

The BASES Expert Statement on Trainability during Childhood and Adolescence

Produced on behalf of the British Association of Sport and Exercise Sciences by Dr Melitta McNarry, Dr Alan Barker, Dr Rhodri S. Lloyd, Dr Martin Buchheit, Prof Craig Williams FBASES and Dr Jon Oliver.

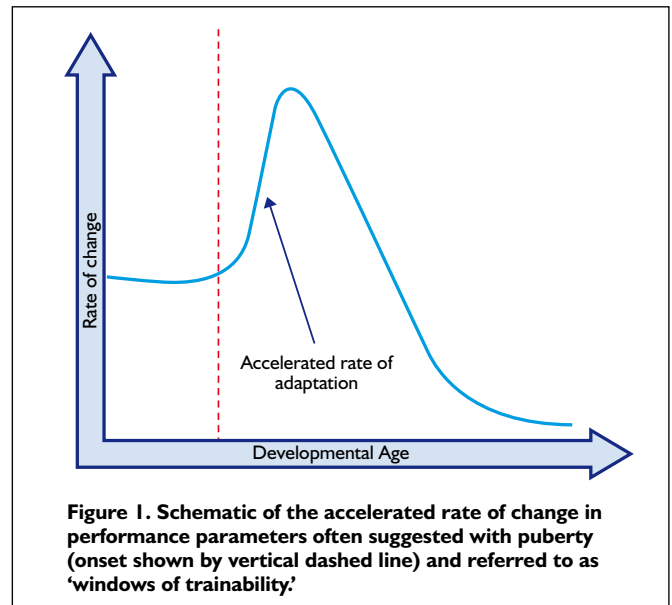
Background to the project

The trainability of children and adolescents remains an important, but contentious, issue in pediatric exercise science. In particular, it has been suggested that the periods of naturally occurring accelerated adaptation during puberty reflect 'golden periods' or 'windows of opportunity' where the effects of training are especially pronounced. The 'trigger hypothesis' or maturational threshold are prominent examples of this theory and dictate that training-induced gains during childhood and adolescence will be either minimal or not apparent until the trigger provided by the onset of puberty is reached (Katch, 1983). It has been hypothesised that changes in the hormonal milieu, and other growth factors, associated with puberty provides a period of accelerated adaptation and trainability (see Figure 1).

This debate regarding the trainability of children has had a significant impact on the design of training programmes for children and adolescents by coaches and researchers. Windows of optimal trainability represent a cornerstone of many long-term athlete development models that have been widely adopted by UK National Governing Bodies. An understanding of the development of fitness during childhood and adolescence is not just applicable to a sporting context however, such an understanding also has important implications for the promotion of health and well-being throughout childhood and adolescence. The purpose of this statement is therefore to: 1) Provide an overview of the current evidence regarding the trainability of aerobic fitness, strength and speed in children and adolescents; 2) Evaluate the strength of this evidence base and 3) Provide recommendations for researchers and practitioners.

Aerobic fitness

One of the most commonly studied variables with regard to the presence of a maturational threshold in training adaptability is aerobic fitness, operationally defined as peak oxygen uptake ($\dot{V}O_2$), likely due to its beneficial relationship with performance and health outcomes. Although early studies purportedly demonstrated a maturational threshold, potentially due to various methodological limitations as discussed below, a recent review observed that 9/14 (64%) studies in children under 11 years old and 4/7 (57%) studies in children and adolescents aged 11-18 years reported a significant increase in peak $\dot{V}O_2$ following training (Armstrong & Barker, 2011). Furthermore, the magnitude of this increase was similar in those <11 (7.7%) and ≥ 11 years of age (8.6%), a finding supported by studies demonstrating comparable adaptations in children and adults when the same training programme is completed. Perhaps the most important influential factor with regard to the trainability of peak $\dot{V}O_2$ in children and adolescents is the baseline level of fitness. Indeed, both original (Tolfrey *et al.*, 1998) and review (Armstrong & Barker 2011) studies have shown the magnitude of change is inversely related to baseline fitness. That is, the greatest gains are seen in those with the lowest level of fitness. Finally, in addition to peak $\dot{V}O_2$, studies indicate that the magnitude of training-related differences in other parameters of aerobic function (e.g., lactate threshold, O_2 cost of exercise and $\dot{V}O_2$ kinetics) is independent of maturity (McNarry & Jones, 2014),



although the cross-sectional nature of this data limits interpretation. Taken collectively, these findings suggest children and adolescents are aerobically trainable throughout maturation with no evidence of a period of enhanced trainability. It is important to note, however, that no prospective study has attempted to address this question across the maturational stages.

Strength

Resistance training in children and adolescents has been highly controversial but, if appropriately implemented by qualified professionals, it is a safe and effective mode of training (Behringer *et al.*, 2010). Furthermore, it has been shown to be advantageous for enhancing a range of physical performance measures (e.g., strength, speed and power) (Lloyd *et al.*, 2014). In a recent review of 42 studies it was shown that pre-pubertal children were able to make training induced gains in strength (ES = 0.81), however mid-/post-pubertal children achieved gains that were approximately double that of their less mature peers (ES = 1.91) (Behringer *et al.*, 2010). It was noted that responsiveness to training increased steadily with advancing age and maturational status, however a puberty-related 'boost' in strength gains was not evident. Interestingly, the transference of resistance training gains to other motor skills (such as sprinting, jumping and throwing) appears to be more pronounced in less mature individuals. Therefore, strength development does not appear to be associated with accelerated growth around puberty and, thus, is unlikely to be a simple function of enhanced hormonal status.

Speed

The most commonly investigated parameter of sprint ability is locomotor speed. A recent review of 17 studies showed that similar gains in speed following training were evident in both pre-pubertal and post-pubertal children, albeit in response to different

training methods (Rumpf *et al.*, 2012). Interestingly, whilst mid-pubertal boys were trainable, the magnitude of training gains were approximately 50% that of pre- and post-pubertal groups. Thus, contrary to puberty representing a golden period, this stage of development appears the least sensitive to adaptations in speed.

Methodological limitations

Whilst the above conclusions are based on the critical analysis of recent review papers that synthesised the current evidence, there are certain methodological limitations common to all the aforementioned parameters that need to be considered and which temper the confidence in the conclusions. Specifically:

- The absence of a control group, which is essential for the concomitant processes of growth and maturation to be accounted for and thus any additional changes observed being attributable to training *per se*.
- A failure to appropriately assess maturation status, thereby limiting inter-study comparisons due to the considerable variability in the relationship between chronological and biological age.
- A male participant bias such that the influence of sex remains to be fully elucidated.
- A lack of studies that have investigated trainability across all the different maturity stages.
- Variation in the training prescription (type, duration, frequency, volume and intensity of training).
- A failure to account for baseline fitness and habitual physical activity levels of participants; higher levels of either factor may be associated with smaller subsequent responses to training.
- A lack of research that explains the underlying mechanisms of adaptation across different stages of maturation.
- A lack of commonality between the outcome measures and performance, which thus limits practical application of research findings.

The final important issue is that many studies, which have purportedly observed a maturational threshold (or trigger point), may simply have used an insufficient training dose (duration and/or intensity) in the younger participants, thereby supporting an artificial influence of maturation. More pronounced adaptations during puberty may be related to a greater overall training dose (i.e., longer duration of training and/or higher baseline fitness/physical activity levels) rather than to physiological changes associated with puberty *per se*.

Future research

Key directions for future research are that:

- Research must include a control group and accurate assessment of maturity.
- Further studies are required in girls and with participants across the maturity range, including populations around the onset of puberty.
- Prospective, longitudinal studies are needed that specifically investigate the presence of a maturational threshold in the trainability of children.

Conclusions

In conclusion, a maturational threshold prior to which no effect of training is manifest is not supported by the majority of empirical evidence, which shows children and adolescents are trainable pre, circa- and post-puberty. If a period of *enhanced* trainability exists, it is likely to be fitness component-specific: aerobic fitness appears to be equally trainable throughout maturation whilst strength is trainable throughout maturation with greater gains evident with advancing age and speed demonstrates attenuated trainability during puberty but is nonetheless trainable throughout maturity. It is important to consider the limitations associated with the current evidence base. Firm conclusions are precluded until valid

and reliable evidence specifically investigating the presence of a maturational threshold in these parameters is available.

Practical recommendations

- The common practice of planning intensive training around periods of accelerated adaptation, particularly puberty, should cease; the possible benefits of enhanced trainability of some limited aspects of performance is outweighed by the potential negative risks of overtraining and burnout.
- Children and adolescents should engage in a variety of age-appropriate training methods and not be constrained by supposed 'windows of opportunity'.
- No definitive answer is available as to whether pre-pubertal children who undergo training will demonstrate superior physiological responses after puberty than would occur if training was only experienced mid- or post- puberty. ■



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