Safety Science xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Special Issue Article: Cycling Safety

The different ways to get on and off a bicycle for young and old

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ARTICLE INFO

Article history:
Received 4 March 2015
Received in revised form 18 December 2015
Accepted 17 January 2016
Available online xxxx

Keywords:
Cycling kinematics
Elderly
Getting on or off a bicycle
Mounting and dismounting

ABSTRACT

In the Netherlands, each year 12,000 older cyclists require medical attention due to a single-bicycle accident where no other party is directly involved. Most of these accidents occur at low cycling velocities and 20% occur during (dis)mounting the bicycle. Little is known about the strategies and corresponding kinematics of (dis)mounting. This study aims to classify (dis)mounting strategies of young and older cyclists and assess corresponding kinematics.

Thirteen young (18–40 years) and 33 older (65–90 years) cyclists, 13 with and 20 without a bi-cycle fall-history, participated. They were asked to mount the bicycle, cycle normally, stop and wait, continue cycling and dismount the bicycle at a certain point. Bicycle and cyclist motions were recorded with 10 Inertial Measurement Units and 2 video cameras. Kinematic parameters during the (dis)mounting period were assessed. First, a qualitative analysis of the different methods of (dis)mounting and 'waiting' was made from the videos. Second, a quantitative assessment of the relationships between age, fall-history, gender and the kinematic parameters during (dis)mounting and waiting were studied.

We identified 2 mounting, 3 dismounting and 2 waiting categories, which each consisted of 2 or 3 sub-types based on timing to get on or off saddle and swing leg through frame or over saddle. The categories can mainly be distinguished by the first foot that is lifted on or off the pedal. Older cyclists and females prefer other strategies compared to young cyclists and males, respectively. E.g. during mounting, 70% of the young cyclists lift their inside foot, the foot closest to the bicycle, and place it on the pedal, while 80% of the older cyclists lift their outside foot and put it on the pedal and start pushing off with their inside foot from the ground one or more times. Furthermore, bicycle and cyclist kinematics could be related to age, fall-history and gender. Higher thigh angular velocities and accelerations (around mediolateral axis) were found for older cyclists and females compared to young cyclists and males, respectively. These differences, among others, may explain the high injury risk for older cyclists and females in single-bicycle accidents.

1. Introduction

The Dutch use cycling on a daily basis as the main means of short distance transport. Older adults, aged 65 years and older, cycle as much as younger adults, though the reason for transportation may be different. During the last decade our older population has increased in number and also their cycling has increased (Consumer Safety Institute, 2011; Statistics Netherlands, 2007). Unfortunately, also the number of older cyclists admitted to hospitals after a bicycle accident has increased with 40%: each year 18,000 cyclists aged 55 years and older require first aid medical attention or hospital admission (Consumer Safety Institute, 2011, 2010). Accident analysis in the Netherlands has shown that three-quarters of these reported accidents are single bicycle crashes, an accident where no other road user is directly involved (Consumer Safety Institute, 2011). Furthermore, the relative risk of sustaining an injury due to a single bicycle crash is 2–5 times higher for cyclists aged 65 years and older compared to other adults (Berveling and Derriks, 2012). The high injury risk in single bicycle crashes, and especially for older cyclists is not a Dutch phenomenon alone. In a review, Schepers and international colleagues report similar findings in single bicycle crash frequencies from all over the world (Schepers et al., 2014a). Also the increased injury risk for older cyclists has been pointed out (Niska et al., 2013;

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http://dx.doi.org/10.1016/j.ssci.2016.01.010
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Rodgers, 1995). Awareness has grown for this vulnerable cycling group for whom cycling is an important means of transportation, social interaction and health (Berveling and Derriks, 2012; Ministry of Infrastructure and Environment, 2012).

In-depth accident analyses have been performed to attain better insight in accident causes and mechanisms of single bicycle crashes in order to develop countermeasures. Accident causes may be infra-structure related such as collision with an obstacle or road quality, or cyclist related (Consumer Safety Institute, 2010; Niska et al., 2013; Kruijer et al., 2013; Schepers and Klein-Wolt, 2012; Davidse et al., 2013; Hagemeister and Tegen-Klebingat, 2013; Reynolds et al., 2009; Scheiman et al., 2010). Cyclist related factors include, among others, cyclist distraction and loss of control at low cycling velocities, due to steering or braking manoeuvres. Of the older cyclists that require medical attention after a single bicycle crash, 22% fell during (dis)mounting their bicycle compared to 8% for the other adults (Niska et al., 2013; Scheiman et al., 2010). No external factors such as bicycle type or baggage carriage could be related to this higher fall risk during (dis)mounting for older cyclists compared to younger cyclists (Schepers and Klein-Wolt, 2012). Furthermore, Kruijer et al. (2013) reported more single bicycle accidents occurred during dismounting (13%) compared to mounting (9%) among older cyclists who were questioned after being admitted to emergency treatment ($N = 245$). Schepers and Klein-Wolt (2012) suggested that physical abilities and the (dis)mounting method may play a role. Hagemeister and Tegen-Klebingat (2013) confirm that physical ability is related to (dis)mounting problems, but not to fall-history. So far, little is known about (dis)mounting methods, the difference between mounting and dismounting, and the relationships between physical abilities, (dis)mounting methods and fall risk. A better understanding of the (dis)mounting methods and corresponding bicycle and cyclist kinematics could be used as starting point in future accident risk studies.

This observational study aims to classify the different ways older and younger cyclists use to mount or dismount a bicycle by means of a qualitative description of body part movements. Secondly, we aimed to explore the relationships between age, gender and fall-history and (dis)mounting kinematics to attain insight in possible fall risks. Finally, mounting kinematics were compared to dismounting kinematics.

2. Methods

2.1. Participants

This observational study was part of a larger study during which cycling behaviour of young and older cyclists was assessed while performing various cycling tasks. The participants were recruited through an advertisement in the local newspaper or by means of flyers at local meeting points. Inclusion criteria for the study were: younger participants aged between 18 and 40 years and older participants aged 65 years or older, regular cycling experience of at least twice a week and the ability to cycle 20 min without motor support. The exclusion criteria included: serious visual or auditory impairments and a history of bicycle falls resulting in serious injuries. Bicycle fall-history was registered and was defined as a single bicycle crash within the last 2 years.

Fifteen healthy young and 33 older cyclists participated in this study after signing an informed consent. A physiotherapist was always present and extra supporting staff was present for those cyclists with high fall risk (self-reported fall-history) or unsafe cycling behaviour. Unsafe cycling behaviour could be observed during the phase of getting acquainted with the bicycle and included difficulties (dis)mounting the bicycle in terms of balance disturbances while standing on one leg or problems lifting foot over the frame, difficulties cycling off in terms of slow acceleration and a lot of sway. This study was approved by the Medical Ethical Committee Twente, Enschede, The Netherlands. The following demographic data were recorded: gender, age, body weight, height, self-reported medication usage and degenerative diseases, and fall-history.

2.2. Test protocol

The cycling tests were performed outside on a large parking lot with no other road users interfering. The participants were asked to perform the following activities in a self-selected way: stand next to the bicycle, mount the bicycle, cycle for 200 m at self-selected comfortable velocity, break, dismount and come to a halt next to the bicycle. The participants were also asked to stand next to the bicycle, mount the bicycle in a self-selected way, cycle for about 400 m at a comfortable velocity, break and wait at predefined stopping point, continue cycling when indicated for about 400 m, break, dismount and come to a standing posture next to the bicycle. From the first described test trials the mounting and dismounting tasks were analysed, from the second described test trials the waiting task (including dismounting and re-mounting) was analysed. Each test trial was repeated thus 2 (dis)mounting and waiting tasks were available for analysis. Cycling test preparation took about 30 min. The described cycling tests were part of a more extensive test protocol which took about 1–1.5 h. When tired, the cyclists could take a rest in between the different cycling trials. The participants were able to retreat from the tests at any stage.

2.3. Measurement system

3D cycling movement data was recorded from wireless 3D inertial movement sensors (MTw-38A70G20 Xsens, Enschede, The Netherlands) with the FusionTools software (Roessingh Research and Development, Enschede, The Netherlands) built around the Xsens sensor SDK MT 3.81. One sensor was attached to the frame and one sensor was attached to the handle bar of the bicycle to assess the bicycle kinematics. To measure the movement of the cyclist, a total of 8 sensors were attached to the following body segments: left foot, right foot, left shank, right shank, left thigh, right thigh, pelvis and sternum (Fig. 1). All sensors were attached to the bicycle and cyclist by means of easy click-on click-off holding straps (Xsens standard wireless elastic strap set).

Prior to the tests, a ‘segment calibration’ procedure was performed to facilitate translation of the sensor orientation data (orientation of sensor casing in global inertial world frame aligned with magnetic north) into body segment orientation data (orientation of body segment or bicycle segment in a global inertial world frame aligned with cycle track direction). This also facilitated translation of sensor casing acceleration and angular velocity data into body segment acceleration and angular velocity. Subsequently joint kinematics were defined as ‘child’ segment kinematics relative to ‘parent’ kinematics and estimated (E.g. ‘joint’ knee data equals ‘child segment’ shank data in global frame relative to parent segment ‘thigh’ data in same global frame). The calibration procedure of the bicycle included controlled lifting of the bicycle front wheel around the bicycle ‘left to right’ axis and controlled rolling around the bicycle’s long axis to define the bicycle frame segment; and controlled rotation of the steer around its steer axis. For the body segment calibration, the participants performed controlled squats and heel rises around their medio-lateral axis (Baten et al., 2004). A rotational segment orientation axes error of less than 1° was obtained after repeated bicycle frame calibration. Calibration errors in limb segment orientation axes may lead to

Please cite this article in press as: Dubbeldam, R., et al. The different ways to get on and off a bicycle for young and old. Safety Sci. (2016), http://dx.doi.org/10.1016/j.ssci.2016.01.010