HR**  **(beats.min-1)** | **V̇O2**  **(L.min-1)** | **EE**  **(kcal.min-1)** | **METs** | **RPE** | **Feeling scale** |
| **Laboratory** | **5** | 10 | 105 ± 8 | 0.68 ± 0.19 | 3.3 ± 1.0 | 2.7 ± 0.5 | 9 ± 1 | 3 ± 1 |
| **10** | 20 | 128 ± 13† | 1.09 ± 0.18† | 5.5 ± 0.9† | 4.4 ± 0.7†\* | 13 ± 1†\* | 3 ± 1 |
| **15** | 30 | 155 ± 17†‡\* | 1.52 ± 0.31 | 7.6 ± 1.6 | 6.1 ± 1.2\* | 16 ± 1†‡\* | 4 ± 1 |
| **Setting** | **Time**  **(mins)** | **Stroke rate**  **(strokes.min-1)** | **HR**  **(beats.min-1)** | **Estimated V̇O2**  **(L.min-1)** | **Estimated EE**  **(kcal.min-1)** | **Estimated METs** | **RPE** | **Feeling scale** |
| **Field** | **5** | 10 | 107 ± 17 | 0.72 ± 0.28 | 3.6 ± 0.9 | 2.7 ± 0.9 | 10 ± 2 | 3 ± 1 |
| **10** | 20 | 121 ± 14† | 1.01 ± 0.24† | 4.3 ± 1.8† | 3.5 ± 1.0† | 11 ± 2† | 3 ± 1 |
| **15** | 30 | 136 ± 18†‡ | 1.32 ± 0.36†‡ | 6.3 ± 2.1†‡ | 4.6 ± 1.4†‡ | 13 ± 2†‡ | 4 ± 1 |
| Note: Significant differences (*P*<0.05) between 10 and 20 strokes.min-1 within the trial are denoted by † and ‡, respectively. Significant differences (*P*<0.05) between trials for 10, 20 and/or 30 strokes.min-1 are denoted by \*. HR: heart rate, V̇O2: oxygen uptake, METs: metabolic equivalents; RPE: rating of perceived exertion. | | | | | | | | | |

**Laboratory- *vs.* field-setting SUP trials:**

A main effect and interaction were found for laboratory- and field-setting trials across SUP stroke rates for mean HR (F(2,36)=115.22, *P*<0.001, np2=0.865 and F(2,36)=8.78, *P=*0.001, np2=0.328), % of HRmax (F(2,36)=122.63, *P*<0.001, np2=0.872 and F(2,36)=9.20, *P=*0.001, np2=0.338), RPE (F(2,36)=88.08, *P*<0.001, np2=0.830 and F(2,36)=12.67, *P<*0.001, np2=0.413), estimated METs (F(2,36)=79.39, *P*<0.001, np2=0.815 and F(2,36)=7.52, *P=*0.002, np2=0.295) and estimated V̇O2 (F(2,36)=77.28, *P*<0.001, np2=0.828 and F(2,36)=5.13, *P=*0.012, np2=0.243), respectively. A main effect, but no interaction were found for estimated EE (F(2,36)=48.63, *P*<0.001, np2=0.802 and F(2,36)=3.23, *P=*0.057, np2=0.212, respectively).

Mean HR and % of HRmax were higher during the laboratory trial at 30 strokes.min-1 (*P*=0.022 and *P*=0.010) but not 10 (*P*=0.661 and *P*=0.671) or 20 strokes.min-1 (*P*=0.275 and *P*=0.203). This corresponded to a higher RPE during the laboratory trial at 20 (*P*=0.013) and 30 strokes.min-1 (*P<*0.001), but not 10 strokes.min-1(*P*=0.900). Likewise, METs were higher during the laboratory trial at 20 (*P*=0.021) and 30 strokes.min-1 (*P=*0.019), but not 10 strokes.min-1 (*P*=0.780). Post-hoc analysis found no significant differences in estimated V̇O2 between trials for 10 (*P*=0.159), 20 (*P*=0.271) or 30 strokes.min-1 (*P=*0.232) (Table 2).

**Discussion**

The aim of this study was to; 1) quantify the physiological (EE, V̇O2, HR and METs) and perceptual responses (RPE and feeling scales) associated with SUP at stoke rates of 10, 20 and 30 strokes.min-1 in a laboratory- and field-setting; 2) compare data from these settings, and; 3) ascertain which SUP intensity stroke rate meets ‘*Moderate’* criteria (3.0–5.9 METs) for PA guidelines for young healthy adults. Results demonstrated significant linear increases in HR (105-155 and 107-136 beats.min-1), VȮ2 (0.68-1.52 and 0.72-1.32 L.min-1), EE (3.3-7.6 and 3.6-6.3 kcal.min-1) and METs (2.7-6.1 and 2.7-4.6) as SUP stroke rate increased from 10 to 30 strokes.min-1 during laboratory and field trials, respectively. The percentage of HRmax ranged from 56-84% (laboratory-setting) and 58-73% (field-setting) for 10-30 strokes.min-1. Strong correlations were also found between stroke rate and; HR (r=0.997 and 0.999) and EE (r=1.000 and 0.958), with a corresponding RPE of 10-13 for laboratory- and 9-16 for field-setting SUP trials. When comparing SUP trials, mean HR and % of HRmax at 30 strokes.min-1, and, METs and RPE at 20 and 30 strokes.min-1 were higher during the laboratory SUP trial. These findings are the first to investigate recreational SUP users’ physiological and perceptual responses during ecologically valid and well-controlled SUP intensities in a field-setting, whereby, 20-30 strokes.min-1 can be classified as ‘*Moderate’* exercise intensities (3.0-5.9 METs). These findings can therefore be included in the latest Compendium of Physical Activities and conceivably, exercise prescription guidelines for cardiorespiratory improvements if young and healthy recreational SUP users regularly participate in this form of alternate PA.

**Physiological responses:**

**Metabolic equivalents and energy expenditure:**

Whilst numerous aquatic-based activities are included within the Compendium of Physical Activities (Ainsworth et al., 2000, 2011), SUP is missing and there lacks specific exercise intensity details for certain activities (surfing [3.0 METs] and kayaking [5.0 METs]). Therefore, our findings are the first to provide informative data that SUP in a field-setting on a river equates to METs of 2.7±0.9, 3.5±1.0 and 4.6±1.4 for exercise intensities of 10, 20 and 30 strokes.min-1, respectively (Table 2). Furthermore, results demonstrate that SUP at 20 and 30 strokes.min-1 can be classified as *Moderate* exercise intensities (3.0-5.9 METs) and can be used to meet PA guidelines (O'Donovan et al., 2010; Departments of Health, 2011). These findings provide novel data for a range of SUP stroke rates, comparisons with other water-based activities and typical daily exercises for PA recommendations in recreational SUP users. For example, the METs whilst SUP on a river at 20 strokes.min-1 (3.5 METs) are similar to that of surfing (3.0 METS), and, canoeing and rowing at a light effort (3.0 METs) or general pleasure (3.5 METs). Whereas, SUP at 30 strokes.min-1 (4.6 METs) are similar to that of kayaking and sailing in competition (both 5.0 METs) (Ainsworth et al., 2000). In comparison to other non-weight bearing, but land-based activities, the METs whilst SUP at moderate intensities (20 and 30 strokes.min-1) are similar to bicycling (<10 mph) for leisure or commuting (4.0 METs [Ainsworth et al., 2000]), general horseback riding (4.0-5.0 METs [Ainsworth et al., 2000; Beale et al., 2015]), skateboarding (5.0 METs [Ainsworth et al., 2000]) and scootering at speeds of 6.0-9.0 km.hr-1 (4.1-5.2 METs [Willmott and Maxwell, 2019]).

As expected, EE increased linearly with SUP stroke rate (Table 2), however, with research seldom investigating similar responses to fixed- or self-paced SUP exercise (whether in laboratory- or field-settings), we are unable to directly compare our results with existing EE SUP data. Nonetheless, similar EEs have been reported for recreational surfing (~7-8 kcal.min-1 [Meir et al., 1991; Wattsford et al., 2006]) and scootering (3.8-6.4 kcal.min-1 [Kijima et al., 2007; Willmott and Maxwell, 2019]). However, SUP EE data was lower than canoeing (9.5 kcal [Williams, 1999]), skateboarding (~10 kcal.min-1 [Hetzler et al., 2011]) and kayaking (~10-12 kcal.min-1 [Zamparo et al., 1999]). Furthermore, the EE of SUP in the field-setting at 10 and 20 strokes.min-1 (~3.6 and 4.3 kcal.min-1, respectively) are classified as *Light* (2.0-4.9 kcal.min-1) and at 30 strokes.min-1 (~6.3 kcal.min-1) as *Moderate* exercise intensities (>7.5-9.9 kcal.min-1) (Jette and Blumchen, 1990). As such, to achieve the recommended 800-1200 kcal weekly EE (O’Donovan et al., 2010), SUP at 20-30 strokes.min-1 for 60-mins.day-1 on 3-4 days.week-1 would be required (e.g. 30 strokes.min-1: 6.3 kcal.min-1 x 60-mins = 378 kcal.session-1, x 3 days = 1134 kcal.week-1). Therefore, it is suggested, SUP at ≥20 strokes.min-1 (moderate-intensity) conforms to current PA guidelines (O’Donovan et al., 2010; Departments of Health, 2011) and can now be included in the latest Compendium of Physical Activities, as well as being promoted as an alternate mode of exercise and PA option by public health professionals for recreationally active individuals. Sufficient SUP stroke rates (full paddle stroke every 2-3 seconds) can be achieved in safe, open waters without strong undercurrents/tides, such as lakes and rivers. Whilst the authors acknowledged that higher stroke rates may be challenging for recreational and/or novice users, with the increasing popularity and services offered (professional and guided tutorials, classes and tours), and strong recommendations of wearing protective equipment/appropriate attire (life vest/wet-suit), SUP exercise may offer an easily-accessible, relatively risk-free (in calm water *vs.* wave surfing [Waydia and Woodacre, 2016]) and enjoyable non-weight bearing PA for those who wish to improve long-term physiological and psychological health. Indeed, short- and long-term examples of these positive effects to health have been reported following 6 weeks (improved: self-rated quality of life [physical and psychological domains], and aerobic and anaerobic capacity, [Schram et al., 2016b]) and 12 months of SUP exercise (reduced: body mass, body fat % and BMI, and improved: self-rated quality of life [physical, psychological, social relationships and environment domains] and aerobic endurance capacity [Schram et al., 2017b]).

**Heart rate:**

The % of HRmax data whilst SUP at 20 and 30 strokes.min-1 in the laboratory- (69% and 84%) and field-setting (65% and 73%) conforms to exercise intensity guidelines for cardiorespiratory benefits (>65% HRmax) (Pollock et al., 1998). However, a higher cardiovascular strain was experienced at 30 strokes.min-1 within the laboratory SUP trial, most likely due to the participant’s familiarity to the SUP ergometer (postural control) and muscle activation (Ruess et al., 2013b), as previous research reports no differences between elite SUP athletes’ HR during maximal aerobic power tests in the laboratory- (181 beats.min-1) and field-settings (183 beats.min-1) (Schram et al., 2016c). Nonetheless, a training program including; long, low intensity (1-10 km distance) and; intermittent, high intensity SUP (2-min of 10-s paddling then 10-s rest, progressing to 5-min of 10-s, then 10-s rest), three times per week (180-mins.week-1) for 6 weeks, improved V̇O2max (+23.6%) in a sedentary population (Schram et al., 2016b). The authors acknowledge the difficulty when comparing HR data to other SUP or aquatic activities due to exercise intensity differences and lack of scientific research investigating the responses of recreational SUP users. Nonetheless, similar HR data were been reported while stationary on a surfboard (127 beats.min-1), recreational surfing (135 beats.min-1) and paddling on a surfboard (143 beats.min-1), respectively (Meir et al., 1991). However, SUP allows for a more continuous and constant HR, as demonstrated during a marathon SUP competition (mean: 168 beats.min-1 and peak: 187 beats.min-1) (Schram et al., 2017a) compared to the intermittent nature of competitive surfing (mean: 139 beats.min-1, peak: 190 beats.min-1) (Farley et al., 2011). Here we recognise the need for further research investigating randomised stroke rates and self-paced SUP activity among sedentary populations and/or recreational SUP users to further understand the cardiovascular responses whilst SUP.

**Perceptual responses:**

As expected, RPE significantly increased in association with SUP stroke rates (Table 2), however, the laboratory trial was perceived to be harder at 20 (13: “*Somewhat* *Hard*” *vs.* 11: “*Light*”) and 30 strokes.min-1 (16: between “*Hard*” and “*Very Hard*” *vs.* 13: “*Somewhat* *Hard*”) compared to the field trial. Nonetheless, our findings support suggestions that SUP is fun and enjoyable (Schram & Furness, 2017), as participants reported feeling “*Good’* (3 on feeling scale), and between ‘*Good’* and ‘*Very good’* (4 on feeling scale), suggesting a positive outcome of increased pleasure whilst SUP as stroke rates increased during laboratory and field trials (Rejeski et al., 1987; Hardy and Rejeski, 1989) (Table 2).

**Application:**

SUP offers an alternate, non-weight bearing PA, which is typically chosen for fun and fitness motives (Furness et al., 2017). SUP is growing in popularity across the globe, yet seldom are there robust, scientific research conducted in both laboratory- and field-settings. Our findings advocate the regular use of SUP, which may encourage improvements to cardiorespiratory fitness and/or reductions in premature mortality risk associated with chronic disease (Haskell et al., 2009; De Nazelle et al., 2011) if regularly utilised by young healthy adults. For recreational SUP users wishing to benefit from SUP but who are unable to use HR monitors to prescribe and/or sustain exercise intensity (one stroke every 3 seconds), the linear relationship between HR and RPE (*r*=0.994) for SUP strokes rates on an inflatable board in the field trial of this study, may permit users to gauge intensity from their perceived effort to ensure the threshold of physiological stimulus is achieved (>65% HRmax = 11-13 RPE [‘*Light*’ to ‘*Somewhat Hard*’]) (Willmott and Maxwell, 2019).

**Limitations and future direction:**

The field-setting SUP trial was conducted on a river and whilst precautionary measures were undertaken to ensure participants paddled in the same direction for each exercise intensity, the flow of the river was not recorded and may have affected individual responses. Future research should utilise different settings (sea and lake) and consider investigating alterations in board dimensions (8-15 foot lengths and narrow/wide widths), materials (carbon, fiberglass and plastic) and designs (surfing, racing and touring). Finally, results from this study are only applicable to recreational SUP users who are young, healthy adults, therefore, future research should consider investigating other populations (adolescent or sedentary individuals) and different levels of skill/experience (novice and elite users).

**Conclusion:**

This study provides novel data on the physiological and perceptual responses of SUP at a range of stroke rates in a laboratory- and field-setting. Findings from recreational SUP users display stroke rates of 20-30 strokes.min-1 meet the criteria for moderate-intensity PA (3.0-5.9 METs). Therefore, with recreational SUP increasing in popularity and use among the general public, specific MET data for this alternate form of exercise, and specific stroke rate may now be included in the latest Compendium of Physical Activities and contribute to cardiorespiratory improvements if undertaken regularly in young healthy adults.

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**Declaration of interest:**

The authors declare no conflicts of interest.

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**Figure captions:**

Figure 1. Schematic overview of the experimental protocol (Top), SUP in laboratory- (Bottom Left) and field-settings (Bottom Right).

Figure 2. Mean ± SD HR and EE for SUP stroke rates for laboratory- (Top) and field-setting trials (Bottom) (\* denotes a significant difference between stroke rates [*P*<0.05] for 10, 20 and 30 strokes.min-1).