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World J Clin Cases 2021 August 6; 9(22): 6178-6581



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Editorial Board Member of *World Journal of Clinical Cases*, Salma Ahi, MD, Assistant Professor, Research Center for Noncommunicable Diseases, Jahrom University of Medical Sciences, Jahrom 193, Iran. salmaahi.61@gmail.com

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The *WJCC* is now indexed in Science Citation Index Expanded (also known as SciSearch®), Journal Citation Reports/Science Edition, Scopus, PubMed, and PubMed Central. The 2021 Edition of Journal Citation Reports® cites the 2020 impact factor (IF) for *WJCC* as 1.337; IF without journal self cites: 1.301; 5-year IF: 1.742; Journal Citation Indicator: 0.33; Ranking: 119 among 169 journals in medicine, general and internal; and Quartile category: Q3. The *WJCC*'s CiteScore for 2020 is 0.8 and Scopus CiteScore rank 2020: General Medicine is 493/793.

RESPONSIBLE EDITORS FOR THIS ISSUE

Production Editor: Yan-Xia Xing; Production Department Director: Yan-Jie Ma; Editorial Office Director: Jin-Lai Wang.

NAME OF JOURNAL

World Journal of Clinical Cases

ISSN

ISSN 2307-8960 (online)

LAUNCH DATE

April 16, 2013

FREQUENCY

Thrice Monthly

EDITORS-IN-CHIEF

Dennis A Bloomfield, Sandro Vento, Bao-Gan Peng

EDITORIAL BOARD MEMBERS

<https://www.wjgnet.com/2307-8960/editorialboard.htm>

PUBLICATION DATE

August 6, 2021

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INSTRUCTIONS TO AUTHORS

<https://www.wjgnet.com/bpg/gerinfo/204>

GUIDELINES FOR ETHICS DOCUMENTS

<https://www.wjgnet.com/bpg/GerInfo/287>

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<https://www.wjgnet.com/bpg/gerinfo/240>

PUBLICATION ETHICS

<https://www.wjgnet.com/bpg/GerInfo/288>

PUBLICATION MISCONDUCT

<https://www.wjgnet.com/bpg/gerinfo/208>

ARTICLE PROCESSING CHARGE

<https://www.wjgnet.com/bpg/gerinfo/242>

STEPS FOR SUBMITTING MANUSCRIPTS

<https://www.wjgnet.com/bpg/GerInfo/239>

ONLINE SUBMISSION

<https://www.f6publishing.com>

Observational Study

Health-related risky behaviors and their risk factors in adolescents with high-functioning autism

Ya-Jing Sun, Ling-Zi Xu, Zeng-Hui Ma, Yu-Lu Yang, Ting-Ni Yin, Xiao-Yun Gong, Zi-Lin Gao, Yan-Ling Liu, Jing Liu

ORCID number: Ya-Jing Sun 0000-0003-3136-001X; Ling-Zi Xu 0000-0001-7861-9063; Zeng-Hui Ma 0000-0003-4745-204X; Yu-Lu Yang 0000-0002-7991-7940; Ting-Ni Yin 0000-0001-9669-3793; Xiao-Yun Gong 0000-0002-5430-1373; Zi-Lin Gao 0000-0002-5746-1954; Yan-Ling Liu 0000-0002-4561-6947; Jing Liu 0000-0002-6720-2171.

Author contributions: Sun YJ, Xu LZ, Ma ZH, Yang YL, Yin TN, Gong XY and Gao ZL performed the study; Sun YJ and Liu YL analyzed the data; Sun YJ wrote the manuscript; Xu LZ, Ma ZH and Liu J revised the manuscript; all authors have read and approved the final manuscript.

Supported by National Key R&D Program of China, No. 2017YFC1309900; and Beijing Municipal Science & Technology Commission, No. Z171100001017088 and No. Z161100000116098.

Institutional review board

statement: This study was approved by Ethics Committee of Peking University Sixth Hospital (No. 2016-11-7-1).

Informed consent statement: All study participants provided written informed consent prior to

Ya-Jing Sun, Ling-Zi Xu, Zeng-Hui Ma, Yu-Lu Yang, Ting-Ni Yin, Xiao-Yun Gong, Jing Liu, Peking University Sixth Hospital, Peking University Institute of Mental Health, NHC Key Laboratory of Mental Health (Peking University), National Clinical Research Center for Mental Disorders (Peking University Sixth Hospital), Beijing 100191, China

Zi-Lin Gao, Quanzhou Children's and Women's Hospital, Quanzhou 362000, Fujian Province, China

Yan-Ling Liu, Department of Mathematics, Changzhi Medical College, Changzhi 046000, Shanxi Province, China

Corresponding author: Jing Liu, MD, Chief Physician, Peking University Sixth Hospital, Peking University Institute of Mental Health, NHC Key Laboratory of Mental Health (Peking University), National Clinical Research Center for Mental Disorders (Peking University Sixth Hospital), No. 51 Huayuan North Road, Haidian District, Beijing 100191, China. ljjyuch@bjmu.edu.cn

Abstract**BACKGROUND**

Health-related risky behaviors generally refer to behaviors that have a negative impact on health and quality of life. Health-related risky behaviors in adolescents with high-functioning autism (HFA) have not been well understood so far. Adolescents with HFA may have more health-related risky behaviors than neurotypical adolescents.

AIM

To investigate health-related risky behaviors and their risk factors with HFA.

METHODS

This is an observational study. Our study enrolled 110 adolescents aged 12-19-years-old meeting Diagnostic and Statistical Manual of Mental Disorders 4th edition criteria for HFA. They were recruited from Peking University Sixth Hospital. There were also 110 age, sex and nationality matched controls enrolled who came from a public school in Beijing, China. Both groups completed the Adolescents Health-related Risky Behavior Inventory. Nonparametric tests were carried out for comparison of the Adolescents Health-related Risky Behavior Inventory scores between the two groups. Expression recognition, the Inventory

study enrollment.

Conflict-of-interest statement: All authors declare no conflicts of interest in this study.

Data sharing statement: Statistical code and data are available from the corresponding author.

STROBE statement: The authors have read the STROBE Statement-checklist of items, and the manuscript was prepared and revised according to the STROBE Statement-checklist of items.

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Manuscript source: Unsolicited manuscript

Specialty type: Medicine, research and experimental

Country/Territory of origin: China

Peer-review report's scientific quality classification

Grade A (Excellent): 0
Grade B (Very good): B
Grade C (Good): C
Grade D (Fair): 0
Grade E (Poor): 0

Received: May 15, 2021

Peer-review started: May 15, 2021

First decision: May 23, 2021

Revised: May 25, 2021

Accepted: June 2, 2021

Article in press: June 2, 2021

Published online: August 6, 2021

P-Reviewer: Contaldo A, Uljarevic M

S-Editor: Gao CC

L-Editor: Filipodia

of Subjective Life Quality for Child and Adolescent, Chinese Wechsler Intelligence Scale for Children, Wechsler Intelligence Scale for Adult-Chinese Revised, Theory of Mind test and Autism Spectrum Screening Questionnaire were assessed in the autism group to explore factors associated with health-related risky behaviors. Multivariate regression analysis was conducted to explore the risk factors of health-related risky behaviors in the HFA group.

RESULTS

The results showed that the total score of the Adolescents Health-related Risky Behavior Inventory and scores of "aggression and violence," "suicide and self-injury," "health compromising behavior" and "unprotected sex" subscales in the HFA group were significantly higher than those in the control group (Z range -4.197 to -2.213, $P < 0.05$). Among the associated factors, poor emotional experience ($B = -0.268$, $P < 0.001$), depression ($B = -0.321$, $P < 0.001$), low score of intelligence ($B = -0.032$, $P = 0.042$), low score of Theory of Mind test ($B = -1.321$, $P = 0.003$) and poor adaptation to school life ($B = -0.152$, $P = 0.006$) were risk factors. These risky behaviors may promote the occurrence of health-related risky behaviors in adolescents with HFA.

CONCLUSION

This study showed that adolescents with HFA were more likely to be involved in health-related risky behaviors. Different health-related risky behaviors have different reasons.

Key Words: High-functioning autism; Adolescents; Health-related risky behaviors; Associated factors; Risk factors; Cross-sectional study

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Core Tip: We comprehensively explored health-related risky behaviors in a large sample of adolescents with high-functioning autism. These risky behaviors can be detrimental to the physical and mental status of individuals with high-functioning autism. Low cognitive function, unhealthy emotional state, *etc.* may be related to health-related risky behaviors in autistic adolescents. Through this study, we provide better understanding of health-related risky behaviors in adolescents with high-functioning autism.

Citation: Sun YJ, Xu LZ, Ma ZH, Yang YL, Yin TN, Gong XY, Gao ZL, Liu YL, Liu J. Health-related risky behaviors and their risk factors in adolescents with high-functioning autism. *World J Clin Cases* 2021; 9(22): 6329-6342

URL: <https://www.wjgnet.com/2307-8960/full/v9/i22/6329.htm>

DOI: <https://dx.doi.org/10.12998/wjcc.v9.i22.6329>

INTRODUCTION

Autism is a neurodevelopmental disease characterized by social interaction difficulties, repetitive behaviors and communication disorders. The prevalence of autism is about 1%, during which, high-functioning autism (HFA) is not uncommon[1, 2]. HFA refers to autism with a developmental age close to chronological age or with an intelligence quotient (IQ) ≥ 70 . HFA is often associated with a variety of mental disorders and behavioral problems. In a study by de Giambattista *et al*[3], they found that 2.9% of high-functioning autistic adolescents had depression, 4.3% had anxiety, 2.8% had obsessive-compulsive disorder, and 1.4% had eating disorders. Other researchers reported similar findings, with a lifetime psychiatric visit rate of 78%[4]. Among them, health-related risky behaviors are worthy of attention. Adolescent health-related risky behaviors refer to behaviors that affect their own health and quality of life. These behaviors mainly include aggressive behavior, smoking and drinking alcohol, self-injury behavior, unprotected sexual behavior, unhealthy eating habits and lack of exercise[5]. There are few studies on health-related risky behaviors

P-Editor: Zhang YL



of HFA. Gao *et al*[6] published a study in 2019 to describe the characteristics of health-related risky behaviors of high-functioning autistic individuals. The results suggested that high-functioning autistic adolescents were more prone to aggressive behavior, disciplinary behavior, unhealthy eating behavior and self-injury behavior than neurotypical adolescents. However, the relevant factors were not discussed. In a survey of 138 high-functioning autistic individuals, 41 (29.71%) had aggressive behavior, while 24 (17.39%) were classified as bullied[7]. Rattaz *et al*[8] found that self-injury behavior of autistic individuals was significantly higher than that of normal controls. In Rattaz's study, the main manifestations of self-injury behavior in autism group were cuts, head bumps, bites and so on. However, most of the studies focused on a specific kind of health-related risky behavior of autism. There are few related studies on health-related risky behaviors and their associated factors of HFA.

In order to comprehensively research health-related risky behaviors in adolescents with HFA, an efficient evaluation tool is of great importance. Recently, many tools have been developed, such as the Youth Risk Behavior Survey Questionnaire[9], Child Behavior Checklist[10], the Adolescent Risk Behavior Screening Form[11] and Composite Measure of Problem Behaviors[12,13]. However, these questionnaires have some disadvantages: (1) The validity of Youth Risk Behavior Survey Questionnaire is yet to be improved, meanwhile this questionnaire did not report test-retest reliability; (2) There are only two subscales of Child Behavior Checklist related to risky behaviors, which do not cover a comprehensive or most domains of risky behaviors; (3) In the Adolescent Risk Behavior Screening Form, there are only nine questions, five of which are related to substance abuse; and (4) The Composite Measure of Problem Behaviors is scored on a 6-point Likert scale from "very much like me" to "very much unlike me." This scoring method is similar to personality questionnaires. However, it may not be appropriate to rate a particular behavior. We usually use frequency to evaluate behavior.

To overcome the shortcomings of the above questionnaires, Wang *et al*[14] developed the Adolescents Health-Related Risky Behavior Inventory (AHRBI) which measures six kinds of risky behaviors: suicide and self-injury (SS), health compromising behavior (HCB), aggression and violence (AV), rule breaking (RB), substance use and unprotected sex (US) behaviors in adolescents. A study conducted in mainland China verified that this questionnaire had good reliability and validity during adolescence[14]. The AHRBI has been used for the assessment of health-related risky behaviors in adolescents with various characteristics, such as antisocial personality or psychosis[14-18]. It was also used in a study that found that health-related risky behaviors were increased in adolescents with HFA compared to normal controls[6]. However, this study enrolled only 50 adolescents with HFA and did not explore factors associated with health-related risky behaviors in the HFA group.

Therefore, in order to comprehensively explore health-related risky behaviors in a large sample of adolescents with HFA, we conducted the current study using the AHRBI. We also explored factors associated with health-related risky behaviors in adolescents with HFA. We hypothesized that individuals in the HFA group might have more health-related risky behaviors than neurotypical adolescents. These risky behaviors may be correlated with core symptoms, cognitive function, anxiety or depression, family situation, *etc.* We hope our results will provide better understanding of health-related risky behaviors in adolescents with HFA and lay the foundation for comprehensive intervention by discovering factors associated with such behaviors.

MATERIALS AND METHODS

Study design

This is a cross-sectional study. The HFA group and control group were matched according to age, gender and nationality. Childhood Autism Rating Scale and Schedule for Affective Disorders and Schizophrenia for School-Age Child-Parent and Lifetime Version (K-SADS-PL) were performed at enrollment to establish diagnosis[19, 20]. Chinese Wechsler Intelligence Scale for Children (C-WISC) and Wechsler Intelligence Scale for Adult-Chinese Revised (WAIS-RC) were used to screen autistic subjects with IQ greater than 70[21,22]. AHRBI was assessed in both groups. Apart from AHRBI, C-WISC (for participants of 12-16-years-old), WAIS-RC (for participants over 17-years-old), Theory of Mind (ToM) test[23,24], expression recognition[25], the Inventory of Subjective Life Quality for Child and Adolescent[26] (ISLQ) and Autism Spectrum Screening Questionnaire[27] (ASSQ) were also assessed in the HFA group

for exploration of factors associated with health-related risky behaviors. Parents in both groups filled in the general information sheet, which included age, gender, parents' education levels, relationship of family members, family financial situation, family history of mental illness, *etc.* Personal information and family information were displayed in the [Table 1](#) (personal information) and [Table 2](#) (family information).

Study size

Sample size was estimated based on pre-experiment results. In the pretest, the average of the total score of the AHRBI in the autism group was 53.22, with a standard deviation of 10.57. The average of the total score in the control group was 47.30, with a standard deviation of 4.73. According to the method of sample size estimation based on group matching measurement data, the probability of a type I error was 0.05, and the test power was $1-\beta = \pm 0.80$. A sample size of at least 31 in cases and 31 in controls was required for this study. This study expanded the sample size to include 110 participants in each group.

Participants

In our study, the subjects in the HFA group were enrolled *via* both outpatient and inpatient at the Child and Adolescent Mental Health Department in Peking University Sixth Hospital from March 2018 to December 2019. The inclusion criteria were as follows: (1) individuals were diagnosed with autism by two experienced child psychiatrists according to the criteria of autism in the Diagnostic and Statistical Manual of Mental Disorders 4th edition; (2) individuals' ages were between 12 and 19 years; (3) total score of Childhood Autism Rating Scale evaluated by child psychiatrists was at least 30; (4) total score of C-WISC and WAIS-RC of the autism group evaluated by personnel was at least 70; and (5) individuals were able to understand and fill out the AHRBI. The exclusion criteria were: (1) individuals had comorbid diagnosis of another severe mental disorder evaluated by child psychiatrists using K-SADS-PL (*e.g.*, psychotic disorders, major depressive or manic disorder); (2) individuals had a severe medical condition; or (3) individuals could not understand the AHRBI or could not cooperate in filling it out. There were 110 adolescents with HFA enrolled in the autism group, including 93 males and 17 females aged 12-19 years.

The subjects of the control group were enrolled from a public school in Beijing and matched to the HFA group by gender, age and race on a 1:1 ratio. The inclusive criteria included: (1) individuals' ages were between 12 and 19 years; and (2) individuals could understand and fill out the AHRBI. The exclusion criteria were: (1) individuals had mental disorders diagnosed by clinical evaluation and K-SADS-PL. We used clinical assessment and diagnosis to exclude autism; (2) individuals had a severe medical condition; or (3) individuals could not understand the AHRBI or could not cooperate in filling it out. Based on the above criteria, a total of 110 neurotypical adolescents, including 93 males and 17 females aged 12-19 years, were included in the control group.

Research tools

The Childhood Autism Rating Scale and K-SADS-PL were performed at enrollment to establish diagnosis.

The general condition sheets were self-designed by the investigators. It consisted of a series of items regarding participant gender, race, residence, age, father's educational level, mother's educational level, family relationships, family financial situation and family history of psychiatric disorders (more details in [Supplementary material](#), Appendix 1).

The AHRBI includes 38 items regarding health-related risky behaviors. Participants were asked to choose from 1 = never, 2 = hardly ever (once a month), 3 = sometimes (2-4 times a month), 4 = often (2-3 times a week), and 5 = very often (more than 4 times a week). The inventory had six subscales: "aggression and violence," "health compromising behavior," "rule breaking," "unprotected sex," "suicide and self-injury" and "substance use."

Chinese Wechsler intelligence scale included two versions, C-WISC (for subjects of 12-16-years-old) and WAIS-RC (for subjects over 17-years-old). We used these two tools to screen individuals with autism with an IQ greater than 70 and to explore the relationship between health-related risky behaviors and IQ in adolescents with HFA.

We also used the ToM test. ToM refers to the individual's ability to understand self and others' intentions or beliefs and to explain or predict the behavior of others. It mainly includes the first-level false belief task[23] and the second-level false belief task [24]. Computing methods were shown in the supplementary material.

Table 1 Demographic characteristics of the high-functioning autism and control groups (personal information)

| Items | Autism group, <i>n</i> = 110 | Control group, <i>n</i> = 110 | Z/ χ^2 | <i>P</i> value |
|-------------------------|------------------------------|-------------------------------|-------------|----------------|
| Age, median (min, max) | 14.5 (12.0, 19.1) | 14.4 (12.1, 19.0) | -0.268 | 0.789 |
| Gender, <i>n</i> (%) | | | 0 | 0.999 |
| Female | 17 (15.5) | 17 (15.5) | | |
| Male | 93 (84.5) | 93 (84.5) | | |
| Race, <i>n</i> (%) | | | 0.474 | 0.491 |
| Han nationality | 101 (91.8) | 98 (91.8) | | |
| Ethnic minority | 9 (8.2) | 12 (8.2) | | |
| Residence, <i>n</i> (%) | | | 0.372 | 0.830 |
| City | 94 (85.5) | 97 (88.2) | | |
| Town | 12 (10.9) | 10 (9.1) | | |
| Village | 4 (3.6) | 3 (2.7) | | |

In this study, 20 items of expression were selected to test the ability of expression recognition of autistic individuals[25]. This measurement was mainly to test whether subjects could accurately recognize other people's expressions. A part of the computing methods was shown in the supplementary material.

The ISLQ mainly measured the quality of life in children and adolescents. There are two subscales in the ISLQ: cognitive subscale and emotional subscale. The cognitive subscale has five factors: family life, peer interaction, school life, life environment and self-cognition; and the emotional subscale has three factors: somatosensory, anxiety experience and depression experience[26]. The higher the score, the better the life experience (full text of the scale in [Supplementary Table 1](#)).

ASSQ consisted of three factors, restricted and repetitive behavior, social interaction disorder and communication barriers. The higher the score, the more severe the symptom[27].

Statistical analysis

SPSS 25.0 was used for statistical analysis. A χ^2 test was employed to analyze differences between two groups among count data. The results of the Kolmogorov-Smirnov test showed that scores of AHRBI and its subscales did not conform to normal distribution, therefore median (min, max) was presented in the descriptive analysis. Nonparametric tests were carried out for comparison of AHRBI scores between the two groups. Spearman's rank correlation analysis was performed to investigate the correlation between the results of AHRBI and the results of ISLQ, IQ, ToM, ASSQ and expression recognition. Multivariate regression analysis was conducted to explore the risk factors of health-related risky behaviors in the HFA group. Subscales of AHRBI that were significantly different between the two groups were selected as dependent variables for regression analysis. Factors with a significant association in the Spearman's rank correlation analysis were selected as potential independent variables, and positive variables were screened according to the forward method.

RESULTS

Comparison of AHRBI results between autism and control groups

Nonparametric tests were carried out for the comparison of AHRBI scores between the HFA and control groups. We used median (minimum, maximum) to describe the scores of both groups. The results showed that the total score ($Z = -3.314$, $P = 0.001$) and scores of four subscales (AV, HCB, US and SS) of AHRBI (Z value range -4.197 to -2.213 , all $P < 0.05$) in the HFA group were significantly higher than those in the control group, suggesting that AV, HCB, US and SS behaviors were more prominent in adolescents with HFA. No significant differences were found between the two groups in the scores of RB and substance use subscales (details in [Table 3](#)). Among the 38 items of the AHRBI, 19 items showed significantly higher scores (Z value range -5.428

Table 2 Demographic characteristics of the high-functioning autism and control groups (family information)

| Items | Autism group, <i>n</i> = 110 | Control group, <i>n</i> = 110 | Z/ χ^2 | <i>P</i> value |
|--|------------------------------|-------------------------------|-------------|----------------|
| Paternal education, <i>n</i> (%) | | | 19.45 | 0.001 |
| Primary school | 1 (0.9) | 2 (1.8) | | |
| Middle school | 3 (2.7) | 18 (16.4) | | |
| High school | 22 (20.0) | 31 (28.2) | | |
| Undergraduate | 60 (54.5) | 49 (44.5) | | |
| Postgraduate | 24 (21.9) | 10 (9.1) | | |
| Maternal education, <i>n</i> (%) | | | 19.38 | 0.003 |
| Primary school | 1 (0.9) | 4 (3.6) | | |
| Middle school | 5 (4.5) | 17 (15.5) | | |
| High school | 20 (18.2) | 29 (26.4) | | |
| Undergraduate | 64 (58.2) | 52 (47.3) | | |
| Postgraduate | 20 (18.2) | 8 (7.3) | | |
| Family relationship, <i>n</i> (%) | | | 0.942 | 0.624 |
| Harmonious | 73 (66.4) | 78 (70.9) | | |
| Fine | 29 (26.4) | 23 (20.9) | | |
| Disharmony | 5 (4.5) | 6 (5.5) | | |
| Parents divorced | 3 (2.7) | 3 (2.7) | | |
| Family financial situation, <i>n</i> (%) (annual income CNY) | | | 15.84 | 0.003 |
| < 30000 | 15 (13.6) | 6 (5.5) | | |
| 30000-50000 | 28 (25.5) | 13 (11.8) | | |
| 50000-70000 | 19 (17.3) | 24 (21.8) | | |
| 70000-100000 | 27 (24.5) | 27 (24.5) | | |
| > 100000 | 21 (19.1) | 40 (36.4) | | |
| Family history of mental illness | | | 13.21 | < 0.001 |
| Positive | 15 | 1 | | |
| Negative | 95 | 109 | | |

to -2.194, all $P < 0.05$) in the HFA group compared with those in the control group, as shown in [Supplementary Table 2](#). These results indicated that adolescents with HFA had more health-related risky behaviors than controls, especially in AV, HCB, US and SS.

Correlation analysis between AHRBI scores and demographic characteristics, scores of ISLQ, IQ, ToM, ASSQ and expression recognition in HFA group

Our results clearly show that adolescents with HFA have increased health-related risky behaviors. In order to explore factors potentially associated with health-related risky behaviors in adolescents with HFA, we conducted Spearman's rank correlation analysis between AHRBI scores and sociodemographic data, results of ISLQ, IQ, ToM, ASSQ and expression recognition. Given that there were no significant differences in the RB and SS subscale scores of AHRBI between the autism and the control groups, only the subscales AV, HCB, US and SS were considered in the following analysis. Correlation coefficients between the AHRBI scores and the results of demographic characteristics, ISLQ and ASSQ were shown in [Table 4](#). Meanwhile, correlation coefficients between the AHRBI scores and the results of IQ, ToM and expression recognition were shown in [Table 5](#).

As shown in [Table 4](#), the score of the AV subscale was positively correlated with residence ($r = 0.236$, $P = 0.013$) and family relationship ($r = 0.195$, $P = 0.041$). These results suggest that adolescents with HFA living in rural areas were more likely to

Table 3 Comparison of Adolescent Health-related Risky Behavior Inventory total score and subscale scores between the two groups

| Total scale/subscales | Autism group, <i>n</i> = 110 | Control group, <i>n</i> = 110 | Z | P value |
|------------------------------|------------------------------|-------------------------------|--------|---------|
| Total score | 55.0 (38, 177) | 49.5 (38, 88) | -3.314 | 0.001 |
| Aggression and violence | 15.0 (10, 50) | 13.0 (10, 29) | -3.045 | 0.002 |
| Health compromising behavior | 10.0 (5, 19) | 8.0 (5, 17) | -2.213 | 0.027 |
| Rule breaking | 10.0 (7, 35) | 9.5 (7, 18) | -0.741 | 0.458 |
| Unprotected sex | 5.0 (5, 25) | 5.0 (5, 7) | -4.197 | < 0.001 |
| Suicide and self-injury | 6.0 (5, 25) | 5.0 (5, 17) | -2.581 | 0.010 |
| Substance use | 6.0 (6, 25) | 6.0 (6, 9) | -0.766 | 0.444 |

Higher scores represent more frequent health-related risky behaviors.

Table 4 Correlation coefficients between the Adolescents Health-related Risky Behavior Inventory scores and the results of demographic characteristics, Autism Spectrum Screening Questionnaire and Inventory of Subjective Life Quality for Child and Adolescent

| Total scale/subscale | AV | HCB | US | SS | Total score of AHRBI |
|------------------------------------|---------------------|---------------------|--------------------|---------------------|----------------------|
| Residence | 0.236 ¹ | 0.300 ² | -0.132 | 0.151 | 0.251 ² |
| Father's education background | 0.031 | -0.344 ² | 0.217 ¹ | -0.173 | -0.091 |
| Mother's education background | -0.115 | -0.239 ¹ | 0.143 | -0.195 ¹ | -0.162 |
| Family financial situation | -0.031 | 0.001 | 0.024 | -0.008 | 0.003 |
| Family relationship | 0.195 ¹ | 0.136 | 0.009 | 0.173 | 0.224 ¹ |
| ASSQ | | | | | |
| Restricted and repetitive behavior | 0.079 | 0.146 | 0.144 | 0.010 | 0.136 |
| Social interaction disorder | 0.015 | 0.201 | 0.019 | -0.005 | 0.093 |
| Communication barriers | 0.072 | 0.252 ¹ | 0.128 | -0.025 | 0.151 |
| ISLQ | | | | | |
| Cognitive subscale | -0.233 ¹ | -0.133 | -0.027 | -0.238 ¹ | -0.250 ¹ |
| Family life | -0.233 ¹ | -0.036 | -0.013 | -0.145 | -0.181 |
| Peer interaction | -0.128 | -0.177 | -0.095 | -0.110 | -0.181 |
| School life | -0.293 ² | -0.288 ¹ | 0.066 | -0.297 ² | -0.335 ² |
| Life environment | -0.047 | -0.063 | -0.047 | -0.038 | -0.095 |
| Self-cognition | -0.130 | 0.013 | -0.030 | -0.181 | -0.110 |
| Emotional subscale | -0.381 ² | -0.059 | -0.131 | -0.354 ² | -0.354 ² |
| Depression experience | -0.315 ² | -0.100 | -0.107 | -0.330 ² | -0.315 ² |
| Anxiety experience | -0.327 ² | -0.039 | -0.112 | -0.285 ¹ | -0.301 ² |
| Body emotion | -0.345 ² | 0.058 | -0.122 | -0.222 ¹ | -0.243 ¹ |

¹Correlation is significant at the 0.05 level (2-tailed).

²Correlation is significant at the 0.01 level (2-tailed). AHRBI: Adolescent Health-related Risky Behavior Inventory; ASSQ: Autism Spectrum Screening Questionnaire; AV: Aggression and violence; HCB: Health compromising behavior; ISLQ: Inventory of Subjective Life Quality for Child and Adolescent; SS: Suicide and self-injury; US: Unprotected sex.

have AV than in urban areas. The autistic individuals with disharmonious family relationship were more likely to have aggressive behavior. In the ISLQ, scores of family life, peer interaction, school life, life environment, self-cognition, depression experience, anxiety experience, somatosensory, cognitive subscale and emotional subscale were significantly correlated with AV (*r* range -0.233 to -0.381, *P* < 0.05).

Table 5 Correlation coefficients between the Adolescents Health-related Risky Behavior Inventory scores and the results of intelligence quotient, Theory of Mind and expression recognition

| Total scale/subscale | AV | HCB | US | SS | Total score of AHRBI |
|--|--------|---------------------|---------------------|--------|----------------------|
| IQ | | | | | |
| Verbal IQ | 0.042 | -0.138 | -0.164 | -0.050 | -0.008 |
| Performance IQ | 0.012 | -0.181 | -0.245 ¹ | -0.059 | -0.047 |
| Full-scale IQ | 0.048 | -0.075 | -0.247 ² | 0.006 | 0.009 |
| ToM test | | | | | |
| First-order belief test | 0.087 | -0.181 | 0.035 | -0.014 | -0.037 |
| Second-order belief test | -0.061 | -0.011 | -0.274 ¹ | -0.050 | -0.043 |
| Expression recognition | | | | | |
| Easy facial recognition score | -0.122 | -0.214 | -0.306 ² | 0.022 | -0.124 |
| Complex facial recognition score | 0.144 | -0.104 | -0.031 | 0.076 | 0.097 |
| Total scores of expression recognition | -0.017 | -0.243 ¹ | -0.233 ¹ | 0.075 | -0.043 |

¹Correlation is significant at the 0.05 level (2-tailed).

²Correlation is significant at the 0.01 level (2-tailed). AHRBI: Adolescent Health-related Risky Behavior Inventory; AV: Aggression and violence; HCB: Health compromising behavior; IQ: Intelligence quotient; SS: Suicide and self-injury; ToM: Theory of Mind; US: Unprotected sex.

The score of HCB subscale was positively correlated with residence ($r = 0.30$, $P = 0.001$), negatively correlated with father's education background ($r = -0.344$, $P < 0.001$) and mother's education background ($r = -0.239$, $P = 0.012$). Individuals with HFA in rural and county areas were more likely to have HCB than those in urban areas. The lower the educational background of parents, the more likely the autistic individuals were to have HCB. As shown in Table 4, the score of the HCB subscale was positively correlated with the score of communication disorder in ASSQ ($r = 0.252$, $P = 0.022$). Score of school life experience was significantly correlated with HCB ($r = -0.288$, $P = 0.010$). As shown in Table 5, the score of HCB subscale was negatively related to total score of expression recognition.

The score of US subscale was positively correlated with father's education background ($r = 0.217$, $P = 0.023$). US had no relation with factors of ISLQ and ASSQ. As for the IQ, we found that the score of US subscale was negatively correlated with the score of performance IQ and full-scale IQ ($r = -0.245$, -0.247 ; $P < 0.05$). This result indicated that the lower the level of IQ, the more likely for adolescents with HFA to have US. About the ToM test, only the US subscale score was significantly related to second-order belief test ($r = -0.274$, $P = 0.012$), which means that the lower the score of second-order belief test, the higher the unprotected sexual behavior. The score of US subscale was negatively related to the scores of easy facial recognition and the total score of expression recognition ($r = -0.306$, -0.233 ; $P < 0.012$). More details available in Table 5.

The score of SS subscale was negatively correlated with mother's education level ($r = -0.195$, $P = 0.041$). Scores of school life experience, depression experience, anxiety experience, somatosensory, cognitive subscale and emotional subscale were significantly negatively correlated with SS (r range -0.354 to -0.222 , $P < 0.05$).

The total score of health-related risky behaviors was positively correlated with residence ($r = 0.251$, $P = 0.008$) and family relations ($r = 0.224$, $P = 0.018$), indicating that adolescents with HFA living in rural area and with disharmonious family relations were more likely to have health-related risky behaviors. Scores of school life experience, depression experience, anxiety experience, somatosensory, cognitive subscale and emotional subscale were significantly negatively correlated with the total score of AHRBI (r range -0.354 to -0.243 , $P < 0.05$).

Multiple regression analysis of factors associated with health-related risky behaviors in adolescents with HFA

Based on the results of Spearman's rank correlation analysis, multiple linear regression was used to explore the risk factors of health-related risky behaviors in adolescents with HFA. The total score and scores of AV, HCB, US and SS subscales of AHRBI were

analyzed as dependent variables. Independent variables were chosen based on our theoretical model and on results from the correlation analysis.

In our analysis, the results showed that the score of emotional subscale was an independent risk factor for AV behavior ($B = -0.268, P < 0.001$). HCB subscale scores were statistically significantly associated with the score of school life experience ($B = -0.152, P = 0.006$). The US subscale was significantly associated with the total score of IQ ($B = -0.032, P = 0.042$) and the score of the second-order belief test ($B = -1.321, P = 0.003$). When SS subscale was chosen as a dependent variable, regression results show that the score of depression experience ($B = -1.603, P = 0.001$) was an independent risk factor of SS but not with other related factors. For the total score of the AHRBI, we found that depression experience was an independent risk factor ($B = -1.603, P < 0.05$). The specific results were shown in [Table 6](#).

DISCUSSION

Autism has adverse effects on the social function of individuals and leads to a burden for one's family and society[28]. This study found that there were more health-related risky behaviors in the HFA group than in the control group. Different health-related risky behaviors were related to their general situation, quality of life, intelligence level or core symptoms. These results were consistent with the results of previous studies[8, 29-32].

AV of high-functioning autistic individuals was significantly higher than that of controls. Among the associated factors, poor emotional experience, which was also called emotional subscale, was a risk factor for AV. Emotional subscale included three factors: physical discomfort, anxiety and depression experience. A review published by Lai *et al*[1] showed that autistic individuals often share several somatic disorders, such as epilepsy (8%-30%), intestinal disorders (9%-70%) and immune system disorders (38%). Somatic discomfort will bring a lot of troubles and pains to autism, so adolescents with autism may experience adverse emotions such as anxiety and emotional instability. As autism spectrum disorders has deficits in emotion management and impairments in verbal communication, these two factors contribute to the difficulty of expressing somatic discomfort[33]. When it is difficult for them to express the pain caused by physical discomfort in words, adolescents with HFA may use violence to relieve the pain in a state of emotional out-of-control. Anxiety and depression are also common in autism. These two mental disorders are also closely related to problem behaviors in individuals with autism[34-36]. Meeus *et al*[37]'s theory of emotion control also found that adolescents with autism may have aggressive behavior secondary to their inability to relieve anxious or depressive moods.

Poor school life experience was a risk factor for HCB. This factor mainly refers to whether you feel comfortable at school or like to go to school. Adolescents spend a large amount of time at school. They are easily affected by negative behaviors among their peers, such as drinking carbonated drinks and not eating vegetables. Peer influence may make it difficult for adolescents with autism to establish good eating habits. Additionally, HCB in autistic adolescents was related to communication disorder, which is consistent with the research results of Geng *et al*[38]. Because of communication disorders, it is difficult for autistic adolescents to understand why parents want them to have healthy eating habits or physical exercise. As a result, adolescents with HFA were more likely to develop unhealthy eating habits as well as less exercise.

Our study also found that adolescents with HFA have more US than neurotypical adolescents. Autistic adolescents with low IQ were more likely to have US. Ousley and Mesibov[39] found that the level of sexual knowledge was significantly positively correlated with IQ. The lower the IQ of adolescents with autism, the less knowledge they have about sexual behavior and the less they understand how to protect themselves effectively. ToM refers to the ability to recognize other's mental status. However, individuals with HFA have defects in this aspect, and they often have difficulty understanding the mental state of others[40]. Therefore, when autistic individuals cannot correctly understand the mental state of others, they are likely to have sex with others under coercion or against their own wishes. US behavior was also significantly related to facial expression recognition. Facial recognition disorder has long been considered as an important neuropsychological mechanism of autism[41]. Because adolescents with HFA cannot accurately recognize the expressions of others, they may not be able to understand family members' rejection of US nor can they

Table 6 Multiple linear regression analysis of aggression and violence, health compromising behavior, unprotected sex, suicide and self-injury subscales and total score of Adolescents Health-related Risky Behavior Inventory

| Model | Unstandardized coefficients | | t | P value | 95% Confidence interval for B | |
|-----------------------------------|-----------------------------|-------|--------|---------|-------------------------------|-------------|
| | B | SE | | | Lower bound | Upper bound |
| AV | | | | | | |
| Emotional subscale | -0.268 | 0.068 | -3.954 | < 0.001 | -0.403 | -0.133 |
| HCB | | | | | | |
| School life experience | -0.152 | 0.053 | -2.841 | 0.006 | -0.258 | -0.045 |
| US | | | | | | |
| Total IQ scores | -0.032 | 0.015 | -2.066 | 0.042 | -0.062 | -0.001 |
| Score of second-order belief test | -1.321 | 0.428 | -3.088 | 0.003 | -2.173 | -0.470 |
| SS | | | | | | |
| Depression experience | -0.321 | 0.073 | -4.371 | < 0.001 | -0.467 | -0.175 |
| Total score of AHRBI | | | | | | |
| Depression experience | -1.603 | 0.444 | -3.613 | 0.001 | -2.487 | -0.719 |

AHRBI: Adolescent Health-related Risky Behavior Inventory; AV: Aggression and violence; HCB: Health compromising behavior; IQ: Intelligence quotient; SS: Suicide and self-injury; US: Unprotected sex.

correctly identify possible dangers, thereby increasing the risk of autistic adolescents having US.

The results of this study show that self-harm and suicidal behaviors in individuals with HFA were positively correlated with the severity of depression. For individuals with autism, depression and self-injury can occur simultaneously[42]. Storch *et al*[43] investigated 102 adolescents with autism spectrum disorders. They found that approximately 11% of autism spectrum disorder subjects exhibited depression and suicidal behaviors, which is consistent with our results.

There was no significant difference in the RB score between autistic adolescents and neurotypical adolescents. The reason might be that because of the impairment of social interaction and communication ability, they rarely gather with others to commit illegal crimes together[44,45]. In addition, stereotypical features may make autistic adolescents follow rules more strictly, which will reduce the occurrence of RB behaviors.

Our study did not find substance abuse in the autism group to be more common than in the control group, which is consistent with Mangerud *et al*[46]'s and Gao *et al* [6]'s studies. Unhealthy habits in adolescents, such as smoking and drinking alcohol, are closely related to parent education and behaviors[47]. Most parents in this study had higher education levels, which might lead to bias in the results. However, adolescents with autism tend to exhibit poor self-control and repetitive and rigid behavior patterns. Once they are exposed to alcohol, tobacco, *etc.*, the risk of substance dependence and abuse will be far greater than that of neurotypical peers[48]. As a result, we still need to pay attention to substance use among individuals with HFA.

Through this study, we found that adolescents with HFA may suffer from a variety of health-related risky behaviors, such as attack and violence, suicide or self-injury, health compromising and US behaviors. Affective disorder is an important risk factor influencing health-related risky behaviors in HFA. Parents of autistic adolescents should pay attention to their children's emotional changes and provide timely guidance to prevent aggressive behavior and self-harm or suicide. Psychiatrists should also pay more attention to the anxiety and depression of adolescents with HFA and intervene in time. Cognitive dysfunction is also an important risk factor for US, which may occur on adolescents with HFA. Parents and trainers of autism should educate autistic adolescents about sexual knowledge and let them know why they should protect their own sexual safety and how to protect themselves. Relevant trainers should also cultivate the ability of autistic adolescents to infer other people's thoughts and the ability to recognize other people's expressions. This may help individuals with autism avoid danger and protect their own safety. The school life of autistic

individuals also needs attention. Whether autistic adolescents like school life or not, how they get along with their peers will affect their living habits. As important members in school, teachers should also take the responsibility of educating adolescents with HFA to develop good living habits, such as regular physical exercise, eating breakfast on time, not eating high carbohydrate food, *etc.*

There are some flaws in this study. First, the number of subjects was relatively small. Furthermore, males accounted for the majority of the sample. Subjects in the autism group were enrolled from a single medical center, which may introduce bias. Therefore, future studies need to expand the sample size, include more female autistic individuals and recruit subjects from more medical centers to explore health-related risky behaviors and their risk factors with HFA in more depth.

CONCLUSION

This study shows that adolescents with HFA are more likely to be involved in health-related risky behaviors, especially in AV, HCB, US and SS behaviors. Different health-related risky behaviors have different risk factors. Close attention should be paid to such phenomena in order to carry out a more comprehensive intervention for adolescents with HFA.

ARTICLE HIGHLIGHTS

Research background

Our study mainly explored health-related risky behaviors in adolescents with high-functioning autism (HFA) and their risk factors. Autism is a neurodevelopmental disorder with an increasing prevalence. Adolescents with HFA are in a critical period with many physical and mental changes. Except for social interaction disorder, communication barriers and stereotyped or repetitive behaviors, adolescents with HFA are more likely to be involved in health-related risky behaviors. These behaviors have not been understood so far.

Research motivation

Most of the previous researchers focused on a single risky behavior with HFA. Related risk factors of health-related risky behaviors in autistic individuals have not been fully explored. Our results may provide a better understanding of health-related risky behaviors in adolescents with HFA.

Research objectives

We aimed to explore health-related risky behaviors and their risk factors in adolescents with HFA. This study may lay a foundation for comprehensive intervention by discovering factors associated with such behaviors.

Research methods

The study was set up into autism group and control group. Both groups completed the Adolescents Health-related Risky Behavior Inventory. Expression recognition, the Inventory of Subjective Life Quality for Child and Adolescent, Chinese Wechsler Intelligence Scale for Children, Wechsler Intelligence Scale for Adult-Chinese Revised, Theory of Mind Test and Autism Spectrum Screening Questionnaire were assessed in the HFA group to explore risk factors of health-related risky behaviors in autistic adolescents.

Research results

We found that individuals with HFA had more aggression and violence, suicide or self-injury, health compromising behavior and unprotected sex than neurotypical teenagers. Uncomfortable emotional experience, depression, low intelligence quotient score, low score of theory of mind test and not adapted to school life experience were risk factors.

Research conclusions

Through this cross-sectional study, we found that adolescents with HFA have more health-related risky behaviors than neurotypical adolescents. Different health-related

risky behaviors have different risk factors. We should pay attention to the emotional experience and school life experience of autistic adolescents and teach them self-protection knowledge.

Research perspectives

This information will assist in the comprehensive evaluation and lay the foundation for intervention of health-related risky behaviors in adolescents with HFA. Future study should expand the sample size and enroll more female participants. More related factors should be taken into consideration, such as health status of subjects' parents.

ACKNOWLEDGEMENTS

The authors thank Peking University Sixth Hospital for providing platform support. We also thank all participants and their families. We appreciate Chen HG and other colleagues who gave advice and professional support on data collection and methodology.

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