VALIDITY, SENSITIVITY AND REPRODUCIBILITY OF STAGES AND GARMIN VECTOR POWER METERS WHEN COMPARED WITH SRM DEVICE

Anthony Bouillod[1,4], Julien Pinot[1, 2], Georges Soto-Romero[3,4] and Frederic Grappe[1, 2]

EA4660, C3S Health - Sport Department, Sports University, Besancon, France[1]
Professional Cycling Team FDJ[2]
ISIFC, Université de Franche-Comté[3]
LAAS-CNRS, Toulouse, France[4]

The measurement of power output (PO) during cycling has led some manufacturers to develop mobile power meters. However, such devices have to provide a valid, sensitive and reproducible PO. This study aimed to determine the validity, sensitivity and reproducibility of the Stages and Garmin Vector during both laboratory and field cycling tests. The results demonstrate that the Stages and the Garmin Vector systems appear to be reproducible. However, the validity and the sensitivity of the two systems must be treated with some caution.

KEYWORDS: mobile power meter, power output, comparison, laboratory, field, cycling.

INTRODUCTION: The measurement of power output (PO) during cycling allows the assessment of the cyclist's training and racing intensity zones according to their skills and thus, to their race performance profile (Pinot & Grappe, 2011). In this way, several manufacturers developed mobile power meters. To be used, such devices have to provide a valid, sensitive and reproducible PO (Bertucci, Duc, Villerius, Pernin, & Grappe, 2005). The SRM power meter (SRM, Schoberer, Rad, Messtechnich, Julich, Germany) is the most commonly used system in cycling (Sparks, Dove, Bridge, Midgley, & McNaughton, 2015). It is considered as a gold standard due to the high validity, sensitivity and reproducibility of the measurement. The high cost of the SRM led manufacturers to develop less expensive systems. Some of them have been studied for their validity, sensitivity and reproducibility (Max one, Polar S710, Ergomo, Look Keo Power, Powertap), whereas others newer power meter have not been yet studied (Stages, Garmin Vector).
The aim of this study was to assess the validity, sensitivity and reproducibility of the Stages and Garmin Vector systems during both laboratory and field cycling tests.

METHODS: After a familiarisation session, a national level male competitive cyclist (age: 23 years old, height: 1.88 m, body mass: 80 kg) performed all testing sessions with the same road racing bicycle fitted with a SRM crank set (SRM 9000 comprising 8 strain gauges), a Stages left-arm crank (STG, Boulder, USA) and Garmin Vector pedals (VCT, Olathe, USA).
The validity, the sensitivity and the reproducibility of Stages and Garmin Vector were investigated in the laboratory at submaximal and maximal intensities from three experimental protocols which included 1) a sub-maximal incremental test, 2) a sub-maximal 30-min continuous test, and 3) a sprint test. The incremental and continuous sub-maximal tests were performed on a motorized treadmill, whereas the sprint test was performed on a Cateye ergometer (CS-1000, Cateye, Osaka, Japan). The subject performed the three protocols on the same day and repeated each protocol three times on three different days. One extra test was performed in the field to study the validity of the three systems during real cycling locomotion.
A sub-maximal incremental test was performed on a motorized treadmill with 19.5, 21, 22.5, 24 and 25.5 $km.h^{-1}$ velocities (150 to 350 W). The mass of the system (subject + bicycle) contributes to the PO required to ride on a treadmill at a given speed, that's why we controlled this parameter adding or removing water from two bottles in the bottle cages of the bicycle. On each velocity, both the pedalling cadence (60, 80 and 100 rpm) and the position (seated and standing) effects on PO were tested. The combinations of the different speeds, pedalling cadences and positions resulted in 30 different data sets.

A 30-min continuous exercise test was performed in seated position at 21 km.h^{-1} on a 3 % slope with a pedalling cadence of 80 rpm.
The sprint test consisted of three 8-sec sprints in a seated position to determine the maximal 1-sec PO (PO_{max}) and 5-sec PO (PO_{5sec}). The magnetic resistance of the Cateye ergometer was set at a simulated grade of 7 %. Three different gear ratios were used (53/15, 53/17 and 53/19) to determine three different maximal pedalling cadences. Sprints were separated by 5-min of active recovery periods at low intensity (<150 W).
The field test consisted of a 2-h road cycling session on a hilly terrain including the different laboratorial experimental conditions.
Bland-Altman plots and 95 % limits of agreement were applied to assess agreement between PO_{STG}, PO_{VCT} and PO_{SRM} during sub-maximal incremental test. The data of the four protocols were not normally distributed. Thus, the analysis of differences between the mean PO_{STG}, the mean PO_{VCT} and the mean PO_{SRM} of each protocol were assessed with a non-parametric Kruskal-Wallis test. Pedalling cadence and cycling position effects on PO_{STG}, PO_{VCT} and PO_{SRM} during sub-maximal incremental test were evaluated with a non-parametric two-way repeated measures test (Friedman). To assess the reproducibility, the mean coefficient of variation (CV) and the intraclass correlation coefficient (ICC) were calculated. In all statistical tests significance was set at $p < 0.05$.

RESULTS: During the sub-maximal incremental test there were strong correlations between PO_{SRM} and PO_{STG} ($r = 0.985$, $p < 0.001$) and PO_{VCT} ($r = 0.996$, $p < 0.001$). The mean PO from 19.5 to 25.5 km.h^{-1} (150 to 350 W) was not significantly different between the three systems. Bland-Altman analysis (fig. 1) shows that the mean bias between PO_{SRM} and PO_{STG} was -13.7 ± 12.4 W (95 % CI: -37.9 and 10.6 W) and 0.6 ± 6.2 W (95 % CI: -11.6 and 12.7 W) between PO_{SRM} and PO_{VCT}.

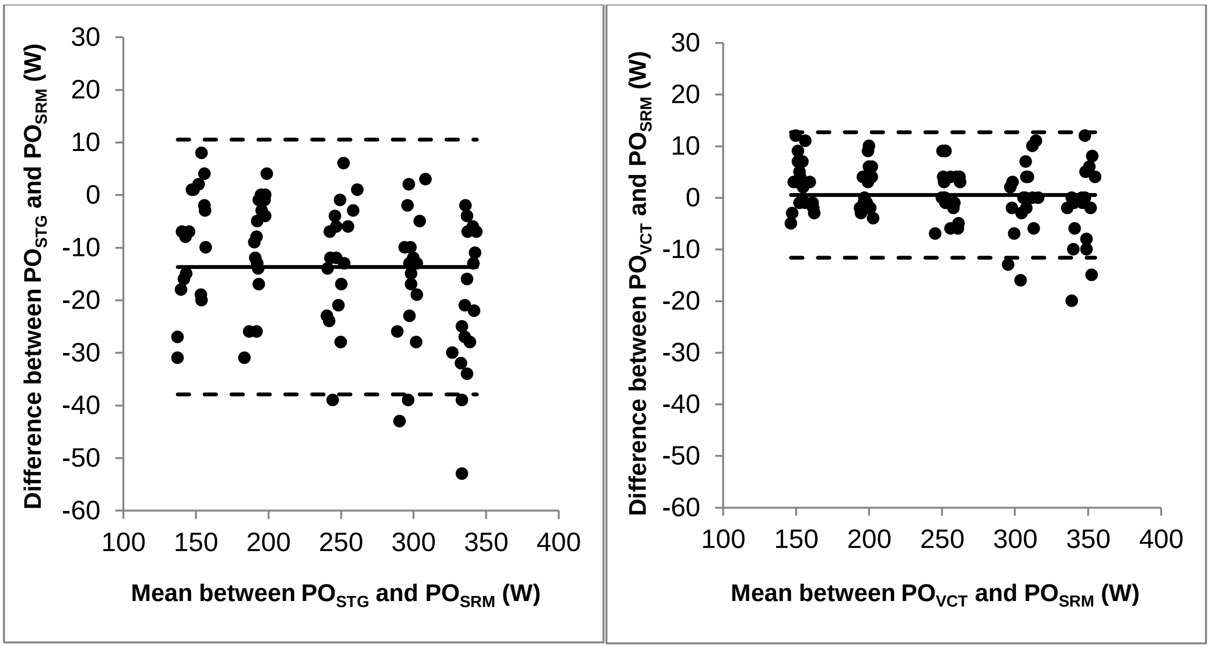

Figure 1: Bland-Altman plots of the differences between PO_{SRM} and PO_{STG} and PO_{VCT} during sub-maximal incremental test. The dashed lines represent the high and low 95 % confidence interval (CI), whereas the solid line represents the bias.

No significant difference was measured between the mean POs during the 30-min continuous tests and the mean CV was 3.6 %, 2.0 % and 2.8 % for PO_{STG}, PO_{VCT} and PO_{SRM}. However, the figure 2 shows that the 5-sec PO_{VCT} was significantly lower (-36.9 %, $p < 0.05$) compared to PO_{SRM} with the lowest gear.

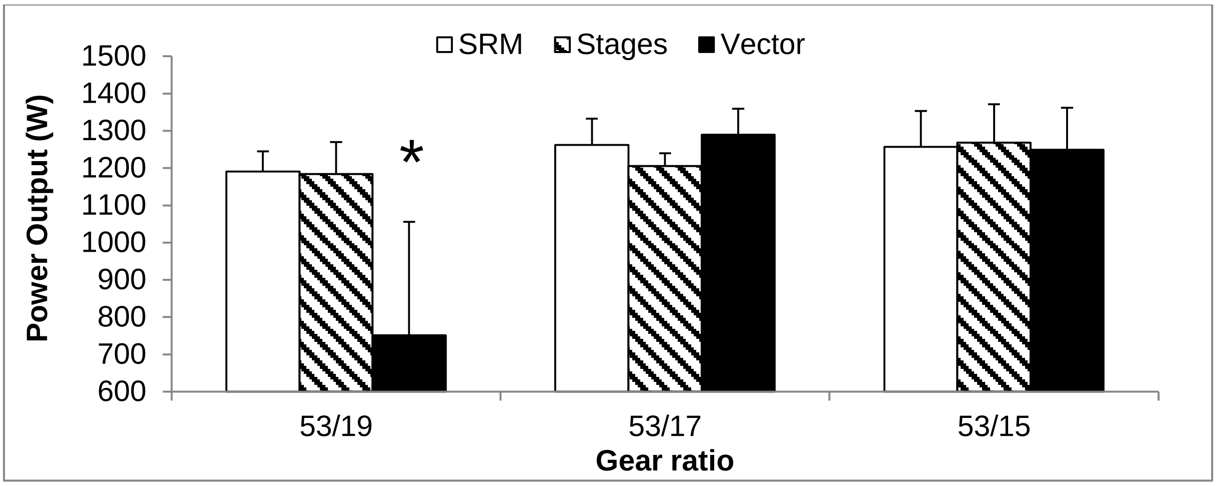

Figure 2: SRM, Stages and Garmin Vector 5-sec PO obtained during the sprint tests.
** Significant difference (p < 0.05)*

The mean PO was not significantly different with SRM (178.5 ± 200.4 W) and Stages devices (168.3 ± 166.7 W) during the field test. However the Garmin Vector under estimates ($p < 0.001$) the PO of 16.5 % (149.1 ± 187.7 W) compared to the SRM.

The pedalling cadence had no effect on PO among the different power meters. However, the cycling position had a significant effect on PO_{STG} and PO_{SRM} (fig. 3). Indeed, with the SRM device PO was significantly higher in standing position (+ 2.1 %, $p < 0.001$). In contrast, PO_{STG} was significantly lower in standing position (-4.4 %, $p < 0.001$).

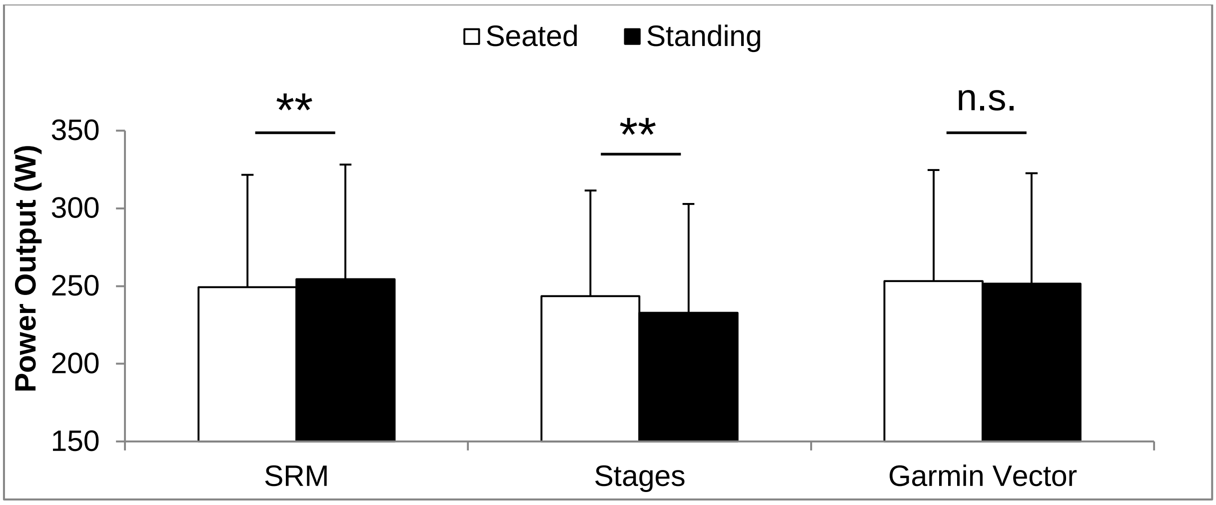

Figure 3. Effect of cycling position on PO during sub-maximal incremental test.
*** Significant difference (p < 0.001)*
n.s. Non-significant difference (p > 0.05)

For all the incremental tests, the mean CVs for all the cycling conditions (5 velocities, 3 pedalling cadences, 2 pedalling postures) were 3.0 ± 1.9 % for PO_{STG}, 2.5 ± 1.3 % for PO_{VCT} and 1.9 ± 1.3 % for PO_{SRM}. Additionally, ICC was 0.87, 0.87 and 0.92 respectively whereas no difference was detected with the Kruskal-Wallis analysis.

DISCUSSION: This is the first study that analyse the validity, sensitivity and reproducibility of the Stages and Garmin Vector power meters in comparison with the SRM. The results demonstrate that the Garmin Vector provide a valid PO during sub-maximal exercise in laboratory. However, this power meter under estimates the PO during both the sprints with the low gear ratio (-36.9 %) and the field test (-16.5 %). Concerning the Stages power meter,

the large CI cannot consider this system as valid during the sub-maximal incremental test. PO_{STG} was significantly lower in standing position compared with seated position, probably due to the only left-crank measurement. Because asymmetry depends on the subject, further studies must be realised on several cyclists controlling this parameter especially with the Stages device.
The Garmin Vector system didn't measure the PO change between seated and standing positions. Both Stages and Garmin Vector power meters are not considered as sensitive given that the PO_{SRM} was significantly higher in standing position compared with seated position (Bouillod *et al.*, 2014).
The importance of reproducible power meters to detect small changes in performance has been emphasised in a review (Hopkins, Schabort, & Hawley, 2001). The detectable change in performance represents a magnitude less than 2 % in elite athletes. The mean CVs obtained with the Stages and Garmin Vector devices are slightly higher than 2 % but the statistical analysis indicates that the three power meters provide reproducible PO during sub-maximal tests in laboratory.

CONCLUSION: Our study demonstrates that the Stages and Garmin Vector systems are reproducible mobile power meters. However, the validity and the sensitivity of the two systems must be treated with some caution.

REFERENCES:

Bertucci, W., Duc, S., Villerius, V., Pernin, J.N., & Grappe, F. (2005). Validity and reliability of the Powertap mobile cycling powermeter when compared with the SRM device. *International Journal of Sports Medicine*, 26, 868–873.

Bouillod, A., Pinot, J., Valade, A., Cassirame, J., Soto Romero, G., & Grappe, F. (2014). Gross efficiency is improved in standing position with an increase of the power output. *Journal of Science and Cycling*, 3, 6.

Hopkins, W.G., Schabort, E.J, & Hawley, J.A. (2001). Reliability of power in physical performance tests. *Sports Medicine*, 31, 211-234.

Pinot, P., & Grappe, F. (2011). The record power profile to assess performance in elite cyclists. *International Journal of Sports Medicine*, 32, 839-844.

Sparks, S.A., Dove, B., Bridge C.A., Midgley, A.W., & McNaughton, L.R. (2015). Validity and reliability of the look keo power pedal system for measuring power output during incremental and repeated sprint cycling. *International Journal of Sports Physiology and Performance*, 10, 39-45.