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# Predicting bicycle setup for children based on anthropometrics and comfort

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ABSTRACT

Bicycling is a popular activity for children. In order for children to enjoy cycling and to minimize injury, it is important that they are positioned appropriately on the bicycle. The purpose of this study was therefore to identify a suitable bicycle setup for children aged between 7 and 16 years which accommodates developmental differences in anthropometrics, flexibility and perceptions of comfort. Using an adjustable bicycle fitting rig, we found the most comfortable position of 142 children aged 7 to 16. In addition, a number of anthropometric measures were recorded. Seat height and the horizontal distance between seat and handlebars were strongly predictable ($R^2 > 0.999$, $p < 0.001$ and $R^2 = 0.649$, $p < 0.001$ respectively), whilst the predictability of the vertical distance between seat and handlebars was weaker ($R^2 = 0.231$, $p < 0.001$). These results have practical implications for children and parents, paediatric researchers and clinicians as well as bicycle manufacturers.



## 1. Introduction

Bicycling is a popular activity in recreational, sports performance and clinical contexts. The position of the rider on the bicycle is an important consideration, and it is dependent on the cyclists' motivations and physical characteristics. Bicycle fitting has been described as "the detailed process of evaluating the cyclist's physical and performance requirements and abilities and systematically adjusting the bike to meet the cyclist's goals and needs" (Cramblett, 2013).

The bicycle fitting process needs to be tailored to the individual for three reasons. Firstly, anthropometric characteristics are variable and inter-individual differences in body size and body proportions need to be taken into consideration. For example, children will require a different bicycle setup than adults based on differences in body size. Second, the rider's motivations for cycling have important effects on the desired riding position. For example, a time triallist is likely to choose a position that minimizes aerodynamic drag and sacrifices comfort, whereas for a recreational rider comfort may be more important, with the cyclist adopting a more upright posture to avoid overstressing the lumbar and cervical spinal regions (de Vey Mestdagh, 1998; Mellion, 1991).

Within this context the concept of comfort is important. Pineau (1982) and Slater (1986) define comfort as a state of "well-being" (Pineau, 1982, p. 291) characterized by "physiological, psychological and physical harmony between a human being and their environment" (Slater, 1986, p. 158). While performance and bicycle fitting has been well researched (Bini et al., 2011; de Vey Mestdagh, 1998; Gross and Bennett, 1976), comfort and bicycle fitting is "largely underexplored in the scientific literature" (Ayachi et al., 2015). Taking the subjective perception of comfort into consideration is important to avoid discomfort in the back and neck (Asplund et al., 2005), hands and arms (Mellion, 1991) and in the lower limbs (Callaghan, 2005). Thus, the third reason for the individual nature of a bicycle fit is inter-individual differences in the subjective perceptions of comfort.

The position of the rider on the bicycle can be uniquely described by seat height, seat angle, crank length, as well as horizontal and vertical distances between the seat and the handlebar ("reach" and "rise") as shown in Fig. 1.

Several methods exist to predict the desired bicycle configuration based on anthropometric characteristics. Crank length is often recommended to be 20% of leg length (Gross and Bennett, 1976; Martin and Spirduso, 2001). Seat height is typically calculated from leg length (Bini et al., 2011; LeMond and Gordis, 1990; Peveler et al., 2005), and seat tube angle is often determined by the requirement of the tibial tuberosity being vertical above the pedal

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spindle when the corresponding pedal is in its horizontal position (i.e. at a crank angle of 90° to the vertical) (de Vey Mestdagh, 1998; Silberman et al., 2005). Arguably, the most subjective components of the bicycle setup are reach and rise. For adults, several recommendations exist to predict reach and rise from anthropometric measures (e.g. arm and torso length) and hamstring, hip and lower back flexibility (ArgonautCycling, 2014; Burke and Pruitt, 2003; de Vey Mestdagh, 1998; FitKit, 2014a; LeMond and Gordis, 1990; Silberman et al., 2005). Although some of these recommendations lack a scientific evidence base, they are useful in practice to predict a suitable position of the rider on the bicycle.

The vast majority of recommendations and scientific evidence in terms of bicycle fitting and bicycle setup are intended to be used for adults. However, cycling is not only an attractive activity for adults but also for children. In the UK, around 80% of young children have access to bicycles (DoT, 2013). The majority of children cycle for recreational purposes (Brockman et al., 2011; Owen et al., 2012; Payne et al., 2013), with a small, yet significant, amount competing in cycling races and triathlons (Aragón-Vargas et al., 2013; Dallam et al., 2005). Cycling is also a common activity used in paediatric clinical contexts (Fowler et al., 2010; Korff et al., 2009b; Summerbell et al., 2004). Identifying a bicycle setup for children that takes into account children's unique anthropometric characteristics and their subjective comfort is important to reduce the risk of injury, to make the riding experience more enjoyable, and to give parents, paediatric clinicians and vendors of children's bicycles a guide to choosing a bicycle that is most appropriate for the child. For the aforementioned reasons, it is important that recommendations relating to bicycle setup are evidence based.

To the best of our knowledge, only two studies have investigated bicycle setup in children:

Donkers et al. (1993) measured the anthropometric dimensions of 279 children to assess whether existing bicycles at the time complied with corresponding safety standards. Whilst the importance of the relationship between anthropometrics and the dimensions of the bicycle is acknowledged, the authors make assumptions about this relationship without explicitly verifying them. Laios and Giannatsis (2010) measured the anthropometric dimensions of 1400 children with the goal of validating a range of bicycle frame sizes for the children in the sample. Once again, these authors make unverified assumptions about the child's desired position on the bike. In particular, they recommend a trunk angle of 15° and knee angles of no less than 65° when the pedal is in the top dead centre position (TDC) and no more than 150° when the pedal is in the bottom dead centre position (BDC). These recommendations are taken from experiments conducted on adults in contexts that are partially irrelevant to the bicycle fitting process including Christiaans and Bremner (1998); Craig (1960) and de Vey Mestdagh (1998).

Thus, within the context of bicycle fitting in children previous literature exhibits two major shortcomings. First, the assumptions made in the adult literature are only partially based on relevant evidence. Second, independent of the lack of evidence in the adult literature, one cannot assume that recommendations for adults can simply be applied for children, as children are not miniature adults. Relative segment lengths, relative mass proportions and centre of mass locations change between infancy and adulthood (Korff, 2012; Prader et al., 1988; Timiras, 1972), which implies that different segments grow at different rates. It is possible that such changes could affect the perception of comfort for a given position on the bicycle.

Therefore the main purpose of this study was to identify a suitable bicycle setup for children between 7 and 16 years which accommodates developmental differences in anthropometrics, flexibility and perceptions of comfort. Within this context, a secondary purpose was to verify the assumptions about the recommended position of the rider on the bike in previous studies relating to bicycle setup in children.

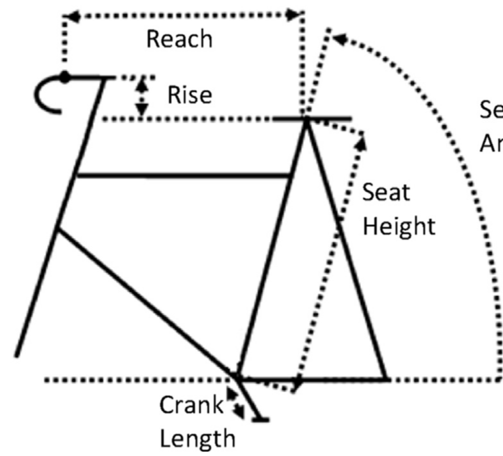


**Fig. 1.** Reach and rise defined (Korff et al., 2011).

## 2. Method

### 2.1. Subjects

One hundred and forty two subjects between 7 and 16 years of age volunteered to participate in the study (Table 1).

All subjects were free from any physical impairments or injury. All subjects knew how to ride a bicycle, but did not compete in any cycling events. Procedures and risks were explained verbally and in writing. The study was approved by the University's Research Ethics Committee. Subjects provided verbal assent, and parents/guardians of the subjects provided written informed consent. Ten subjects attended a second time where the data collection process was repeated to assess test re-test reliability.

### 2.2. Procedure

Data collection comprised 4 components: 1) measurement of anthropometrics, 2) assessment of flexibility, 3) determination of comfortable bicycle position and 4) assessment of bicycle fit limits.

#### 2.2.1. Anthropometrics

Twenty anthropometric measures were taken in accordance with Norton and Olds (1996) and FitKit (2014b). Definitions of anthropometrics taken and method of measurement are documented in Appendix A, Anthropometric Measurements.

#### 2.2.2. Flexibility

A modified "sit and reach test" was used to assess the combined hamstring, hip and lower back flexibility of each subject (Dwyer and Davis, 2008). A standard sit and reach box was placed on the

**Table 1**
Sample descriptive data.

| | Male | Female | Total |
|---|---|---|---|
| *N* | 73 | 69 | 142 |
| Age (years) | 12.4 ± 2.5 | 12.4 ± 2.0 | 12.4 ± 2.2 |
| Mass (kg) | 46.8 ± 15.0 | 45.6 ± 13.5 | 46.2 ± 14.3 |
| Stature (cm) | 151.7 ± 14.6 | 150.4 ± 11.3 | 151.1 ± 13.0 |

Values are mean ± standard deviation.