NHS Health Scotland

Executive summary: adolescent physiological development and its relationship with health-related behaviour

SCPHRP Scottish Collaboration for Public Health Research and Policy

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0131 314 5300

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[1] Scottish Collaboration for Public Health Research and Policy, University of Edinburgh, UK

[2] NHS Health Scotland, UK

[3] Department of Psychology, University of Oregon, Eugene, OR, USA

[4] Institute of Cognitive Neuroscience, University College London, UK

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1 South Gyle Crescent
Edinburgh EH12 9EB

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Contents

Background

Adolescence is characterised by the transition from childhood to adulthood. This period has implications for health as a result of interactions between early childhood development, specific biological, psychological and social role changes, and wider social determinants.

In December 2012, NHS Health Scotland and the Scottish Collaboration for Public Health Research and Policy (SCPHRP) established a Youth Health Behaviour Development and Change (YHBD&C) Advisory Group, consisting of academic, policy and practice experts in adolescent health, to consider health behaviour development and change during adolescence. The overall goal of the group was to provide information on the evidence and theory related to health behaviour development and change for children and young people, in order to support health improvement policy and practice development in Scotland. A subgroup formulated research priorities and agreed that the first step should be an understanding of theories of adolescent development across six key domains: physiological, psychological, physical, social, socio-economic and cultural environments (see Figure 1).

Theories developed to explain, predict or describe the determinants of adolescent health-related behaviour are mainly constructed within separate disciplines, which do not necessarily value or understand theories from other disciplines. For example, social, cultural, and economic approaches to the study of adolescence are often separated from biological analyses. However, neural and hormonal changes during adolescence play an important role in influencing the ways adolescents think, feel, behave and more importantly interact with the wider environment to influence an individual's overall life trajectory.

This report synthesises theories of physiological development, mainly because of a dearth of information in this domain. Subsequent work will address the other five domains.

Focus of this review

Adolescence is a time in which substantial physiological changes are occurring in parallel with changing environments and opportunities. As such, adolescence is a transition period offering unique opportunities to influence health-related behaviours. Understanding these changes can help to inform and improve health policy and intervention development. The aim of this systematic review is to gain an understanding of the relationship between physiological development and health-related behaviours in adolescence, as a fundamental step in the wider project outlined in Figure 1.

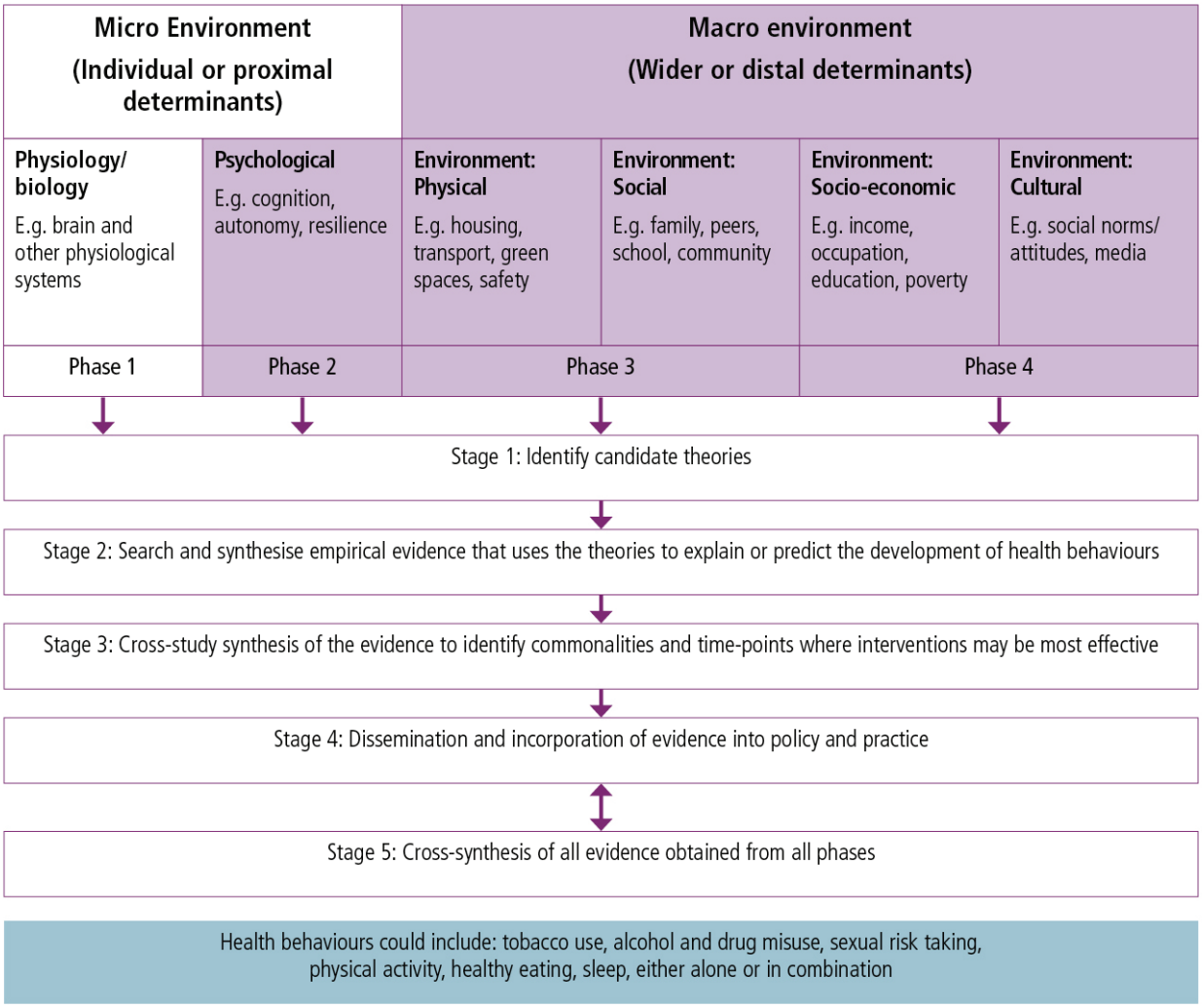

Figure 1. Dimensions of adolescent development (purple shaded boxes are not included in this particular project)

The objectives are to:

- identify and describe the range of theories that explore the relationship between physiological development and health behaviours in adolescence
- identify and describe the range of evidence which explores and/or explains the relationships between physiological development and health behaviours in adolescence
- determine which theories are underpinned by rigorous scientific evidence and which are not
- provide recommendations in relation to the findings that could be used to develop policy and practice
- provide recommendations to inform future research priorities.

Method

This systematic review is based on the principles of an integrative review in order to identify a broad range of studies, following PRISMA guidelines. Integrative reviews are the most comprehensive of all review approaches, facilitating the inclusion of different methodological approaches, and both published and unpublished literature. The method involves standard systematic review procedures – specifying inclusion/exclusion criteria, literature searching, data extraction and data synthesis. In-depth formal quality assessment was not feasible due to the breadth and scope of papers included in the review, in terms of discipline, focus and study design. However, the quality of the studies is highlighted where relevant in the narrative summary. Papers were screened by two reviewers to assess eligibility and relevance.

Studies with participants aged between 10 and 24 (inclusive) years were included, although no definitive age barriers were used to avoid excluding potentially relevant research, with the proviso that the topic focus related to the adolescent life stage. The main variables of interest were theories and hypotheses related to physiological development during adolescence and relationships with health-related behaviour. Physiological development was defined as encompassing a broad range of biological

systems (e.g. musculo-skeletal, nervous, endocrine, integumentary, cardiovascular, respiratory, digestive, reproductive) and associated biochemical and hormonal processes. Health-related behaviours included areas such as diet and nutrition, physical activity, substance use, smoking, sexual behaviour, and sleep. Papers were included if they focused upon the impact of physiological systems upon those behaviours (rather than the opposite direction of effect, i.e. those behaviours upon physiological systems). Theoretical or discussion papers were included if they contributed to our understanding of mechanisms or effects. We further excluded studies in which the direction of effect was unclear or focused explicitly upon the impact of health behaviour upon physiological outcomes and not vice versa. Studies dating from 1980 up to 2016 were included.

A project advisory group monitored all stages of the review process and comprised researchers with a background in public health, neuroscience, adolescence, and systematic reviews, as well as policy/decision makers with a remit to improve youth health across Scotland.

Results

In total, 13,633 papers were identified. Following screening, 341 papers were selected. Due to the large volume of studies relating to brain physiology (n=181), these studies were grouped together. Papers that did not fall into the category of brain physiology (n=108) were grouped separately. These studies generally referred to other aspects of physiological development, e.g. the endocrine or musculoskeletal systems.

Papers reporting findings with implications for health behaviours in adolescence

A total of 58 papers reported findings with implications for health behaviours in adolescence. These papers were exclusively focused upon brain physiology, and were primarily theory papers or laboratory studies that investigated the broad

cognitive and affective processes thought to be involved in health-related behaviour in adolescence.

Emotion regulation

The studies identified suggest that the physiological underpinnings of emotional regulation (i.e. emotional control) continue to mature in adolescence, and an individual's ability to regulate her/his emotions has certain implications for health-related behaviours. Specifically, adolescents might respond faster, and with less inhibition, in emotionally charged situations. Also, there are individual differences in how adolescents adapt to emotionally charged contexts, with more anxious adolescents less likely to show neural habituation to emotional cues than less anxious adolescents. More anxious adolescents may therefore find it harder to control behaviour in emotional situations.

Cognitive control

Studies identified suggested to a broad consensus that maturing brain physiology is associated with maturing cognitive control abilities between childhood and early adulthood (i.e. the ability to override habitual and reflexive reactions to act according to one's intentions). Several studies noted that different aspects of cognitive control develop at different rates during adolescence, which is likely related to a differential development of related brain regions and networks. Other studies found that cognitive control abilities may be impacted by the presence of a rewarding or affective context. Adolescents may be better at inhibiting inappropriate behaviour in the presence of an anticipated reward (e.g. access to social media contingent on doing homework), and may find it more challenging in affective contexts (e.g. high-emotional situations, such as having fun with friends).

Temporal discounting

The studies identified suggested that, on average, as adolescents get older, they show increasing tolerance to wait for larger rewards rather than take immediate smaller rewards. However, there are individual differences across development in

this preference, and these individual differences are related to differences in neural architecture as well as processing. How one comes to choose a smaller immediate reward (e.g. unhealthy snacks) over a larger distant reward (e.g. feeling good as a consequence of healthy weight) could be related to how that individual values the proposed reward, or it could be related to how well that individual can inhibit reflexive urges or is able to think about the future. The development of brain systems involved in evaluating rewards, cognitive control, and thinking about the future all appear to contribute to the developmental changes in how we process situations that involve us making a choice between an immediate outcome and a distant outcome.

Probabilistic learning

Studies suggest that the ability to integrate feedback from the environment in order to make better subsequent decisions continues to improve across adolescence and into young adulthood. Young adolescents seem more likely to continue making disadvantageous decisions even when given negative feedback longer than older adolescents placed in the same context. While there are mixed results on whether adults are more or less likely to learn from observing an outcome that was worse than expected, it appears that adolescents are just as likely to learn from both positive and negative surprising outcomes. Adolescents might have a harder time integrating feedback from uncertain environments in order to make better subsequent decisions.

Reward processing

The studies identified challenged theories that adolescents are overall ‘hyper’ or ‘hypo’ sensitive to rewards, with several showing great individual variability within age groups, as well as differential recruitment patterns for different stages of reward processing. Studies increasingly supported the idea that reward processing regions are recruited more during the receipt of reward in younger individuals, whereas these same regions were recruited more during reward anticipation in older individuals. This pattern mimics what occurs across a shorter timescale regarding how individuals learn about a specific rewarding outcome.

Risky decision making

Studies suggest that decision making plays a key role in the uptake of health-related behaviours. Some behaviours require the individual to weigh the benefits of risking something to obtain a potentially rewarding outcome, e.g. consumption of alcohol in pursuit of an enjoyable time with friends. Contrary to popular belief, the studies identified do not suggest that adolescents are more likely to choose the riskier option, but instead support the idea that adolescence is a time of differentiation in how an individual responds to risk: with some adolescents showing increasing risk aversion and some showing increasing risk tolerance. As with other cognitive processes, decision making under risk is affected by contextual factors, and adolescents are less likely to select risky decisions when they have been given expert advice, but could be more prone to select a risky decision when the potential reward is highly valued.

Papers reporting health behaviour data

A total of 283 papers reported health behaviour data in relation to adolescent physiological development. These papers spanned both brain physiology and other physiological systems, and focused upon sleep, eating behaviours, physical activity, substance use, sexual behaviour, and risk behaviours in general.

Sleep

Studies suggest that insufficient sleep during adolescence is common and potentially a result of increasing age and pubertal hormone levels rather than changes in brain physiology. However, shifts in bedtime routines during adolescence tend to alter brain activity when processing rewarding outcomes, something detrimental to decision-making in relation to health choices or otherwise, particularly in presence of easily accessible alternative and immediate reward-based activities (entertainment media, etc.). This, coupled with traditional waking times dictated by school hours or social relational factors and so on contributes to sleep deprivation. This can have potential negative effects on mood, attention levels, behaviour, examination grades

and overall learning capacity, ultimately posing health and lifestyle risks both in the short and long term.

Eating behaviour

Studies suggest that neurobiology may predispose adolescents to make healthier eating choices. However, certain individual and physiological factors such as deviations in the typical brain responses to food cues, genetic variants associated with reduced dopamine signalling, varied hormonal influences during puberty or otherwise (especially in case of females), taste sensitivity differences, altered sleep patterns and an individual's overall style of decision making can increase the likelihood of engaging in unhealthy eating. The existing literature comprises multiple theories exploring why and how adolescents naturally predisposed to eating healthy food end up making poor dietary choices. However, for most, causality and direction of influence is unclear, making the evidence relatively inconclusive and the whole issue complex and intangible.

Physical activity

In general, there were very few studies specifically examining how adolescent brain structure or function relates to physical activity during adolescence. The only empirical study that matched the inclusion criteria for this review suggested that aerobic fitness in adolescence may be positively associated with healthier brain signalling between areas of the brain involved in motor function and executive functions. With respect to the influence of other physiological systems on physical activity, the findings seemed to be rather conflicting, particularly regarding the influence of maturity on levels of physical activity, and activity engagement in girls. Disparities in findings were due to a variety of factors, including differing means of measuring biological maturity, the use of maturity status rather than maturation rates, and the range/classification of physical activities used in studies. Thus the available evidence suggests that the relationship between maturation and physical activity is complex and influenced by psychosocial and biological factors that should be taken into account when applying the findings in practice.

Substance use

Studies suggest that developmental changes occurring in the adolescent brain could impact on the likelihood of substance use (alcohol, tobacco, cannabis, etc.) in both adolescence and adulthood. This relationship is complex and bi-directional with certain individual differences in brain structure appearing to predispose individuals to increasing substance use risk, whereas others who use these substances or are over-exposed to them during adolescence may also process substance-use related cues differently and overall follow a different trajectory of brain development than their counterparts. Furthermore, evidence highlights the possible effects of age of exposure, pubertal onset, adaptation to chronic stress, and specific genes or alleles, in conjunction with other socio-economic factors.

Sexual behaviour

Studies suggest that adolescent sexual behaviour is influenced by differing hormonal profiles across both genders and concurrent psychosocial factors that could either enhance or subdue their effect. For instance, for boys, hormonal effects (e.g. from testosterone) appear to be more influential in relation to sexual activity initiation and motivation. For girls, psychosocial factors such as peer influence appear to play a role in decisions to engage in sexual activity. Studies also highlighted links between early sexual maturity and early sexual activity suggesting that advanced physical maturity may be associated with increased risk due to a variety of factors such as greater likelihood of having a romantic partner or experimenting with risky substances. However, due to lack of overall consistency with respect to specific sexual behaviour outcomes measured in various studies identified, the impact on individual behaviours is difficult to ascertain.

Conclusion

Interventions to improve adolescent health and subsequent health outcomes in later life are implemented within the context of many changes unique to this stage of the life course. This review has considered health behaviours in general, and more specifically sleep, eating behaviours, physical activity, substance use and sexual behaviour, within the context of the physiological changes occurring during adolescence. To our knowledge, this review is the first of its kind and represents an up-to-date primer of research that has applicability to those working with and for young people across the policy, practice and research sectors. One key point derived from this review is that although physiological changes on occasions seem to have their independent impact on adolescent health behaviour development, they do not occur in isolation. Rather, they exist alongside myriad other influences, i.e. socio-environmental determinants, shaping and reshaping adolescent health and life trajectories.

The findings of this review indicate a number of nuances specific to adolescent development with clear implications for how we might support young people towards better health. For example, our findings suggest that the adolescent brain is wired in such a way that interventions should be tailored to both ‘hot’ emotional contexts as well as ‘cold’ deliberative contexts, since different processes are used to make decisions under these contexts. Adolescents therefore need to be equipped to deal with both. Thus, interventions to reduce risk-taking behaviour may have more success if they provide adolescents with strategies for dealing with impulsive action (hot) in addition to strategies to support decision making (cold). Other implications are listed throughout this report, with the intention of serving as a guide for those involved in youth health.

With respect to assessing the quality and robustness of evidence, it is important to interpret the findings of this review with some caution, taking into account the context of the studies identified. Many of the brain physiology studies were conducted in laboratory settings, given the inherent difficulties of measuring brain function in non-laboratory settings. The controlled context of such studies is markedly different from the environments in which our young people grow up on a day-to-day basis, and

their attendant challenges and opportunities. There was also a paucity of longitudinal studies. It could therefore be argued that while these studies provide valuable insight into the adolescent brain, there is still much to learn about brain function in relation to how it operates in complex non-laboratory contexts. Additionally, there was a paucity of longitudinal studies across both brain and other physiological systems.

This review represents the foundation for a larger project that aims to understand the full breadth of influences, proximal, distal and their interaction, impacting upon adolescent health behaviour. A comprehensive understanding of such influences will help us to optimise interventions to support young people towards healthy outcomes.

Implications

General implications

- Physiological changes occurring during adolescence should be considered when designing or delivering interventions to improve adolescent health outcomes.

- These changes should be viewed in the context of the wider social environment, and not in isolation.

Interventions – general

- Interventions designed to help adolescents respond healthily in emotionally charged situations may benefit from targeting ‘gut’ responses to potentially problematic situations rather than relying solely on deliberative processes.

- Interventions should emphasise the rewarding aspects of engaging in healthy behaviours as well as the rewarding aspects of not engaging in unhealthy behaviours.

- Situations that require high attentional demand may predispose adolescents to failing at inhibiting unhealthy behaviours. Interventions and support should take this into consideration when discussing strategies to combat unhealthy behaviours.

- Interventions should support young people during the early formation of associations between health-related experiences and outcomes (positive or negative). These early associations have the potential to stem future negative health behaviours, as well as spur future positive health behaviours.

- Interventions that focus upon impulse control may not be appropriate for younger adolescents, who might not be physiologically ready to benefit from this approach.

- Interventions might focus on the anticipation of an outcome for older adolescents, whereas focusing on the receipt of an outcome might be more rewarding in the case of younger adolescents.

- Interventions should be tailored to both 'hot' (emotional) contexts as well as 'cold' (deliberative) contexts. Adolescents use different processes to make decisions under these different contexts.

Interventions – specific behaviours

Sleep

- Those developing interventions should consider how shifts in sleep schedule may impact on health behaviour, in addition to the role of social media and IT equipment.

- Involving the views of adolescents on what would be most helpful to them with regard to optimising sleep and functioning is a vital part of intervention development.

Eating behaviour

- Early dietary advice predating puberty may help to prevent unhealthy dietary behaviours from being exacerbated during adolescence.

- Interventions targeting eating behaviour should consider including components related to optimal sleep and physical activity.

- Effective coping strategies may reduce the likelihood of unhealthy eating. These could be incorporated into life skills interventions present already in school curricula as a general, and inclusive, preventative measure.

Physical activity

- Gender and maturation-rate differences, and perceptions of body image and self-esteem, may inform the development of appropriate strategies to encourage physical activity levels.

Substance use

- Early adolescence might be a particularly vulnerable period. Younger adolescents and older adolescents should be given distinct intervention efforts tailored to their specific age group.

- Early maturity appears to be associated with increased risk of substance use, and an increased length of risk, which may then impact on adult behaviours and health problems. Interventions to target those who mature early may be more beneficial than blanket coverage.

- Psychosocial aspects, including peer influence, family poverty, romantic partners, and parental behaviours, need to be taken into account, and may also help identify the most appropriate intervention target groups.

Sexual behaviour

- Gender differences in maturity need to be taken into account when designing interventions to promote sexual health. Stage of readiness to receive interventions may differ according to maturity levels.

- Social context, cultural and religious influences need to be acknowledged in, and adaptability built into intervention development in this area.

Research implications

- More robust longitudinal studies are needed in this area, enabling the inference of causality and to further categorise trajectories of adolescent development.

- Follow-through data into adulthood is necessary to clarify the links between adolescent physiological development, behaviours in adolescence and subsequent behaviours and outcomes in adulthood.

- The inclusion of lay summaries and explanatory comments would increase the accessibility of research papers of this sort to practitioners and policy makers.

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