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VALIDITY AND RELIABILITY OF THE CYCLEOPS HAMMER CYCLE ERGOMETER

Submission type: Original Investigation

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ABSTRACT

Purpose: To validate the new drive indoor trainer Hammer designed by Cycleops®. ***Methods:*** Eleven cyclists performed 44 randomized and counterbalanced graded exercise tests (100-500W), at 70, 85 and 100 rev.min^{-1} cadences, in seated and standing positions, on 3 different Hammer units, while a scientific SRM system continuously recorded cadence and power output data. ***Results:*** No significant differences were detected between the three Hammer devices and the SRM for any workload, cadence, or pedalling condition (P value between 1.00 and 0.350), except for some minor differences (P 0.03 and 0.04) found in the Hammer 1 at low workloads, and for Hammer 2 and 3 at high workloads, all in seated position. Strong ICCs were found between the power output values recorded by the Hammers and the SRM (≥0.996; P=0.001), independently from the cadence condition and seated position. Bland-Altman analysis revealed low Bias (-5.5-3.8) and low SD of Bias (2.5-5.3) for all testing conditions, except marginal values found for the Hammer 1 at high cadences and seated position (9.6±6.6). High absolute reliability values were detected for the 3 Hammers (150-500W; CV<1.2%; SEM<2.1). ***Conclusions:*** This new Cycleops trainer is a valid and reliable device to drive and measure power output in cyclists, providing an alternative to larger and more expensive laboratory ergometers, and allowing cyclists to use their own bicycle.

Keywords: cycling, powermeter, ergometry, calibration, power output

INTRODUCTION

One of the biggest advances in cycling physiology during the last decades has been the commercial availability of power-measuring tools, allowing the direct measurement of power output (PO) produced at the bicycle during cycling training, competition and laboratory testing. A cycle trainer is a device which, attached to an individual bicycle, could allow cyclists and researchers to work with the best standards of quality, especially those without the space or funding necessary to get a standalone one. Even though there are a great variety of cycle trainers, few of them have the capacity to measure cycling PO. Furthermore, relatively little information is available regarding the reliability and validity of these devices. There are several specialised standalone ergometers for laboratory use whose high level of reliability and validity have been confirmed (Lode[1], Ergoline[2], Monark[2], Velotron[3], Wattbike[4], or SRM[5-7]). However, their size, weight and price can limit their use in laboratories with low financial resources and by private cyclists and teams [8]. Moreover, even if the ergometers, handlebars, saddles and pedals were customised specifically for an individual cyclist (not always possible), there would be considerable variations between bicycles in some decisive metrics such as the crank width (Q-factor), crank length, and other differences related to specific geometry of the bicycle itself that could affect muscle geometry, comfort, pedalling performance and even injury incidence[9]. Very often, ergometers have different flywheels inertial characteristics involving crank inertial load (CIL) values which are significantly lower than the real road cycling conditions. According to Bertucci et al.[10] to optimise the quality of the fitness assessment tests, it is important to use an ergometer that allows control of the inertial characteristics to simulate the actual cycling conditions, valid, reliable and sensitive PO measurements and finally, the use of the cyclist's own bicycle to maintain the cyclist's usual riding position.

It is well known that poor reliability in power output (PO) does not allow for optimisation of the training program, comparison with previous or future tests, nor an accurate analysis of the data. Thus, the validity and reliability of the equipment is linked with the efficacy of the information obtained. Without a high level of reliability for the measurement of PO, changes in performance and training status cannot be determined[11,12]. For the evaluation of the effect of training or detraining with PO measurement, it is important to know the variation due to the technical error of the powermeter[13]. Vanpraagh et al.[14] suggests that the range of the technical error for PO recorded using ergometers should be within ±5%. When using it to test high-level athletes, this technical error could be closer to ±2%.

The recent development of the Cycleops Hammer (CycleOps, Madisson, USA) has introduced another power measuring trainer to the market. Besides its small size and its low cost (≈$1600 US, far cheaper than the more established laboratory ergometers), it allows cyclists to use their own bicycle by replacing the rear wheel with the Hammer inertial wheel. This device allows the elimination of the friction of the wheel on the brake, significantly reducing the noise of the ergometer when pedalling, and avoiding the influence of the tyre pressure over the power measurement. Resistance of this device is adjusted via a computer controlled system with an inexpensive and easy to use software. Therefore, the main purpose of this study is to examine the validity, reliability and accuracy of this new cycle trainer compared with the well-known scientific SRM crankset, under all cycling conditions.

MATERIALS AND METHODS

Participants

Eleven well-trained male cyclists and triathletes volunteered to take part in this study. Mean (SD) characteristics of participants were as follows: age 32.4 ± 9.0 years; height 186.4 ± 8.0 cm; body mass 78.6 ± 12.9 kg; cycling training experience 11.2 ± 2.7 years. All participants trained for 6 hours or more per week during a minimum of twelve months preceding the study. They were all informed of the experimental procedures, and they signed a written informed consent agreeing to participate in the study. Participants were asked to avoid strenuous exercise, caffeine or alcohol for at least 24 hours prior to each testing session. The study, which was conducted according to the Declaration of Helsinki, was approved by the Bioethics Commission of the University of Murcia and, after being informed of the purpose and experimental procedures, participants signed a written informed consent form.

Testing Procedures

Three brand new Hammer direct drive indoor trainer units (Cycleops, Wisconsin, EEUU) were compared against an SRM crank-based powermeter (scientific model with adjustable crank length; Schoberer Rad Messtechnik, Julich, Germany, 1% accuracy). For all testing sessions, a medium size road bicycle (2010 Giant Giant-Bicycles, Taiwan; Aluminium alloy frame with carbon fibre fork) was fitted with the SRM 172.5mm crank powermeter. This precision strain-gauge-based crank and sprocket dynamometer transmits data to a unit display (Power Control V) fixed on the handlebar.

The relationship between the frequency output and the strain gauges and torque is determined during manufacture and considered constant. The validity of this SRM system has been previously demonstrated[5-7], and therefore taken as our Gold Standard power meter device. To minimize the possible influence in the validity and reliability values of the three Hammer devices, we have used the same bicycle and SRM powermeter in all testing conditions. A dynamic calibration of the SRM crankset was performed by the manufacturer prior to the beginning of the study. Also, according to the manufacturer’s recommendations, before each testing session, we calibrated the offset value of the SRM.

The rear wheel of the bicycle was removed and attached to three different Cycleops Hammer devices with 10 speed (11-25 tooth) rear gear ratio and 39-53 tooth front gear ratio. For all tests, the gear ratio 39x15 was selected, and cyclists were not allowed to change it to prevent a potential effect of this variable on pedalling technique.

Previously to each testing session, calibration of each Hammer ergometer according to the manufacturer's recommendations was done, so the Hammers determine the power required to overcome bearing and belt friction, and set the zero-offset of strain gauges. Likewise, the front fork of the bicycle was attached to the accompanying steering apparatus for stability purposes. The bicycle seat height position was matched to the cyclist's own training geometry and was fitted with clipless pedals. Cyclists used their own cycling shoes fitted with Look cleats.

Protocol

Participants visited the laboratory on three separate occasions to test the three Hammer devices. All testing protocols began with a standardized warm-up of 5 minutes at 100 W with a free chosen cadence. Following this period, the validity and reliability of the three devices were assessed in the laboratory during three different testing protocols:

a. Three randomized and counterbalanced graded exercises tests, one for each selected fixed cadence (70_{CAD}, 85_{CAD} and 100_{CAD}), at six sub-maximal workloads (i.e., 100, 150, 200, 250, 300 and 350 W) of 75 seconds of duration [5], separated by 5 min of recovery at 75 W with free chosen cadence. The 3-graded exercise tests were done in seated position. The order of the three cadence levels was randomized to ensure that the validity of the results was not affected by increments on the ergometer break temperature or by the cyclists' fatigue.
b. After 5 min of recovery at 75 W, cyclists performed a 75-s seated free cadence 500 W workload.
c. Finally, they performed a graded exercise test at three sub-maximal PO (i.e., 250, 350 and 450 W) of 75 seconds with a free chosen cadence, in a standing pedalling position. Two minutes of recovery at 75 W with free-chosen cadence were kept between the three workloads tested.

Following the recommendation of Jones [5], only PO and cadence values from the10th to the 70th second of each 75 second steps were analysed, to allow the ergometer enough time to stabilise the assigned breaking load. During each test, PO (W) and cadence (rev.min^{-1}) of Hammer Cycleops were recorded at a frequency of 1Hz using the Cycleops Hammer on-line software (VirtualTraining s.r.o., Vimperk, Czech Republic). Additionally, PO and cadence of the SRM crankset were also recorded at a frequency of 1Hz using the Power Control V. The recorded data were downloaded from the previously mentioned units and further analysed using publicly available software (Golden Cheetah, version 3.4) and Microsoft Excel 2016 (Microsoft Software). All tests were performed in the same exercise laboratory under standardized conditions (22.9 ± 2.0 ºC; 39.3 ± 3% humidity).

Statistical analysis

Standard statistical methods were used for the calculation of means, standard deviations (SD), coefficient of variation (CV) and standard error of the mean (SEM). Intraclass correlation coefficients (ICC) were used to determine the degree of association between the PO of the SRM (PO_{SRM}) and the PO of the Hammers (PO_{HAMMER}) during every graded exercise test. Additionally, given the fact that a high correlation does not necessarily imply that there is good agreement between any two methods, Bland–Altman plots were used to assess and display the agreement and systematic difference among the SRM and Hammer PO values[15]. The PO differences were drawn in relation to the mean values and 95% of the differences were expected to lie between the two limits of agreement (LoA) that were mean difference ± 2 standard deviation (SD) of the differences, expressed as bias ± random error as recommended by Atkinson[16]. Every test data was checked on heteroscedasticity by calculating heteroscedasticity correlation[16]. The Kolmogorov-Smirnov test and complementary analyses of normality were used to determine that both PO_{SRM} and PO_{HAMMER} were normally distributed. Then, a t-test was performed to establish PO_{SRM} and PO_{HAMMER} differences. Statistical significance for all tests was regarded as $p < 0.05$. Analyses were performed using GraphPad Prism 6.0 (GraphPad Software, Inc., CA, USA), SPSS software version 19.0 (SPSS, Chicago, IL) and Microsoft Excel 2016 (Microsoft Corp, Redmond, WA, USA).

RESULTS

Validity

No significant differences were detected between the three Hammer devices assessed and our Gold Standard powermeter (SRM scientific model) for any workload (from 100 W to 500W), cadence (70, 85 and 100 rev·min^{-1}) or pedalling position (seated or standing pedalling) (P values between 1.00 and 0.35), except for some minor differences (P = 0.03 and 0.04) found between PO_{SRM} and PO of the Hammer 1 at low workloads (100W–200W), and for Hammer 2 and 3 at high workloads (350 W), all in seated position (Table 1). Also, a strong ICC was found between the PO values recorded by the three Hammers and the SRM system (≥ 0.996), regardless of the cadence condition and seated position (Table 1 and Fig. 1). A Bland-Altman analysis (Table 1 and Fig. 2) revealed low bias (range between -5.5 and 3.8) and a low SD of Bias (ranged between 2.5 and 5.3) for all testing conditions, except values founded for the Hammer 1 at high cadences and seated position (9.6 ± 6.6).

Reliability

The mean CV for the sitting graded exercise tests were 2.8 vs. 0.6%, 1.7 vs. 0.5 % and 2.5 vs. 0.6% for the SRM compared with the Hammer 1, 2 and 3, respectively. These values are considerably lower if the 100W workload is excluded (2.0 vs. 0.5%, 1.5 vs. 0.4% and 2.0 vs. 0.6%). The mean CV for standing pedalling tests of both devices (SRM vs. Hammer 1, 2 and 3) were 2.2 vs. 0.6%, 2.1 vs. 0.6% and 1.6 vs. 0.4%, respectively, while CV for the high workload (i.e., 500 W) at seating position remains also very low (1.9 vs 1.0%, 1.3 vs. 0.7% and 1.4 vs 0.4%) (Table 1). The SEM for the three Hammer devices remains at very low values for all testing conditions (range between 0.7 and 2.8).

Sensibility

According to the data, the pedalling cadence had no effect on PO among the power meters. As shown in table 1, the CV, SEM, ICC and Bland Altman bias result for sitting positions and pedalling conditions have very similar values.

DISCUSSION

The main finding of this study is that the Hammer Cycle Ergometer is a highly valid and reliable tool for testing and training purposes in cycling under all assessed workloads (100 W - 500 W), cadences (70, 85 and 100 rev.min^{-1}) and pedalling positions (seated and standing). In addition, other advantages of this system are the use of the cyclist's own bicycle, maintaining the usual riding position, low cost, small noise level and its size.

Laboratory based ergometers (i. e., SRM, Lode, Velotron or Wattbike) are still considered the "gold standard" due to their high level of validity and reliability[1,4,5,17-20]. Thus, for a cycle trainer to be useful in a research setting it must have a similar level of validity and reliability. Different researchers have tested the validity of other mobile ergometers like Tacx Fortius[8], KICKR Power Trainer[21], LeMond Revolution[22], and Elite Axiom Powertrain[23]. This is the first study, to our knowledge, to evaluate this new cycle ergometer when compared with the recognized and extensively used SRM scientific device. It should be noted that the SRM as the reference powermeter, is also affected by some measurement error. Previous studies have used the SRM scientific model comprising 20 strain gauges[5,24,25] as well as the SRM professional model (4 strain gauges)[26], and the accuracy claimed by the manufacturer was ± 0.5 % and ± 2.5 %, respectively. The data collected in our study indicate that PO does not significantly differ between the Hammers and the SRM scientific model, with significant high, "near perfect", relationships ($r \geq 0.996$) from 100 W to 500 W in each of the three checked devices, either sitting or standing pedalling at low, medium and high cadences.

Although there were significant differences between the three tested Hammer devices for some loads, the differences were small for PO between 150 W and 350 W. Hammer 1 slightly overestimated PO, while Hammer 2 and 3 underestimated PO but with small mean bias (between -5.5 W and 3.8 W), narrow 95% LoA (between -8.8 W and 22.8 W), and little differences depending on the device (Table1). It is also important to remark that our study has not found any significant differences between the PO_{SRM} and PO_{HAMMER} data comparing standing versus seated position, even though it is known that standing pedalling which causes lateral sways, affects the biomechanics of pedalling [27]. In our opinion the folding legs and the integrated front wheel tray of the cycle ergometer provide a wide footprint adding stability and reducing the effects of the above-mentioned lateral sways.

Similar mean biases values were found when testing Wahoo KICKR Power Trainer[21] at loads over 250 W to 700 W, and cadences of 80 and 120 rev·min^{-1} (-1.1% and 95% LoA -3.5% to 1.4%), and higher for loads from 100 W to 200 W (4.5 % and 95 % LoA-2.3 % to 11.3 %). When we compared current results with the Wattbike Cycle Ergometer [20], lower 95% LoA were found for the Hammer device (−16 to 8 W at 150 W, −20 to 1 W at 200 W, −22 to −6 W at 250 W and −31 to −9 W at 300 W). Again, similar biases of -1.3 ± 5.3 W (95% LoA) were reported for Garmin Vector Pedals[28] when used in laboratory. Some authors[11,18] have suggested that, in elite athletes, a magnitude lower than 2% is required to detect changes in performance from either, an ergogenic or training intervention. When compared to the SRM, the mean error of the Hammer ergometer shows that, in our data, it falls this range. Based on the current study's evaluation of three Hammers, a mean error of ~2% compared to the SRM would be acceptable for talent identification purposes. Hopkins[11] suggested that an 84% confidence interval is a more reasonable threshold than the traditional 95% interval when attempting to detect changes in athletic performance. Based on a PO of 350 W, changes of ≥ 2% (7.0 W) and > 1% (3.5 W) would be required to be sure (84%) that a trained cyclist had changed PO because of a training intervention. These results suggest that the Hammer Cycle Ergometer is sufficiently accurate to track performance changes over time, and thus would serve as an acceptable training tool.

Regarding reliability (table1), when we compare the Hammer device with other ergometers in previous studies, mean CV are comparable to the findings of the current study. Kirkland et al.[29] reported a mean CV of 2.3 % across 137 separate PO. Similarly, Bertucci et al. [24] reported a mean CV of 1.7 % for an SRM (scientific model) crankset over PO from 100 to 420 W. These results mean that CV for the SRM in the current study concurs with reliability data from previous studies.

Cycling technique and type of ergometer can affect cycling efficiency[30]. In our opinion using cyclists adds more reliability to the real use of the cycle ergometer. From this point of view, the good results of the present research, confirm that this biological variability doesn’t affect the validity of the PO in the Hammer Cycle ergometer. What is more, we test each ergometer and cyclist with three different and representative cadences to analyse if this item affects the reliability of the PO. Besides, the number of participants and their fitness level (i. e., well trained cyclists) are consistent with other published research studies assessing the reliability and validity of cycle ergometers[8,17,23].

There are some limitations in the current study which may be possible to overcome in future studies. Due to the time constraints of the data collection period and the magnitude of the experimental protocol, data was collected over a 60-s period for each experimental intensity after a ~10-s period for stabilization at the new intensity. It could be argued that a longer period should be used to collect the data, but given how fast the Hammer adapt to each load, we decided that this was not necessary. In addition, the reliability of the Hammer to measure power in longer trials was not assessed. It was considered that linking the three graded tests in the same protocol allow each ergometer to work around 45 minutes. Besides, the use of cyclists to perform the tests instead of comparing with a calibration rig, could have added biological variability to the overall measure of variability between tests and can explain part of the differences due to the individual characteristics of pedalling [19]. Since the tests were developed with loads up to 500 W, additional research must be done to test the reliability and validity of the Cycleops Hammer for sprint cycling tests above 500 W

PRACTICAL APPLICATIONS

This study confirms that this new Cycleops Hammer cycle ergometer is a valid and reliable device to drive and measure power output in cyclists, providing an alternative to larger and more expensive laboratory ergometers, and allowing cyclists to use their own bicycle. Current results demonstrate that the Cycleops Hammer provides valid readings of power output from 100 to 500 W, in either seated or standing positions, at cadences of 70, 85 and 100 rev.min^{1}. It is therefore a valid, reliable and accurate mobile cycle ergometer compared with the worldwide recognized Gold Standard scientific SRM.

CONCLUSIONS

To date, the Cycleops Hammer remains a reliable system for sport scientists, practitioners, coaches or individuals who wish to perform and measure cycling PO, but may not have the space or funding to obtain a traditional laboratory ergometer, providing similar levels of validity and reliability. Further studies would be required to verify the accuracy, reliability and validity of this device for sprint cycling above 500 W.

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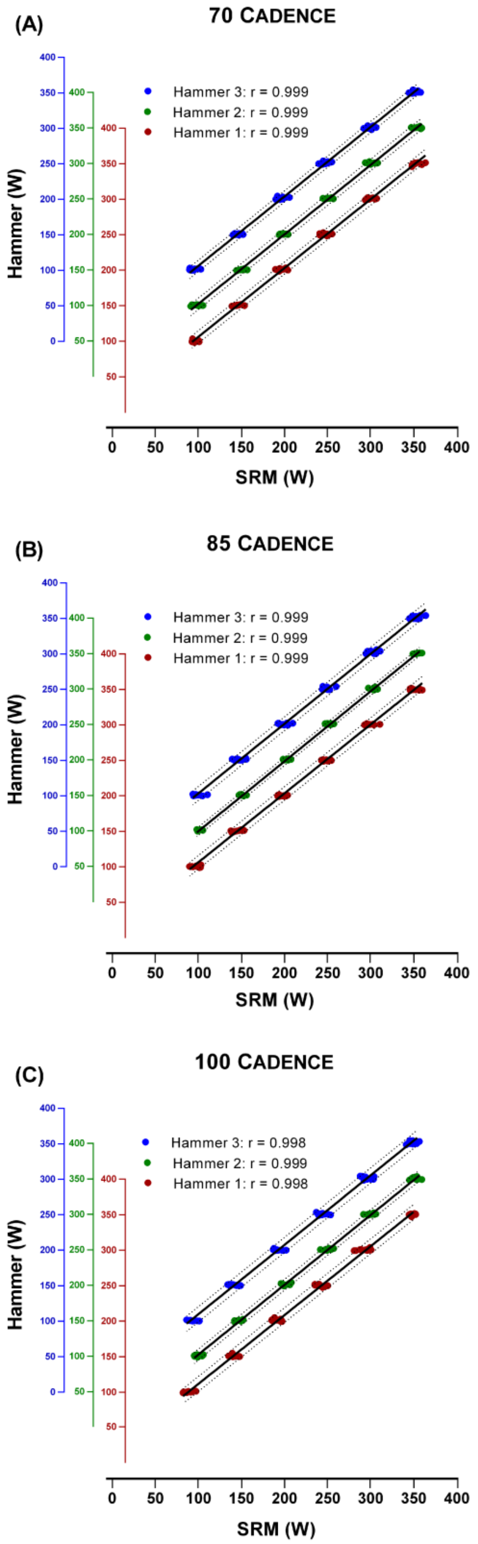

Figure 1. ICC of the three Hammer devices assessed during the submaximal graded exercises tests compared to the scientific SRM powermeter at 70 (A), 85 (B) and 100 (C) rev·min^{-1}.

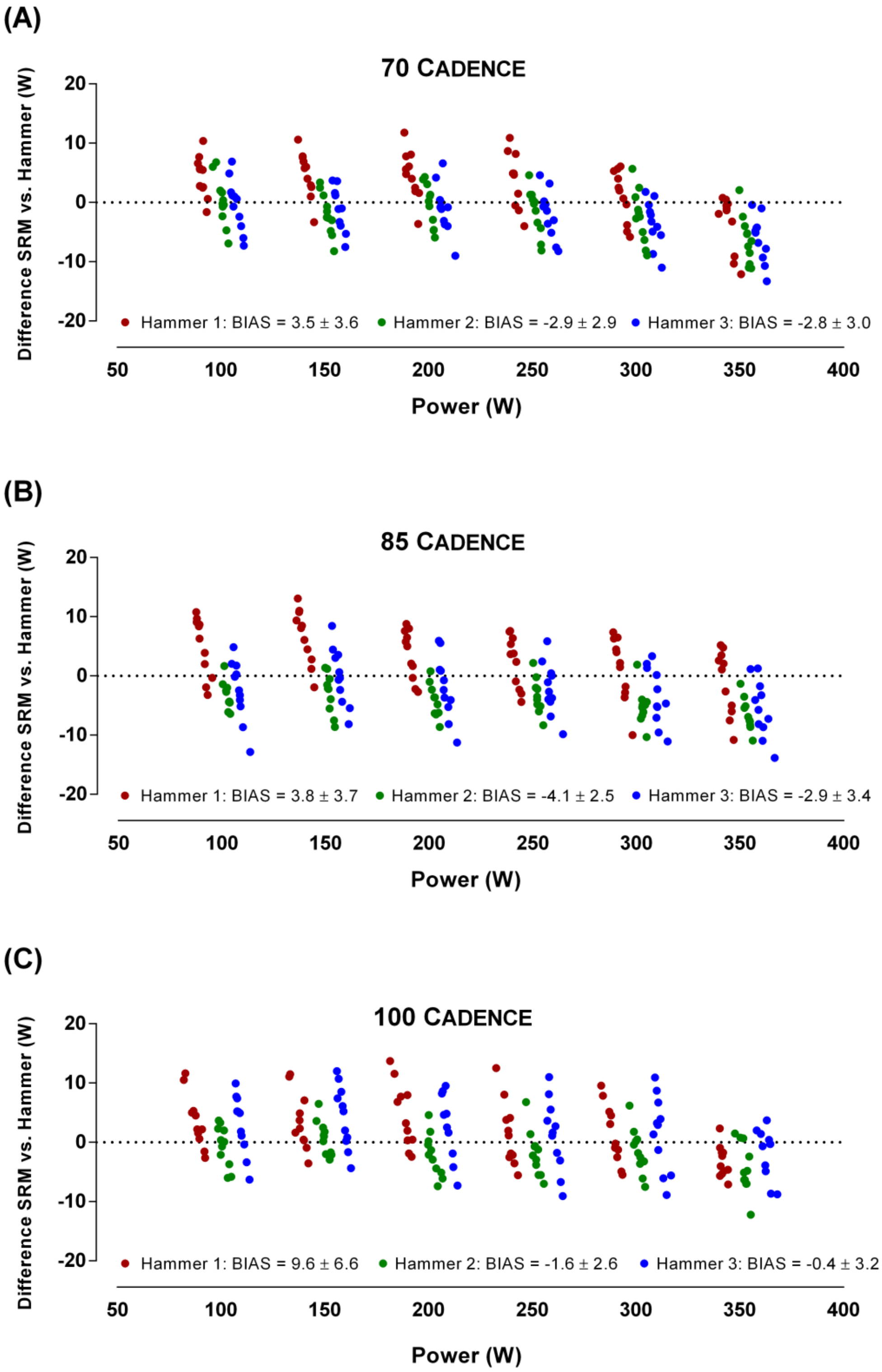

Figure 2. Bland–Altman plots of the 3 Hammer devices assessed during the submaximal graded exercises tests compared to the scientific SRM powermeter at 70 (A), 85 (B) and 100 (C) rev·min^{-1}.

Table 1: Validity and reliability values of the three Hammer devices analysed.

HAMMER 1

		SRM (W) Mean SD	SRM (W) CV	Hammer (W) Mean SD	Hammer (W) CV	SEM	ICC r value	Bland Altman Bias	Bland Altman SD Bias
70 CAD	100 W	94±5	5.0%	100±1*	1.4%	1.4			
	150 W	143±3	2.3%	150±1*	0.5%	1.0		3.5	3.6
	200 W	196±4	1.8%	200±1*	0.7%	1.1	0.999		
	250 W	243±3	1.3%	251±1	0.5%	1.0		LoA 3.7 to 10.7	
	300 W	299±4	1.3%	301±1	0.3%	1.1			
	350 W	352±4	1.1%	350±2	0.5%	1.2			
85 CAD	100 W	95±5	4.9%	101±1*	0.9%	1.4			
	150 W	143±4	3.0%	151±1*	0.7%	1.3		3.8	3.7
	200 W	196±3	1.7%	200±1*	0.4%	1.0	0.999		
	250 W	247±4	1.5%	250±1	0.3%	1.1		LoA 3.5 to 11.1	
	300 W	298±4	1.3%	301±1	0.2%	1.2			
	350 W	350±5	1.3%	350±2	0.6%	1.3			
100 CAD	100 W	88±8	9.5%	101±1*	1.0%	2.5			
	150 W	139±7	5.0%	151±2*	1.2%	2.1		9.6	6.6
	200 W	189±7	3.6%	201±2*	0.8%	2.0	0.998		
	250 W	241±6	2.5%	250±1*	0.5%	1.8		LoA 3.6 to 22.8	
	300 W	292±7	2.2%	300±1	0.2%	2.0			
	350 W	347±3	0.8%	350±2	0.4%	0.8			
250 w FC-S		248±7	2.8%	249±1	0.6%	2.1		0.1	5.3
350 w FC-S		350±7	2.1%	350±2	0.6%	2.2	0.996		
450 w FC-S		452±8	1.8%	450±3	0.6%	2.4		LoA 10.5 to 10.8	
500 w FC		492±9	1.9%	496±5	1.0%	2.8			

HAMMER 2

		SRM (W) Mean SD	SRM (W) CV	Hammer (W) Mean SD	Hammer (W) CV	SEM	ICC r value	Bland Altman Bias	Bland Altman SD Bias
70 CAD	100 W	101±3	3.3%	101±1	0.5%	1.0			
	150 W	153±4	2.3%	150±1	0.5%	1.0		-2.9	2.9
	200 W	202±3	1.7%	201±1	0.3%	1.0	0.999		
	250 W	253±3	1.4%	251±1	0.3%	1.0		LoA -8.7 to 2.9	
	300 W	304±4	1.2%	300±1	0.3%	1.1			
	350 W	358±4	0.7%	350±1*	0.3%	0.8			
85 CAD	100 W	104±2	2.1%	101±1	0.9%	0.7			
	150 W	153±3	1.9%	150±1	0.4%	0.9		-4.1	2.5
	200 W	205±3	1.4%	201±1	0.3%	0.9	0.999		
	250 W	254±3	1.1%	251±1	0.2%	0.8		LoA -9.1 to 0.9	
	300 W	306±3	0.8%	301±1*	0.4%	0.8			
	350 W	357±3	0.9%	350±1*	0.1%	0.9			
100 CAD	100 W	101±4	3.6%	101±1	1.1%	1.1			
	150 W	150±4	2.4%	150±1	0.8%	1.1		-1.6	2.6
	200 W	203±4	2.0%	201±2	0.8%	1.2	0.999		
	250 W	253±4	1.6%	251±1	0.4%	1.3		LoA -6.8 to 3.6	
	300 W	302±4	1.4%	300±1	0.3%	1.2			
	350 W	355±4	1.1%	350±2	0.4%	1.2			
250 w FC-S		256±7	2.6%	249±2	0.7%	2.0		-5.5	3.6
350 w FC-S		353±4	1.6%	352±2	0.6%	1.7	0.996		
450 w FC-S		456±9	2.1%	449±2	0.5%	2.8		LoA -17.3 to 6.9	
500 w FC		504±7	1.3%	499±3	0.7%	2.0			

HAMMER 3

		SRM (W) Mean SD	SRM (W) CV	Hammer (W) Mean SD	Hammer (W) CV	SEM	ICC r value	Bland Altman Bias	Bland Altman SD Bias
70 CAD	100 W	102±5	4.4%	101±1	1.0%	1.4			
	150 W	152±4	2.5%	151±1	0.6%	1.1		-2.8	3.0
	200 W	203±4	2.1%	201±2	0.8%	1.3	0.999		
	250 W	254±5	1.8%	251±2	0.6%	1.4		LoA -8.8 to 3.2	
	300 W	305±4	1.3%	301±2	0.6%	1.2			
	350 W	357±4*	1.1%	351±2*	0.4%	1.2			
85 CAD	100 W	104±5	4.7%	101±1	0.7%	1.5			
	150 W	151±5	3.3%	151±1	0.7%	1.5		-2.9	3.4
	200 W	203±5	2.6%	201±1	0.6%	1.6	0.999		
	250 W	254±4	1.7%	252±2	0.7%	1.3		LoA -9.6 to 3.9	
	300 W	306±5	1.7%	302±2	0.7%	1.6			
	350 W	357±5*	1.4%	353±2*	0.6%	1.6			
100 CAD	100 W	99±5	4.6%	101±1	0.52%	1.4			
	150 W	148±5	3.2%	151±1	0.51%	1.4		-0.4	3.2
	200 W	200±5	2.6%	200±1	0.45%	1.5	0.998		
	250 W	251±5	2.2%	251±1	0.51%	1.6		LoA -5.9 to 6.7	
	300 W	302±5	1.8%	302±2	0.69%	1.6			
	350 W	355±4	1.2%	352±2	0.63%	1.3			
250 w FC-S		253±4	1.6%	251±2	0.7%	1.3		-3.2	4.3
350 w FC-S		354±6	1.8%	352±2	0.4%	1.9	0.997		
450 w FC-S		455±6	1.3%	450±1	0.2%	1.7		LoA -11.5 to 5.5	
500 w FC		501±7	1.4%	499±2	0.4%	2.2			

CAD = Cadence; FC-S = Free cadence standing; SD = Standard Deviation; CV = Coefficient of variation; SEM = Standard error of the mean; ICC = Intraclass correlation coefficient; LoA = 95% Limits of Agreement; * Significant differences compared to the SRM device ($p < 0,05$).