Validation of dynamic forces measured by an instrumented crankset

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Abstract: Power output is directly related to final performance in cycling. To calculate it, we need to measure the angular velocity of the crankset and the propulsive forces applied on it. The aim of this study is to assess the validity of static and dynamic forces measured by an instrumented crankset (IC) developed by Phyling, by comparing it with a reference force sensor (RS). Results show a very high degree of agreement between the two systems (ICC>0.99), proving that the instrumented crankset can accurately measure the forces applied to the crankset throughout pedaling cycles.

1. Introduction

Power measurement systems constitute essential tools in the quantitative assessment of performance in cycling. These systems are able to compute power by multiplying the crankset angular velocity by the force applied on the crankarms. Force measurement is based on various technologies such as measuring the force applied to the pedals, crank arms, or even chain tension [1]. In addition to the average power per pedaling cycle, power measurement throughout the cycle can reveal asymmetries [2] or provide information on muscular properties [3,4]. The instrumented crankset (IC) by Phyling (Palaiseau, France) has a high acquisition frequency (200Hz), which allows dynamic measurement throughout the pedaling cycle. Pedaling dynamics exhibit varying force levels during a cycle (Figure 1). This study aims to evaluate the accuracy of the Phyling instrumented crankset.

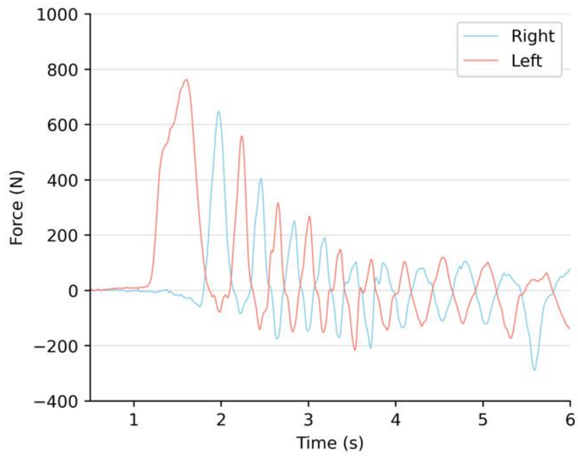

Figure 1: Raw pedaling data on an ergometer equipped with the IC.

2. Method

2.1. The instrumented crankset (IC)

For this study, a ZED crankset designed by Look (Nevers, France) was instrumented with strain gauges positioned on both crankarms to only measure propulsive forces (i.e., forces applied perpendicular to the crankarms). In the following Fzr denotes the right force and Fzl the left force. The sensors data are then collected by an electronic board (Mini-Phyling V1) placed on the left crankarm which contains all the electronics required for data acquisition. The sampling frequency is set to 200Hz.

2.2. Measurement setup

To evaluate the accuracy of the IC, a measurement setup was developed to dynamically apply forces on the sensors. The IC was locked in a custom-made bottom bracket. While a force is applied to one crankarm, the other one is blocked by a rigid steel cable.

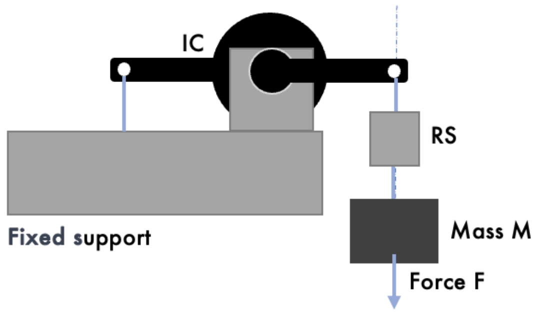

Figure 2: Schematics of the experimental setup.

2.3. IC calibration procedure

The calibration coefficient of each IC force sensor was determined using a static calibration procedure with calibrated masses. Five different known masses (M) were alternatively applied on each crankarms during ten seconds. Linear coefficient, and regression coefficient score are computed between mean raw values measured by IC and M values during each interval of ten seconds.

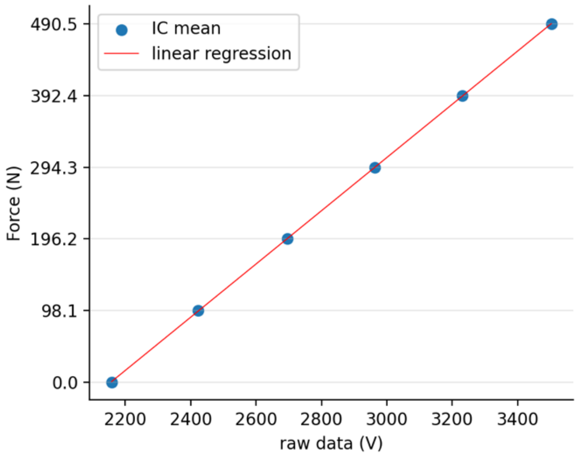

Figure 3: Example of the calibration regression for the left crank.

The regression coefficient calculated between M and IC is 0.99. Regression coefficient score close to 1 indicates a strong positive linear relationship between IC data and M.

2.4. Dynamic procedure

To assess validity of the IC dynamic measurement, a reference sensor (RS) was placed between the Mass and the IC (Figure 2). The operator loaded a 500N mass and applied additional forces by pushing vertically the mass to reach 1000N at each repetition. The operator repeated the operation 25 times for each crankarm. Data from RS and IC are compared for each dynamic solicitation. Raw data are presented in Figure 4.

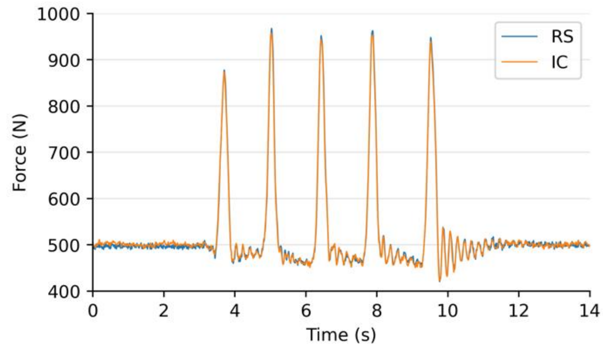

Figure 4: Raw data from 5 cycles of force application on the right crank.

3. Results

Mean values and standard deviations (sd) for IC and RS are presented in Table 1, as well as the results of intraclass correlation (ICC (3,1)) and Bland-Altman analysis.

Table 1: Mean values and sd for RS and IC, ICC, mean bias RS/IC limits of agreements (LOA), ratio of limits of agreements (RLOA).

	Values	
Statistics	Fzr	Fzl
Mean RS ± sd	664 ± 38	645 ± 37
Mean IC ± sd	662 ± 38	645 ± 37
ICC $_{(3,1)}$ [95% CI]	**0.99** [1.0, 1.0]	**0.99** [1.0, 1.0]
Mean bias (LOA) (low. lim, upp. lim)	1 .48 (-13, 16)	-0.79 (-14,12)
RLOA (%)	**0.22**	**-0.12**

ICC values for Fzr and Fzl showed a very strong correlation between values (>0.99).

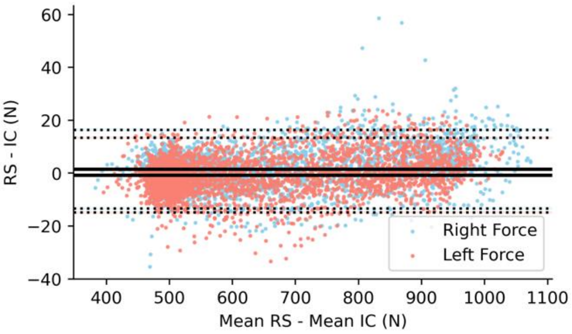

Figure 5 : Summary graph of the Bland-Altman analysis.

The Bland-Altman analysis [5] revealed a high degree of agreement between IC and RS. On the one hand, the very low mean bias between the two measurement systems (Fzr: 1.48N, Fzl: -0.79N) shows that there is a minor overestimation of values for Fzr and an underestimation for Fzl. On the other hand, the ratio of the limits of agreement (Fzr: 0.22%, Fzl: -0.12%) shows that 95% of the measured errors occur within a very small interval around the mean difference. Bland-Altman graph (Figure 5) shows that errors measured at low force values is similar to those measured at higher values.

4. Discussion

The aim of the study was to assess the validity of the IC force sensors. Results showed an excellent degree of agreement in comparison to a gold standard sensor. LOAs showed that the IC is a valid measurement system to estimate forces applied on crankarms.

It has been observed that the calibration coefficients may slightly vary when the crankset is installed on the bike. So we developed a calibration setup with the crankset mounted on the bike to calculate accurately the calibration coefficients. This specific procedure will be presented in a future article.

Finally, this study showed that the IC accurately measures the forces applied on the crankarms but it could be interesting to assess the validity of the power output measured by the IC. To achieve this, a comparison between IC power output and a gold standard power meter could be conducted.

5. Conclusion

The aim of this study was to assess the validity of forces measured at the crankarms using an IC by Phyling. Results showed that these sensors accurately assess propulsive forces developed by cyclists. The IC can therefore be used not only to assess forces, but also to analyze other key indicators throughout the pedaling cycle.

6. Bibliographie

1. Bouillod, A.; Soto-Romero, G.; Grappe, F.; Bertucci, W.; Brunet, E.; Cassirame, J. *Sensors* 2022, *22.*
2. Rannama, I.; Port, K.; Bazanov, B.; Pedak, K. *Journal of Human Sport and Exercise* 2015
3. Dorel, S. Springer International Publishing, 2018.
4. Sachet, I. *Phd thesis,* 2022.
5. Martin Bland, J.; Altman, D.G. 2010.