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ORIGINAL ARTICLE

Upper and lower body responses to repeated cyclical sprints

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Abstract

Purpose: To compare the physiological and perceptual responses of the upper and lower body to all-out cyclical sprints with short or long rest periods between sprints.

Methods: Ten recreationally trained males completed four 10 × 10 s sprint protocols in a randomized order: upper body with 30 s and 180 s of rest between sprints, and lower body with 30 s and 180 s of rest between sprints. Additionally, maximum voluntary contractions (MVC) were measured at pre-sprint and post-sprints 5 and 10. Normalized (% of first sprint) peak power, MVC, heart rate (HR) and rating of perceived exertion (RPE) were compared between upper and lower body within the same recovery period, and absolute values (Watts, bpm, RPE scores) were compared within the same body part and between recovery periods.

Results: Trivial differences were identified in normalized peak power, HR and RPE values between the upper and lower body in both recovery conditions (<2%, $d \leq 0.1$), but MVC forces were better maintained with the upper body (~9.5%, $d = 1.0$) in both recovery conditions. Absolute peak power was lower (~147 Watts, $d = 1.3$), and HR was higher (~10 bpm, $d = 0.73$) in the 30 s compared to 180 s condition in both the upper and lower body whereas RPE scores were similar (<0.6 RPE units, $d \leq 0.1$). Despite the reductions in peak power, MVC forces were better maintained in the 30 s condition in both upper (2.5 kg, $d = 0.4$) and lower (7.5 kg, $d = 0.7$) body.

Conclusions: Completing a commonly used repeated sprint protocol with the upper and lower body results in comparable normalized physiological and perceptual responses.

Keywords: *Exercise, fatigue, performance, physiology*

Highlights

- When normalized, upper and lower body repeated sprints led to comparable physiological and perceptual responses.
- Maximum voluntary contraction was decreased to a greater extent following upper body than lower body repeated sprinting.
- Upper and lower body repeated sprint peak power outputs were recovery time-dependent.

Introduction

The ability to produce maximal power in a repeated manner is an important quality in many sports (Bishop, Girard, & Mendez-Villanueva, 2011; Girard, Mendez-Villanueva, & Bishop, 2011; Meckel, Machnai, & Eliakim, 2009). Repeated sprint ability (RSA) – commonly defined as a number of high-intensity sprints (5 to ≥10 s) interspersed with brief recovery time (10 to ≤60 s) – has been thoroughly investigated in recent years (Bishop et al., 2011; Girard et al., 2011). This includes different sprinting modalities (e.g. running vs. cycling) (Rampinini et al., 2016), work-to-rest ratios (e.g. 10 vs 60 s of rest) (Saraslanidis et al., 2011), and the pathways leading to observed fatigue (e.g. central vs. peripheral) (Pearcey et al., 2015). The vast majority of RSA studies investigated lower body exercises whereas fewer studies examined the upper body. Specifically, while a number of studies examined upper body repeated sprints in ice sledge

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hockey (Baumgart & Sandbakk, 2016; Sandbakk et al., 2014) and ski poling (Sandbakk et al., 2015), only a few have examined cyclical upper body activities (e.g. Pearcey et al., 2016). Given that the lower body muscles are a driving force in athletic success, it is understandable why lower body exercises were mostly investigated. However, RSA of the upper body muscles is also of relevance in many sports (Sandbakk et al., 2014; Sandbakk et al., 2015). For example, Kamandulis et al. (2018) observed that three rounds of 14 × 3 s of all-out punches completed three times a week for four weeks improved punching forces and maintenance of punching frequency and forces of competitive boxers, illustrating the potential significance of upper body RSA.

A broader understanding of upper body RSA can be achieved by comparing the established effects of RSA in the lower body to the less established effects of RSA in the upper body. There are reasons to speculate that the upper and lower body will respond differently to repeated sprints, even when completed at similar cyclical maximal repeated sprint exercise (e.g. arm vs. leg-cycling as opposed to poling vs. cycling). Compared to upper body muscles, the lower body muscles are stronger (Harbo, Brincks, & Andersen, 2012), have greater mass (Janssen, Heymsfield, Wang, & Ross, 2000), and possess higher percentage of fast twitch high threshold muscle fibres (Miller, MacDougall, Tarnopolsky, & Sale, 1993). Stronger and larger muscles may fatigue faster leading to reduced ability to maintain RSA (Hunter & Enoka, 2001). Maximal effort contractions with stronger and larger muscles could lead to different perception of effort. Mayo, Iglesias-Soler, and Fernández-Del-Olmo (2014) reported that the ratings of perceived exertion were higher when participants completed five sets to task failure in the squat exercise compared to the bench press exercise even when relative intensity (% of 1 Repetition Maximum [1 RM]) and rest periods were the same. Thus, activation of stronger and larger muscles found in the lower limbs may be associated with greater levels of fatigue and sensation of effort compared to the upper body. A direct comparison between the upper and lower body RSA could be insightful and of practical value. For example, if one is associated with a greater degree of fatigue than the other it could be factored in when designing repeated sprints training programmes and testing.

One variable that has been linked to the degree of fatigue in RSA studies is the recovery period between the sprints (10 to ≤60 s) (Bishop et al., 2011; Girard et al., 2011). Longer rest durations (>1–3 min) allows performance to be better maintained likely due to lower accumulations of metabolic by-products in the muscles, such as inorganic phosphate and hydrogen ions. Rest durations longer than one minute have been defined as intermediate-sprint (rather than repeated sprint) as they commonly lead to trivial or to no performance deficits (Girard et al., 2011). It could be, however, that due to the noted differences between upper and lower body musculature, performance and perceptual responses will be dissimilar when measured across sprint protocols with different rest periods.

Accordingly, the main goal of this study was to compare the normalized (% of the first sprint) physiological and perceptual responses of the upper and lower body to an all-out cyclical sprint protocol (Pearcey et al., 2015) completed with either a short or long rest period between each sprint. As such, the two body parts were compared under each rest condition (upper vs. lower short rest; upper vs. lower long rest). A secondary goal of this study was to compare the absolute physiological and perceptual responses of the same body parts as completed under the two rest conditions (upper long rest vs. upper short rest; lower short rest vs. lower long rest). It was hypothesized that compared to the upper body, lower body repeated sprints would lead to further performance, physiological and perceptual decrements which would all be exacerbated by a shorter rest period. Similarly, it was hypothesized that irrespective of body part, the short rest period will hinder performance to a greater extent than the longer rest period. Note that parts of this study which had a strong neurophysiological focus pertaining to the lower body were published elsewhere (Monks, Compton, Yetman, Power, & Button, 2017).

Methods

Participants

Ten recreationally active (~10 hours of activity/week) male participants (187.1 ± 5.1 cm, 83.9 ± 10.6 kg, 23.8 ± 4.8 years) were recruited. All subjects were free from orthopaedic and/or neurological disorders which could affect the study findings.

All participants were accustomed to maximal bouts of exercise (leg-cycling) and had prior experience performing maximal voluntary contractions (MVC) with the upper and lower body as previous research participants. Participants were verbally informed of all procedures and read and signed a written consent form. The University ethics committee approved the study.

Maximal cycling sprint protocol

Participants performed all sprints on a Monark ergometer (Monark 874E, Monark Exercise AB, Sweden).

Arm-cycling. Participants were positioned so that the centre of the crank was in line horizontally with the acromion. Initiation of the sprint occurred when participants reached a RPM of 80 and the mechanical break applied a 5% torque factor (i.e. the participant pedalled against a resistance that was equal to 5% of their body mass) (Forbes, Kennedy, Boule, & Bell, 2014).

Leg-cycling. Saddle height was adjusted so that the participant's knee joint was almost in full extension (approximately 170°) when the crank position was at bottom dead centre (6° clock position), with the foot secured to the pedal with toe clips fastened, and the sole of the foot parallel to the ground. Initiation of the sprints occurred when participants reached a RPM of 100 and the mechanical break applied a 10% torque factor (Bar-Or, 1987). It should be noted that the torque factors were dissimilar between the upper and lower body because our pilot work demonstrated that attempting to control for torque across the body parts led to one of the two outcomes: (1) subjects were unable to complete the upper body sprinting protocol when the torque was set to 10% in the upper body and (2) the lower body sprinting protocol was easy for subjects when the torque was set at 5% in the lower body. As such, we decided to match for intensity based on the outcomes of our pilot work rather than to control for external intensity which would likely not have allowed subjects to complete the protocols with adequate intensity on the one hand, or would have been too difficult to complete on the other hand.

Sprint phase. Each sprint was preceded by 10 s of slow cycling (active rest) at 50–75 RPM for arm-cycling and 60–95 RPM for leg-cycling against no resistance. Immediately following the 10 s of slow cycling, the participants began the sprint phase, where participants were given verbal encouragement to cycle as hard as they could for 10 s. Sprints were interspersed with either 20 s or 170 s of passive rest. Thus, total passive and active rest between sprints were 30 s and 180 s. The participants repeated this process 10 times. For all sprints, participants were told to accelerate following the initiation of the mechanical break (i.e. to eliminate any over-estimates in power due to increased acceleration before break application). All power output data were recorded using Monark Wingate Software and stored on a computer. Peak power (Watts) (i.e. the highest average power output over a 1 s duration) was measured during each sprint. Peak power as opposed to mean power output was used here because part of the data based on changes in peak power outputs have been reported elsewhere (Monks et al., 2017) and because both peak and mean power have been shown to follow a similar patterns in repeated sprint efforts (i.e. Billaut & Basset, 2007; Pearcey et al., 2015).

Maximum voluntary contraction

To determine knee extensor forces, participants sat on a custom-built chair with hips and knees flexed at 90° with arms crossed in front of their body. The upper torso rested against the backrest and was secured with straps placed around the chest. The ankle was inserted into a padded strap attached by a chain to a load cell (Omegadyne Inc., Sunbury, Ohio). To determine elbow flexor forces, participants were seated in the custom-built chair with hips and knees flexed at 90°. The arm was slightly abducted with the elbow resting on padded support at an angle of 90°. The forearm was held horizontal in a position midway between neutral and supination, and placed in a custom-made orthosis that was connected to a load cell. The load cell detected all force outputs, which was amplified (×1000) (CED 1902, Cambridge Electronic Design Ltd., Cambridge, UK). Data were sampled at 2000 Hz. Verbal encouragement and visual feedback were given to all participants during all contractions. The set-up to measure knee extensor and elbow flexor MVC forces was placed next to the leg- or arm-cycling set-up so that the participant could perform the MVCs immediately following the sprint and be ready to do another sprint within 20 s (Monks et al., 2017; Pearcey et al., 2015).

Heart rate

All participants wore a Polar (T-31, PolarElectro, Kempele, Finland) heart rate monitor for the duration of their visit to the laboratory. Heart rate (HR) recordings were taken immediately post each sprint.

Ratings of perceived effort

Participants reported their rating of perceived exertion (RPE) score immediately following each sprint using the 6–20 Borg's RPE scale (Borg, 1982), with 6 being equivalent to complete rest and 20 being equivalent maximum effort.

Experimental design

Participants randomly completed four experimental sessions on four separate days with at least 48 h between sessions. For each session, participants performed 10 × 10 s sprints of (1) leg-cycling with 30 s rest between sprints, (2) leg-cycling with 180 s rest between sprints, (3) arm-cycling with 30 s rest between sprints and (4) arm-cycling with 180 s rest between sprints. Participants began each experimental session with a 5 min warm up on a Monark cycle ergometer which they pedalled against a resistance of 1 kp at a self-selected pace for both leg- and arm-cycling. Participants then completed the sprints on a Monark cycle ergometer. HR, Rating of perceived exertionRPE was recorded following each sprint. During the leg-cycling and arm-cycling sprint sessions knee extensor and elbow flexor MVC forces, respectively, were measured prior to and immediately post-sprints number 5 and 10. The chair in which participants set on when measuring knee extensor and elbow flexor MVC forces was placed right behind the participant.

Statistical analysis

Given the growing criticism of null-hypothesis testing (Gigerenzer, Krauss, & Vitouch, 2004; Goodman, 2008; Wilkinson, 2014), and encouragement to use other statistical approaches (Cumming, 2014; Dragicevic, 2016), we decided to use the statistical methodology advocated by Cumming and others (Cumming, 2013, 2014; Cumming & Fidler, 2009; Dragicevic, 2016). This includes limiting the number of overall comparisons, calculating 95% confidence internals (CI) and Cohen d effect sizes using the following equation ($d = \text{Mean differences}/\text{SD average}$) in which SD average is $(\sqrt{\text{SD condition 1} + \text{SD condition 2}})/2$. This was then followed by a d unbiased equation $= (1 - 3/(4\ \text{df} - 1)) \times d$. 95% CI were used rather than p-values to provide the imprecision of the point estimate of the effects and to prevent dichotomous interpretation of the results (Cumming, 2013, 2014; Cumming & Fidler, 2009; Dragicevic, 2016). Since we were interested specific comparisons only two separate sets of analyses were performed. The first was intended to compare the effects of upper and lower body cycling with the same rest period condition. Since the lower body produces considerably greater absolute peak power and force than the upper body, we decided to normalize all dependent values (Peak power, RPE and HR) of sprints number 5 and 10 to the first sprint, and to analyse and compare the percent differences between the upper and lower body. For example, calculating (Sprint 5/Sprint 5) × 100 for both upper and lower body within the 30 s recovery period and then compare. The second and third MVCs were also normalized to the first MVC and compared across body parts.

The second was intended to investigate the effects of different recovery periods within the same body part. For this, sprints number 5 and 10 were compared within the same body part between the 30 s and 180 s conditions for all absolute dependent variables and the second and third MVC. Results are presented in written, table and graphs forms. The written section includes comparisons between and within conditions for all outcomes when averaged across all sprints. The tables include detailed comparisons between and within conditions for the 1st, 5th and 10th sprints. The graphs present all data points (means + SD) for all conditions across all sprints. The interpretation of effect sizes results are based on the general guidelines proposed by Cohen of trivial (<0.20), small (0.2), medium (0.5) and large (0.8) (Cohen, 1992). All statistics were performed on Exploratory Software for Confidence Intervals excel sheet (https://thenewstatistics.com/itns/esci/).

Results

Note that the first sprint of one participant was not properly recorded, and as such, it was impossible to normalize the subsequent sprint values. For this reason, it was decided to remove his normalized peak power data from the analysis.

Between body parts

Descriptive data are presented in Figure 1 and effect sizes and CI differences between sprints 5 and 10 are presented in Table I.

30 s recovery period. Trivial differences were observed between upper and lower body across all sprints in normalized peak power (~2%, $d = 0.11$, 95% CI: 0, 3%), normalized (~1%, $d = 0.12$, 95% CI: −1, 2%) and absolute (~1 bpm, $d = 0.01$, 95% CI: −1, 1 bpm) HR and normalized (2%, $d = 0.06$, 95% CI: 0, 3%) and absolute (~0.4 RPE unit, $d = 0.05$, 95% CI: −1, 2) RPE values. Normalized MVC forces were largely higher in the upper compared to lower body across the second and third MVCs (10%, $d = 1.02$, 95% CI: −10, −7%).

180 s recovery period. Trivial differences were observed between upper and lower body across all sprints in normalized peak power (~2%, $d = 0.12$, 95% CI: −3, 0%), normalized (~1%, $d = 0.06$, 95% CI: −2, 1%) and absolute (>1 bpm, $d = 0.01$, 95% CI: −1, 1 bpm) HR and normalized (2%, $d = 0.07$, 95% CI: 0, 4%) and absolute (1 RPE unit, $d = 0.14$,

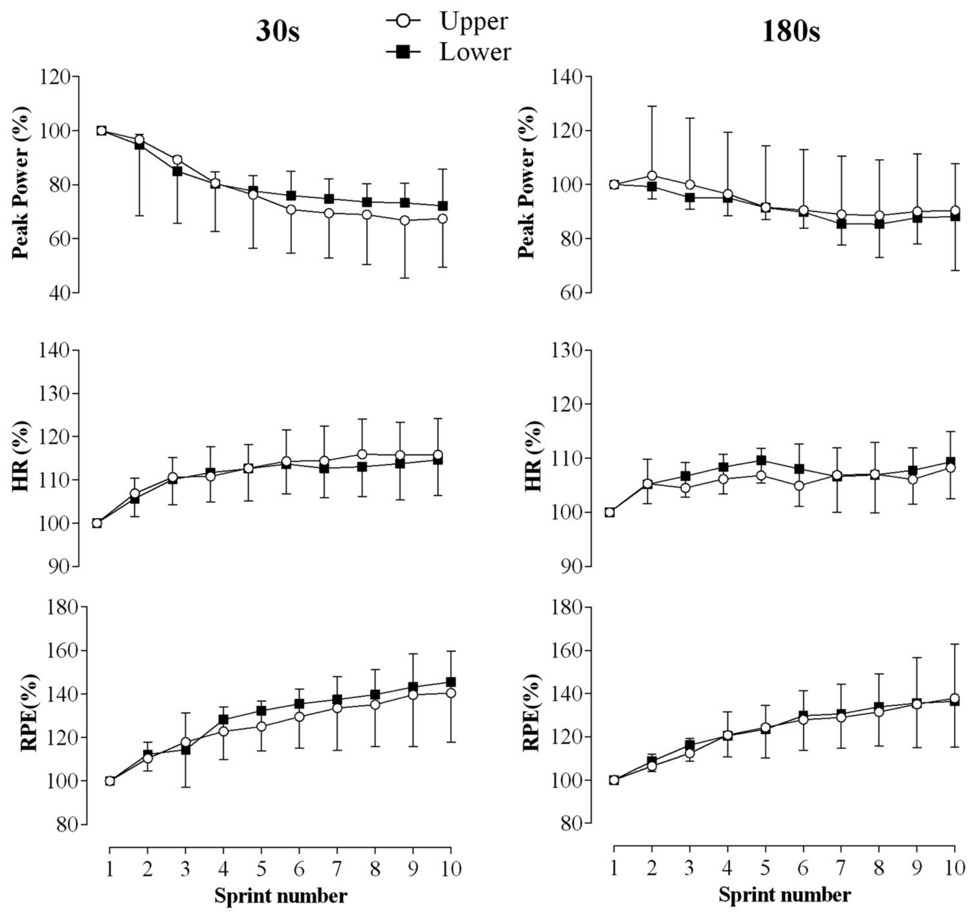

Figure 1. Illustrates the normalized differences between the outcome measures in the upper and lower body as measured in the 30 s (left column) and 180 s (right column) conditions. Error bars represent SD.

Table I. Comparisons of normative data (% of the first sprint) between body parts within the same recovery period (mean ± SD).

Number	Upper	Lower	Cohen *d*	95%CI
30 s				
Sprint 5 (%)	76 ± 19	79 ± 7	0.08	−15, 18
Sprint 10 (%)	68 ± 18	72 ± 13	0.24	−15, 24
HR 5 (%)	112 ± 6	113 ± 7	0.13	−6, 8
HR 10 (%)	115 ± 8	114 ± 8	0.06	−7, 6
2nd MVC (%)	93 ± 6	86 ± 11	0.72	−15, 1
3rd MVC (%)	89 ± 7	77 ± 5	1.77	−18, −5
RPE 5 (%)	125 ± 11	125 ± 30	0.01	−16, 17
RPE 10 (%)	142 ± 20	155 ± 42	0.21	−18, 34
180 s				
Sprint 5 (%)	91 ± 22	91 ± 5	0.07	−20, 19
Sprint 10 (%)	90 ± 17	88 ± 20	0.10	−29, 25
HR 5 (%)	108 ± 6	110 ± 6	0.33	−0.3, 3
HR 10 (%)	108 ± 7	108 ± 7	0.02	−7, 7
2nd MVC (%)	86 ± 8	77 ± 7	1.02	−20, 2
3rd MVC (%)	82 ± 7	70 ± 8	1.4	−17, −5
RPE 5 (%)	124 ± 10	125 ± 27	0.04	−14, 16
RPE 10 (%)	140 ± 26	136 ± 32	0.10	−20, 13

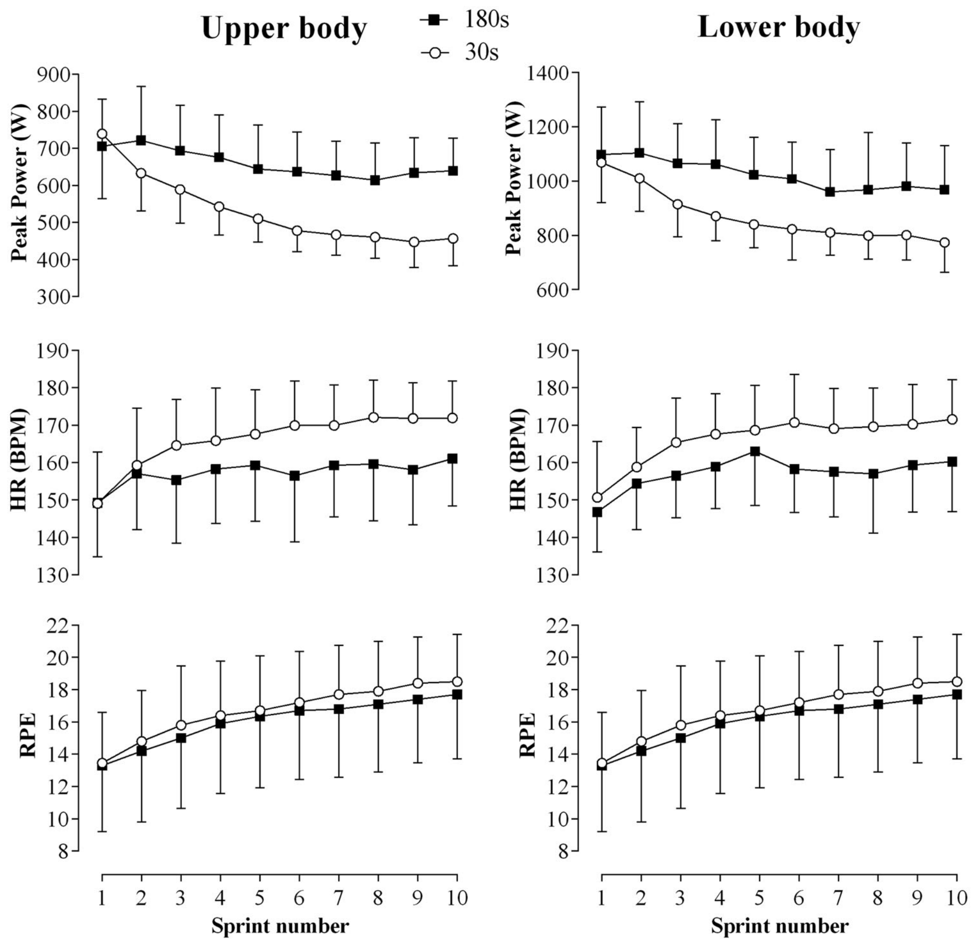

Figure 2. Illustrates the absolute differences between the outcome measures in the 30 s and 180 s conditions as measured in the upper (left column) and lower (right column) body. Error bars represent SD.

95% CI: −1, 2%) RPE values. Normalized MVC forces were largely higher in the upper compared to lower body across the second and third MVCs (9%, *d* = 1.0, 95% CI: −10, −7%).

Within body parts

Descriptive data are presented in Figure 2 and effect sizes and CI differences between sprints 5 and 10 are presented in Table II. Given that only trivial differences were observed or expected in the values of the first sprint due to the fact that recovery periods were not present to lead to any differences, they were excluded from the overall analysis. Thus, the comparisons were made between sprints 2 and 10.

Upper body. Peak power was largely lower in the 30 s compared to the 180 s condition with an overall difference of 144 Watts (*d* = 1.32, 95% CI: 143, 146 Watts, range: 88–186 Watts). HR was largely higher in the 30 s compared to 180 s conditions across sprints by 10 bpm (*d* = 0.70, 95% CI: −11, −8 bpm, range: 2 −14 bpm). A medium effect was observed for MVC forces which were 2.5 kg higher in the 30 s compared to 180 s condition across the second and third MVCs (*d* = 0.43, 95% CI: −4, −1 kg). Trivial differences were observed between conditions across all sprints in RPE scores (~0.6 RPE units, *d* = 0.14, 95% CI: −2, 1 RPE units).

Lower body. Peak power was largely lower in the 30 s compared to the 180 s condition with an overall difference of 150 Watts (*d* = 1.3, 95% CI: 143, 146 Watts, range: 90–191). HR was largely higher in the 30 s compared to 180 s conditions across sprints by 10 bmp (*d* = 0.76, 95% CI: −11, −8 bpm, range: 4–14). MVC forces were 7.6 kg higher in the 30 s compared to the 180 s condition across the second and third MVCs (*d* = 0.70, 95% CI: −9, −6 kg). Trivial differences were observed between conditions across all sprints in RPE scores (~0.3 RPE units, *d* = 0.04, 95% CI: −1, 2 RPE units).

Table II. Comparisons of absolute data between recovery periods within the same body parts (mean ± SD).

Number	30 s	180 s	Cohen *d*	95%CI
Upper body				
Sprint 1(Watts)	705 ± 146	730 ± 126	0.20	−84, 34
Sprint 5 (Watts)	510 ± 63	644 ± 118	1.28	63, 204
Sprint 10 (Watts)	456 ± 73	639 ± 87	2.05	140, 225
HR 1 (BPM)	149 ± 14	149 ± 14	0.01	−6, 6
HR 5 (BPM)	167 ± 12	159 ± 15	0.56	−13, −3
HR 10 (BPM)	171 ± 10	161 ± 13	0.86	−16, −5
1st MVC (Kg)	47 ± 7	47 ± 7	0.01	−4, 4
2nd MVC (Kg)	44 ± 4	42 ± 5	0.36	−6, 2
3rd MVC (Kg)	42 ± 6	39 ± 6	0.45	−6, 2
RPR 1	13.4 ± 3	13.3 ± 4	0.03	−1.7, 1.4
RPE 5	16.7 ± 3.4	16.3 ± 4.4	0.09	−1.7, 1.0
RPE 10	18.5 ± 3	17 ± 7	0.21	−1.8, 0.2
Lower body				
Sprint 1(Watts)	1068 ± 147	1097 ± 175	0.16	−23, 81
Sprint 5 (Watts)	840 ± 86	1023 ± 137	1.4	126, 239
Sprint 10 (Watts)	782 ± 113	968 ± 162	1.2	95, 277
HR 1 (BPM)	150 ± 15	147 ± 11	0.27	−9, 3
HR 5 (BPM)	170 ± 12	162 ± 15	0.47	−14, 0
HR 10 (BPM)	171 ± 11	158 ± 13	1.00	−20, −6
1st MVC (Kg)	65 ± 17	65 ± 16	0.01	−1, 1
2nd MVC (Kg)	58 ± 14	54 ± 13	0.27	−5, −2
3rd MVC (Kg)	53 ± 11	47 ± 10	0.54	−7, −4
RPR 1	13.1 ± 3.2	14 ± 3.6	0.2	0, 2
RPE 5	18 ± 2.2	17.9 ± 2.3	0.04	−1.2, 1
RPE 10	19.3 ± 1.1	19.3 ± 1	0.00	−0.6, 0.6

Discussion

In this study, we investigated if the upper and lower body responds differently to a similar repeated sprint protocol completed with two recovery periods: 30 s and 180 s. No normalized differences were observed between upper vs. lower body sprints in all outcome measures other than MVC forces which were better maintained with the upper body in both conditions. A secondary goal was to compare the absolute outcome measures within upper or lower body sprints under the two recovery periods. Participants produced considerably less absolute peak power, and had higher HR in both the upper and lower body in the 30 s condition. Whereas MVC forces were higher in the 30 s condition in both upper and lower body, RPE scores were similar. Overall, the results deepen our understanding of upper body RSA in relation to the known effects of lower body RSA, and expand our knowledge concerning the effects of two different recovery periods on RSA.

Given the differences between the upper and lower body muscles in size (Janssen et al., 2000), force generation capacity (Harbo et al., 2012), and fibre type distribution (Miller et al., 1993), the lack of differences observed in this study in normalized peak power in both recovery conditions are somewhat surprising. While the sprinting protocol led to fatigue in both upper and lower body as indicated by the decrements in normalized peak power in the 5th and 10th sprint in both recovery conditions, the degree of decrement was similar which strengthens the notion that both body parts respond in a similar fashion. In the 30 s condition, the normalized peak power was reduced by 32% and 28% in the 10th sprint in the upper and lower body, respectively (Table I). In the 180 s, in which fatigue was expected to be lessened compared to the 30 s condition, normalized peak power was reduced by 10% and 12% in the 10th sprint in the upper and lower body, respectively (Table I). As such, these results suggest that reductions in normalized peak power are comparable during repeated sprints efforts with both the upper and lower body.

Whereas most studies comparing the cardiovascular responses of upper and lower body exercises observed higher HR with lower limbs exercises (Al-Hazzaa & Al-Hazzaa, 2014; deJong, Bonzheim, Franklin, & Saltarelli, 2009; Schneider, Wing, & Morris, 2002), in the present study both normalized and absolute HR responses were comparable in both recovery conditions. This inconsistency could stem from the implemented exercise modalities. While the current study used repeated sprints, other studies examined longer submaximal activities (Al-Hazzaa & Al-Hazzaa, 2014; deJong et al., 2009; Schneider et al., 2002). Rest-to-work ratios of 1:3 and 1:18 implemented in the present study may not allow for enough accumulated exercise time to elicit different HR responses between body parts. RPE scores were also similar between body parts in both recovery conditions. A limited number of studies reported higher RPE scores in the lower, compared to the upper body (Al-Hazzaa & Al-Hazzaa, 2014; Mayo et al., 2014), however, as with the HR, it is difficult to pinpoint the causes for the inconsistencies given the diverse exercise modalities and work-to-rest ratios used in these studies. The similar normalized and absolute RPE and HR responses observed in the upper and lower body are of interest for coaches and scientists, but more work is required to extend and verify these findings.

Normalized MVC forces, on the other hand, differed between the upper and lower body. Forces were better maintained in the elbow flexors in both recovery conditions. The aforementioned differences between the upper and lower body may be better illustrated through MVCs rather than dynamic cyclical contractions. Another possibility accounting for this disparity is that cycling activities depend on both the extensors and flexors muscles, whereas the MVCs were only collected from the flexors (upper body) or extensors (lower body) and that the fatigue profiles of flexors and extensors may differ. Indeed, the development of neuromuscular fatigue differs between knee extensors and elbow flexors fatiguing isometric contractions (Senefeld, Yoon, Bement, & Hunter, 2013; Vernillo, Temesi, Martin, & Millet, 2018). We choose to compare the MVCs of the elbow flexors and knee extensors muscles because both are very active during upper (Forman, Philpott, Button, & Power, 2015) and lower body (Billaut, Basset, & Falgairette, 2005) cycling, respectively. However, it may be that their relative contribution to cycling activities in the upper and lower body differs from one another, and as such, interpreting this particular finding from this study should be done cautiously.

When interpreting the normalized and absolute differences between body parts across all outcome measures, it is important to note that the upper and lower body sprinting protocols were performed against torque factors equivalent to 5% and 10% of body weight, respectively. Using similar torque factors or optimal torque factors to produce peak power outputs may have reduced absolute and normalized peak power, RPE, HR and MVC force for upper and lower body sprinting differently than found in the current study. Despite the dissimilar torque factors, which can be loosely defined as a measure of external intensity, the RPE scores, which can be loosely defined as a measure of internal intensity, were similar between upper and lower body. We thus speculate that comparing relative workloads between different body part (e.g. percentage of first sprint or pre-test), as we have done in the present study, may be a more suitable way to match for intensity. However, this speculation remains to be established in future studies. Furthermore, the use of individually calculated torque factors is a strategy that needs to be investigated in comparing different body parts as done in the present study.

The differences between the recovery periods within the same muscle groups were mostly in line with our expectations. The absolute peak power and HR were largely lower and higher, respectively, in the 30 s compared to the 180 s condition. It can be assumed that the greater levels of metabolites that likely accumulated within the working muscles during the 30 s condition could have reduced the peak power to a greater extent due to central reduction of neural drive and/or peripheral effects on contractile properties (Allen, Lamb, & Westerblad, 2008; Amann, 2012). However, since the level of metabolites was not measured in the current study, this possibility is speculative. Conversely, RPE was similar in both conditions. The requirement for maximal efforts in each sprint may partly explain the RPE similarities. An unexpected and difficult to explain finding was that MVC was better maintained for both the elbow flexors and knee extensors in the 30 s compared to 180 s despite the greater reductions in peak power during upper body and lower body sprints, respectively. It may be that recovery time-dependent reductions in peak power output during fast dynamic movements may not reflect changes occurring in maximal effort isometric contractions.

Practical application

The results of this study offer a number of applied perspectives. First, coaches and scientists may find the lack of normalized differences between the upper and lower body in cyclical RSA of practical interest. This information can be accounted for when designing and incorporating upper and lower body repeated sprint training and testing. Second, given the importance of RSA of the upper body in many sports, and the likely usefulness to incorporating it in training (Kamandulis et al., 2018), the result deepens our understanding of how people respond to upper body repeated sprints activities, its acute effects and possible applications. For example, knowing that the physical and perceptual responses of the upper and lower to a repeated sprint effort is approximately similar, may assist coaches to decide when and what frequency to implement upper body sprinting training intervention with athletes. Third, the comparison between the two opposed recovery periods strengthens past findings that shorter rest durations lead to greater reductions in peak power and higher HR compared to longer rest periods in both body parts. Depending on the training goals, this is an important aspect to consider when planning a series repeated sprints sessions.

Conclusions

The results of this study shed light on the less established effects of upper body RSA on physiological and perceptual responses in comparison to the well-established effects of lower body RSA, across two opposed recovery periods. Normalized values were similar in the upper and lower body across the two recovery periods. The only difference that occurred between the body parts was in the ability to produce maximal isometric forces, which were better maintained with the upper body. These comparable responses should encourage future comparison studies between the upper and lower body RSA using different outcome measures and protocols. Additionally, shorter rest durations led to considerably lower peak power compared to the longer rest durations across in both the upper and lower body.

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