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The reproducibility of 10 and 20 km time trial cycling performance in recreational cyclists, runners and team sport athletes.

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Abstract

Objective: This study aimed to determine the reliability of 10 and 20 km cycling time trial (TT) performance on the Velotron Pro in recreational cyclists, runners and intermittent-sprint based team sport athletes, with and without a familiarisation. **Methods:** Thirty-one male, recreationally active athletes completed four 10 or 20 km cycling TTs on different days. During cycling, power output, speed and cadence were recorded at 23 Hz, and heart rate and rating of perceived exertion (RPE) were recorded every km. Multiple statistical methods were used to ensure a comprehensive assessment of reliability. Intraclass correlations, standard error of the measurement, minimum difference required for a worthwhile change and coefficient of variation were determined for completion time and mean trial variables (power output, speed, cadence, heart rate, RPE, session RPE). **Results:** A meaningful change in performance for cyclists, runners, team sport athletes would be represented by 7.5, 3.6 and 12.9% improvement for 10 km and a 4.9, 4.0 and 5.6% for 20 km completion time. After a familiarisation, a 4.0, 3.7 and 6.4% improvement for 10 km and a 4.1, 3.0 and 4.4% would be required for 20 km. **Conclusion:** Data from this study suggest not all athletic subgroups require a familiarisation to produce substantially reliable 10 and 20 km cycling performance. However, a familiarisation considerably improves the reliability of pacing strategy adopted by recreational runners and team sport athletes across these distances.

Keywords: Reproducibility, variation, pacing, Velotron Pro, endurance

Introduction

Laboratory cycling time trials (TTs) attempt to replicate real-world race conditions, and often serve as endurance performance criteria[1]. In research settings, determining the effect of treatments or interventions on exercise (e.g., supplementation[2], cooling[3], heat-based training[4]) is commonly achieved using cycling TTs, irrespective of the athletic population recruited (e.g., cyclists, team sport athletes). Such investigations are reliant on the task being highly reproducible in the studied population, so to allow the detection of small but meaningful changes in performance[5]. The use of cycling TT tasks in non-cycling athletic populations might be attributed to: the space efficiency of ergometers, the capacity to safely test multiple individuals at the same time and easily accessible performance and pacing data. The Velotron Pro is a commonly used cycle ergometer for the assessment of TT performance[2,4,6]. The reliability of constant-work performance on this ergometer has been determined for distances of 4[7], 16.1[8] and 20 km[10,11], on simulated flat[10,11] and uphill[12,13,14] courses, in different cycling populations[11] and across various cycling levels[8]. In trained cyclists (VO_{2peak}: >56 $ml \cdot kg^{-1} \cdot min^{-1}$), completion time and mean power output have been shown to be highly reproducible on flat courses[9,10,11].

The reliability of performance on the Velotron Pro has previously been examined in manner so to inform the impact of multiple familiarisations[9,10,11]. However, the practical constraints of human testing (e.g., visits required, time and expense) may only permit a familiarisation to the ergometer but not the TT task itself, or a single practice trial at best. Moreover, depending on the experimental design, it may not be possible to exclusively recruit trained cyclists. To the authors' knowledge, no study has quantified the reliability of TT performance on the Velotron Pro in non-cycling athletic populations. Therefore, the primary aim of this study was to determine the reliability of 10 and 20 km cycling TT performance on the Velotron Pro, with and without a familiarisation in recreational cyclists, runners and intermittent-sprint based team sport athletes. A secondary aim of the study was to establish the reliability of the pacing strategy adopted by these athletic groups for 10 and 20 km. We hypothesised: (1) cyclists would demonstrate the most reliable performances over both distances; and (2) a familiarisation would improve the reliability of runners and team sport athletes performance.

Methods

This study consisted of two parts that involved completing four 10 (10TT) or 20 km (20TT) cycling TTs. The experimental design and methods were identical for the 10TT and 20TT. During a fifth visit, participants performed an incremental cycling test (commencing at 75 W, increased by 25 W·min^{-1}; Excalibur Sport; Lode, Groningen, Netherlands) with open circuit spirometry (TrueOne 2400, Parvo Medics, Provo, Utah, USA) to determine their peak oxygen consumption ($\dot{V}O_{2peak}$), peak power (P_{peak}) and peak heart rate (HR_{peak})[15]. Participants reported to the laboratory (24.5±1.3 °C; 59±4% relative humidity) at the same time of day (±2 h) for each TT, at least 2 d apart. Participants were instructed to avoid alcohol, caffeine and strenuous exercise in the 24 h before each visit; and asked to consume a similar diet on each testing day. During cycling, the consumption of fluids was not permitted, and no fan cooling was provided. The University Human Research Ethics Committee approved the study, and written informed consent was attained before commencing data collection.

Thirty-one male, recreationally trained athletes volunteered for this study. Eighteen athletes completed 10TT: (1) cyclists (n=6; age: 28.7±8.4 y; height: 180.1±7.2 cm; body mass: 76.3±5.0 kg); (2) runners (n=5; 25.9±2.4 y; 175.3±2.4 cm; 72.4±4.3 kg); (3) team sport (n=7; 24.0±2.1 y; 174.8±6.1 cm; 69.4±9.2 kg). Seventeen athletes completed 20TT: (1) cyclists (n=5; 28.6±2.8 y; 184.3±4.2 cm; 82.6±7.0 kg); (2) runners (n=6; 26.8±4.4 y; 177.9±6.9 cm; 72.6±4.0 kg); (3) team sport (n=6; 25.5±3.5 y; 177.0±7.1 cm; 80.6±11.3 kg]. Four participants (two cyclists, two runners) completed both 10TT and 20TT. For these individuals, there were at least 12 days between finishing 10TT and commencing 20TT.

At the time of the investigation, participants were amateur-level club athletes, training and/or competing in their respective sport at least twice per week. For team sport athletes, this included a minimum of one-structured training session (≥60 min), and one club-level competitive match each week. For 10TT, mean (±SD) training activities from the previous month: (1) cyclists: 4±1 sessions·wk^{-1}, 440±228 min·wk^{-1}; (2) runners: 4±1 sessions·wk^{-1}, 175±80 min·wk^{-1}, 38±8 km·wk^{-1}; and (3) team sport: 3±1 sessions·wk^{-1}, 180±75 min·wk^{-1}. For 20TT, (1) cyclists: 5±2 sessions·wk^{-1}, 515±220 min·wk^{-1}; (2) runners: 4±2 sessions·wk^{-1}, 218±87 min·wk^{-1}, 41±13 km·wk^{-1}; and (3) team sport: 5±1 sessions·wk^{-1}, 288±88 min·wk^{-1}. Runners provided their best 5 km run time achieved in the previous six-months; 10TT: 19:26±1:39 min; and 20TT: 18:49±1:19 min.

TTs were performed on the electromagnetically braked Velotron Pro cycle ergometer (RacerMate Inc., Washington, USA). This ergometer is highly accurate in measuring power output during constant load protocols (manufacturer reported: ±1.5% across 5-2,000 W) and is commonly used in research settings[16]. Factory calibration was confirmed using the 'Accuwatt' function. During cycling, gearing was freely altered via a toggle shifter located above the right brake hood. The Velotron 3D software (Version NB04.1.0.2101, RacerMate Inc., Washington, USA) was used to design the 10 and 20 km straight flat courses. During their first visit, participants were fitted to the ergometer, and these settings (seat and handlebar height, seat setback and handlebar reach) remained the same throughout testing. The type of pedals used by a participant during this initial visit (flat or Shimano SPD-SL clipless) was also kept consistent for each subsequent TT.

Participants were pre-screened (Exercise and Sports Science Australia questionnaire) and familiarised to the perceptual measures during their first visit. These measures were: the modified profile of mood states (POMS; active, energetic, restless, fatigued, exhausted and alert); Borg's[17] 6-20 rating of perceived exertion (RPE) and the CR-10 session RPE (sRPE) scales[18].

The procedures herein were replicated for each testing day. On arrival, participants provided a urine sample for the assessment of urine specific gravity (U_{SG}; PAL-10S; Atagi Ci. Ltd, Tokyo, Japan) and urine colour (scale: 1-8 au) as indicators of hydration status[19]. If U_{SG} >1.020, participants were provided with 500 mL of water, and U_{SG} was reassessed after 30 min. Nude body mass (WB-110AZ; Tanita Corp., Tokyo, Japan) was recorded, and participants completed the modified POMS. Following this, a heart rate (HR) monitor and wrist watch receiver (F1, Polar, Electro-oy, Kempele, Finland) were fitted, and participants donned their cycling attire. For cyclists, this consisted of bibs (without a jersey), socks and cleats; and for runners and team sport athletes, a t-shirt, shorts, socks and rubber soled shoes. Each participants' attire was standardised across all TTs.

After a 5 min warm up (100 W with a 5 s maximal effort on every minute), participants began their TT under the instruction of completing the distance in the fastest time possible. During trials, the 3D software was used to display an avatar of each participant on a computer monitor, in addition to elapsed distance (km), gear selection, and instantaneous power (W), speed ($km \cdot h^{-1}$), and cadence (RPM). Elapsed time was not shown on the monitor. Minimal verbal encouragement was provided. Time and all performance data were recorded at 23 Hz. HR and RPE were recorded every 1 km. Following each TT, performance data was downloaded, and exported to Excel 2013 (Microsoft Corp., Redmond, Washington, USA), nude body mass was recorded to determine pre-post trial fluid losses, and sRPE was collected.

The normal distribution of data was confirmed using descriptive methods (skewness, outliers and distribution plots), and inferential statistics (Shapiro-Wilk Test). To ensure participants arrived in a similar state each testing day, a repeated measures analysis of variance (ANOVA) was used to detect between TT differences for the baseline measures of hydration status (U_{SG}, urine colour, body mass), and the modified POMS, for the entire cohort.

Multiple methods were employed to ensure a comprehensive assessment of reliability. Firstly, a repeated measures ANOVA determined the within- and between-participant variance, partitioning error between systematic, and random error[20]. Intraclass correlation's (2,1; Equation 1) were calculated using a two-way fixed-effects model, where both systematic and random error were considered[21,22].

Equation 1. Intraclass correlation coefficient (ICC; 2,1) using a two-way fixed-effects model.

$$\mathrm{ICC} = \frac{\mathrm{MS_S} - \mathrm{MS_E}}{\mathrm{MS_S} + (\mathrm{k} - 1) \cdot \mathrm{MS_E} + \frac{\mathrm{k} \cdot (\mathrm{MS_T} - \mathrm{MS_E})}{\mathrm{n}}}$$

where: MS_S = participant mean square, MS_E = error mean square (i.e., random error), and MS_T = trials mean square (i.e., systematic error); k = the number of trials performed by a participant; and n = group size. ICC's were used to classify reliability as: <0.10 virtually none, 0.11–0.40 slight, 0.41–0.60 fair, 0.61–0.80 moderate, and >0.80 substantial[23].

The standard error of the measurement (SEM) was calculated as an index of absolute reliability[20,24]. The SEM was determined as per Equation 2, ensuring: (1) the SEM was not affected by the between-participant variability (as is the case with the ICC); (2) only random error was considered; and (3) the SEM was calculated independently of the ICC[20].

Equation 2. Standard error of the measurement (SEM)

$$\mathrm{SEM} = \sqrt{\mathrm{MS_E}}$$

Once calculated, the SEM was used to determine the minimum difference required for a worthwhile change (Equation 3). The minimum difference is an index based on the variability of the difference 'scores' (e.g., power output) between multiple trials, and the construction of 95% confidence intervals[20]. Therefore, any change greater than the minimum difference would be deemed meaningful. Herein the minimum difference will be denoted WC (i.e., worthwhile change).

Equation 3. Minimum difference required for a worthwhile change (WC)

$$WC = SEM \cdot 1.96 \cdot \sqrt{k}$$

Finally, the coefficient of variation (CV) was calculated as per Equation 4. The CV expresses the variability of a 'score' (as a percentage) in relation to the group mean.

Equation 4. Coefficient of variation (CV)

$$CV = (SD/mean) \cdot 100$$

where SD = standard deviation.

For each group (i.e., cyclists, runners, team sport), the ICC, SEM, WC and CV across the four TT was determined for completion time, mean trial performance variables (i.e., power output, speed, cadence), HR, and RPE. To describe the reliability of pacing strategy across the four TT, these same reliability calculations were performed on power output data assigned to 1 km 'bins' (i.e., mean power per kilometre)[7,10]. To evaluate the impact of a single familiarisation on reliability, these same processes were repeated for TT 2-4, thus excluding the first TT from the analysis.

Statistical analyses were performed using the Statistical Package for the Social Sciences version 23.0 (SPSS Inc., Chicago, IL), and manual calculations were undertaken in

Excel 2013. For all statistical tests, α was set at 0.1. Descriptive statistics are presented as mean±SD.

Results

For 10TT athletic groups, $\dot{V}O_{2peak}$, P_{peak} and HR_{peak} were: (1) cyclists: 57.7±7.7 ml·kg^{-1}·min^{-1}, 400±50 W (5.2±0.6 W/kg), 193±8 b·min^{-1}; (2) runners: 46.2±6.1 ml·kg^{-1}·min^{-1}, 305±41 W (4.2±0.4 W/kg), 181±9 b·min^{-1}; and (3) team sport: 43.6±3.5 ml·kg^{-1}·min^{-1}, 267±54 W (3.9±0.4 W/kg), 181±8 b·min^{-1}, respectively.

For 20TT groups, $\dot{V}O_{2peak}$, P_{peak} and HR_{peak} were: (1) cyclists: 56.8±6.8 ml·kg^{-1}·min^{-1}, 412±48 W (5.1±0.8 W/kg), 199±5 b·min^{-1}; (2) runners: 52.0±4.9 ml·kg^{-1}·min^{-1}, 342±30 W (4.7±0.5 W/kg), 180±9 b·min^{-1}; and (3) team sport: 47.9±3.8 ml·kg^{-1}·min^{-1}, 330±21 W (4.1±0.5 W/kg), 185±8 b·min^{-1}, respectively.

Baseline descriptive values are reported as the entire cohort mean (±SD) across the four TTs. For 10TT, participants arrived in a hydrated state (U_{SG}: 1.013±0.010; urine colour: 3±1 au; and body mass: 72.6±7.2 kg), and there were no statistical differences (P=0.47–1.00) between TTs for U_{SG}, urine colour or body mass. No differences (P=0.14–1.00) were observed between TTs for the modified POMS items: active (3.4±0.7), energetic (3.2±0.8), restless (2.4±0.8), fatigued (2.5±0.9), exhausted (2.2±0.8) and alert (3.5±0.7).

For 20TT, participants arrived hydrated (U_{SG}: 1.016±0.015; urine colour: 3±2; and body mass: 78.3±8.5 kg), and there were no statistical differences (P=0.17–1.00) between TTs for U_{SG}, urine colour or body mass. No differences (P=0.14–1.00) were observed between TTs for the modified POMS items: active (3.4±0.7), energetic (3.3±0.8), restless (2.3±0.9), fatigued (2.5±0.8), exhausted (2.2±0.8) and alert (3.5±0.8).

Mean trial values and corresponding reliability outcomes for measured variables are presented in Table 1. Pacing strategy (i.e., power assigned to 1 km 'bins') has been visually shown in Figure 1, and related reliability outcomes are presented in Table 2.

For 10TT, without a familiarisation, cyclists, runners and team sport athletes would require a 7.5, 3.6 and 12.9% respective change in completion time to be deemed meaningful (i.e., relative WC) and following a familiarisation, a 4.0, 3.7 and 6.4% change, respectively.

For 20TT, without a familiarisation, cyclists, runners and team sport athletes would require a 4.9, 4.0 and 5.6% respective change in completion time to be deemed meaningful and after a familiarisation, a 4.1, 3.0 and 4.4% change, respectively.

Heart rate responses were most stable in cyclists and runners across both distances (Table 1). There appeared to be a limited consistency between the reliability of RPE and sRPE for 10TT runners and 20TT cyclists (Table 1).

Discussion

This is the first study to demonstrate: (1) recreational runners produce substantially reliable 10 km performance data (completion time, and mean power and speed) without a familiarisation (Table 1); (2) team sport athletes produce substantially reliability 20 km performance without a familiarisation (Table 1); and (3) a familiarisation trial considerably improves the reliability of 10 and 20 km pacing strategy in recreational runners and team sport athletes (Table 2). This study also confirms the ability of recreational cyclists to produce substantially reliable TT data, even without a familiarisation.

The highly reliable performance by cyclists in this study supports previous findings[9,10,11]. Despite absolute differences in finish time and performance variables, runners in this study were similarly adept as cyclists at producing reliable 10 km data. This is somewhat surprising, as unlike the cyclists who had used other ergometers, completed races and sustained efforts for a similar duration in training, the runners were unfamiliar with cycling and reported having no recent ergometer experience (previous 6 months). These data might indicate a familiarisation is not necessary for runners for this distance. In light of these findings, it was interesting that runners exhibited only fair-to-moderately reliable data for 20 km. An explanation for this might be related to this study's runners being more accustomed to pacing for approximately 20 min (equivalent to a 5 km run) but being unfamiliar with sustaining a vigorous pace for the extended duration of the 20 km cycling task. Team sport showed the greatest 10 km variation of the three groups when a familiarisation trial was not undertaken; however, a familiarisation resulted in marked improvements. Team sport athletes displayed substantially reliable 20 km data, and this was only marginally improved by a familiarisation. This is unexpected, as these individuals are more accustomed to intermittent-sprint efforts, as opposed to a constant work task.

The secondary aim of this investigation was to establish the pacing strategy reliability of recreational cyclists, runners and team sport athletes for 10 and 20 km. Pacing is known to be important for overall performance[25] and is thought to be modulated by physiological, psychological and environmental factors[26], in addition to task-specific aspects such as familiarity[27] and prior experience[28,29]. In trained cyclists, a familiarisation has been found to alter pacing but not finish time[7], and these adjustments appear to remain for subsequent TTs[27]. Thomas and colleagues[10] found that without a 20 km familiarisation, well-trained cyclists (VO_{2max}: ~64 $ml\cdot kg^{-1}\cdot min^{-1}$) adopted a *J shaped* strategy, progressively reducing their power during the trial until the latter stages, where power output dramatically increased. The most variation was observed in the first ~10% of the task, and this remained unchanged after a familiarisation[10]. These findings are consistent with the 20 km performance of cyclists in the current study.

Figure 1 shows 10 km pacing strategy differed for each group, with cyclists employing an *even* strategy until the end spurt, runners a *J shaped* strategy and team sport a *U shaped* strategy. The adoption of a *U shaped* strategy by team sport athletes may reflect their inexperience with maintaining prolonged consistent effort in an exercise task, resulting in this athletic group beginning the TT in an explosive manner, which was not sustainable for the duration of the trial[30]. Excluding their start (1 km), the strategy adopted by runners was moderately reliable for 10 km (Table 2). After a familiarisation, team sport athlete's 10 km strategy was considered substantially reliable. During the 20TT, similar to the cyclists, both runners and team sport athletes adopted a *J shaped* pacing strategy (Figure 1). A familiarisation trial improved runners 20 km pacing strategy from slight-to-moderately reliable to moderately reliable, with the greatest benefit observed in the middle-third of the TT. Interestingly, the runners' starting strategy remained unaffected by a familiarisation in the 20TT (Table 2). For team sport athletes, a 20 km familiarisation improved the reliability (higher ICC and reduced SEM) of the pacing strategy in the first half of the task. Considerable variation was observed from the 10th km onwards, and this may be at least partially explained by the intermittent nature of activity in team sports[30].

There is no consensus from statistical sciences on the number of participants required for adequate stability for the calculations of ICC and SEM[20]. Nonetheless, a potential limitation of this study may be the small sample sizes of the 10TT and 20TT athletic subgroups.

Conclusion

This study provides evidence that following familiarisation, TT performance on the Velotron Pro is substantially reproducible in recreational cyclists, runners and team sport athletes for 10 km, but only in cyclists and team sport athletes for 20 km. Even after familiarisation, runners only produce moderately reliable 20 km TT data. After a familiarisation, a meaningful change in performance would be represented by a 4.0, 3.7 and 6.4% improvement in 10 km and a 4.1, 3.0 and 4.4% improvement in 20 km completion time for cyclists, runners and team sport athletes, respectively.

Practical implications

- Recreational runners may not require a familiarisation to produce substantially reliability 10 km cycling performance data.
- Intermittent-sprint based team sport athletes produce substantially reliable 20 km performance data without a familiarisation.
- A familiarisation improves the reliability of pacing strategy adopted by recreational runners and team sport athletes in a 10 and 20 km cycling time trial.

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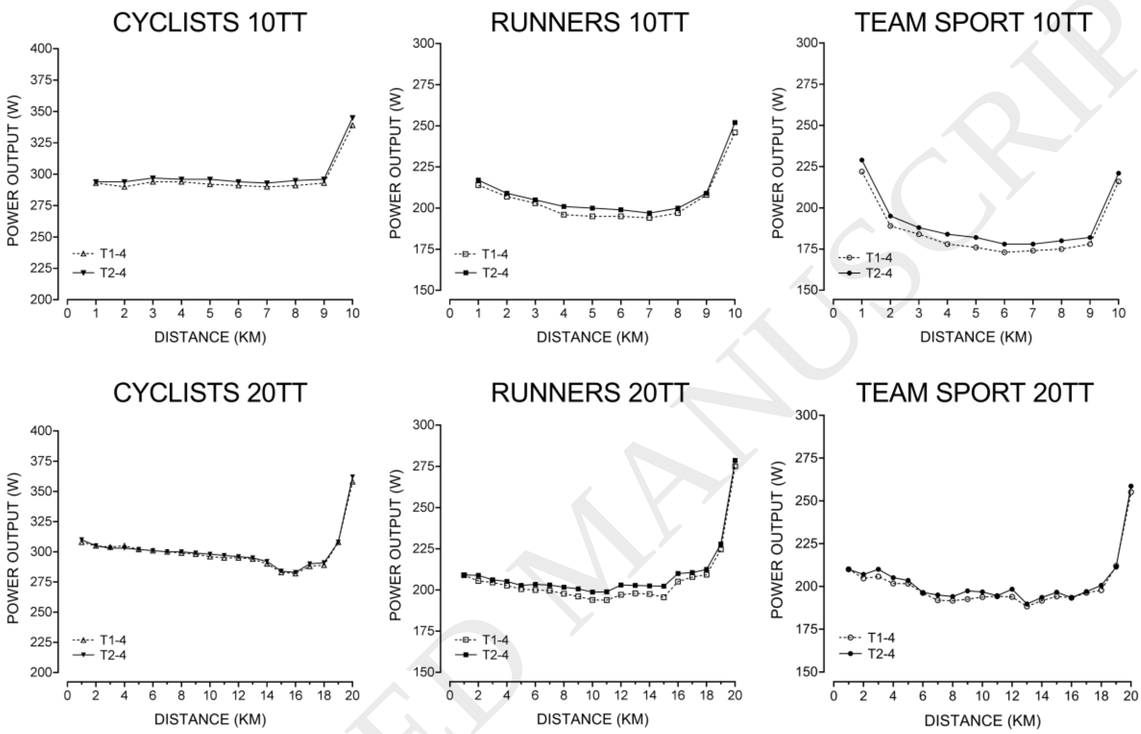
Figure legends

Figure 1. Athlete group pacing strategy for 10 (10TT) and 20 km (20TT) performance, as shown by mean power output per km. Dashed line indicates performance with no familiarisation (i.e., time trials 1-4; T1-4) and solid line indicates performance following a familiarisation (i.e., time trials 2-4; T2-4).



Figures

See attached figure.

Table 1. Ten and 20 km intraclass correlations, standard error of the measurement, minimum difference required for a worthwhile change and coefficient of variation for completion time and mean performance, physiological and perceptual variables. Values reported as mean±SD.

		10 km						20 km					
Athlete group		Cyclists (n=6)		Runners (n=5)		Team sport (n=7)		Cyclists (n=5)		Runners (n=6)		Team sport (n=6)	
		T1-4	T2-4	T1-4	T2-4	T1-4	T2-4	T1-4	T2-4	T1-4	T2-4	T1-4	T2-4
Finish time (min:s)		15:43 ±0:52	15:40 ±0:49	18:02 ±0:50	17:54 ±0:48	18:50 ±1:25	18:37 ±1:22	31:03 ±1:13	31:00 ±1:14	35:55 ±1:32	35:40 ±1:33	36:20 ±1:39	36:09 ±1:39
	ICC	0.88	0.95	0.88	0.95	0.69	0.93	0.92	0.93	0.74	0.80	0.83	0.87
	SEM	0:18	0:11	0:10	0:12	0:37	0:21	0:23	0:22	0:22	0:19	0:31	0:28
	WC	1:11	0:38	0:39	0:40	2:25	1:12	1:31	1:16	1:27	1:03	2:03	1:35
	CV	1.1	0.8	1.8	0.9	2.9	1.6	1.1	0.9	2.2	2.0	1.7	1.6
Power (W)		294±44	296±42	205±24	208±24	186±36	191±37	299±31	301±32	205±23	209±23	199±22	202±22
	ICC	0.91	0.95	0.89	0.96	0.70	0.95	0.91	0.93	0.58	0.64	0.83	0.85
	SEM	13	10	5	5	16	8	11	10	9	8	7	7
	WC	51	35	20	18	64	26	42	34	34	27	27	23
	CV	3.0	2.1	3.9	2.1	6.9	3.9	2.9	2.4	5.8	5.1	4.2	3.9
Speed (km·h^{-1})		38.4± 2.1	38.5± 2.0	33.4± 1.5	33.7± 1.5	32.1± 2.4	32.5± 2.4	38.8± 1.5	38.8± 1.6	33.5± 1.4	33.8± 1.5	33.2± 1.5	33.3± 1.5
	ICC	0.89	0.95	0.89	0.95	0.68	0.95	0.91	0.92	0.62	0.66	0.81	0.85
	SEM	0.69	0.47	0.32	0.37	1.10	0.50	0.52	0.50	0.45	0.38	0.50	0.46
	WC	2.70	1.60	1.27	1.37	4.33	1.69	2.03	1.71	1.77	1.30	1.95	1.55
	CV	1.1	0.7	1.6	0.9	2.8	1.6	1.1	0.9	2.0	2.0	1.8	1.6
Cadence (RPM)		96±6	96±7	91±10	90±10	92±7	91±6	98±6	98±5	93±8	93±8	92±8	92±8
	ICC	0.95	0.98	0.70	0.93	0.25	0.54	0.73	0.73	0.93	0.96	0.74	0.88
	SEM	2	1	6	3	7	4	3	3	2	2	4	3
	WC	6	4	23	9	29	15	13	9	9	6	17	9
	CV	1.5	0.9	4.2	2.2	4.6	3.9	3.0	2.2	2.6	1.9	2.8	2.6
Heart rate (b·min^{-1})		176±9	176±8	168±12	168±12	174±9	174±9	186±7	185±7	158±8	159±7	169±7	170±7
	ICC	0.83	0.80	0.85	0.84	0.62	0.95	0.76	0.80	0.62	0.65	0.60	0.64
	SEM	4	4	5	5	7	2	2	2	5	4	4	4
	WC	17	14	20	18	27	7	9	6	19	12	17	13
	CV	2.2	2.0	2.6	2.7	2.1	1.0	1.9	1.6	3.2	2.5	2.4	2.1
RPE (6-20 scale)		16.2± 1.4	16.0± 1.4	15.4± 0.7	15.5± 0.6	16.0± 1.1	16.1± 1.0	16.7± 1.2	16.7± 1.2	15.2± 0.8	15.2± 0.9	15.1± 0.9	15.1± 0.9
	ICC	0.84	0.88	0.23	0.22	0.53	0.61	0.79	0.81	0.67	0.71	0.68	0.69
	SEM	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.5	0.5	0.6	0.6

	WC	2.2	2.0	2.2	1.9	2.7	2.1	2.4	2.1	1.9	1.6	2.2	1.9
	CV	3.6	2.9	3.6	2.9	4.6	3.8	2.3	2.0	2.9	2.8	3.0	3.1
sRPE (0-10 scale)		8.8±1.1	8.9±1.0	7.9±1.3	7.9±1.4	8.0±1.0	8.5±0.7	9.0±0.9	9.0±0.9	7.9±0.9	8.1±0.8	7.8±2.0	8.1±1.9
	ICC	0.75	0.81	0.22	0.66	0.19	0.50	0.22	0.64	0.69	0.78	0.60	0.58
	SEM	0.5	0.4	1.5	0.9	0.5	0.4	1.1	0.6	0.4	1.4	1.0	0.9
	WC	2.1	1.5	6.0	3.0	2.0	1.2	4.2	2.1	1.7	1.5	3.9	2.9
	CV	6.0	4.4	9.7	8.2	12.3	5.3	4.7	4.0	6.5	3.7	15.6	13.7

CV = Coefficient of variation; ICC = Intraclass correlations; SEM = Standard error of the measurement; WC = Minimum difference required for a worthwhile change

Table 2. Ten and 20 km pacing strategy (power output assigned to 1 km 'bins') reliability: intraclass correlations, standard error of the measurement, minimum difference required for a worthwhile change and coefficient of variation.

	Cyclists								Runners								Team sport athletes							
	T1-4				T2-4				T1-4				T2-4				T1-4				T2-4			
	ICC	SEM	WC	CV	ICC	SEM	WC	CV	ICC	SEM	WC	CV	ICC	SEM	WC	CV	ICC	SEM	WC	CV	ICC	SEM	WC	CV
10 km																								
1	0.91	19	76	4.1	0.98	7	26	2.2	0.36	48	188	8.7	0.34	48	189	9.3	0.76	32	124	10.5	0.88	26	100	6.4
2	0.83	23	89	4.6	0.98	6	23	2.1	0.80	14	54	3.9	0.89	10	41	3.8	0.78	16	62	8.7	0.88	14	53	5.4
3	0.95	11	43	3.6	0.97	8	31	2.4	0.88	8	33	4.3	0.88	9	36	3.9	0.87	10	40	6.6	0.92	10	38	4.5
4	0.96	11	42	3.2	0.98	7	27	1.9	0.80	7	29	5.9	0.91	8	33	3.6	0.76	13	51	8.8	0.81	15	59	5.5
5	0.92	13	50	3.5	0.96	9	36	2.7	0.74	8	32	5.9	0.94	6	25	2.8	0.49	21	82	9.6	0.82	12	47	6.4
6	0.89	15	59	3.4	0.89	16	63	3.0	0.80	8	30	5.4	0.84	9	34	3.7	0.21	13	50	8.1	0.89	12	47	6.1
7	0.85	17	68	3.1	0.86	17	65	2.5	0.79	8	32	4.8	0.80	10	39	4.0	0.72	15	58	6.9	0.94	8	32	4.5
8	0.82	10	40	3.4	0.97	6	24	1.9	0.79	7	27	4.5	0.85	8	30	3.6	0.82	12	47	7.7	0.95	8	32	5.0
9	0.90	12	47	3.3	0.89	14	53	3.5	0.77	10	39	3.9	0.83	9	36	3.6	0.53	23	89	7.4	0.94	8	31	3.8
10	0.81	24	93	7.0	0.79	26	103	6.9	0.80	17	68	5.5	0.97	7	29	2.9	0.82	18	71	8.0	0.93	14	54	5.2
20 km																								
1	0.43	26	102	6.5	0.72	11	44	5.9	0.18	36	141	11.4	0.16	36	141	11.7	0.32	30	116	9.8	0.60	14	53	7.7
2	0.75	16	61	4.3	0.87	9	37	3.1	0.42	20	78	9.0	0.30	23	89	9.1	0.52	14	56	7.5	0.37	14	55	6.3
3	0.77	14	54	4.1	0.85	9	34	3.3	0.57	14	53	6.9	0.46	14	54	6.7	0.72	14	54	8.2	0.76	11	42	6.3
4	0.83	11	44	3.7	0.86	9	34	3.1	0.56	14	54	6.1	0.68	8	32	5.3	0.68	13	52	8.2	0.74	9	34	6.6
5	0.85	12	45	3.7	0.85	9	36	3.1	0.63	9	35	6.1	0.63	7	27	5.7	0.77	13	52	7.1	0.85	8	33	5.9
6	0.86	12	46	3.5	0.87	9	34	2.8	0.57	12	46	7.1	0.61	10	39	6.3	0.71	18	72	7.8	0.83	11	45	4.9
7	0.83	13	51	3.8	0.86	9	34	2.9	0.54	12	49	7.3	0.64	9	36	6.7	0.81	9	34	5.5	0.88	6	22	4.4
8	0.83	14	54	4.1	0.88	9	36	2.3	0.44	11	45	7.6	0.52	10	40	6.8	0.80	9	37	5.1	0.90	6	22	3.7
9	0.83	14	56	4.2	0.87	10	38	2.7	0.51	8	33	7.6	0.58	8	30	6.8	0.69	12	48	6.8	0.79	12	49	4.9
10	0.85	14	56	4.3	0.86	10	39	2.7	0.56	10	38	7.1	0.69	8	33	5.9	0.62	15	59	7.2	0.67	15	60	6.3

11	0.87	12	48	3.7	0.91	9	35	2.5	0.30	16	63	7.6	0.67	9	35	6.5	0.54	20	78	8.6	0.57	16	63	7.4
12	0.88	12	46	3.5	0.90	10	40	2.8	0.63	10	40	7.4	0.75	10	39	4.4	0.71	16	63	7.9	0.80	16	63	5.3
13	0.88	12	48	3.6	0.87	13	50	3.7	0.39	19	73	7.7	0.55	17	68	5.9	0.71	15	59	7.0	0.73	14	54	5.8
14	0.85	14	54	4.3	0.86	14	54	4.0	0.53	16	63	8.9	0.68	15	57	7.2	0.79	11	44	5.8	0.77	12	48	5.7
15	0.85	15	59	4.5	0.84	16	64	4.6	0.29	23	92	10.0	0.72	15	59	7.3	0.67	14	56	6.4	0.67	16	61	6.5
16	0.74	21	84	4.1	0.73	22	87	4.4	0.59	19	74	8.4	0.80	13	51	6.8	0.67	15	58	6.7	0.73	14	53	6.7
17	0.79	20	80	5.9	0.85	19	74	5.1	0.83	12	49	6.3	0.81	14	53	6.2	0.72	15	61	7.1	0.70	16	64	7.5
18	0.83	19	74	5.6	0.77	24	94	4.7	0.89	9	34	5.1	0.91	8	32	3.9	0.70	20	78	8.9	0.65	21	83	8.9
19	0.83	26	101	7.0	0.87	20	77	5.5	0.69	22	88	9.5	0.73	23	91	9.5	0.79	16	63	6.4	0.79	15	60	6.0
20	0.80	28	108	6.9	0.90	17	68	5.4	0.66	16	64	7.8	0.65	15	59	8.2	0.44	18	69	7.0	0.31	19	75	7.0

CV = Coefficient of variation; ICC = Intraclass correlations; SEM = Standard error of the measurement; WC = Minimum difference required for a worthwhile change