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Analysis of heart rate variability amongst cyclists under perceived variations of risk exposure

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ABSTRACT

Cycling as a mode of travel provides an opportunity for many people to increase their levels of regular physical activity and contribute to their mental and physical health. Heart rate is often used as a means of measuring the intensity and energy expenditure of physical activity. However, heart rate is also linked to emotional factors such as anxiety and fear. Perceptions of risk due to external factors such as other road users and infrastructure may arouse such emotions in urban cyclists. The present study set out to investigate whether or not perceptions of risk among urban cyclists may lead to increased heart rates. Cyclists completed a test route in normal traffic conditions in Cork, Ireland and heart rates and self-reported risk ratings were recorded in real time. Evidence was found of a link between perceptions of risk and heart rates. This raises questions regarding the use of heart rate to estimate exercise intensity and energy expenditure during urban cycling. The perceptions of cyclists of their safety in relation to various road elements on familiar routes were also assessed, as well as specific events which they perceive to be high in risk. The results indicate that incidents involving car traffic and busy roads which offer no protection from interaction with car traffic are associated with greatest perceptions of risk.

1. Introduction

Incorporating cycling into daily routine is increasingly being recognised as an effective means of increasing physical activity levels (Cavill, Kahlmeier, Rutter, Racioppi, & Oja, 2008; Kahlmeier, Racioppi, Cavill, Rutter, & Oja, 2010; Rutter et al., 2013). Regular physical activity is a major contributor to physical and mental health and promotion of active travel has been identified by WHO Regional Office for Europe as a supporting intervention for the prevention and control of non-communicable diseases (WHO, 2011). However, in order to ensure that any programme of increased physical activity brings health benefits, both the quantity and quality of exercise taken should be considered. The American College of Sports Medicine (ACSM) has published specific recommendations regarding both intensity and total energy expenditure of exercise for maintaining fitness (Garber et al., 2011). It is well established that heart rate (HR) increases linearly with oxygen consumption (VO_2) (ACSM, 2011; Åstrand, 1976; Åstrand, Rodahl, Dahl, & Stromme, 2003; Bassett, Rowlands, & Trost, 2012). Based on this principal, the ACSM has also identified optimum HR zones for various levels of exercise intensity (Garber et al., 2011) and a leading HR

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monitor manufacturer has published cycling specific HR zones (Polar, 2013). Activity energy expenditure (AEE) can also be estimated based on a linear relationship with HR (Bassett et al., 2012).

There are many commercially available HR monitors that are used during cycling and other exercise routines in order to target specific HR zones and calculate AEE. However, HR may be elevated by emotional and environmental factors which could produce non-linearities in the relationship between HR and oxygen consumption (VO_2) (Åstrand et al., 2003; Crouter, Churilla, & Bassett, 2008). It has been suggested that the combination of HR monitoring and movement registration may improve estimates of AEE (Brage et al., 2004). Some devices attempt to do this by using both HR monitors and accelerometers. An evaluation study compared AEE estimated by one such monitor using a combined activity and HR algorithm to a reference AEE calculated from measured VO_2 and carbon dioxide consumption (VCO_2), for 18 activities (Crouter et al., 2008). The AEE estimations calculated by the combined activity and HR algorithm differed significantly from the reference values for 3 of the 18 activities. Also, none of the activities studied would have been likely to arouse fear or anxiety.

It is recognised that feelings of fear and anxiety may be associated with increased HR. In 1992, a major study (Levenson, 1992) studied the differences in autonomic nervous system (ANS) responses between different emotions. Large increases in HR were consistently found in response to a variety of fear inducing stimuli. Cacioppo (2000) later performed a meta-analysis across 22 studies on the question of whether there are emotion-specific physiological patterns. It was found that fear was associated with higher HR responses when compared to happiness, sadness or disgust. Levenson (1992) suggests that that the association of fear with increased HR may reflect a close association of fear with the motor program of "flight". The "flight" response, described in detail by Cannon (1929), refers to the fear induced bodily responses which prepare an organism for the great exertions which may follow. A more recent study of drivers' emotions found that anxiety, but not anger or happiness, was associated with increased perceptions of risk and with increased HR (Mesken, Hagenzieker, Rothengatter, & de Waard, 2007). Another recent study (Lerner, Gonzalez, Dahl, Hariri, & Taylor, 2005) studied differences in HR responses to anger and fear in participants performing a difficult arithmetic task. Fear was positively correlated with HR, whereas anger was negatively correlated with HR. All this evidence indicates that if an activity arouses feelings of fear or anxiety, these emotions may have an increasing effect on HR.

Several recent studies have suggested that cycling is perceived by transport users as being an unsafe mode of transport, particularly in an urban commuting environment where cyclists are exposed to motor vehicle traffic (Lawson, Pakrashi, Ghosh, & Szeto, 2013; Winters, Davidson, Kao, & Teschke, 2011; Winters et al., 2012). The perceptions of safety by cyclists are influenced by a wide range of factors such as age, regularity of cycling, road type and attitudes of vehicle drivers (Lawson, Pakrashi et al., 2013). Individual events such as conflicts with other road users and near misses are likely to be perceived as particularly high in risk but there is little information available in relation to these types of events. This implies that cyclists are likely to experience varying levels of fear and anxiety due their perceptions of risk while cycling in a mixed mode network and it can reasonably be expected that this fear and anxiety may lead to variations in their HR. Also, there is no evidence to suggest that any currently available HR-based exercise intensity or AEE measurement devices are capable of compensating for the effects of significant levels of fear and anxiety. Therefore, the perceptions of risk among cyclists in a mixed more urban environment may cause miscalculation of exercise intensity and AEE as measured by the aforementioned devices.

The present study aimed to investigate the relationship between HR and perceptions of risk among cyclists. Evidence of a link was demonstrated, showing that the response of cyclists to situations which are perceived as being high in risk is not just psychological but physiological also. The link between risk perceptions and HR may be an indication of the "flight" response which is typically accompanied by other physiological responses such as a release of adrenaline. The link between risk perceptions and HR also raises questions regarding the accuracy of devices which rely on HR for evaluation of the benefits of exercise in the context of active travel.

Recent evidence has also shown that there is disagreement between cyclists' perception of the safety of particular road elements and actual safety and that perceptions of safety have more influence on cycling modal share than actual safety (Dill & Voros, 2007; Keegan & Galbraith, 2005; Noland, 1995; Parkin, Wardman, & Page, 2007; Winters et al., 2012). Previous researches into perceptions of risk among cyclists have used methods such as site interviews (Moller & Hels, 2008), video clips (Klobucar & Fricker, 2007; Parkin et al., 2007), test courses (Landis, Vattikuti, & Brannick, 1997; Landis et al., 2003), surveys (Lawson, Pakrashi et al., 2013; Leden, Garder, & Pulkkinen, 2000) and simulations (Hughes & Harkey, 1997). With the exception of Lawson, Pakrashi et al. (2013), the tests mentioned above focus on specific sites, (with which the participant may or may not be familiar) and consider a small number of variables. They are also conducted over short time frames and so, the likelihood of a particularly high risk event such as a near miss occurring is low. One case-crossover study addressed these limitations by recruiting cyclists who had sustained an injury while cycling, but since participants were recruited based on hospital records; minor injuries and near misses were not captured (Winters et al., 2012). The present study addresses the limitations of previous studies by exploring the risk perceptions of each individual cyclist in relation to their regular route. Each route is characterised into discrete road elements so that the cumulative experiences of the cyclists with respect to each type of road element can be studied. Another key contribution of this study is the ability to capture and characterise any specific event which may be perceived by a cyclist as being high in risk, such as a conflict or near miss.

The next section of this paper describes the methodology employed in each element of the study. This is followed by a presentation of the results observed, a discussion of those results and finally, the conclusions which may be drawn.