

The impact of carbon insoles in cycling on performance in the Wingate Anaerobic Test

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Abstract

The usage of innovative technologies in high performance cycling is essential. Special insole devices made of carbon are expected to have an impact on the anatomical and biomechanical structures of the foot. They aim to prevent cycling-specific overuse injuries, as well to increase output power. Therefore, the effects of a cycling-specific carbon insole were evaluated with respect to its impact on the output power in a Wingate Test (WAnT). 18 male cyclists and triathletes (age: 26.3 ± 5.6 years, height: 181.9 ± 4.7 cm, mass: 76.7 ± 4.4 kg, foot length 28.2 ± 0.8 cm) on at least a national level were tested for peak and mean power during three WAnT with randomized and blind application of a standard insole or the cycling-specific carbon insole. The mean power of the standard insole (790.6 ± 50.3 W) was in overall trials 0.6 % higher than with the carbon insole (786.0 ± 45.0 W). The peak power with the standard insole (891.7 ± 74.6 W) was 1.5 % higher than with the carbon insole (878.4 ± 64.9 W). Neither for mean power ($P = 0.76$) nor for peak power ($P = 0.53$) the difference was significant. The usage of the cycling-specific carbon insole thus shows similar output power values as standard devices.

Keywords: cycling, foot orthoses, insole, wingate test, performance

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Introduction

Aspects which are considered to increase the performance in top level cycling include targeted training, talent, nutrition, the optimal position on the bike, as well as innovations concerning the bike frame, wheel sets, handlebars, and clipless pedals. Lately, individual bike fittings and cycling specific insoles have been used for better performance and at the same time for the prevention of overuse injuries (Burke 2003; Dettori and Norvell 2006; Jeukendrup and Martin 2001; Schmidt et al. 2011; Wanich et al. 2007). The biomechanical, anthropometric optimal position of the athlete on the bike is a key factor for the power output (Bini et al. 2011; Bini et al. 2013; Burke and Pruitt 2003; Silberman et al. 2005) and is set with the three contact points handlebar, saddle and pedals. The position of each of them and the relation to the other two lead to the optimal position regarding comfort, power distribution, and aerodynamics of the athlete-bike system (Burke and Pruitt 2003; Salai et al. 1999; Silberman et al. 2005). Besides for the importance of good performance, the proper position is also a necessary aspect for the long-term prevention of overuse injuries (Bini et

al. 2011; Dettori and Norvell 2006). In addition to the influence on the postural stability of the athlete-bike system and the increased power output, a preventive effect of customized insoles is anticipated regarding overuse injuries for people with predispositions, such as leg length differences and/or strong valgus or varus foot position (O'Neill et al. 2011; Sanner and O'Halloran 2000). A main point considering the improvement of postural stability is in particular the improvement of the left-right balance of the power output (Dinsdale and Williams 2010; Sanderson 1990; Sinclair et al. 2013). Currently, a great amount of cycling-specific insoles are available in bike shops, which are built for the usage in the tight and narrow cycling shoe. Some of them are manufactured from carbon and are more or less customized (Bauer et al. 2012; Schmidt et al. 2011). Due to the characteristics of the material the manufactures are able to build a thin and lightweight carbon device, which is also stiff and inherently stable and therefore ideal for the link of pedal, cycling shoe, and foot. A rigid and medially placed support with the highest point under-neath the talonavicular joint prevents the longitudinal arch from pronating and keeps the ankle joint in a neutral position during the whole pedal stroke (O'Neill et al. 2011). The lateral raise supports the metatarsal heads III-V and serves as a counter support for the medial support to stabilize the foot in a torsion-free position, even under stress (O'Neill et al. 2011; Solestar 2013). It is anticipated that the innovative form of the cycling-specific carbon insole reduce the shear forces during the pedal stroke and lead thereby to an increased power output and a reduction of cycling-specific overuse injuries (Bauer et al. 2012; Jarboe and Quesada 2003). Schmidt et al. (2011) showed that the customized carbon insole re-



sults in a 6.9 % higher performance in 8-second isokinetic sprint tests. However this study didn't use a control group or any randomization technic. Since the current state of research does not show empirical evidence regarding carbon insole devices in cycling, it is the aim of this study to examine expected effects of carbon insoles on maximal power parameters in a Wingate Anaerobic Test.

Materials and methods

Participants

18 male and licensed cyclist resp. triathletes (mean \pm SD: age: 26.3 ± 5.6 years, range 20-42 years, height: 181.9 ± 4.7 cm, mass: 76.7 ± 4.4 kg, foot length 28.2 ± 0.8 cm) on at least a national athletic level (Cyclist: 1 CT-professional, 2 A-grade, 6 B-grade, 5 C-grade, Triathletes: German League participants) took part in this study. Five of them were already familiar with the carbon made cycling insoles, whereas the other 13 participants had no experiences with them. The participants were reminded to maintain their usual nutritional and lifestyle habits, including manual work and sport specific activities throughout the study period. All participants were thoroughly informed about the study design, risks and possible benefits associated with the present study and provided written informed consent prior to participation. The study complied with ethical guidelines as outlined in the Declaration of Helsinki as well as with the ethical standards of *Journal of Science and Cycling* (Harriss and Atkinson 2011).

Study design and procedure

In the study, a Cyclus 2 Ergometer (RBM elektronik-automation Leipzig) with the athlete's own bike frame and therefore individual seat position was used. According to the manufacturer, the maximal resistance is 3000 Watt with a machine-inherent measurement tolerance of maximal 2 %. To examine the short-run maximal anaerobic capacity the Wingate Anaerobic Test (WAnT) was used (Bar-Or 1987). The standardized warm-up took 15 minutes. The WAnT started as soon as

the participant exceeded a cadence of 90 rpm and lasted 20 seconds. In contrast to a regular WAnT (30 sec all-out effort) the WAnT in this test had a duration of only 20 seconds due to the study design (Laurent et al. 2007). The resistance was calculated with body weight \times 0.75 / crank arm length in meters (Laurent et al. 2007; Ledford and Branch 1999). In total, 3 consecutive WAnTs were performed with a standard foam rubber insole or the cycling-specific carbon insole, respectively. Either the carbon-made cycling insole or the standard insole were selected and placed into the athletes cycling shoe in randomized order (Figure 1). The standard insole was covered with the same material as the carbon insole to ensure that there was no noticeable optical difference between both insoles. The participants only knew that different insoles are tested regarding the effect in the WAnT. Three WAnTs were performed to eliminate potential sequential or short-term habituation effects.

Between the various WAnTs, the athlete paused 10 minutes (active rest) plus 2 minutes for adaptation after the insole switch, which took 2 minutes as well. The resistance during the adaptation phase was 100 W. The relevant parameter was mean power and peak power during the WAnT. The test design is shown in Figure 2.



Figure 1. Placebo and cycling shoe insoles, back and front (left: placebo insole, right: carbon insole).

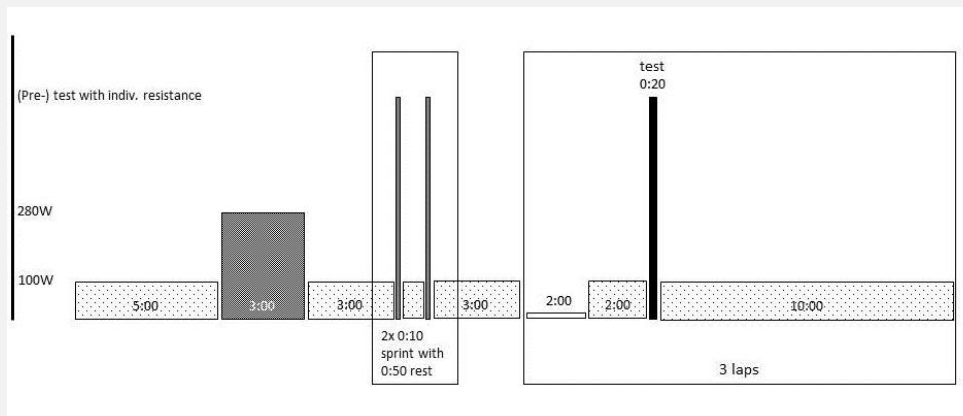


Figure 2. Test design of the study.

Statistical analysis

All data were tested for Gaussian distribution and homoscedasticity normality prior to conducting statistical analysis. A two-way analysis of variance (ANOVA) (trial x treatment) was calculated. When a significant main effect was obtained, a Scheffé test was applied. In addition, the percentage changes were described. The significance level was set at $P < 0.05$, and the data are presented as mean values \pm standard deviations. IBM SPSS version 19 was used for statistical analysis.

Results

The maximal power (peak power) over all tests is 884.2 ± 68.9 W and was reached after 5.6 ± 1.4 s (peak time). The average power within the WAnT was 788.0 ± 46.9 W (mean power). Table 1 shows mean power, peak power, peak time, mean cadence, and peak cadence decrease between the three trials.

In addition, no significant difference was found for mean power between the trials ($P = 0.68$), and between the standard insole and the carbon insole ($P = 0.76$). The interaction of trial and insole was also not significant ($P = 0.38$).

Furthermore, there was no significant difference in peak power between the trials ($P = 0.75$), the insole application ($P = 0.53$), and the interaction of trial and insole ($P = 0.35$).

The mean power of the standard insole (790.6 ± 50.3 W) was 0.6 % higher in comparison with the carbon insole (786.0 ± 45.0 W) during the three trials (Table 2). In terms of peak power, the standard insole (891.7 ± 74.6 W) performance was 1.5 % higher than that of the carbon device (878.4 ± 64.9 W).

Discussion

In contrast to the research of Schmidt et al. (2011), which however had some methodological problems in the study design, the present study cannot show a significant effect of the cycling-specific carbon insole in comparison with the standard insole in respect to mean power and peak power measured in the WAnT. The mean power

and peak power with 0.6 % and 1.5 %, respectively were even higher with the standard insole. Over the consecutive trials, mean power, peak power, peak time, mean cadence and peak cadence decreased due to fatigue. Furthermore, no systematic effect regarding mean power, peak power, peak time, mean cadence and peak cadence occurred under the test conditions for either standard insole or carbon insole.

Dinsdale and Williams (2010) examined the influence of forefoot varus wedges (foot orthotics) on the power output during a 30 s Wingate Anaerobic Test. They did not find any significant effect on mean power, peak power and anaerobic fatigue, either but concluded that correcting forefoot varus using wedges can improve short-term power output during cycling for individuals possessing high levels of forefoot varus. Nevertheless, Schmidt et al. (2011) described an average increase of 6.9 % for the power output while using the carbon insole. They explained the improvement by the optimization of the foot position in the cycling shoe. However, the present study using a randomized and placebo-controlled blinded design does not show any improvements of power using the carbon insole instead of a standard insole. Among other aspects, this can be explained by the differences in test protocol, the utilized study design and the performance level of the participants. Whether the usage of a special carbon insole reduces cycling-specific overuse injuries or can prevent such could not be concluded by the present study. In total, the state of research is limited and inconclusive. Therefore, no direct and explicit relations can be pointed out (Dettori and Norvell 2006; O'Neill et al. 2011).

Limitations

The calculated resistance during the WAnT (Laurent et al. 2007) led to cadences of 146-149 rpm in average. Such high cadences are not usual in road cycling and may have influenced the power output due to coordinative limitations (Marsh and Martin 1997). Higher resistances could reduce the coordinative aspects and increase the forces, as well as the pressures on the insole devices (Bauer et al. 2012; Sanderson et al. 2000). Therefore, the potential effects of the special carbon insole may have been more obvious. Neither physiological parameters, such

Table 1. Performance parameters between the trials (mean \pm SD).

	Trial 1 (n=18)	Trial 2 (n=18)	Trial 3 (n=17)
Mean Power (W)	794.2 \pm 45.5	788.9 \pm 48.4	780.5 \pm 48.7
Peak Power (W)	893.4 \pm 63.2	882.3 \pm 71.9	876.3 \pm 74.3
Time to Peak Power (s)	5.7 \pm 1.3	5.6 \pm 1.6	5.4 \pm 1.2
Mean cadence (rpm)	134.7 \pm 10.1	133.7 \pm 9.0	132.2 \pm 9.3
Peak cadence (rpm)	149.7 \pm 12.9	147.5 \pm 10.9	146.2 \pm 10.8
Ratio carbon/standard insole	10/8	10/8	10/7

W = Watt, s = seconds, rpm = round per minutes

Table 2. Mean power, and peak power between the trials as well as between the insole applications (mean \pm SD).

	Trial 1 (n=18)		Trial 2 (n=18)		Trial 3 (n=17)	
	standard insole	carbon insole	standard insole	carbon insole	standard insole	carbon insole
Mean power(W)	788.9 \pm 54.4	798.4 \pm 39.5	805.7 \pm 55.0	775.5 \pm 40.1	775.4 \pm 41.2	784.0 \pm 55.2
Peak power (W)	892.3 \pm 75.1	894.4 \pm 56.1	911.4 \pm 88.1	859.1 \pm 48.7	868.6 \pm 59.9	881.7 \pm 85.6

as heart rate, lactate, and VO_{2max} , nor subjective criteria (BORG-scale) were measured to quantify the de facto exhaustion. In addition, there was no phase for familiarization. In laboratory settings a familiarization phase is needed. In our study we disclaim about a familiarization phase because we will give a more sport specific setting, and will transfer the results into life praxis. Therefore, medium and long-term adaptation, which might have occurred with prolonged usage, is not considered in this study. Even though the insole devices looked the same, different proprioceptive feedback because of their shape cannot be precluded.

Conclusions

On the basis of the present study no statistically relevant effect can be shown for the usage of the cycling-specific carbon insole. Nevertheless, on an individual basis, effects occurred, which could be relevant in high-performance sports, e.g. during repetitive sprint efforts. If the customized insoles influence the performance in a longer aerobic test needs to be shown in further studies.

Practical applications

Because individual performance is crucial in performance-oriented cycling, each athlete has to decide if the cycling-specific carbon insole helps to improve their performance. Whether the carbon insoles have preventive effects regarding overuse injuries (Bauer et al. 2012) or other cycling-specific issues could not be estimated at this time.

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