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Astract

Influence of non-circular chainrings on kinematics during stationary and outdoor cycling

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1. Abstract

The present research deals with two main topics. Firstly, the influence of non-circular chainrings (NCC) on the kinematics of the lower limbs. NCC are designed to extend the pushing phase and reduce the time spent at the dead spots during each crank revolution (Bini & Dagnese, 2012), which should lead to a better usage of time pedal forces are applied perpendicular to the crank (Fonda & Sarabon, 2010). A second purpose is to investigate differences in kinematics between riding on a stationary trainer versus riding outdoors. Therefore, an alternative to the common way of tracking the motion of the legs by a video analysis had to be found. Inertial measurement units (IMUs) are used to solve this problem.

Five experienced male cyclists cycled in four test conditions (2 W/kg and 4.5 W/kg, indoor and outdoor, each at a self-selected cadence) with a Rotor Q-Ring (Madrid, ESP; ovality = 12.5%) in three chainring positions and a circular chainring. All measurements were done on a cyclocross bike, which was mounted on a stationary trainer for the laboratory measurements. The outdoor measurements were executed on a straight and flat tarmac section. Kinematics of the right leg were measured with six IMUs of the MTw system (Xsens MTw Awinda, XsensTechnologies, Enschede, NED) at a sampling rate of 100 Hz. Considered were the rotations of the IMUs around the z-axis, which represent the movements of the lower limbs in the sagittal plane (Figure 1 a). A comparison of this method with 3D-video analysis (ViconMotion System Ltd., Oxford, UK) was done beforehand with one subject (Figure 1 b). The results of the kinematic analysis include the mean joint angle courses of hip-, knee- and ankle joint and sacrum to the horizontal, as well as their joint angular acceleration.

For the comparison of NCC versus CC, the results showed no significant differences in joint angles and joint angular accelerations at the hip, knee, and sacrum in terms of mean progression, maximum and minimum values as well as range of motion. Joint angular acceleration showed differences when using an NCC, but only at the ankle in one test condition, when cycling indoors at low intensity. No differences were found in hip-, knee and sacrum angular acceleration between NCC and CC.

Indoor versus outdoor results showed no significant differences between the indoor and outdoor in terms of the joint angles and angular accelerations at the hip and the sacrum. Knee joint angles also showed no differences, whereas knee joint angular acceleration showed a significant difference at the maximum acceleration during cycling at high intensity (4.5 W/Kg), but only between the indoor and outdoor results of one NCC test condition. Ankle angular acceleration showed no significant

differences between indoor and outdoor data, but a significant difference between indoor and outdoor was found at the minimum ankle angle for one of the NCC test conditions, where a larger minimum angle was observed during the indoor condition However, the two significant differences can be traced back to two individual outliers, which led to a significant difference in the mean values, due to the small number of subjects.

Similar to previous studies changes in crank angular velocity during the downward phase of the crank cycle were found using a NCC, it was expected that this effects the kinematics of the lower limb as well. However, no significant differences were found except from the ankle angular acceleration in one test condition. These results are in line with another study, where only differences for the ankle angular velocity were found when using a NCC, whereas hip and knee angular velocities remained unchanged (Leong et al., 2017). Leong et al. suggested that the cyclists changed the movements at the ankle to maintain their normal movements at the knee and hip to preserve the power production. Although in this study, no differences between the indoor and outdoor results were found, the study showed that using IMUs as an alternative enables outdoor analysis of kinematics in cycling with similar accuracy as indoors. The outdoor measurements in this study were carried out on a flat section, which could be the reason that no significant differences occurred. Future investigations should be done regarding cycling outdoor on different terrains like on climbs or sprinting out of the saddle, where alterations in the kinematics are more likely occur. Concerning the used method for measuring the kinematics in this study, it must be mentioned, that only the movements in sagittal plane were considered. Movements in frontal plane like shank rotation were not detected.

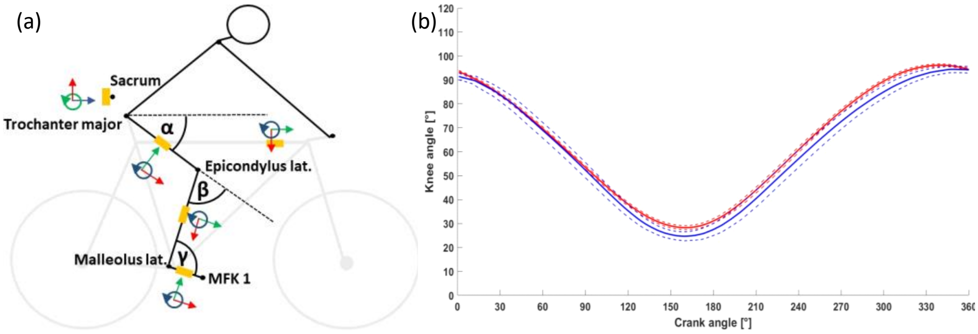

Figure 1Figure 1: (a) IMU positions (orange) on the body and their axes (x-axis = green; y-axis = red; z-axis = blue) and analysed joint angles (α = hip angle; β = knee angle; γ = ankle angle); (b) knee flexion angle measured with Vicon (red) and IMUs (blue) with Vicon (red) and IMUs (blue) with the CC at low intensity

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