

# The Reliability and Accuracy of the Garmin Vector 3 Power Pedals

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## **Abstract**

The aims of this study were to 1) investigate the reliability of the Garmin Vector 3 (V3) pedals, and 2) compare power output and cadence between the Lode Excalibur Sport ergometer and the V3 pedals. Seven male cyclists completed six x 2-min sub-maximal cycling stages (100, 150, 200, 250, 300 and 350 W) and two x 10-s maximal sprints, completed on two occasions within seven days. A Mann-Whitney U test identified significant differences between the Lode Excalibur Sport and the V3 pedals at 150–350 W and during all-out sprinting ( $P < 0.05$ ) with a mean relative difference during sub-maximal cycling of 1.8%. Results also suggested there was no significant differences between the Lode Excalibur Sport and V3 pedals for cadence at all power outputs tested ( $P > 0.05$ ), with a mean relative difference of 0.2%. Results suggest that the V3 pedals are reliable for both power output and cadence with a coefficient of variation of  $<5.05\%$  and  $<3.87\%$ , respectively. Furthermore, the technical error of measurement for power output was 2.4–5.3 W between 100–350 W, and  $<8.04 \text{ rev}\cdot\text{min}^{-1}$  for cadence at all power outputs tested. It is suggested that the V3 pedals are reliable and accurate during sub-maximal testing; however, the V3 pedals over-estimate power output during all-out sprinting.

**Keywords** validation, power meter, laboratory-based test, field-based testing

## Introduction

Power meters are regularly used within cycling to allow coaches to set individualised training plans based on the power output and cadence data collected from training and race performances.<sup>1</sup>

Laboratory-based ergometers are ideal for research; however, with a purchase price of more than \$20,000, recent research has focused on validating cheaper more portable systems.<sup>2</sup> The development of the cycle-mounted power meter has provided the opportunity to monitor performance (e.g. power output and cadence) using the athlete's bicycle, rather than being restricted to a laboratory-based ergometer.<sup>3,4,5</sup> The SRM Powermeter (crank) is regarded as the "gold standard" cycle-mounted power meter.<sup>1</sup>

Pedal-based power meters have recently been developed at a lower cost compared to traditional systems. Several studies have focused on their reliability and validity of these meters. It has previously been suggested that the Garmin Vector pedals (V1) overestimate power output<sup>6,7</sup>, with a typical error of 3.3% (20 W)<sup>6</sup>. In contrast, studies suggested that the second version of the Garmin Vector pedals (V2) are comparable to the SRM Powermeter, with no significant difference in power output during sub-maximal cycling observed; however, significant differences were seen during sprint cycling.<sup>8</sup> The P1 pedals have also been reported to demonstrate excellent levels of agreement when compared to a Wattbike Pro cycle ergometer during a 16.1 km time-trial, with an intra-class correlation of >0.8.<sup>9</sup> Both the V2 and P1 pedals have demonstrated acceptable test-retest reliability during sub-maximal cycling. Previous studies have suggested that the P1 pedals are reliable between 150–500 W, with a coefficient of variation (CV) of 2.3%<sup>10</sup>, and between ~100-400 W, with a CV of ≤2%.<sup>11</sup> Similarly, the V2 pedals have been reported as reliable between 100–300 W when compared to the SRM Powermeter (CV = ~3.0%).<sup>8</sup> Garmin has recently released the third version of the Vector power pedals (V3), but to date, it has not been established if these are reliable or accurate.

Therefore, the aim of this study was to 1) investigate the test-retest reliability of the V3 pedals, and

2) compare power output and cadence between the V3 pedals and the Lode Excalibur Sport ergometer.

## **Methods**

### ***Participants***

Seven male cyclists (mean  $\pm$  SD: age  $21 \pm 1$  years,  $181.6 \pm 8.0$  cm, body mass  $75.3 \pm 9.9$  kg,  $\dot{V}O_{2max}$   $58.3 \pm 7.0$  ml·kg<sup>-1</sup>·min<sup>-1</sup>) were recruited to take part in this study, with all providing written informed consent. The study was approved by the host university's ethics committee.

### ***Procedures***

Testing was completed using an electronically-braked cycle ergometer (Excalibur Sport, Lode, The Netherlands),<sup>12</sup> with the power pedals (V3, Garmin, USA) installed and zeroed following the manufacturer's guidelines. For each testing session, the participants wore their own cycling shoes, fitted with Vector cleats (Arc 2, Garmin, USA). Following a 10-min warm-up, participants cycled at a self-selected cadence at 350 W, 300 W, 250 W, 200 W, 150 W and 100 W for 2 min, each separated by a 4-min rest period. Once these tests were completed, the participants were allowed a 10 min rest period, followed by 2 x 10-s maximal sprints from a rolling start (90 rev·min<sup>-1</sup>) whilst in a seated position. A 2-min rest was allowed in between maximal sprint tests. This testing procedure was completed on two occasions, separated by 48 hours.

### ***Data Analysis***

Power output and cadence for the V3 pedals were recorded using a bike computer (Edge 820, Garmin, USA) and downloaded for analysis. The sampling frequencies of the V3 pedals and the Lode Excalibur Sport were 1 Hz and 4 Hz, respectively. A Mann-Whitney U test and limits of agreement (LoA) were used to make comparisons between the V3 pedals and the Lode Excalibur Sport, with CV

and absolute technical error of measurement (TEM) used to determine the test-retest reliability of the V3 pedals. TEM was calculated using Eq. 1 (1):

$$\text{TEM} = \sqrt{\frac{\sum D^2}{2n}} \quad (1)$$

, where  $\sum D^2$  represents the sum of deviations raised to the 2<sup>nd</sup> power.<sup>13</sup> All data are reported as mean  $\pm$  SD with statistical significance set to  $P < 0.05$ .

## Results

A Mann-Whitney U test identified significant differences between the Lode Excalibur Sport and the V3 pedals for power output at 150 W ( $P < 0.001$ ), 200 W ( $P = 0.001$ ), 250 W ( $P < 0.001$ ), 300 W ( $P < 0.001$ ), 350 W ( $P < 0.001$ ) and during all-out sprinting ( $P = 0.001$ ). There were no significant differences between the Lode Excalibur Sport and the V3 pedals at 100 W ( $P = 0.210$ ). Additionally, a Mann-Whitney U test identified no significant differences for cadence at 100 W ( $P = 0.946$ ), 150 W ( $P < 0.982$ ), 200 W ( $P = 0.982$ ), 250 W ( $P < 0.946$ ), 300 W ( $P < 0.982$ ), 350 W ( $P < 0.910$ ) and during all-out sprinting ( $P = 0.635$ ). The mean difference between the Lode Excalibur Sport and V3 pedals was 1.8% for power output during sub-maximal cycling; however, this increased to 21% during all-out sprinting (Figs. 1 and 2). The mean difference for cadence was 0.2% for all tested power outputs (Table 1).

During sub-maximal cycling, the V3 pedals had a mean CV of 1.4% and a TEM of 3.0 W for power output. For cadence, the mean CV was 2.4% and the mean TEM was 3.6 rev·min<sup>-1</sup>. During all-out sprinting, the CV and TEM for both power output and cadence were higher than sub-maximal cycling (CV = 5.1% and 3.9%, respectively; TEM = 74.8 W and 8.0 rev·min<sup>-1</sup>, respectively) (Table 2).

\*\*\*Insert Figures 1 and 2 near here\*\*\*

1 **Table 1.** Comparisons in power output and cadence between the Lode Excalibur Sport and the Garmin Vector 3 pedals.

Power Output				Cadence				2
Lode Excalibur Sport (W)	Garmin Vector 3 (W)	Absolute Difference (W)	Relative Difference (%)	Lode Excalibur Sport (rev·min <sup>-1</sup> )	Garmin Vector 3 (rev·min <sup>-1</sup> )	Absolute Difference (rev·min <sup>-1</sup> )	Relative Difference (%)	3
100 ± 0	100 ± 3	0 ± 3	0.0	89 ± 15	89 ± 15	0 ± 0	0.0	4
150 ± 0	153 ± 3	3 ± 3	1.9	90 ± 15	90 ± 15	0 ± 0	0.0	5
200 ± 0	205 ± 4	5 ± 4	2.5	90 ± 15	90 ± 15	0 ± 0	0.0	6
250 ± 0	256 ± 4	6 ± 4	2.4	89 ± 15	89 ± 15	0 ± 0	0.0	7
300 ± 0	305 ± 5	5 ± 5	1.7	90 ± 16	90 ± 16	0 ± 0	0.0	8
350 ± 0	357 ± 4	7 ± 4	2.0	92 ± 16	93 ± 16	1 ± 0	1.1	9
900 ± 128	1111 ± 152	211 ± 24	21.0	165 ± 10	166 ± 11	1 ± 1	0.6	10

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23 **Table 2.** Coefficient of Variation (CV) and Absolute Technical Error of Measurement (TEM) between Testing Sessions 1 and 2 for power output and cadence (including 95%  
 24 Confidence Intervals).

Power Output	Power Output		Cadence	
	CV (%)	TEM (W)	CV (%)	TEM (rev·min <sup>-1</sup> )
100 W	2.5 (1.4–3.7)	2.9 (1.8–4.0)	2.7 (-0.9–6.3)	4.4 (1.4–7.4)
150 W	1.4 (0.9–1.9)	2.4 (1.6–3.2)	1.7 (-1.1–4.5)	3.3 (0.9–5.6)
200 W	1.2 (0.6–1.8)	2.9 (1.6–4.2)	1.5 (-0.1–3.1)	2.0 (0.7–3.3)
250 W	0.9 (0.2–1.6)	3.3 (1.4–5.2)	2.2 (-0.6–5.0)	3.3 (1.1–5.5)
300 W	1.4 (0.6–2.2)	5.3 (2.9–7.7)	3.1 (-0.6–6.8)	4.5 (1.6–7.4)
350 W	0.7 (0.3–1.1)	3.0 (1.7–4.4)	3.1 (0.6–5.5)	4.1 (1.7–6.5)
Peak Power	5.1 (0.9–9.2)	74.8 (33.3–116.3)	3.9 (1.6–6.1)	8.0 (4.2–11.9)
Mean (100–350 W)	1.4 (0.7–2.1)	3.3 (1.8–4.8)	2.4 (-0.45–5.2)	3.6 (1.2–6.0)



## 26 Discussion

27 The findings of this study suggest that the V3 pedals provide a reliable and accurate measure of  
28 power output and cadence during sub-maximal cycling between 100 and 350 W. The  
29 heteroscedastic nature of power output can be observed from Figs. 1 and 2 with an increased error  
30 and mean bias during higher powers. The mean relative difference between the Lode Excalibur Sport  
31 and the V3 pedals was 1.8% for power output, and 0.2% for cadence during sub-maximal cycling. The  
32 results suggest that the V3 pedals are reliable for power output and cadence, with a CV of <5.1% and  
33 <3.9, respectively, observed at all tested power outputs. Additionally, the TEM for power output was  
34 2.4–5.3 W when tested between 100–350 W, with a TEM for cadence of <8.0 rev·min<sup>-1</sup> observed  
35 during all power outputs.

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37 The results of this study are comparable to studies published using earlier versions of the Garmin  
38 Vector pedals with a CV of 2.0% for the V1 pedals reported between 150 and 350 W.<sup>7</sup> Additionally,  
39 these results are similar to the reported CV of ~3.0% of the V2 pedals when tested between 100–300  
40 W.<sup>8</sup> The results of the present study are also comparable to other pedal-based systems with a CV of  
41 <6.3% observed for the PowerTap P1 pedals when tested at sub-maximal power outputs and during  
42 all-out sprinting.<sup>11</sup> Additionally, the TEM of 75.8 W observed during all-out sprinting is similar to the  
43 PowerTap P1 pedals (75.1 W)<sup>11</sup>. It is noted, however, that the CV observed during sub-maximal  
44 cycling (100–350 W) in the present study is slightly higher than those reported by Czajkowski et al.<sup>14</sup>,  
45 who reported a CV of 0.7% for power output between 150 and 350 W.

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47 A significant difference in power output was observed between the V3 pedals and the Lode Excalibur  
48 Sport at all power outputs measured above 100 W. Similar conclusions have also been made for the  
49 V1 pedals by Novak and Dascome<sup>6</sup> and Bouillod et al.<sup>7</sup>, both suggesting that the V1 pedals over-

50 estimate power output during sub-maximal cycling. The results of the present study also supports  
51 previous literature that suggests that the greatest error in measurement occurs at higher power  
52 outputs (e.g. sprinting). These results could be explained by the different sampling frequencies of  
53 the Lode Excalibur Sport (4 Hz) and V1 pedals (1 Hz), and it has been suggested that power output  
54 should be sampled at a minimum of 5 Hz when testing peak power output.<sup>15</sup> Therefore, it may be  
55 expected that the V3 pedals would measure differently to the Lode Excalibur Sport during all-out  
56 sprinting.

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58 This study provides valuable information to cyclists, coaches or researchers who plan to use the V3  
59 pedals for training or research. It is suggested that additional research is carried out on pedal-based  
60 power meters across a full range of the power curve; however, it is acknowledged that this is  
61 difficult without the use of a calibration rig.

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### 63 **Conclusion**

64 The results of this study suggest that the V3 pedals provide reliable and accurate data between 100  
65 and 350 W when compared to a Lode Excalibur Sport ergometer. It is suggested that these pedals  
66 can be used by cyclists at power outputs <350 W with confidence. Due to the increased CV and TEM  
67 at higher power outputs, some care should be exercised if using these pedals to monitor sprint  
68 performance.

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75 **Declaration of conflicting interests**

76 The author(s) declared no potential conflicts of interest with respect to the research, authorship,  
77 and/or publication of this article.

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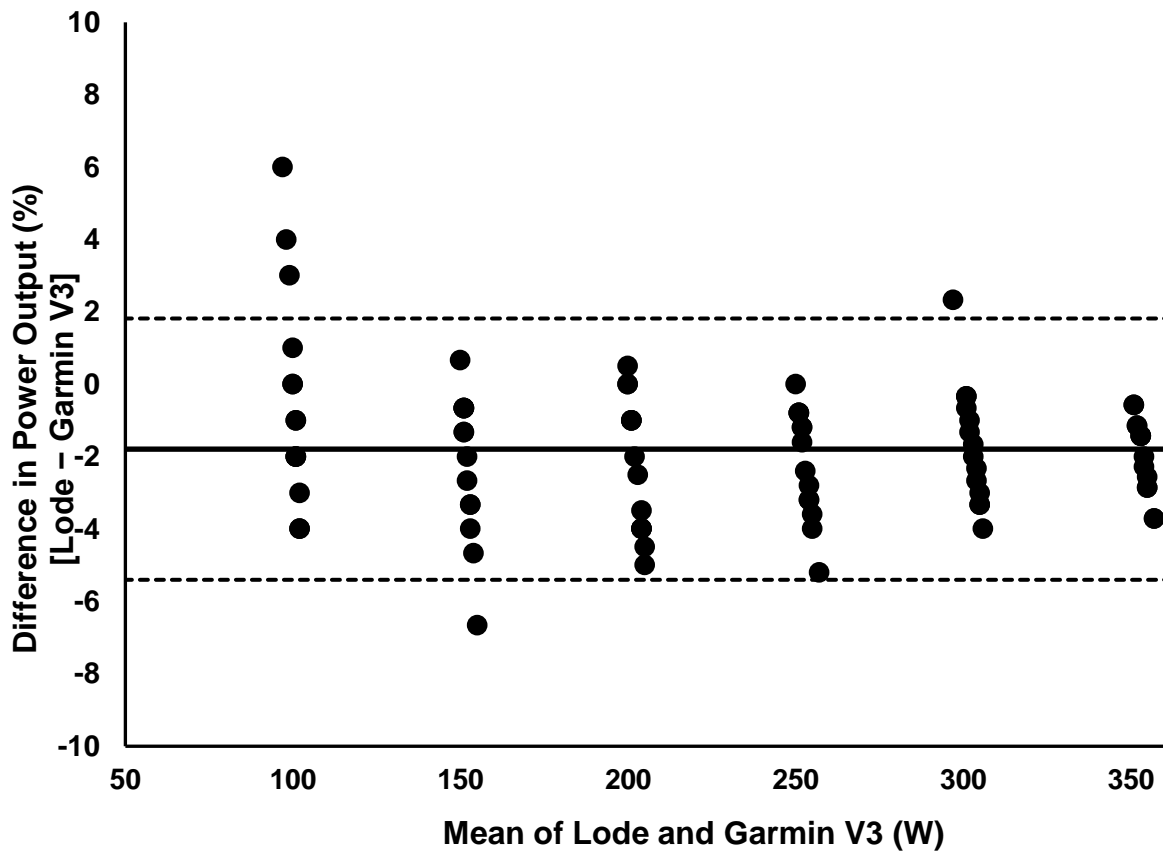
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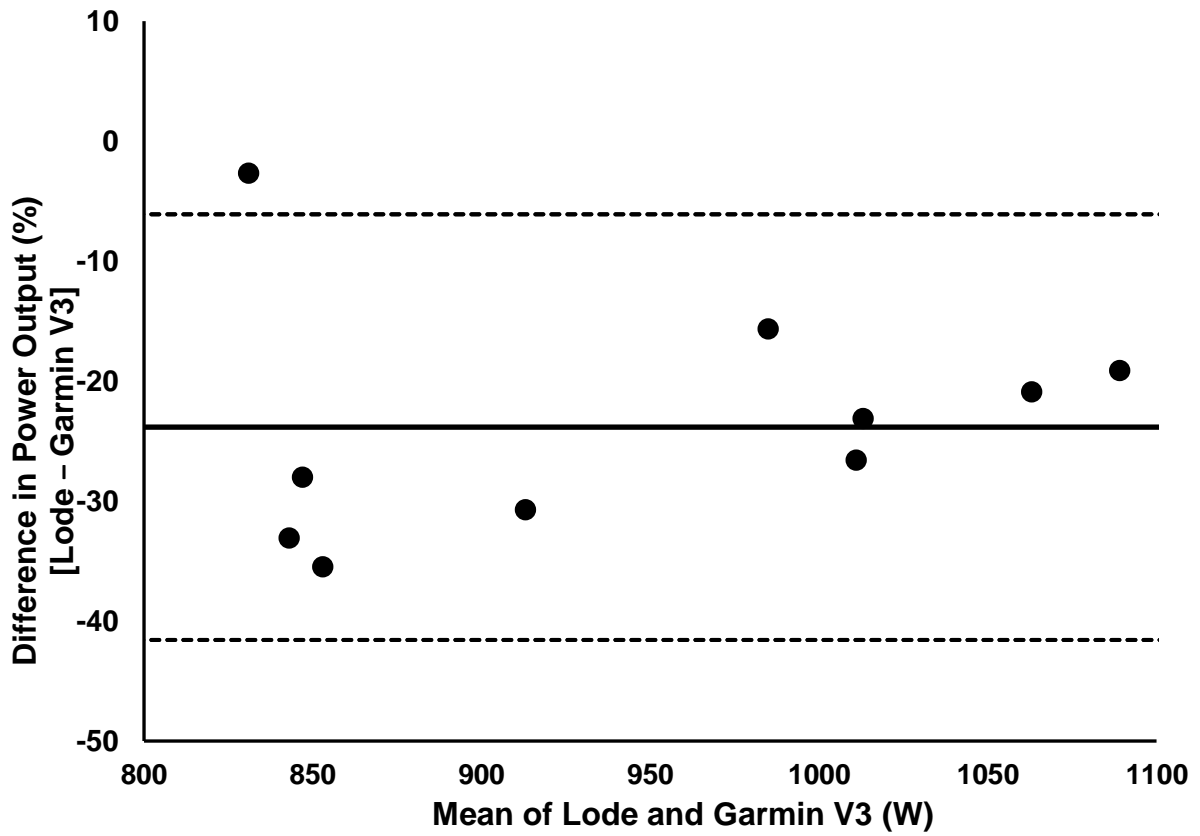


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126 **Figure 1.** Bland-Altman Plot showing the limits of agreement between Lode Excalibur Sport and  
 127 Garmin V3 power pedals at 100 W, 150 W, 200 W, 250 W, 300 W and 350 W. The solid line  
 128 represents the mean difference in power output, with the dashed lines representing the 95% limits  
 129 of agreement.

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133 **Figure 2.** Bland-Altman Plot of the differences between the Lode Excalibur Sport and Garmin V3  
 134 power pedals during all-out sprinting. The solid horizontal line represents the mean bias, with the  
 135 dashed lines represented 95% confidence intervals.

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