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Health behavior, health, and socioeconomic background in adolescence as risk factors for traumatic brain injuries: A longitudinal study

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ABSTRACT

Introduction: Traumatic brain injuries (TBI) are a considerable health burden on adolescents and young adults. This study aims to assess the influence of health compromising behavior, poor perceived health, poor school success, and low family socioeconomic background during adolescence on subsequent TBI in a large cohort of Finnish adolescents with an average 25-year follow-up.

Materials and methods: Baseline Finnish Adolescent Health and Lifestyle survey data gathered biennially (1981–1997) was linked with the diagnosis of subsequent TBI from the Finnish Care Register for Health Care. A structural equation modeling (SEM) was used to analyze the associations between health behavior, poor perceived health, poor school success, and low family socioeconomic background during adolescence on subsequent TBI.

Results: Total of 41 336 persons were included in the analyses. During the follow-up, 1 459 (3.5 %) TBIs occurred. Men were more likely to suffer a TBI. The mean follow-up time was 25.3 years (SD 4.0) and the mean age at the time of TBI was 32.1 years (SD 7.7). Health compromising behavior and not living with both parents in adolescence were associated with the increased risk of TBI. Also, poor perceived health and stress symptoms increased the risk of TBI. Low family socioeconomic status (SES) was only indirectly associated with TBI trough health compromising behavior.

Conclusion: The main finding was that health compromising behavior was associated with TBI, and low family SES was associated with TBI through health compromising behavior in later life. Poor perceived health, stress symptoms, and not living with both parents in adolescence increased the risk of TBI, too. Our findings suggest that adolescents who are at risk of drifting into health compromising behavior and report stress symptoms have an increased risk of TBI in later life.

Introduction

Traumatic brain injury (TBI) is a major global health issue causing long-term health consequences and burden to health systems and societies. Incidence of TBI is higher among adolescents, young adults, and the elderly [1]. Males have a higher risk of suffering TBI compared to females [2,3]. Globally, the overall incidence of TBIs has declined and this has been noticed in the Finnish working age population, too [2]. Despite the declining trend, 27 to 69 million new TBIs will occur annually [4–6].

Both health enhancing and health compromising behaviors are associated with the risk of TBI. Previous studies have linked alcohol consumption, illicit drug use, and smoking to an increased risk of TBI [7–9]. Sports participation, while generally beneficial for health, increases the risk of TBI [10,11], although these are often mild [12,13]. Socioeconomic circumstances of the family shape adolescents' health behavior and health [14–16] and may be indirectly linked to TBI. Among young adults and during adulthood, lower SES increases the risk

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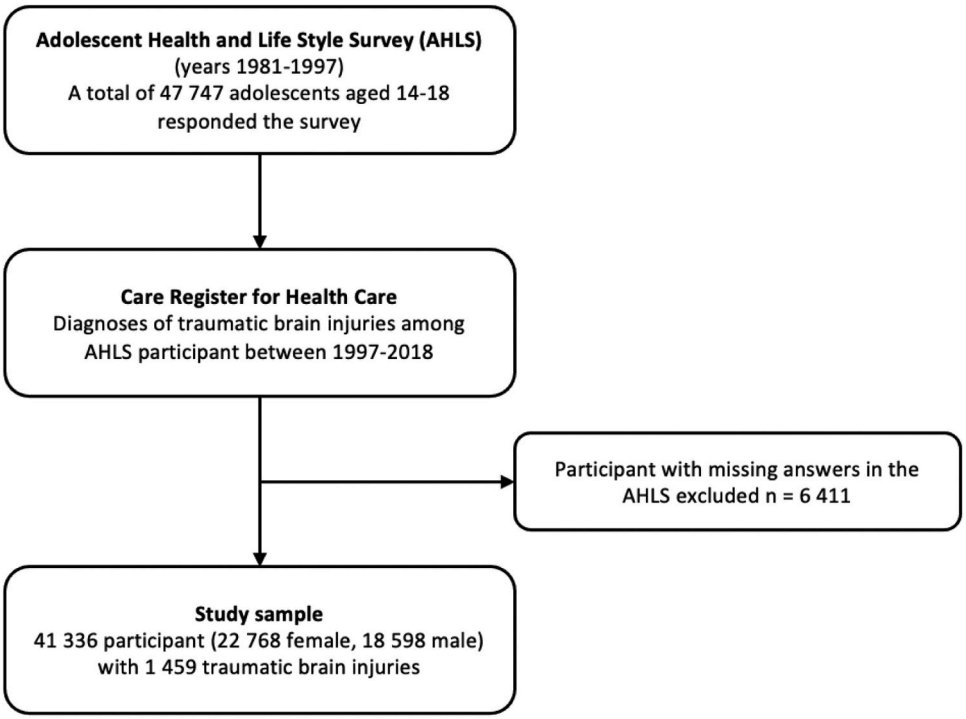

Fig. 1. Flowchart for forming the final study sample.

of TBI [17,18]. There is also evidence of a higher risk for TBI among young males with low educational attainment [9]. Further, childhood adversity and mental health issues are associated with greater susceptibility to TBI [19,20]. Even though, health behaviors, socioeconomic circumstances and psychological factors are known to contribute to the risk of TBI, long follow-up studies among adolescent are scarce [7,21,22]. Our study assesses the influence of health compromising and health enhancing behavior, poor perceived health, poor school success, and low family SES in adolescence on subsequent TBI in a large cohort of Finnish adolescents with an average follow-up of 25 years.

Methods

Study design

In this longitudinal study, the survey data from the Adolescent Health and Lifestyle Survey (AHLS) were individually linked with sociodemographic data from Statistics Finland and with outcome data retrieved from the Care Register for Health Care (formerly the Hospital Discharge Register). The endpoint of the follow-up for each participant was the first hospital visit or admission due to TBI, emigration, or the termination of the follow-up on December 31, 2018. The study protocol was approved by the Institutional Review Board of Statistics Finland and by the Data Protection Ombudsman. The Joint Commission on Ethics of the University of Turku and the Turku University Hospital stated that no human rights were violated in the research protocol and approved it.

Baseline data

The baseline data were sourced from the AHLS data base [23] which covered data on biennial mailed surveys to representative samples of Finnish adolescents from 1977 to 2019. Comparable samples each year covered all Finns aged 14, 16, or 18 in the study year, and who were born on certain days in June, July, or August. The surveys took place between February and March, with individual follow-ups commencing from the conclusion of each survey on April 30 of the survey year. Samples were drawn from the Population Register Centre. Two re-inquiries were mailed to non-responders. The study utilized data collected between 1981 and 1997. If the responders had answered more than one survey, the answer from his/her first survey was used. The baseline cohort consisted of 60 941 individuals from which 47 747 responded to the survey. The overall response rate was 78 %, 71 % in men and 86 % in women. Individuals with missing answers in the AHLS were excluded from the study (n = 6411). The formation of the study sample is shown in the Fig. 1.

Table 1
ICD-10 codes used for TBI.

ICD-10 code	
S06	Intracranial injury
S06.0	Concussion
S06.1	Traumatic cerebral oedema
S06.2	Diffuse brain injury
S06.3	Focal brain injury
S06.4	Traumatic epidural hemorrhage
S06.5	Traumatic subdural hemorrhage
S06.6	Traumatic subarachnoid hemorrhage
S06.7	Intracranial injury with prolonged coma
S06.8	Other intracranial injuries
S06.9	Intracranial injury, unspecified

Outcome variable

The outcome was an outpatient visit or hospitalization due to TBI, independently of other reasons of the admission. Only the first diagnosis was included. Outcome variables were obtained from the Care Register for Health Care, which includes information on participants discharged from inpatient care, day surgeries, and specialized outpatient care [24]. The coverage and accuracy of the Care Register for Health Care are good with high positive predictive value [25–27]. ICD-10 (International Classification of Diseases 10th revision) diagnoses were used to identify TBIs starting from the year 1997 for better data reliability (Table 1).

Table 2
Description of explanatory variables used in the analyses.

Variable and its source	Original variable and formation of the variable used in the analyses	Values
SES, parental educational status, Statistics Finland	Educational-based status of the respondent' mother and father from the national registries of Statistics Finland. The registry data on socioeconomic circumstances had been obtained from national censuses conducted every fifth year until 1995 and from on-line registry data on a yearly basis from 2000 onwards. Classification of Statistics Finland.18	Both parents' high= 1 Either one high = 2 Either one middle = 3 Both parents' low = 4
SES, parental occupational status, Statistics Finland	Occupation-based status of the respondent' mother and father from the national registries of Statistics Finland. The registry data on socioeconomic circumstances had been obtained from national censuses conducted every fifth year until 1995 and from on-line registry data on a yearly basis from 2000 onwards. Classification of Statistics Finland.18	Both parents' unknown = 1 Both parents upper white-collar = 2 Either one upper white-collar = 3 Either one lower white-collar = 4 Either one blue-collar = 5
Family structure, AHLS	Question on living with mother and father	Living with both parents = 1 Other = 2
Daily use of tobacco, AHLS	Combining questions on tobacco experimentation and frequency of tobacco use	No = 1 Yes = 2
Drinking style, AHLS	Question on frequency of alcohol use and drunkenness	Never drunk = 1 Drunk occasionally = 2 Drunk once or twice a month = 3 Drunk once a week or more often = 4
Frequency of physical activity in leisure time, AHLS	Question on frequency of leisure time physical activity	Never = 1 2 to 3 times a week or less = 2 4 or more times a week = 3
Frequency of physical activity in sports clubs, AHLS	Question on frequency of leisure time physical activity	Never = 1 2 to 3 times a week or less = 2 4 or more times a week = 3
Self-reported chronic disease and disabilities, AHLS	Question on long-term disease or disability that disturbs your everyday life.	No = 1 Yes = 2
Perceived health, AHLS	Question on perceived health	Excellent = 1 Good = 2 Average = 3 Poor = 4
High BMI, AHLS	BMI calculated from self-reported height (cm) and weight (kg)	No = 1 Yes = 2 (High BMI according to Cole's criteria) [28]
Self-reported daily stress symptoms, AHLS	A summary variable on the number of daily stress symptoms (stomachache, tension, irritability, sleep difficulty, headache, trembling of the hand, and feeling tired or weak)	None = 1 1 per day = 2 2 or more per day = 3
School success, AHLS	Among 14-year-olds, school success was based on the respondents' self-assessments of their success in relation to the class average. In 16–18-year-olds, the information was based on the success and educational path chosen after completion of comprehensive school education	Excellent = 1 (age 14: much better than average; 16–18: academic track and much better than average) Good = 2 (age 14: better than average; 16–18: academic track and better than average / academic track and better than average / academic track and average/ vocational and much better or better than average) Average = 3 (age 14: average; 16–18: academic track and slightly poorer than average / vocational and average or slightly poorer than average) Poor = 4 (age 14: slightly or much poorer than average; 16–18: academic track and much poorer than average / vocational and much poorer than average / not at school)
Urbanization level of residence, AHLS	Question on urbanization level of residence	Capital area = 1 Large town = 2 Small town = 3 Village = 4 Sparsely populated rural municipality = 5

Explanatory variables

Variables describing health behaviors, chronic disease, stress symptoms, family structure, urbanization level of residence, and school success were obtained from the AHLS and family SES from the national registries of Statistics Finland. Family SES and family structure describes socioeconomic family background. A description and definitions of the variables used in the analyses are shown in Table 2.

Statistical methods

Structural equation modeling (SEM) was used to examine the association of TBIs with explanatory variables. SEM is a set of statistical methods combined to measure how data support the constructed theoretical models describing the web of associations between the studied constructs [29].

Latent variables were formed from the measured ones, exogenous variables, using confirmatory factor analysis [29]. The latent variable "family SES" was formed by using the highest educational level of the mother and father and the highest occupational status of the mother and father. The latent variable "health compromising behavior" included smoking status and drunkenness frequency, while "health enhancing behavior" was measured by frequency of participation in sports clubs and leisure time sport activities.

Based on previous knowledge and hypothesized relations, two models were constructed to describe the relationships of the explanatory variables with TBI. The first model, Health behavior model, described the effect of "family SES" and both latent variables indicating behaviors on TBI. The second model, Health model, dealt with the measured variables of health and their associations with TBI. Family SES, family structure, and school success were included in both models. (Fig. 2).

The analyses were made separately in age-sex subgroups of 14-year-olds and 16–18-year-olds. The age groups were separated because they differ in the phase of the adoption of health compromising behaviors, the older group is more mature, and the school tracking concerns only

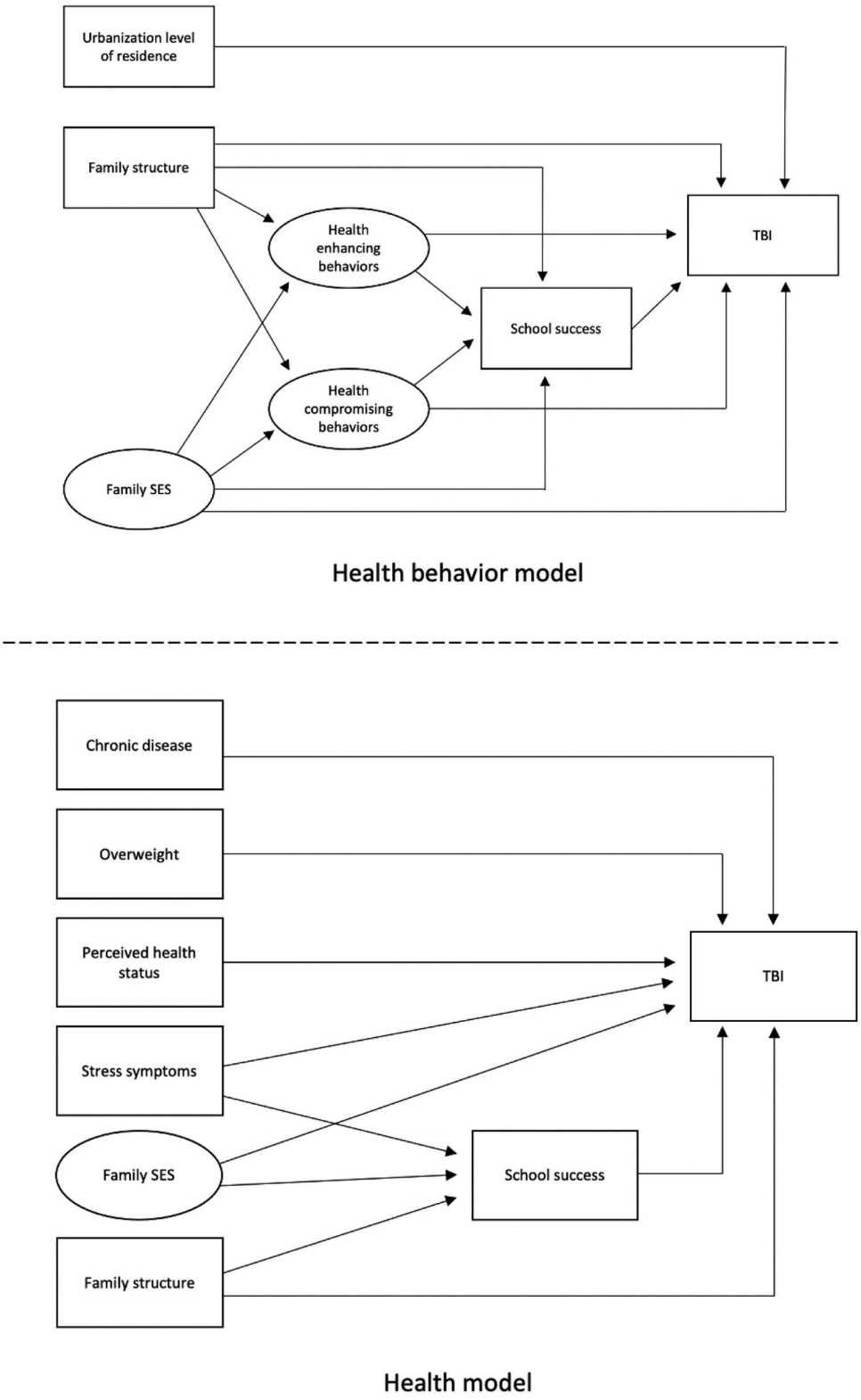

Fig. 2. Hypothesized relationships for adolescent health behavior (Health behavior model) and health (Health model) and subsequent TBI.

the older age group. The results were reported with standardized regression estimates, standard errors (SE), and p-values. Model fit was assessed by root mean square error (RMSEA), Tucker-Lewis index (TLI) and comparative fit index (CFI) [30]. The estimation method used was diagonally weighted least squares (DWLS). Statistical analyses were performed with R version 4.0.5 (R foundation for Statistical Computing, Vienna, Austria) using Lavaan package.

Results

Total of 41 336 persons were included in the analyses, of which 22 768 (55 %) were females and 18 598 (45 %) males. The mean follow-up time was 25.3 years (SD 4.0) (Table 3). During the follow-up period, total of 1 459 (3.5 %) TBIs occurred. Men were more likely to experience TBI. The majority of TBIs were mild as the most common diagnose was

Table 3
Background information for TBIs by subgroups of gender and age used in the analyses.

Subgroup	Sample size, N	TBI, N	Mean follow-up time, years (standard deviation)	Mean age of TBI, years (standard deviation)	Non-hospitalized TBIs, N	Hospitalized TBIs, N	TBIs with surgery, N
14-year-old females	7 410	184	25.3 (3.7)	30.5 (7.6)	139	45	2
16–18-year-old females	15 358	351	25.4 (3.9)	33.9 (7.6)	269	82	11
14-year-old males	6 350	273	25.2 (4.1)	29.5 (7.2)	183	90	14
16–18-year-old males	12 248	489	25.2 (4.3)	32.9 (7.5)	350	139	38
All	41 336	1 297	25.3 (4.0)	32.1 (7.7)	941	356	65

Table 4
Number of TBIs during the follow-up with ICD10 codes.

ICD-10 code	Female 14-year-old	Female 16–18 years old	Male 14-year-olds	Male 16–18-year-olds	All
S06 Intracranial injury	0	1	0	0	1
S060 Concussion	180	332	249	436	1 197
S061 Traumatic cerebral oedema	0	1	2	4	7
S062 Diffuse brain injury	7	14	18	30	69
S063 Focal brain injury	5	10	10	25	50
S064 Traumatic epidural hemorrhage	0	6	6	13	25
S065 Traumatic subdural hemorrhage	4	13	13	32	62
S066 Traumatic subarachnoid hemorrhage	1	2	1	8	12
S067 Intracranial injury with prolonged coma	0	3	2	1	6
S068 Other intracranial injuries	0	0	2	1	3
S069 Intracranial injury, unspecified	5	8	4	10	27
	202	**390**	**307**	**560**	**1459**

concussion ($n = 1197$, 82 %) (Table 4).

In Health behavior model, there were no obvious direct or indirect links between TBI and predicting factors among 14-year-old girls, while among health compromising behavior was associated directly with TBI (standardized estimate 0.15, SE 0.04). In males, not living with both parents and family SES predicted TBI indirectly via health compromising behavior. In both females and males, not living with both parents and low family SES associated to health compromising behavior and poor school success, whereas the connection to health enhancing behavior was negative. Health enhancing behavior was negatively associated with poor school success, while the association was positive in health compromising behavior. School success was not associated with TBI (Fig. 3).

Among 16–18-year-old females, health compromising behavior was associated directly with TBI (standardized estimate 0.11, SE 0.03) in Health behavior model and among males, not living with both parents (standardized estimate 0.14, SE 0.05) and health compromising behavior (standardized estimate 0.14, SE 0.02) directly associated with TBI. In both genders, not living with both parents and low family SES were associated with TBI indirectly via health compromising behavior. The associations between family SES and family structure on health behaviors and school success and the association between health behaviors and school success were similar to that among the 14-year-olds. (Fig. 4).

In Health model of the 14-year-olds, the direct association between overweight and TBI was negative for both genders (standardized estimate: female −0.31, SE 0.14; male −0.26, SE 0.10). In females, daily stress symptoms (standardized estimate 0.09, SE 0.05) was associated directly with TBI, whereas in males, not living with both parents (standardized estimate 0.15, SE 0.07) was directly associated with TBI. In both genders, daily stress symptoms, low family SES, and not living with both parents associated with poor school success. (Fig. 5).

In Health model of 16–18-year-olds, poor perceived health (standardized estimate: females 0.09, SE 0.04; males 0.08, SE 0.03), higher number of daily stress symptoms (standardized estimate: females 0.15, SE 0.03; males 0.10, SE 0.04), and not living with both parents (standardized estimate: females 0.11, SE 0.05; males 0.16, SE 0.05) were associated directly with TBI. In males, there was a direct association between poor school success and TBI (standardized estimate 0.10, SE 0.02) and an indirect association between TBI and number of daily stress symptoms, family SES, and family structure via school success. The associations between stress symptoms, family SES, and family structure were corresponding those among 14-year-olds. (Fig. 6).

Model fit was slightly weaker than ideal in Health behavior model of 16–18-year-olds; TLI was 0.84 in females and 0.85 in males, while CFI was 0.86 in females and 0.87 in males. Also, in Health model among 16–18-year-olds CFI was 0.87 in females and 0.88 in males. The values are considered ideal, if they are greater than 0.9. However, RMSEA was at an acceptable level, <0.10 in all models.

Discussion

Our longitudinal study investigated, if health compromising and health enhancing behavior, poor perceived health, poor school success, and low family SES in adolescence are associated with subsequent TBI. Our results showed that health compromising behavior and not living with both parents in adolescence increased the risk of TBI in adulthood. Low SES had an indirect association to TBI trough health compromising behavior meaning that low SES increased the adoption of health compromising behaviors which increased the risk of TBI. Poor perceived health and stress symptoms in adolescence increased the risk of later TBI.

In our study, health-compromising behavior included alcohol consumption and smoking. Our findings are consistent with previous follow-up studies, where adolescent drinking and substance use have increased the risk of TBI later in life [21,22]. When drinking in adolescence predicts drinking in adulthood [31], the connection of adolescent alcohol use and TBI in adulthood may be partly due to drinking behavior and alcohol intoxication in adulthood [32,33]. On the other hand, adolescents with health compromising behavior are more prone to risk taking behavior in general, which exposes to injuries [34,35], including TBIs. Smoking and alcohol intoxication have been linked to a more severe and complicated TBI outcomes [36,37], while a prior TBI may contribute to increased alcohol misuse [38–41], possibly creating a

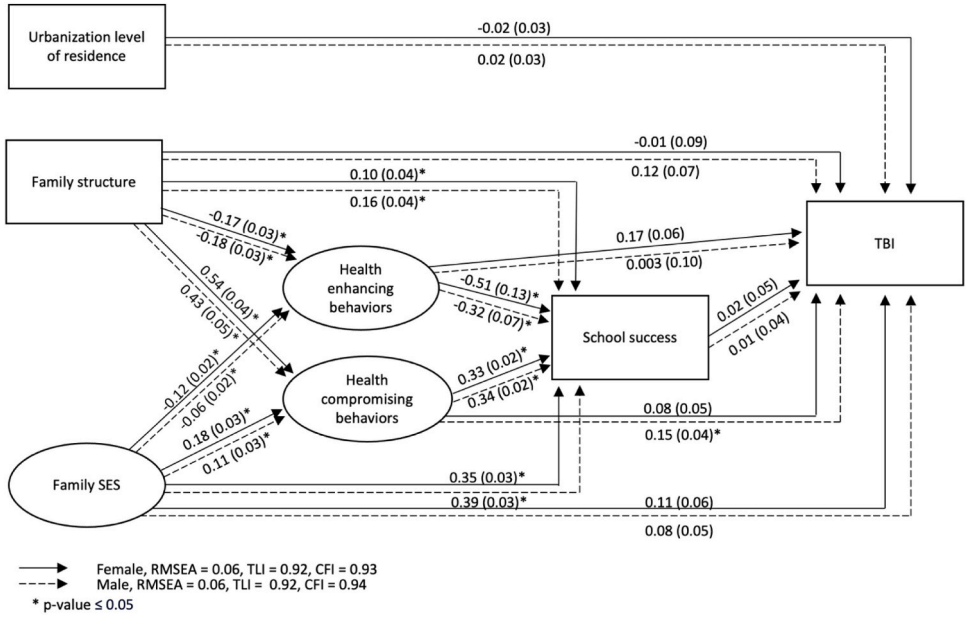

Fig. 3. The fitted Health behavior model for TBI with standardized estimates and standard errors in 14-year-old females and males.

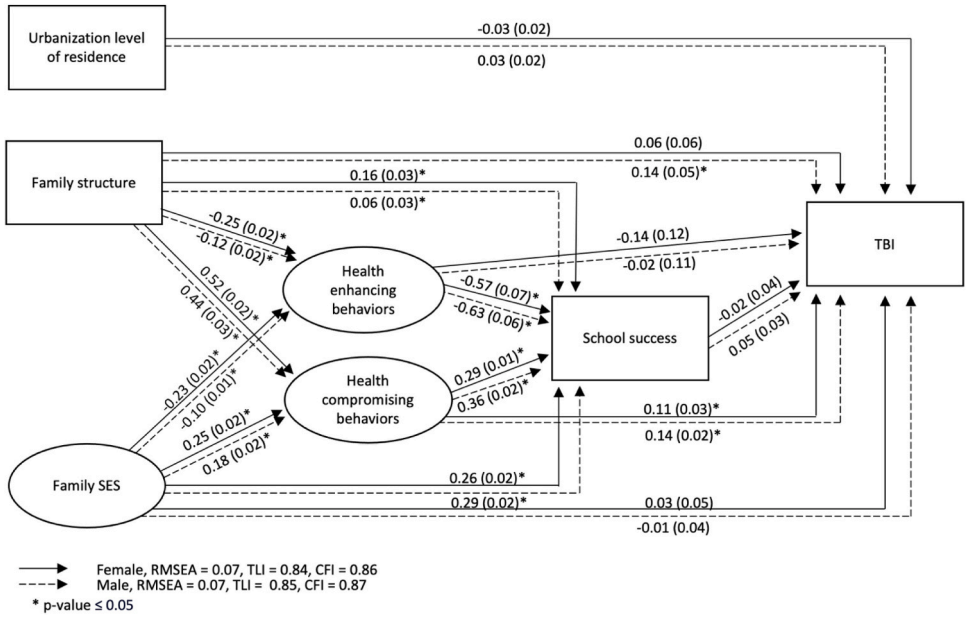

Fig. 4. The fitted Health behavior model for TBI with standardized estimates and standard errors in 16–18-year-old females and males.

hazardous cycle during life course.

We found that poor perceived health and stress symptoms were related to an increased risk of TBI. These indicate poorer physical and mental wellbeing of adolescents. As to mental health, previous studies have shown an association between TBI and mental health conditions and psychosocial adversity [9,20,42–44]. Also, adolescent and adult with psychiatric diagnoses are more likely to sustain injuries in general [45,46]. To our acknowledge, no prior studies on the effects of stress and perceived health in adolescence on the risk of subsequent TBI exist. Stress symptoms in adolescence have been linked with psychological morbidity in adulthood [47]. Also, stress experienced in adolescence often persists into adulthood [48] and self-reported health in adolescence remains stable into adulthood [49], too. Furthermore, depressive symptoms in adolescence have been associated with poor self-rated health in adulthood in a longitudinal study design [50]. An earlier longitudinal study identified poor self-regulation as a mediating factor between childhood adversity and later alcohol and drug use, as well as mental health problems in young adulthood [40]. To cope with emotional and developmental difficulties of that phase of life, adolescents may adopt health compromising behaviors as an escape mechanisms [51,52], further increasing their risk of injury. In this context, our findings on the association of daily stress symptoms and poorer perceived health in adolescence with later increased risk of TBI may reflect anxiety and poorer mental health in adulthood.

We did not find a direct association between family SES and TBI; however low family SES increased the likelihood of health compromising behavior, which in turn predicted TBI. However, previous studies have reported associations between socioeconomic circumstances and TBI [18,53], though using different statistical methods. Supporting the indirect association observed, poorer family SES in childhood have been

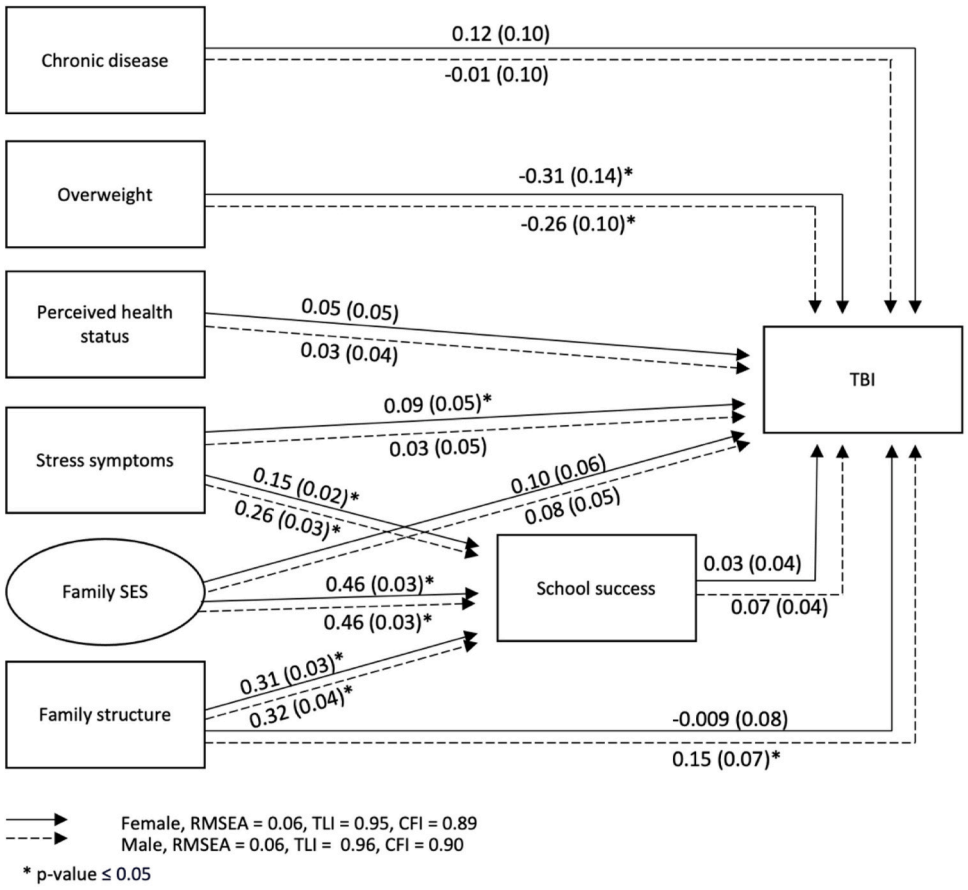

Fig. 5. The fitted Health model for TBI with standardized estimates and standard errors in 14-year-old females and males.

associated with health compromising and risk-taking behaviors in both adolescence and adulthood [54,55].

In addition, in families with low material wealth, health compromising behavior have been more strongly associated with, e.g., violence related injuries compared to wealthy families [56]. Also, possibly epitomizing socioeconomic circumstances, adolescents, particularly males, who were not living with both parents had a higher risk of TBI. In line with our finding, previous studies have reported an association between childhood adverse events and an increased risk of TBI [19], also regarding parental divorce [57]. Not living with both parents may reflect low material wealth as well as other adversities in the family [58]. With changing dynamics of the family, parental divorce, death, or mental and physical violence can be stressful events in a child's life [59], further predisposing to the adoption of health compromising behaviors, as discussed above, and increasing the risk of TBI. These findings highlight the influence of family SES in forming adolescents' health behavior and the complex interplay between early-life experiences, risky behaviors, and TBI risk.

A strength of this study lies in the large nationwide sample comprehensively presenting Finnish adolescents with a long follow up period of 25 years on average. With the long follow up, our study increases scientific knowledge on the effects of living conditions and health in adolescents on adulthood TBIs. This study also has its limitations. Majority of variables were self-reported which may mean inaccuracy and bias in results. Moreover, we did not know how health and health behaviors had changed during the follow-up. In addition, the participants may have had other injuries in addition to TBI and the diagnose of TBI may not have been the primary indication for admission. However, TBI is such significant injury that commonly it has been set as a primary diagnosis in case of a multi-trauma.

Conclusion

This study showed an association between health compromising behavior in adolescence and the later occurrence of TBI. Adolescents experiencing more daily stress symptoms and poor perceived health were also at a higher risk of TBI. Low SES had an indirect association to TBI trough health compromising behavior, whereas, not living with both parents increased the risk of TBI directly, characterizing adverse experiences. The cumulative effect of these factors on the risk of TBI creates burden for both to individuals and societies. This study underlines, that more support should be allocated to adolescents who struggle with stress and drift into negative health behavior.

Funding

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Ethics statement

The Finnish Social and Health Data Permit Authority Finland granted the permit to use social and health care data (https://findata.fi). The study protocol was approved by its Institutional Review Board and by the Data Protection Ombudsman. Identification of the study participants was withheld from the investigators at all stages of the study and the rights and duties of both parties were specified in the contract. The Joint Commission on Ethics of the University of Turku and the Turku University Hospital stated that no human rights were violated in the research protocol and approved it.

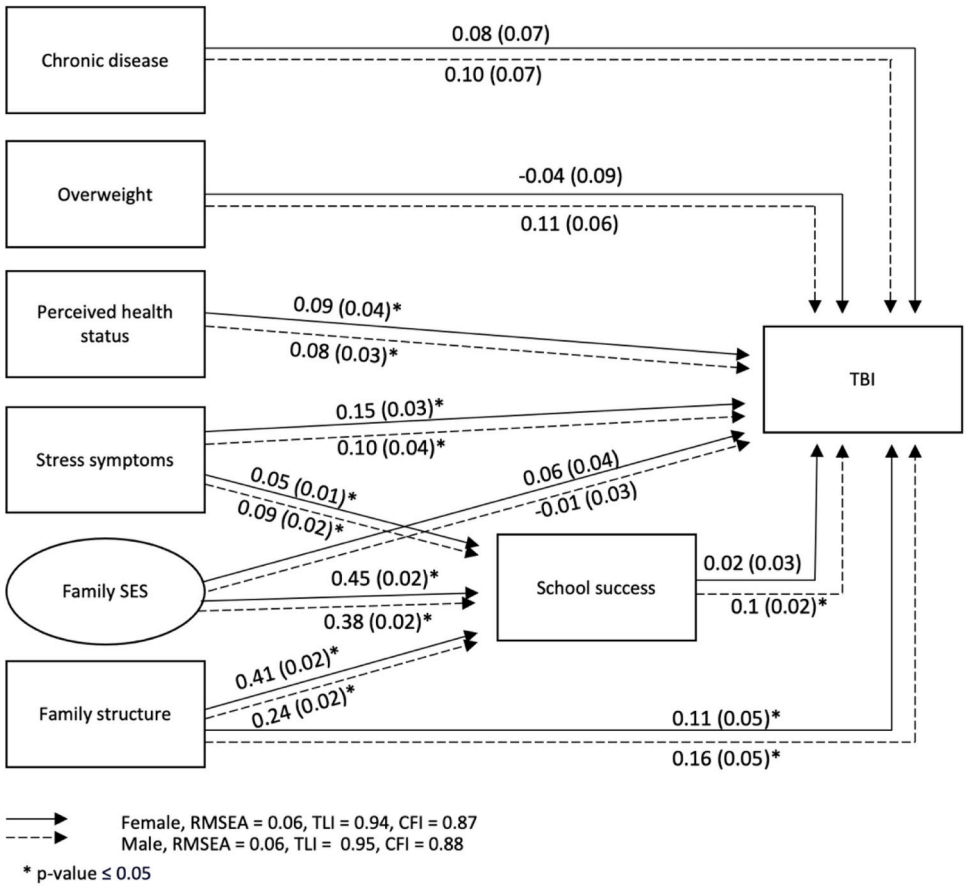

Fig. 6. The fitted Health model for TBI with standardized estimates and standard errors in 16–18-year-old females and males.

CRediT authorship contribution statement

Alisa Teuho: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Matias Vaajala:** Writing – review & editing, Writing – original draft, Visualization, Conceptualization. **Ville Ponkilainen:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Leena Koivusilta:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Arja Rimpelä:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Ville M. Mattila:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interests.

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