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Scottish cycling infrastructure and public health: a study of cyclist hand-arm vibration exposure

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The management of pavement surfaces for walking and cycling is currently a labour intensive task and relies upon user reporting defects and direct visual inspection. Local authorities are being pressed to cut budgets and reduce annual expenditure. Therefore, pavement surfaces associated with walking and cycling are seldom considered to be a priority infrastructure investment. Cycling infrastructure and, in particular, a well maintained pavement surface contributes to a safe and comfortable ride. However, defective pavement surfaces and insufficient maintenance can expose cyclists to excessive hand-arm vibration. Regular exposure to vibration transmitted from work processes is well documented, regulated and controlled in construction and civil engineering industries. However, limited data is available regarding commuter and recreational cyclists' exposure to hand-arm vibration.

A defective pavement surface discourages cycling activity and vibration exposure has been identified as a consequence of poor cycle track quality (Bil *et al.*, 2015). Through an online survey of experienced cyclists (>2000 km per year), Ayachi *et al.* (2015) conducted principal component analysis of the results and identified that road surface condition, bicycle saddle and frame design contribute significantly to rider comfort. Calvey *et al.* (2015) and Gao *et al.* (2018) conducted surveys of pavement surface quality using a combination of user perception questionnaire surveys and instrumented bicycles.

Previous research has assessed the relative contribution of bicycle components on the vibration induced in the hands and buttocks of cyclists. Lépine *et al.* (2015) assessed the relative contribution of vibration through measurement in three different locations. These included the vertical force and acceleration transmitted via the saddle, force and acceleration transmitted through the handle bars and, finally, the force and acceleration transmitted to the hands on break hoods and the handle bars under the hands. Gomes and Savionek (2014) conducted hand-arm vibration exposure

on three pavement surface types: asphalt, precast concrete and interlocking concrete blocks. Using a tri-axial piezoelectric accelerometer fixed to the handle bars, daily exposure to vibration (A(8)) for a daily duration of exposure of two hours (T=2 hrs) was considered to represent an average exposure time for leisure cycling purposes.

Hölzel *et al.* (2012) measured cyclists' exposure to vibration induced by four different cycle path pavement surfaces: asphalt, concrete paving slabs, cobblestones and self-binding gravel. They concluded that cycling pavement surfaces constructed from asphalt improve rider comfort and may encourage greater uptake of cycling. In a review of instrumented probe bicycle (IPB) research, Mohanty *et al.* (2014) summarised the development of comfort and safety prediction models highlighted the need to collect more accurate and continuous real-time data that represents the cycling experience.

Parkin and Eugenie-Sainte (2014) provided a study of comfort and health factors including the nature of vibrations from riding in different circumstances in the city of London. Munera *et al.* (2014) summarised the different standards and guidelines associated with the evaluation of vibration and exposure limits whilst cycling. They focused upon physiological and pathological disorders in performance athletes. The research identified the application of the Directive 2002/44/EC11 in defining the limit of exposure and the limit triggering action for cyclists' vibration exposure. Furthermore, they identified ISO 5349-1 (BSI, 2001) a suitable method for examining cyclists' vibration exposure. Munera *et al.* (2018) analysed the dynamic and physiological response of the human body whilst cycling considering a range of vibration frequencies.

The equipment required to measure and monitor hand-arm vibration is often costly. However, advancement in low-cost electronics engineering has provided a range of vibration sensors and recording devices that can be fitted to a bicycle with relative ease. Instrumented probe bicycles can now be constructed with low cost apparatus to allow a broad range of data to be collected. For example, recording hand-arm or whole-body vibration, geospatial positioning, lighting lux levels and HD video can provide improved asset condition data. Applying the procedures adopted for railway and road maintenance to cycle path maintenance is not common practice in Scotland. Measuring cyclist's vibration exposure and examining the health implications of such exposure may provide a medical rationale for improvements to pavement surfaces.

A survey of Scottish cyclists vibration exposure symptoms was conducted (n=555). The online questionnaire survey instrument was designed to screen participants for hand-arm vibration symptoms. The results show that a considerable amount of Scottish cyclists who commute or undertake recreational cycling are experiencing symptoms. The results of the questionnaire survey are presented. Furthermore, details of a low-cost hand-arm vibration measurement system are provided. Measurements comply with EN ISO 5339-1:2001 with a sample rate of 5 kHz and the application of frequency weighting filters (W_h). Partial and total eight hour equivalent

exposure data ($A(8) \text{ ms}^{-2} \text{ r.m.s.}$) are provided for a range of cycling infrastructure surfaces and typical commuter routes in Edinburgh and Glasgow. These preliminary findings demonstrate that there is a potential public health issue associated with active travel and unsuitable pavement surfaces. Details of ongoing research examining cyclists' hand-arm vibration exposure on a broad range of pavement surfaces and cycling conditions are presented. The results may contribute to the development of pavement engineering design standards for cycling through considering vibration exposure data. The research aims to provide practical guidance relating to health surveillance action local authorities can take in improving cyclist's comfort and safety.

The research aims to contribute improved data collection procedures for the maintenance of cycling infrastructure provision. The present study examines the public health implications of defective pavement infrastructure to professional, commuter and recreational cyclists. The questionnaire explored cyclists' experience of vibration exposure symptoms with specific questions providing medical screening of comorbid disease and medical procedures. The preliminary findings of field measurements and the self-reported symptom questionnaire survey are presented. The results provide an insight into the potential prevalence of hand-arm vibration exposure symptoms among recreational and commuter cyclists in Edinburgh and Glasgow.

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