ARTICLE IN PRESS

Journal of Biomechanics xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Influence of standing position on mechanical and energy costs in uphill cycling

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ARTICLE INFO

Article history:
Accepted 25 February 2018
Available online xxxx

Keywords:
Power output
Gas exchanges
Elite cyclists
Biomechanics
Uphill performance

ABSTRACT

This study was designed to examine the influence of standing position (vs. seated) during uphill cycling on both mechanical cost (MC) and energy cost (EC) in elite cyclists. For the study, thirteen elite cyclists (VO_{2max}: 71.4 ± 8.0 $ml \cdot min^{-1} \cdot kg^{-1}$) performed, in a randomised order, three sets of exercises. Each set comprised 2 min of exercise, alternating every 30 s between seated and standing postures, using different slopes and intensity levels on a motorised treadmill. MC was calculated from the measurement of power output and speed, whereas EC was calculated from the measurement of oxygen consumption and speed. MC was significantly higher (+4.3%, $p < 0.001$) in standing position compared to seated position when all slopes and intensities were considered. However, EC was not significantly affected by the change in position. The standing position also induced a significant increase in rolling resistance power ($p < 0.001$), rolling resistance coefficient ($p < 0.001$) and lateral sways ($p < 0.001$). The significant increase in MC observed in standing position was due to a higher rolling resistance induced by bicycle sways and a shift forward of the centre of mass compared to seated position. This result should lead bicycle tire manufacturers to reduce the increase in rolling resistance between the two positions. Considering the relationship observed between the MC and bicycle sways, cyclists would be well advised to decrease the bicycle sways in order to reduce the MC of locomotion.

1. Introduction

The cycling position has been the subject of many studies in the optimisation approach to cycling performance. Nevertheless, the literature about standing position in uphill cycling remains insufficient. It has been well-established that the standing position elicits higher power output (PO) in maximal 30-s sprints in uphill cycling in the field (Millet et al., 2002). However, the results regarding the effects of change in body position (seated vs. standing) in moderate steady-state uphill cycling are contradictory. Some studies (Arkesteijn et al., 2016; Miller et al., 1988; Ryschon and Stray-Gundersen, 1991; Swain and Wilcox, 1992; Tanaka et al., 1996) have experimented on the physiological differences between seated and standing cycling positions. An increase in oxygen consumption (VO_2), heart rate (HR) and pulmonary ventilation (VE) has been reported at low intensities (between 50% and 60% of VO_{2max}) in standing position (Arkesteijn et al., 2016; Ryschon and Stray-Gundersen, 1991; Tanaka et al., 1996) on treadmills. Conversely, Miller et al. (1988) and Swain and Wilcox (1992) reported no change in VO_2 between seated and standing positions at moderate intensities ($\sim$75% of VO_{2max}) with experienced cyclists on treadmills. Additionally, Tanaka et al. (1996) showed the same VO_2 response between these two positions at a higher intensity ($\sim$83% of VO_{2max}).

These conflicting results did not consider the differences among individuals attributable to cyclists' levels of practice, skills or race performance profiles (sprinters, climbers and flat specialists). More recently, Millet et al. (2002) showed that, when climbing in the field, economy and gross efficiency in standing position are not different from those in seated position. Finally, Duc et al. (2008) demonstrated that, when cycling on a treadmill, the upper body and trunk muscles are more activated during standing pedalling, notably to support the additional weight due to the loss of the saddle support, to stabilise both the pelvis and the trunk, to control

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https://doi.org/10.1016/j.jbiomech.2018.02.034
0021-9290/

Please cite this article in press as: Bouillod, A., et al. Influence of standing position on mechanical and energy costs in uphill cycling. J. Biomech. (2018), https://doi.org/10.1016/j.jbiomech.2018.02.034

body balance and to swing the body and the bicycle side to side. Furthermore, the contradictory and insufficient results in the literature concerning the biomechanical and physiological responses between the seated and standing positions report that there is no common rule to determine the most efficient position during exercise at moderate intensity in uphill conditions. The cyclist may choose to stand or remain seated according to many factors, including the aerodynamic resistance, gradient and length of the hill, intensity, available gearing, situation (training vs. competition), individual experience, body morphology, preference (Harnish et al., 2007) and pacing strategy.

The transition from the seated to standing position allows cyclists to shift their centre of mass forward (Caldwell et al., 1998) and increase both the tangential force applied on the pedals and the mechanical cost (MC) of locomotion (Bouillod and Grappe, 2017). This increase in MC in the standing position was due to several factors such as rolling resistance considering that the standing posture could involve a rise in deformation of certain mechanical parts of the bicycle, especially at the tire level (Bouillod and Grappe, 2017). No study has focused on this topic; the literature has investigated only the physiological response of the cyclist for a given speed/power and never the MC of locomotion during uphill cycling.

To the best of our knowledge, the influence of standing position on MC and energy cost (EC) during cycling locomotion has not been investigated. The purpose of the present study was to identify the effects of a change in body position (standing vs. seated) on MC and EC in elite cyclists, according to different slopes (5, 7.5 and 10%) and exercise intensities (3.8, 4.2 and 4.6 $W{\cdot}kg^{-1}$). It was hypothesised that both the MC and the EC would be higher in standing position compared to seated position.

2. Methods

2.1. Participants

Thirteen elite cyclists participated after being informed of the aims and procedures of the study. Their mean ± standard deviation age, height, body mass and VO_{2max} were 22.7 ± 4.2 years, 179.5 ± 4.5 cm, 68.9 ± 6.4 kg and 71.4 ± 8.0 $ml{\cdot}min^{-1}{\cdot}kg^{-1}$, respectively. VO_{2max} was assessed during the precompetitive period as part of the medical supervision of high-level cyclists licensed to the French Cycling Federation. The riders followed a regular training regimen and participated in races throughout the season. The participants provided written informed consent to participate in this study, which was approved by a local ethics committee that complies with the international ethical standards described by the Declaration of Helsinki.

2.2. Experimental design

The study comprised one testing session in which participants cycled with their own racing bicycle (mean weight of 7.2 ± 0.2 kg) on a large motorised treadmill (S 1930, HEF Techmachine, Andrezieux-Boutheon, France) of 3.8 m length and 1.8 m width in different positions (seated and standing), slopes (5, 7.5 and 10%) and intensities (3.8, 4.2 and 4.6 $W{\cdot}kg^{-1}$). The different intensities corresponded to the zone of moderate exercise intensity (Zone 1) determined from the record power profile (Pinot and Grappe, 2011). An overview of the experimental protocol is provided in the Fig. 1. The participants performed in a randomised order three sets of exercises alternating 2 × (30 s seated/30 s standing), according to the different slopes and intensities. These exercise durations were determined after field observations since previous studies used durations that did not agree with field requirements.

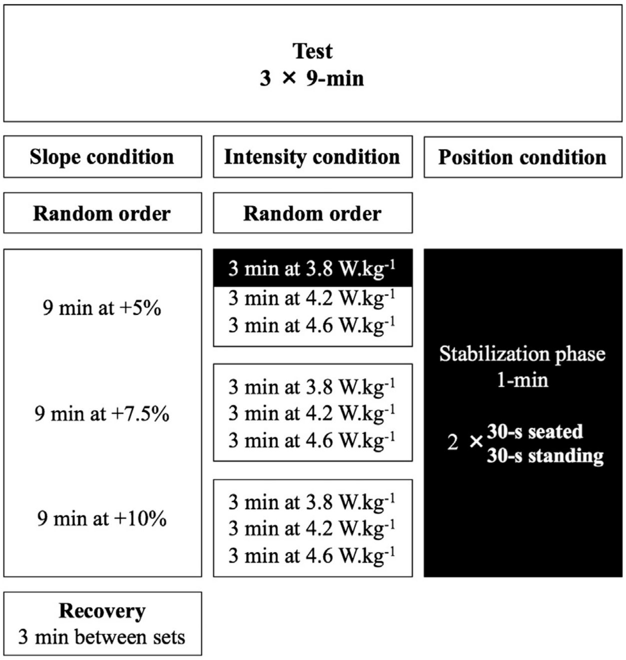

Fig. 1. Schematic representation of the experimental design.

Each intensity trial of 3-min duration was started by a stabilization phase of 1 min. An active recovery period of 3-min duration was respected between each set (2 $W{\cdot}kg^{-1}$). A total of 9 sets of 2 × (30 s seated/30 s standing) were performed by each cyclist during the session. Cyclists were free to change the pedalling cadence between but not within the sets. Therefore, the pedalling cadence was similar between the two positions.

The bicycles were clean and well-lubricated, as recommended by the manufacturers. The same pair of wheels was used for all subjects. Additionally, the tire pressure was set at 700 kPa. During each set, the cyclists gripped the handlebar on the brake levers to standardise the position of the hands as employed during climbing. Indeed, pedalling biomechanics may be affected by a change of hand grip, as the trunk is more flexed in a bottom-hand position on the drops of the handlebar (Savelberg et al., 2003). Before testing, each participant performed several familiarisation trials on the motorised treadmill to get used to the equipment. The protocol started when the participants felt as comfortable in both positions as in real cycling locomotion. We verified this point by assessing the comfort with a visual analogue scale from 0 (very uncomfortable) to 10 (very comfortable), and started when the cyclist gave a rating of at least 8.

2.3. Biomechanical measurement

All the bicycles were fitted with the same rear wheel composed of a PowerTap G3 hub (Powertap, Madison, USA). Then, the PowerTap power meter was paired with a Garmin power control (Garmin 810, Olathe, USA) to record the PO. The PowerTap system determines accuracy between 1% and 2% in standing position when compared with the SRM reference system (Bertucci et al., 2005; Bouillod et al., 2016; Gardner et al., 2004). A specific cassette was used (12 × 28) to optimise the pedalling cadence on steeper slopes (Kohler and Boutellier, 2005).

The MC ($J{\cdot}kg^{-1}{\cdot}m^{-1}$) was calculated from the measurement of PO ($J{\cdot}s^{-1}$), body mass (kg) and speed (V_d, $m{\cdot}s^{-1}$) according to Bouillod and Grappe (2017):

$$MC = (PO/\text{body mass})/V_d$$

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