BMJ Open

Typologies of activity-related behaviours during adolescence and their transitions: a longitudinal analysis of the ELSPAC cohort

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To cite: Janda D, Gába A, Contardo Ayala AM, *et al*. Typologies of activity-related behaviours during adolescence and their transitions: a longitudinal analysis of the ELSPAC cohort. *BMJ Open* 2024;**14**:e088907. doi:10.1136/bmjopen-2024-088907

► Prepublication history for this paper is available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2024-088907).

Received 17 May 2024
Accepted 22 November 2024

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ABSTRACT

Objectives The objective of this study was to identify typologies of activity-related behaviours during adolescence and to explore transitions between the identified typologies. Additionally, we aimed to identify demographic indicators associated with the transitions and typology membership.

Design Prospective cohort study.

Setting Czech Republic.

Participants Individuals involved in the Czech part of the European Longitudinal Study of Pregnancy and Childhood study, aged 11 to 18 years. The study involved over 563 individuals, of whom 380 provided complete data for the analysis.

Primary outcome measures Time spent outdoors, participation in organised physical activity (PA) and sport activities, time spent watching television and using a personal computer, and total sleep duration at ages 11, 15 and 18 years. Typologies were identified using Latent Transition Analysis.

Results Four typologies of activity-related behaviours were identified and labelled to reflect their behavioural profiles: (1) *Actives* (high outdoor time and organised PA and sport participation, low screen time and optimal sleep duration); (2) *Active screeners* (median outdoor time, high organised PA and sport participation, high screen time, and optimal sleep duration); (3) *Poor sleepers* (average outdoor time and organised PA and sport participation, low screen time and not meeting sleep guidelines) and (4) *Averages* (average duration of all behaviours and optimal sleep duration). A major shift in typology membership from 11 to 18 years was observed, with a decreasing proportion of individuals in typologies characterised by a high proportion of outdoor time and participation in organised PA and sport activities (ie, *Actives*; *Active screeners*). A high proportion of individuals also transitioned to the typology with poor sleeping habits (ie, *Poor sleepers*). Sex and maternal education were associated with the typology membership and transition probabilities ($p<0.05$).

Conclusions Targeting lifestyle interventions to those with specific lifestyle patterns in early adolescence may be beneficial for reducing the risk of poor sleep and promoting healthy lifestyle patterns later in life.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The longitudinal design allows an investigation of unique activity-related behaviour patterns across the transition from early to late adolescence.
⇒ Using various activity-related behaviours (eg, outdoor time and screen time) provides a comprehensive understanding of the lifestyle of adolescents.
⇒ Data were collected from a specific geographical region in Central Europe, which may limit the generalisability to a broader population.

INTRODUCTION

Adolescence is a critical stage of human development, during which rapid physical, mental and social changes occur.[1] From early to late adolescence,[2] individuals engage in various lifestyle behaviours and form habits that contribute to their overall physical and mental health.[3 4] Previous evidence has shown that healthy lifestyle habits, characterised by adequate physical activity (PA),[5] low sedentary behaviour (SB)[6] and optimal sleep,[7] when developed during adolescence, can persist into adulthood. Therefore, this period of life offers a valuable opportunity to promote a healthy lifestyle and establish beneficial routines, potentially leading to a positive long-term health trajectory.

Previous longitudinal studies have shown a decline in PA levels and sleep duration, and an increase in SB over the course of adolescence.[8–10] Shifting towards an unhealthy lifestyle can affect both physical and mental health and may result in detrimental health conditions with long-term health consequences.[11] Lifestyle patterns can be better understood by exploring how different behaviours cluster together. This is important as some behaviours may be beneficial, while others may not. Identifying groups of adolescents based on patterns or clustering

of lifestyle behaviours (typologies) and the timing of changes in typologies that occur during adolescence is important for many reasons. Specifically, it can help to identify target population groups and design effective interventions tailored to specific developmental stages of life, with a view to promoting lifelong healthy habits.

Most of the existing research examining typologies of activity-related behaviours concentrates on the clustering of PA, SB and sleep, limiting our understanding of the role of other activity-related behaviours in health and disease prevention. This narrow scope might overlook some specific domains of lifestyle behaviours that may have a substantial impact on overall health and serve as potential targets for intervention strategies. For example, available evidence highlights the protective role of outdoor time in reducing the risk of diabetes and high blood pressure.[12] Excessive screen time, a specific domain of SB, has also been found to be associated with an elevated risk of obesity and depressive symptoms in adolescents.[13] However, how these specific activity-related behaviours contribute to the formation of distinct typologies is unknown.

The systematic review conducted by Parker *et al*[14] reflects an intensive effort that has been devoted to identifying typologies of activity-related behaviours in youth over the past two decades. This review found that youth tend to cluster into distinct groups based on combinations of PA, SB and a range of other lifestyle factors. Older adolescents are more likely to exhibit unhealthy patterns such as low PA and high SB, while younger adolescents are more likely to belong to healthier, more active typologies. However, the majority of published studies were cross-sectional, limiting their ability to investigate how these typologies change over time. Moreover, the limited studies examining transitions between typologies during adolescence have found that most individuals remain in the same typology over time, with only small proportions transitioning to more or less favourable typologies.[15 16] However, these studies generally have short timeframes with limited exploration of typology changes during critical stages such as the transition from early to late adolescence. Although there is a wealth of research on individual activity-related behaviours during adolescence, there remains a lack of clarity regarding how additional activity-related behaviours (eg, outdoor time and screen time) contribute to the formation of typologies, and how individuals transition between these typologies over different stages of adolescence. Furthermore, understanding determinants of changes in typologies over time, as in cross-sectional examples,[17 18] is also important to help identify targets for behavioural interventions.

To address this evidence gap, the present study aims to identify typologies of activity-related behaviours in adolescence, explore transitions between the identified typologies during critical developmental periods and identify demographic indicators of the transitions and typology membership.

METHODS

The present study used longitudinal questionnaire data from participants residing in the Czech Republic who were involved in the European Longitudinal Study of Pregnancy and Childhood (ELSPAC-CZ). The detailed study protocol and the cohort description are provided elsewhere.[19] Briefly, the ELSPAC-CZ study collected perinatal information on 5151 mother–child pairs from maternal self-report questionnaires in 1991–1992 and followed the children's development up to the age of 19 years (n=563). Our analysis specifically used self-reported data on activity-related behaviours collected when participants were 11 years old in 2002–2003, 15 years old in 2006–2007 and 18 years old in 2009–2010. These ages were chosen as they represent critical transition periods during adolescence. The final analytical sample consisted of participants who provided complete data of interest at all three time points (n=380).

Informed consent was obtained from all study participants and their parents or legal guardians prior to completing each questionnaire. All methods were performed in accordance with the relevant guidelines and regulations of the Declaration of Helsinki and the data were anonymised for research purposes. The data collection was carried out by trained secondary medical staff.

Assessment of activity-related behaviours

Data on activity-related behaviours were collected through tailored questionnaires which were used to query participants about their sleep duration, time spent in PA, outdoor time and in front of screens. The questionnaires were administered at three distinct time points, with data collection occurring throughout the entire year. Participants were asked to report their time spent outdoors during school days separately for summer and winter. They also reported their time participating in organised PA and sport activities during school days. Screen time assessment involved quantifying the time spent watching television (TV) and using a personal computer (PC) separately for entertainment purposes on school days. The four possible answers for all listed questions were as follows: 'none', 'less than 1 hour', '1–2 hours' and 'more than 3 hours' per day. Additionally, participants' mothers were asked at all time points about their child's mean sleep duration on school days. For the purpose of the present study, participants were labelled as either 'meeting' or 'not meeting' optimal sleep duration based on the guidelines from the American Academy of Sleep Medicine, which recommend 9–12 hours per day for individuals aged 6–12 years old and 8–10 hours per day for those aged 13–18 years.[20]

Covariates

In this study, sex of participants and maternal education (at 11 years) were employed as covariates. Maternal education, initially recorded in nine categories, was dichotomised into 'non-university education' and 'university

degree' to maintain a meaningful interpretation. There were four cases with missing maternal education, which were missing completely at random. Due to these reasons, a multiple imputation method, involving 10 iterations and 10 imputed datasets, was used to impute missing data for maternal education.

Statistical analysis

Descriptive statistics were calculated using R software V.4.3.1.[21] Latent Transition Analysis (LTA) was conducted using LatentGold V.6.0 (Statistical Innovations, Arlington, USA). LTA, a type of latent Markov model,[22] was employed to analyse longitudinal data and identify distinct typologies and transitions between them at different time points.[23] Activity-related behaviours served as input variables for the LTA models.

We tested models with 2–5 typologies to determine the optimal solution. Model fit was assessed using the Bayesian information criterion (BIC) and Akaike information criterion (AIC),[24] which evaluate the trade-off between model fit and complexity. In case of disagreement in the information criteria, we followed the recommendation by Collins and Lanza,[23] who advise selecting more meaningful and simpler models when BIC and AIC yield conflicting results. The goodness of fit was also evaluated using the Vuong likelihood-ratio test, comparing models with n+1 typologies to those with n typologies ($p<0.001$ indicates that the n model is superior to the n+1 typology model). Entropy was employed to assess the certainty of classifying individuals into distinct typologies based on their activity-related behaviour patterns, with values closer to 1 indicating a better fit. Additionally, we examined the size and meaning of the identified typologies, ensuring that the minimal typology size was not less than 10% of the total sample size, averaged across all time points.[23 25 26]

Due to a theoretical relationship and high bivariate residuals (BVRs) (BVR=27.6)[27] between outdoor time during summer and winter, we included a direct effect between these two variables to account for possible local dependencies and unexplainable variance accounted by the LTA model. To verify how demographic indicators were associated with typology membership at the initial state and transition probabilities, we used the bias-adjusted three-step LTA method.[28] Descriptive statistics for each typology were calculated as weighted proportions, using the posterior probability of assignment to a given typology as a weight for each observation.

Patient and public involvement

Participants and the general public were not involved in the design of this study. All participants were fully informed of the study's objectives, and their own and their parent/guardian's informed consent was obtained. Participation in the survey was entirely voluntary, and no patient input was sought during the interpretation of the data. The findings will not be shared directly with the participants.

RESULTS

The sample (n=380) consisted of 57% of girls. At baseline, the average age was 10.9 (standard deviation [SD]: 0.56) years and 90% of participants attended public schools in the Czech Republic. At the final follow-up, the average age was 18.2 (SD: 0.45). Approximately one-third (35%) of participants' mothers had a university degree. Based on the selection criteria, the best-fitting model revealed that four typologies provided the best fit across the three time points (table 1). The response probabilities for each typology at baseline are presented in table 2. The four typologies can be described as *Actives*, characterised by the highest proportion of time spent outdoors, time spent in organised PA and sports and a low level of screen time (both in front of TV and PC); *Active screeners*, characterised by moderate levels of outdoor time and the highest proportion of time spent in front of TV and PC; *Poor sleepers*, characterised by a low proportion of meeting sleep recommendations and low time spent in front of PC. *Averages* were characterised by median levels of all activity-related behaviours except sleep, which was similar to other typologies other than *Poor sleepers*. The most prevalent typology at the age of 11 years was *Averages* (65.1%), followed by *Active screeners* (21.0%), *Actives* (12.8%) and *Poor sleepers* (1.1%).

The transition probabilities indicated that at least 53.2% of individuals remained stable in their typology during the transition from 11 to 15 years (figure 1). From

Table 1 Statistical indicators for the transition models with 2–5 typologies

	2 states	3 states	4 states	5 states
BIC	14318.5	14164.6	**14145.3**	14168.1
AIC	14212.1	13999.1	**13904.9**	13837.1
Entropy	0.63	0.64	**0.66**	0.69
VLMR (p value)	<0.001	0.007	**0.091**	0.413
Minimal size (%)*	40.7	23.2	**18.4**	13.3

Boldface values indicate best fit based on our selection criteria.
*Reflects the average minimum size of the typologies across all time points in each solution.
AIC, Akaike information criterion; BIC, Bayesian information criterion; VLMR, Vuong likelihood-ratio test.

Table 2 Response probabilities across the identified typologies at baseline

	Overall	Actives	Active screeners	Poor sleepers	Averages
	%	%	%	%	%
Outdoor time during weekdays, average per day (summer)					
≥3 hours	42.7	72.0	54.9	35.7	27.7
1–2 hours	42.0	25.6	38.0	47.7	48.4
<1 hour	14.0	2.4	6.8	15.3	21.6
None	1.3	0.1	0.3	1.2	2.4
Outdoor time during weekdays, average per day (winter)					
≥3 hours	9.9	22.6	14.2	1.9	6.2
1–2 hours	44.5	57.8	54.4	28.0	42.0
<1 hour	41.2	19.2	30.0	59.7	47.3
None	4.4	0.5	1.3	10.4	4.6
Time spent in front of the PC, average per day					
≥3 hours	8.0	0.2	37.5	0.0	2.3
1–2 hours	22.5	6.8	52.1	1.3	26.4
<1 hour	27.5	29.4	9.5	14.8	40.4
None	42.1	63.6	0.9	83.9	30.9
Time spent in front of the TV, average per day					
≥3 hours	12.2	15.7	28.1	3.1	7.9
1–2 hours	49.2	56.9	57.1	34.8	49.1
<1 hour	32.2	24.8	13.9	47.0	36.5
None	6.4	2.6	0.8	15.1	6.5
Organised physical activity and sports participation, average per day					
≥3 hours	12.1	29.8	18.4	7.7	3.6
1–2 hours	37.0	49.6	48.0	37.0	26.6
<1 hour	34.7	18.1	27.5	39.2	43.0
None	16.2	2.6	6.1	16.1	26.8
Sleep, average per day					
Meeting recommendation	74.0	76.7	87.0	37.5	84.4
Not meeting recommendation	26.0	23.3	13.0	62.5	15.6

Sleep recommendations: 11 years: 9–11 hours, 15 and 18 years old: 8–10 hours.[20]
PC, personal computer; TV, television.

Actives (72.1% stability), 18.3% transitioned to *Active screeners*, 9.3% transitioned to *Poor sleepers*, and there was a minimal probability of transitioning to *Averages* (0.3%). From *Active screeners* (85.9% stability), the highest proportion of individuals transitioned to *Actives* (10.6%), while the rest transitioned to *Poor sleepers* (2.6%) and *Averages* (1.0%). Most individuals from the *Poor sleepers* (53.2% stability) at 11 years transitioned to *Actives* (24.6%) and *Averages* (20.5%), while only 1.8% transitioned to *Active screeners*. Moreover, a considerable proportion (18.2%) of individuals from *Averages* (66.8% stability) transitioned to *Actives*, while 9.0% and 6.0% transitioned to *Poor sleepers* and *Active screeners*, respectively. At 15 years, the distribution of the typologies was relatively comparable with 11 years, with the highest proportion of individuals belonging to *Averages* (44.0%), followed by *Active screeners* (24.3%), *Actives* (23.6%) and *Poor sleepers* (8.1%).

The observed transitions (figure 1) between 15 and 18 years were notably different in comparison with the transitions from 11 to 15 years. From *Actives* (64.5% stability), most individuals transitioned to *Poor sleepers* (35.3%), while only 0.1% transitioned to each of the *Active screeners* and *Averages* typologies. *Active screeners* (42.1% stability) transitioned mostly to the *Averages* (29.9%) and the *Actives typologies* (21.1%), while only 6.9% transitioned to the *Poor sleepers* typology. Minimal outflow from *Poor sleepers* was observed due to almost 99.5% stability in this typology, as only 0.2% transitioned to *Actives* and 0.1% transitioned to *Active screeners* and *Averages*. Most individuals transitioning from *Averages* (25.3% stability) transitioned to *Poor sleepers*

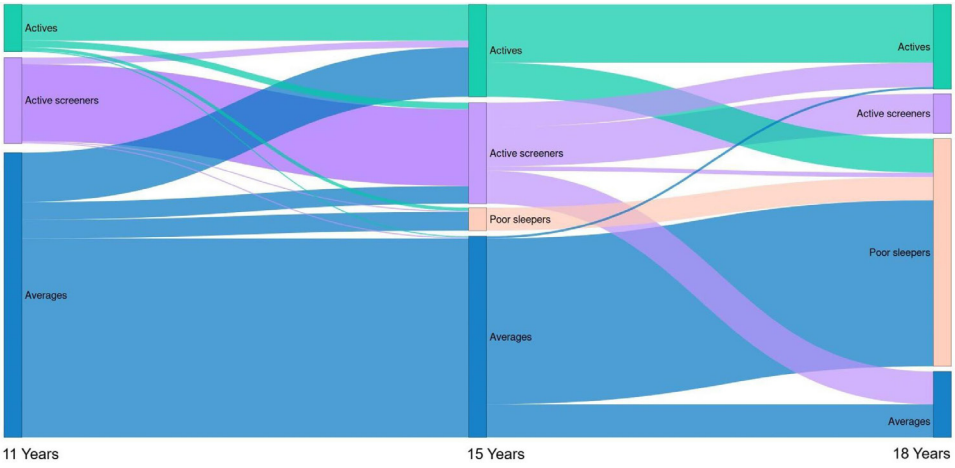

Figure 1 Illustration of transition probabilities across identified typologies (based on a hard assignment).

(74.3%); only 0.3% transitioned to *Active screeners* and 0.1% to *Actives*. The final proportion of individuals in each typology at 18 years of age showed a high proportion of *Poor sleepers* (50.8%), followed by *Actives* (20.4%) and *Averages* (18.4%), while only 10.4% of individuals were observed in the *Active screeners* typology.

The demographic characteristics of the identified typologies are presented in table 3. At the initial time point, girls were more likely to be in the *Poor sleepers* typology in comparison with other typologies (p<0.001). Sex was also associated with the probability of transitioning from one typology to another as boys were more likely to transition to *Averages* from other typologies at a previous time point (p<0.05 for all). Girls were more likely to transition to *Poor sleepers* from *Active screeners* (p<0.001). Children of mothers with higher education were most prevalent in *Poor sleepers* (43%) and *Active screeners* (41%) (p=0.038). The education of mothers was also associated with the transition probabilities (p=0.002).

DISCUSSION

Our study identified four distinct typologies of activity-related behaviours in adolescents based on their participation in organised PA and sports, screen time, outdoor time and sleep. We also revealed that the proportion of adolescents in these typologies changes during the transition from early to mid and late adolescence, and sex and maternal education status were associated with these changes. Specifically, there was a major shift in typology membership from 11 years to 18 years, with a decrease in the proportion of individuals in the *Active screeners* and *Averages* typologies and an increase in the proportion of individuals in the *Poor sleepers* typology. The most common transition was from the *Averages* to the *Poor sleepers* typology.

The typologies were differentiated by most variables used to estimate the typologies, except for sleep. Our study showed a high probability of meeting the recommended sleep duration in three of the four typologies. The observed size of the *Poor sleepers* typology over the follow-up period suggests that many adolescents are not getting the recommended amount of sleep, which is critical for their overall health.[7] This trend highlights the need to focus on improving sleep-related behaviours, such as establishing regular sleep schedules and ensuring a conducive sleep environment. Recent research has shown that factors like strong parental support (eg, enforcing bedtime rules), positive attitudes towards sleep and reducing perceived barriers such as stress or fear of missing out are vital in improving sleep duration and quality among adolescents.[29] To mitigate these risks, schools and healthcare professionals can implement programmes that educate adolescents and their parents about healthy sleep practices and sleep benefits.

An important finding from this study was that *Active screeners* were characterised by the combination of high

Table 3 Demographic indicators of the identified typologies at the initial time point

	Overall	Actives	Active screeners	Poor sleepers	Averages		
	%	%	%	%	%	P value*	P value†
Girls, %	56.6	65.7	20.1	76.7	66.2	**<0.001**	**<0.001**
Mother university degree	34.6	28.8	41.1	42.9	33.7	**0.038**	**0.002**

Boldface values indicate significant difference between typologies at p<0.05.
*Indicates associations between the indicators and typology membership.
†Indicated associations between the indicator and transition probability between the typologies.

screen time and high PA and sports participation. As was previously demonstrated by Ferrar *et al*,[30] these behaviours can coexist. The identification of the *Actives* typology suggests that there is a subgroup of individuals who engage in organised sports activities while also adhering to recommended sleep duration and having lower screen time compared with other typologies. A similar typology was observed in the study by Parker *et al*,[16] suggesting that this combination may be common in different contexts. However, this typology had a proportion below 24% during all three time points, and interventions should be targeted to ensure more adolescents have a similar combination of behaviours.

More than half of individuals remained stable in their typology during the transition from 11 to 15 years; however, there were some notable transitions. The proportion of participants in the *Poor sleepers* typology was minimal at 11 years and slightly increased in size at the age of 15 years. This suggests that there might be a shift towards unhealthy behaviours during mid-adolescence,[2 10] which may be caused by changes in social dynamics, such as parent–child and peer relationships.[31] Starting early with educating children and their parents about the health consequences of poor sleep habits may be necessary. Conversely, the increased proportion of individuals in the *Actives* typology may indicate a potential increase in organised sports participation, which is consistent with previous literature.[32] Approximately 1 in 10 participants transitioned from the *Averages* to the *Actives* typology during this period, suggesting that some individuals may become more physically active as they transition into their teenage years. Future longitudinal studies should focus on these individuals, helping to understand what makes them improve their activity. Individuals in the *Averages* typology may benefit the most from intervention efforts, which could prevent the development of unhealthy activity patterns in later years.

Lower stability was observed throughout the transition from 15 to 18 years in comparison with the earlier period. While *Poor sleepers* and *Actives* remained relatively stable, *Active screeners* and *Averages* manifested strong outflow. With almost half of the proportion of the total sample at 15 years, three-quarters of *Averages* transitioned to *Poor sleepers* by 18 years. These observations indicate that individuals with moderate levels of activity-related behaviours and optimal sleep duration may be inclined to unhealthy sleeping habits when they get older. Unlike the earlier period, late adolescence is characterised by increased autonomy, making adolescents more responsible for managing their behaviours.[31] On the other hand, more than 20% of *Active screeners* transitioned to *Actives*, as these individuals decreased their screen time. However, the *Actives* typology consisted mainly of individuals from the *Actives* and *Active screeners* typologies, suggesting that active individuals may maintain a higher amount of PA into early adulthood relative to others. It is necessary to note that our results are in contrast to previous research focusing on transitions of PA and SB typologies from mid to late adolescence (ages 16–18), which indicated over 80% of stability.[16] These differences might be accounted for by different indicator variables used in our analysis, such as the inclusion of sleep and outdoor time, but also to sample differences, as person-oriented approaches may be sample sensitive.[33]

The association between demographic characteristics, such as sex and maternal education, and typology membership and transitions offers valuable insights into the influence of sociodemographic factors on activity-related behaviours in adolescents. For example, the study revealed that boys were more likely to be classified in the *Active screeners* typology compared with girls. This aligns with previous research suggesting that boys tend to engage in more screen-based activities while staying active compared with girls.[30 34] Furthermore, our study found that individuals with mothers who had a university degree were more likely to be in the *Active screeners* typology compared with those with lower maternal education. These findings contrast current evidence suggesting a positive association between higher parental education and lower screen time.[35 36] Our study focused on screen time for entertainment purposes on school days, and the inclusion of education-based and weekend screen time may provide different results. However, it is possible that households with higher socioeconomic status have more screen devices available at home[37 38] and, therefore, more opportunities for screen time. Additionally, both *Active screeners* and *Poor sleepers* had over 40% of highly educated mothers, but also the highest sex differences were observed between these two typologies, suggesting that sex (in this case males) might be another important predictor of screen time. Nevertheless, it is necessary to interpret these findings cautiously, as these may be influenced by various contextual factors, such as parental modelling, which may play an important role at different stages of development of the children.[35]

Our study is one of the first to examine activity-related typologies and their transitions from early to late adolescence. The use of a longitudinal design allowed for the examination of activity-related behaviour typologies and their transitions over time. Additionally, utilising previously under-researched activity-related behaviour variables (ie, outdoor time and screen time) provided a comprehensive understanding of the lifestyle of adolescents.

Several limitations should also be acknowledged. One limitation is that the study relies on self-reported data, which may be subject to recall bias or social desirability bias. Also, we have used only data about behaviours during school days, when there might be significant variability of movement behaviours between school and weekend days.[39 40] Additionally, the findings may have limited generalisability, as the study sample was drawn from a specific geographical region within the Czech Republic (southeast) and may not represent broader populations. The high level of participant attrition limits the ability to draw general conclusions. Conducting further research

with larger and more diverse samples would help to strengthen the generalisability of these findings. Furthermore, our study did not account for other factors that may influence typology and transition including potential access to spaces for PA, such as a backyard, greenspace, bicycle paths or recreation facilities. Future studies could explore these as environmental correlates of activity-related typologies. Data collection occurred year-round, but response distribution across the years was uneven. This imbalance may introduce bias, particularly for variables related to outdoor time, potentially impacting the generalisability of findings regarding seasonal activities or perceptions. Lastly, LTA was used to identify the typologies, which may oversimplify the complex nature of adolescents' behaviours, potentially overlooking differences in the identified typologies. The data-driven nature of the statistical approaches used is a strength, but different datasets may yield different typologies.

Future research could delve deeper into the specific factors (eg, social and environmental) influencing the transitions between these typologies, allowing for a more nuanced understanding of the dynamics of activity-related behaviours during adolescence. This could lead to the development of targeted interventions that address the specific needs of different groups and explore mental and physical health consequences, ultimately promoting healthier activity-related behaviours and overall well-being.

CONCLUSION

Four distinct typologies of activity-related behaviours in adolescents were identified, along with shifts in typologies over time, shedding light on the dynamic nature of these behaviours during a critical period of development. Most individuals remained in the same typology between the ages of 11 and 15, whereas there was more variability between the ages of 15 and 18 years. This highlights the significant shifts in lifestyle and behavioural patterns, particularly the increase in the proportion of individuals with poor sleep patterns. These findings underscore the importance of implementing interventions that target multiple behavioural patterns and are oriented towards individual characteristics to maintain and improve lifestyle quality.

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Contributors DJ drafted the initial manuscript, conceptualised the study and conducted the analyses; AG, AMCA, AT and LAr conceptualised and designed the study, contributed to writing and critically revised and edited the manuscript; LAn and PP were responsible for the data curation and critically revised the manuscript. All authors have read and approved the final version of the manuscript, and agreed with the order of presentation of the authors. DJ is the guarantor.

Funding The CELSPAC-CZ study is supported by the RECETOX RI project financed by MEYS (LM2023069). This work is supported by the European Union's Horizon 2020 research and innovation program under grant agreement No. 857560. This publication reflects only the author's view, and the European Commission is not responsible for any use that may be made of the information it contains. DJ is supported by a student research grant (DSGC-2021-0022), which was funded by the OP RDE project "Improving schematics of Doctoral student grant competition and their pilot implementation", with Reg. No.: CZ.02.2.69/0.0/0.0/19_073/0016713 and from the Palacký University Olomouc internal grant (IGA_FTK_2023_001). AG is supported by the Czech Science Foundation (22-02392S). LAr is supported by an Australian Research Council Discovery Early Career Researcher Award (DE220100847).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval This study involves human participants and each wave of the study was approved by local ethics committees, the Ethics Committee of the Child Health Research Institute until 2002, and from 2003, the Ethics Committee of the Faculty of Medicine Masaryk University, Brno, the Czech Republic. The secondary use of all ELSPAC-CZ study data was approved by the (C)ELSPAC Ethics Committee (Ref. No. ELSPAC/EK/1/2014, dated 17 September 2014). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The data that support the findings of this study are available from www.elspac.cz by Research Centre for Toxic Compounds in the Environment (RECETOX) but restrictions apply to the availability of these data, which were used under licence for the current study and so are not publicly available.

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