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# Trends of impairment of the activities of daily living in Chinese older adults: an age-period-cohort analysis

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## Abstract

**Background** Based on age, period, and cohort, this study aimed to understand the trend of impairment of activities of daily living (ADL) and its influencing factors in older adults in China and to provide a basis for the development of appropriate interventions.

**Methods** This longitudinal follow-up study was conducted on a sample of 40,748 cases aged ≥ 60 years from the China Family Panel Studies (CFPS) database of 6 periods, using the six-item ADL scale to measure impaired ability to perform daily activities in older adults. Incorporating independent variables affecting ADL impairment in older adults based on the health ecology theory, a stratified age-period-cohort mixed-effects model was used to analyze the factors influencing impaired ADL in older adults.

**Results** Age, different periods, and birth cohort had an independent effect on females suffering from chronic diseases, having lower life satisfaction (dissatisfied, very dissatisfied), living in the western region, residing in rural areas, having per capita household income levels of middle-high, middle-low, lower-middle, lower-middle, and going to specialized and general hospitals were risk factors for ADL impairment in older adults. Smoking, drinking alcohol, exercising, having high life satisfaction (satisfied), being married, having higher education, and having urban/rural/rural residents' health insurance and employee health insurance were protective factors for ADL impairment in older adults.

**Conclusions** It is important to pay further attention to the current situation of ADL impairment in older adults from the perspective of the whole life cycle and the whole population and to take timely and targeted intervention strategies and preventive measures to improve the health of older adults in different dimensions from the individual to the macro level.

**Keywords** ADL impairment, Older adults, Age-period-cohort, Health ecology theory, HAPC-CCREM

## Introduction

Global population aging has become a defining demographic transformation of the twenty-first century. The World Health Organization (WHO) projects that by 2030, 1 in 6 people worldwide will be aged 60 years or older [1]. This demographic shift poses universal challenges to healthcare systems, particularly in managing activities of daily living (ADL) impairment—a critical marker of functional independence. International research had shown that the ADL impairment rate among older people is close to 40%, posing a serious threat to their health [2]. Cross-national studies reveal substantial heterogeneity in ADL trajectories: ADL limitations among Korean older adults significantly

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increase over time [3], the United States exhibits widening socioeconomic disparities in ADL limitations [4]. As individuals and groups make various choices in diverse historical contexts, various risk factors emerge at different age stages and periods, impacting population health in a long-term and cumulative fashion [5]. Age, period, and cohort effects all signify specific changes associated with time [6]. Such variations underscore the need for context-specific investigations of age-period-cohort (APC) dynamics.

In China, this challenge is magnified by accelerated aging. Data from the National Bureau of Statistics of China showed that as of the end of 2023, China's population over 60 years of age accounted for 21.1%, officially entering a moderately aging society [7]. Aging is widely recognized as a major contributor to human disease [8]. As the aging population in China continues to grow, health issues faced by older individuals are becoming more pronounced. The ability of older adults to live independently, whether they are disabled or not, is a crucial factor that reflects their overall health status [9]. In 2020, the number of disabled older adults individuals aged 60 years and older in China surpassed 42 million, representing approximately 16.6% of the population in that age group [10]. As China's population continues to age, the growing number of disabled older individuals adversely affects their health and societal participation and presents significant challenges to society as a whole.

Existing studies on ADL impairment in older people in China have predominantly relied on cross-sectional data collected from various provinces, cities, and rural areas [11–13]. These studies typically focused on correlation analysis or influencing analysis factors such as economic status, chronic diseases, frailty, and other correlates of ADL impairment in older people. The analysis of the influencing factors is the primary focus of these studies [14–16]. Existing APC analyses of ADL impairment predominantly derive from Western contexts. Landmark studies include: an APC analysis in the United States revealing the effects of age, period, and cohort on ADL and IADL in older adults in the United States [17]. The cross-country variation in disability prevalence and its trends over time were analyzed in the United States, Mexico, and multiple countries in Europe and Asia [18]. In Chinese studies addressing the evolving trend of ADL impairment, the majority concentrate on temporal shifts or solely on the influence of age and cohort [19–21].

In addition, the health ecology theory, as a theory and way of thinking used to guide public health practice and solve human health problems, has been widely used to analyze factors influencing individual diseases or health. Health ecology theory emphasizes the multilevel and complexity of the interaction between the environment and personal health. It advocates analyzing the factors influencing health or disease at multiple levels, including the individual and environment, and providing health information for individuals from different dimensions, thus promoting the realization of human health goals [22].

Although previous studies have investigated influencing factors of activities of daily living (ADL) impairment among Chinese older adults, most relied on cross-sectional data primarily focusing on individual-level determinants such as socioeconomic status, chronic diseases, and frailty. Our study used longitudinal data to examine the changing trends of ADL disorders in older people in China. Furthermore, the existing age period cohort (APC) analysis did not include a systematic system of independent variables, such as individual level and living environment, and lacks systematic integration with health ecology theory, making it impossible to test ADL trajectories in China's unique socio-cultural environment. To address these gaps, our study has developed an APC model guided by health ecology theory. Using the personal trait Factors, behavioral psychological factors, family network factors, living environment factors, policy environment factors dimensions of the health ecology theory model, the trend and influencing factors of ADL impairment in Chinese older adults are comprehensively explored from the aspects of age, period, and cohort, providing scientific basis for improving the health status of the older adults.

## Methods

### Data

This study used Chinese Family Panel Studies (CFPS) data from 2010, 2012, 2014, 2016, 2018, and 2020. This database collects data at three levels–individual, family, and community–that reflect China's economic, demographic, educational, health, and other aspects. The CFPS adopts implicit stratification, multi-stage, multilevel, and probability proportional to size sampling (PPS) probability sampling methods and can be regarded as a nationally representative sample. The study included 48,467 samples aged ≥ 60 years, excluding 7,719 cases with missing data on important variables such as activities of daily living, and finally included 40,748 research subjects.

### Dependent variable

Disability in older adults refers to the inability to independently carry out activities such as eating, dressing, going to the toilet, etc., due to old age, disability, disease, cognitive impairment, etc., that is, impairment of ADL [14]. The dependent variable in this study is whether ADL is impaired (0 = ADL is not impaired; 1 = ADL is impaired). Currently, the Activities of Daily Living Scale developed

by Lawton [23]. The CFPS data includes whether independent outdoor activities/dining/kitchen activities/use of public transportation/shopping/cleaning/laundry [24]. Participants were classified as ADL-impaired if they reported difficulty in ≥ 1 ADL item; non-impaired status required no difficulty across all seven items [25].

### Independent variables

The core independent variables included age, period, and cohort. The age range of older adults included in this study ranged from 60 to 110. The method proposed by Reither [26] was used in the age variable by treating age as a continuous variable and adding the age square term. The period was defined according to the time of the CFPS database survey: 2010, 2012, 2014, 2016, 2018, 2020, and the cohorts were divided into before 1925, 1925–1929, 1930–1934, 1935–1939, 1940–1944, 1945–1949, 1950–1954, and 8 groups after 1955. In addition to age, period, and birth cohort, other variables were divided into five dimensions, according to the health ecology theoretical framework, to measure the impact of relevant variables on ADL damage in older adults in old age. (1) Personal characteristics: gender, chronic disease; (2) behavioral lifestyle: smoking, drinking, exercise, life satisfaction; (3) family and community network: region, place of residence, marital status, and education level; (4)) working and living conditions: working status, income level, accessibility of medical services; and (5) policy environment layer: pension insurance, medical insurance.

The definitions of some independent variables are: (1) Smoking: smoking was defined by "whether or not you smoked in the past month"; (2) Drinking: drinking was defined by "whether you drink based on have you drank 3 times a week in the past month"; (3) Region: according to China's economic development level and geographical location [27], the provinces are divided into eastern, central and western regions; (4) Income level: the per capita household income quartile was used to measure [28], and the per capita household income was ranked from high to Low ranking, divided into 4 groups: high-income group, middle-high-income group, middle-low-income group, and low-income group; (5) Accessibility of medical services: according to previous research [29], in the selected database, If you are looking for a doctor, where do you usually go to see a doctor? as a measure of medical service accessibility.

### Statistics analysis

Excel 2021 and Stata 17.0 statistical software were used to organize and analyze the data. Excel 2021 was used to calculate the ADL damage rate and draw graphs. The $\chi^2$ test or rank sum test was used for comparison between groups, and a hierarchical age-period cohort cross-classified random effects model (HAPC-CCREM) [6] was constructed to analyze the influencing factors of the impairment of daily activities of the older Chinese population. HAPC-CCREM solves the collinearity problem between age and birth cohort (birth cohort = period—age) by stratifying the effects of age, period, and cohort on the dependent variable, using individual age as the first layer variable (fixed effects model), while period and cohort were used as another layer of variables (random effects model) nested outside the age group to break the natural collinearity between the three [30]. The HAPC model was used to estimate the age using repeated cross-sectional data., an effective tool for assessing period and cohort effects [31]. This study used the HAPC-CCREM to include age, period, and birth cohort variables, and the remaining variables based on health ecology were placed in the same layer as age. $P < 0.05$ was considered a statistically significant difference.

## Results

### Age, period, and cohort trends in the impaired rate of ADL among older adults (Figs. 1, 2, and 3)

This study involved a total of 40,748 older adults. Regarding the age effects, the rate of ADL impairment among older Chinese adults increased with age. The impairment rate was 11.88% for older adults aged 60 to 64 years, while it reached 62.34% for those aged 85 years and older. In terms of the period effects, the ADL impairment rate among older people in China ranges from 17.12% to 30.64% during 2010–2020, showed an overall increasing trend. The rate was 24.83% in 2010 and increased to 30.64% in 2020. Specifically, the impairment rate decreased from 2010 to 2014 and then fluctuated upward from 2014 to 2020, with the lowest rate observed in 2014. Regarding the birth cohort effects, the overall ADL impairment rate was higher among older adults born earlier. The rate decreased from 66.41% for those born before 1925 to 13.91% for those born after 1950, with the decreasing trend gradually slowing down. The impairment rate for those born after 1955 increased slightly 14.23%, compared to those born in 1950.

### Single-factor analysis of ADL impairment in the older adults with different characteristics (Table 1)

In addition to age, period, and birth cohort, we included other variables based on the health ecological model. Single-factor analysis revealed significant differences in ADL impairment among older adults with varying characteristics, including gender, presence of chronic diseases, smoking status, alcohol consumption, exercise habits, life satisfaction, region of residence, urban vs. rural living, marital status, education level, employment status, income level, access to medical services,

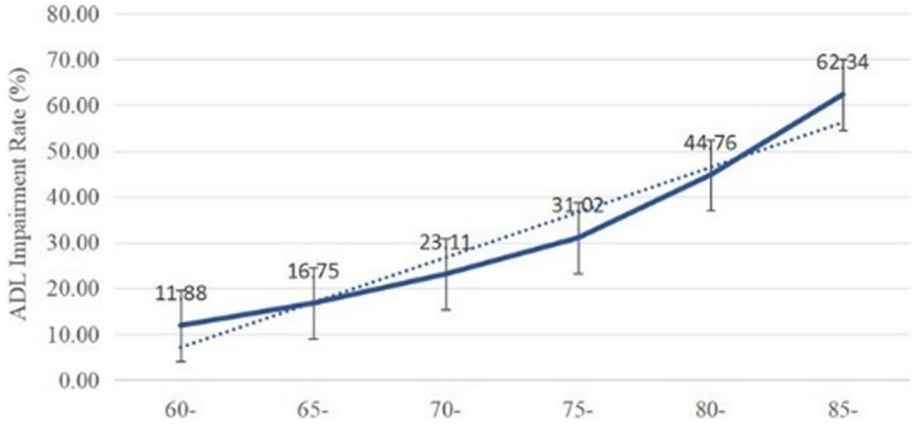


**Fig. 1** Age effects on ADL impairment rates in older adults

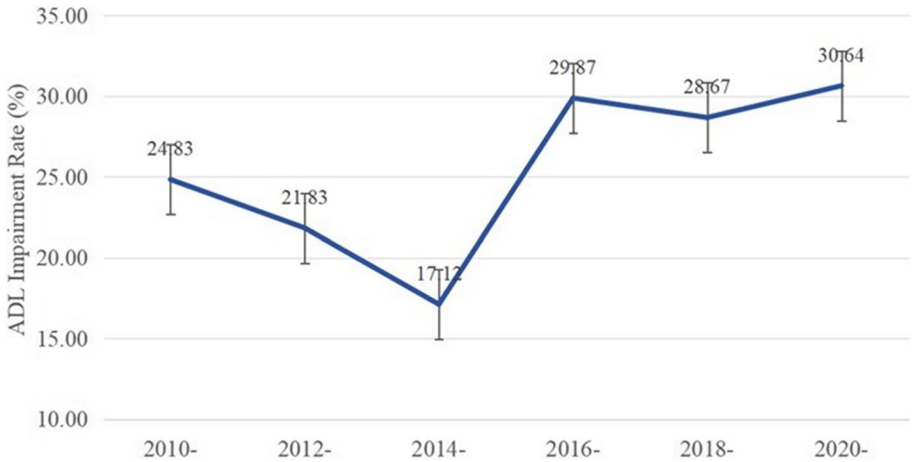


**Fig. 2** Period effects of ADL impairment rates in older adults

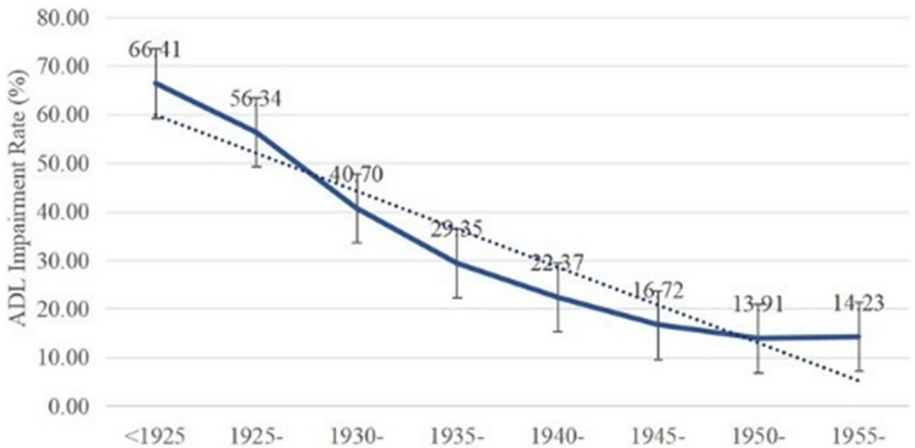


**Fig. 3** Cohort effects on ADL impairment rates in older adults

**Table 1** Comparison of ADL impairment in older adults with different characteristics

| Variable | Category | ADL level | | | | $\chi^2$ /Z | *P-value* |
|---|---|---|---|---|---|---|---|
| | | Damaged (n) | Composition (%) | Undamaged (n) | Composition (%) | | |
| **Personal Trait Factors** | | | | | | | |
| Gender | Male | 3270 | 15.94 | 17,241 | 84.06 | 421.319 | < 0.001 |
| | Female | 4872 | 24.07 | 15,365 | 75.93 | | |
| Chronic illness | No | 5153 | 17.61 | 24,108 | 82.39 | 364.914 | < 0.001 |
| | Yes | 2989 | 26.02 | 8498 | 73.98 | | |
| **Behavioral Psychological Factors** | | | | | | | |
| Smoking | No | 6352 | 21.81 | 22,769 | 78.19 | 214.017 | < 0.001 |
| | Yes | 1790 | 15.40 | 9837 | 84.60 | | |
| Drinking | No | 7336 | 21.55 | 26,704 | 78.45 | 318.682 | < 0.001 |
| | Yes | 806 | 12.02 | 5902 | 87.98 | | |
| Exercise | No | 5438 | 23.90 | 17,316 | 76.10 | 494.644 | < 0.001 |
| | Yes | 2704 | 15.03 | 15,290 | 84.97 | | |
| Life satisfaction | Very dissatisfied | 334 | 28.82 | 825 | 71.18 | 176.385 | |
| | Unsatisfactory | 647 | 26.12 | 1830 | 73.88 | | |
| | Average | 1956 | 18.48 | 8628 | 81.52 | | |
| | Satisfied | 2211 | 17.83 | 10,186 | 82.17 | | |
| | Very satisfied | 2994 | 21.19 | 11,137 | 78.81 | | |
| **Family network factors** | | | | | | | |
| Region | East | 3335 | 17.92 | 15,279 | 82.08 | 207.944 | < 0.001 |
| | Central | 2214 | 18.97 | 9457 | 81.03 | | |
| | West | 2593 | 24.78 | 7870 | 75.22 | | |
| Place of residence | Rural | 4933 | 22.88 | 16,624 | 77.12 | 241.116 | < 0.001 |
| | Urban | 3209 | 16.72 | 15,982 | 83.28 | | |
| Marital status | Single | 2631 | 31.00 | 5857 | 69.00 | 813.632 | < 0.001 |
| | Married | 5511 | 17.08 | 26,749 | 82.92 | | |
| Educational attainment | Never been to school | 5534 | 26.12 | 15,654 | 73.88 | 154.387 | < 0.001 |
| | Elementary school and below | 1350 | 14.96 | 7673 | 85.04 | | |
| | Junior high school and high school | 1094 | 11.92 | 8082 | 88.08 | | |
| | Specialized and above | 164 | 12.05 | 1197 | 87.95 | | |
| **Living environment factors** | | | | | | | |
| Work status | No | 6033 | 24.57 | 18,524 | 75.43 | 812.937 | < 0.001 |
| | Yes | 2109 | 13.03 | 14,082 | 86.97 | | |
| Income level | Low-income group | 3243 | 25.25 | 9600 | 74.75 | 491.666 | < 0.001 |
| | Lower middle income group | 2058 | 21.21 | 7647 | 78.79 | | |
| | Upper middle-income group | 1569 | 17.57 | 7363 | 82.43 | | |
| | High-income group | 1272 | 13.72 | 7996 | 86.28 | | |
| Accessibility of medical services | General Hospital | 2623 | 20.43 | 10,218 | 79.57 | 21.810 | < 0.001 |
| | Specialized hospitals | 401 | 23.51 | 1305 | 76.49 | | |
| | Community/township health service center | 1931 | 19.51 | 7964 | 80.49 | | |
| | Community Health Service Station/Village Health Office | 1813 | 19.04 | 7710 | 80.96 | | |
| | Clinic | 1374 | 20.26 | 5409 | 79.74 | | |

**Table 1** (continued)

| Variable | Category | ADL level | | | | $\chi^2$ /Z | *P-value* |
|---|---|---|---|---|---|---|---|
| | | Damaged (n) | Composition (%) | Undamaged (n) | Composition (%) | | |
| **Policy environment factors** | | | | | | | |
| Pension Insurance | No | 3338 | 19.46 | 13,819 | 80.54 | 5.123 | 0.024 |
| | Yes | 4804 | 20.36 | 18,787 | 79.64 | | |
| Medical insurance | No | 894 | 22.98 | 2997 | 77.02 | 298.731 | < 0.001 |
| | New Rural Cooperative Medical System | 5685 | 21.79 | 20,401 | 78.21 | | |
| | Urban/rural/rural residents' medical insurance | 629 | 17.00 | 3072 | 83.00 | | |
| | Employee Medical Insurance | 934 | 13.21 | 6136 | 86.79 | | |

pension insurance coverage, and type of medical insurance ($P < 0.05$).

### Mixed effects model analysis of ADL impairment in Chinese older adults (Table 2)

Based on the age-period-cohort model, we constructed a mixed-effects model for ADL impairment among older Chinese adults (Model I), with ADL impairment as the dependent variable. The model included age, age squared, period, and birth cohort. The results indicated a U-shaped relationship between age and ADL impairment, with age negatively correlated with ADL impairment ($P < 0.001$) and age squared positively correlated ($P < 0.001$). Additionally, different periods and birth cohorts were significantly related to ADL impairment in older adults ($P < 0.001$). Additionally, different periods and birth cohorts were significantly related to ADL impairment in older people ($P < 0.001$). We then sequentially incorporated five layers of variables from the health ecological model to build Models II-VI. As we added these variables, the AIC and BIC values decreased, indicating improved model fit and prediction performance.

In the final model (Model VI), we identified several risk factors for ADL impairment among older adults: being female, having chronic diseases, reporting dissatisfaction or very dissatisfaction with life, residing in the western region or rural areas, belonging to lower household income groups (upper middle, lower-middle, low-income), and seeking medical treatment at specialized or general hospitals ($P < 0.001$).

Conversely, the following factors were protective against ADL impairment: smoking, drinking alcohol, exercising regularly, reporting satisfaction with life, being married, having higher education levels (primary school and below, junior high school, senior high school, junior college and above), and holding urban/urban–rural resident medical insurance or employee medical insurance ($P < 0.001$).The following factors were protective against ADL impairment: smoking, drinking, exercising, reporting satisfaction with life, being married, having higher education levels (primary school and below, junior high school, senior high school, junior college and above), holding urban/urban–rural resident medical insurance or employee medical insurance ($P < 0.001$).

## Discussion

Life course theory provides an important perspective for analyzing population health or disease outcomes; that is, health or disease outcomes are the longitudinal accumulation of life experiences in early life and are an important theoretical basis for quantitatively analyzing macro-changing trends and patterns in the health status of the old population [19, 32, 33]. This study used the life course theory, studying the age, period, and birth cohort of older people to explore the underlying mechanisms. The results showed that the proportion of disabled older adults continues to increase with age, and the HAPC-CCREM mixed-effects model suggests that age and ADL impairment present a U-shaped trend, which is consistent with the results of other life course studies [6, 19]. On the one hand, it may be that in the initial aging period, due to the development of medical technology, ADL damage in older adults can be effectively controlled; but on the other hand, age is an important factor affecting the development and change of the body functions of older adults. As aging progresses, irreversible physical functional limitations and the continued accumulation of health risk factors [19, 34], as well as the increased likelihood of chronic diseases [35], increase the risk of disability, leading to increased disability rates in older adults.

This study also found that the ADL impairment rate showed a downward trend from 2010 to 2014 and a fluctuating upward trend from 2014 to 2020, with impairment rates ranging from 17.12% to 30.64%. This

**Table 2** Mixed-effects model analysis of ADL impairment in Chinese older adults

| | Model I | Model II | Model III | Model IV | Model V | Model VI |
|---|---|---|---|---|---|---|
| **Fixed effects model** | | | | | | |
| Age | −0.0483*** | −0.0489*** | −0.0435*** | −0.0460*** | −0.0523*** | −0.0521*** |
| | (−7.9090) | (−8.1005) | (−7.3796) | (−7.7651) | (−8.3748) | (−8.3434) |
| Age squared | 0.0005*** | 0.0005*** | 0.0004*** | 0.0004*** | 0.0005*** | 0.0005*** |
| | (10.7219) | (10.9059) | (10.2060) | (10.4101) | (10.6520) | (10.6333) |
| Sex (control: male) | | 0.0743*** | 0.0565*** | 0.0345*** | 0.0263*** | 0.0251*** |
| | | (19.6570) | (12.6979) | (7.4248) | (5.6816) | (5.4101) |
| Chronic disease (control: no) | | 0.0729*** | 0.0744*** | 0.0761*** | 0.0701*** | 0.0704*** |
| | | (17.3124) | (17.7237) | (18.2683) | (16.8443) | (16.9341) |
| Smoking (control: no) | | | −0.0023 | −0.0117** | −0.0096** | −0.0095** |
| | | | (−0.4806) | (−2.4304) | (−2.0062) | (−1.9882) |
| Drinking(control: no) | | | −0.0467*** | −0.0443*** | −0.0349*** | −0.0351*** |
| | | | (−8.6464) | (−8.2477) | (−6.5259) | (−6.5733) |
| Exercise (control: no) | | | −0.0872*** | −0.0613*** | −0.0674*** | −0.0649*** |
| | | | (−22.7196) | (−15.4106) | (−16.9136) | (−16.1970) |
| Life satisfaction (control: very satisfied) | | | | | | |
| Satisfied | | | −0.0195*** | −0.0138*** | −0.0124*** | −0.0120*** |
| | | | (−4.1376) | (−2.9422) | (−2.6654) | (−2.5842) |
| Average | | | −0.0058 | −0.0028 | −0.0037 | −0.0037 |
| | | | (−1.1489) | (−0.5537) | (−0.7516) | (−0.7585) |
| Dissatisfied | | | 0.0574*** | 0.0521*** | 0.0447*** | 0.0450*** |
| | | | (6.8371) | (6.2453) | (5.3942) | (5.4280) |
| Very dissatisfied | | | 0.0734*** | 0.0691*** | 0.0589*** | 0.0583*** |
| | | | (6.3051) | (5.9788) | (5.1279) | (5.0753) |
| Region (Control: East) | | | | | | |
| Central | | | | 0.004 | −0.002 | −0.001 |
| | | | | (0.919) | (−0.475) | (−0.332) |
| West | | | | 0.045*** | 0.044*** | 0.044*** |
| | | | | (9.493) | (9.261) | (9.152) |
| Place of residence (control: urban) | | | | 0.0404*** | 0.0500*** | 0.0441*** |
| | | | | (10.1303) | (11.7185) | (10.0260) |
| Marital status (control: not in marriage) | | | | −0.0317*** | −0.0228*** | −0.0216*** |
| | | | | (−6.4140) | (−4.6296) | (−4.3984) |
| Educational attainment (control: no schooling) | | | | | | |
| Elementary school and below | | | | −0.060*** | −0.059*** | −0.057*** |
| | | | | (−12.299) | (−11.972) | (−11.637) |
| Junior high school and high school | | | | −0.059*** | −0.060*** | −0.053*** |
| | | | | (−11.360) | (−11.307) | (−9.732) |
| Specialized and above | | | | −0.089*** | −0.089*** | −0.079*** |
| | | | | (−8.250) | (−8.106) | (−7.140) |
| Work status (control: no) | | | | | −0.097*** | −0.102*** |
| | | | | | (−22.453) | (−23.125) |
| Income status (control: high-income group) | | | | | | |
| Upper middle-income group | | | | | 0.0235*** | 0.0163*** |
| | | | | | (4.0687) | (2.7631) |
| Lower middle-income group | | | | | 0.0492*** | 0.0377*** |
| | | | | | (8.1525) | (5.9636) |
| Low-income group | | | | | 0.0660*** | 0.0533*** |
| | | | | | (11.1362) | (8.4717) |

**Table 2** (continued)

| | Model I | Model II | Model III | Model IV | Model V | Model VI |
|---|---|---|---|---|---|---|
| Accessibility of medical services (control: clinic) | | | | | | |
| Community health service center/township health center | | | | | −0.0056 | −0.0071 |
| | | | | | (−0.9364) | (−1.2026) |
| Community Health Service Station/Village Health Office | | | | | 0.0036 | 0.0028 |
| | | | | | (0.6031) | (0.4788) |
| Specialized hospitals | | | | | 0.0574*** | 0.0608*** |
| | | | | | (5.6226) | (5.9498) |
| General Hospital | | | | | 0.0165*** | 0.0194*** |
| | | | | | (2.8446) | (3.3213) |
| Pension insurance (control: no) | | | | | | 0.003 |
| | | | | | | (0.722) |
| Medical insurance (control: no) | | | | | | |
| New Rural Cooperative Medical System | | | | | | 0.004 |
| | | | | | | (0.565) |
| Urban/rural residents' medical insurance | | | | | | −0.025*** |
| | | | | | | (−2.877) |
| Employee medical insurance | | | | | | −0.035*** |
| | | | | | | (−4.284) |
| Intercept | 1.3753*** | 1.3468*** | 1.2923*** | 1.4700*** | 1.8219*** | 1.8091*** |
| | (6.2567) | (6.1994) | (6.0811) | (6.8823) | (8.0593) | (8.0064) |
| **Random effects model** | | | | | | |
| Period: | −3.2930*** | −3.3047*** | −3.2699*** | −3.1900*** | −3.1828*** | −3.1934*** |
| | (−9.9788) | (−10.0149) | (−9.9730) | (−9.7658) | (−9.6795) | (−9.7073) |
| Cohort: | −4.3629*** | −4.3851*** | −4.4462*** | −4.4201*** | −4.2208*** | −4.2313*** |
| | (−12.5343) | (−12.6915) | (−12.7413) | (−13.0116) | (−14.8199) | (−14.7978) |
| **AIC** | (−273.2477) | (−275.7617) | (−278.3897) | (−280.6636) | (−282.9639) | (−283.0718) |
| **BIC** | 37,726.02 | 37,044.71 | 36,416.68 | 35,890.11 | 35,377.32 | 35,414.67 |

Outside parentheses, $\beta$ value; In parentheses, the $Z$ value; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; *** $P<0.01$; ** $P<0.05$; * $P<0.1$

is consistent with Zhang et al. [36], who used Chinese older people. The results of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) data from 1998 to 2014 when studying the ADL impairment rate (18.8% to 24.1%) are similar, suggesting that the disability of older adults in China cannot be ignored. The decline in the ADL impairment rate from 2010 to 2014 may be related to improvements in China's economic level and residents' living conditions, as well as improvements in medical standards and technology. Older adults can receive timely medical treatment and good care, resulting in a decrease in the disability rate. However, according to the disease expansion theory [19], as China's aging continues to deepen, although the development of the economic level and improvement of the medical level has brought about a decrease in disease mortality, it has also caused older adults with poor health to extend life, resulting in an increase in the rate of ADL impairment in the old population.

Looking at the birth cohort, for older adults born before 1950, the earlier they are born, the higher the rate of impairment in their activities of daily living. In addition to being affected by the natural aging of the body, it may be caused by differences in early living conditions [37]. With the advancement of science and technology and the improvement in medical standards, older people born later can enjoy relevant benefits during the critical stage of the health reserve [38]. Compared with older people born in 1950, the ADL impairment rate of older people born in 1955 and later increased slightly, which may be related to the fact that the later birth of older adults, with the improvement of living standards and income, brought about an increase in unhealthy lifestyles, such as smoking and drinking, and prolonged sedentary time, which led to an increase in chronic diseases and health risks, resulting in their health impairment [39]. Under the current situation of China's population aging trend, which is large in scale, rapid in speed, and high in age [40], and the increased demand for life care and

medical resources, it is important to further pay attention to the current status of illnesses, medical treatment, and care needs of the disabled old population from the perspective of the entire life cycle and the entire population and to promote the establishment of systems such as long-term care insurance to alleviate the current status of ADL impairment in older adults and to promote the improvement of their health levels.

It was found that being female and having chronic diseases are common risk factors for impaired ADL in older adults using a theoretical health ecology model. The rate of impaired ADL was higher in females than in males, which is consistent with the results reported by Zhang et al. [36]. Women may have a longer life expectancy due to physiological differences between men and women of different genders. It is also possible that women, as a disadvantaged group in society, have fewer social resources available to them in old age and bear heavy domestic work for a long time, leading to poorer ADLs in women than in men [41]. Disability in older adults with chronic diseases is not optimistic, consistent with the results of Chen Yuxing [42] who noted that diseases such as stroke affect older adults with impaired ADLs and that having a chronic disease puts older adults at a superimposed risk of illness and death. This study also found that participation in physical activity reduced the prevalence of impaired ADLs in older adults, consistent with the results of Li et al. [43]. Therefore, the Government needs to focus on the problem of disability among women and older persons with chronic illnesses and promote publicity and education in communities and village committees to encourage older persons to engage in physical exercise and improve the health of older persons.

Our analysis shows a negative correlation between smoking/alcohol consumption and ADL impairment. Contrary to the findings of Lee et al. [44], which suggest that drinking and smoking worsen overall physical health. Some researchers have also found that alcohol does not provide any advantages for Europeans but could shorten lifespan [45]. Additionally, our results are consistent with previous studies in China [46, 47]. However, contrast with a Chinese study, which found that never smokers live longer and healthier than current smokers and persons who quit smoking [48]. On the one hand, although smoking and drinking groups may be affected by their own health differences, the more crucial reason may be that our results reflect the opposite causal relationship rather than the true protective effect. Compared to older adults with unimpaired ADL, older adults with impaired ADL will reduce their frequency of smoking/drinking owing to their own limitations. However, the negative impact of unhealthy lifestyles on the body still exists, thereby reversing the true causal relationship.

Living in the western region and living in rural areas were risk factors for ADL damage in older adults, and increasing education level had a protective effect on ADL damage in older adults. Compared to older adults in the eastern region, those living in the western region were more likely to suffer from ADL impairment, which is consistent with the results of Li Ting [20] who proposed that ADL impairment presents a reverse socioeconomic gradient. The ADL impairment rate in the rural older adults (22.88%) was higher than that in urban older adults (16.72%). Similar to the conclusions of Li Lei et al. [49], this may be because, compared to rural areas, the popularity of health education in urban areas is higher, and urban older adults have a stronger awareness of timely medical treatment after ADL damage. It is suggested that regional and urban–rural specific intervention measures and related decisions should be formulated to reduce the disability rate of the older people in China and narrow the health disparities that exist between regions and urban and rural areas.

In addition, this study found that, compared with older people who had not attended school, the rate of ADL impairment among older people at other educational stages was lower, and older people with lower family incomes were more likely to have ADL impairment. These results are consistent with Du Xinyuan et al. [20, 50]. This may be because educational level and socioeconomic status are important factors that lead to differences in health awareness among people and access to medical and health services. Older people with higher educational levels and better socioeconomic status have stronger health awareness, and the population has a stronger awareness of their health care and access to medical care. Health services are more capable, and health outcomes are better.

Older adults with residential and employee health insurance were less likely to experience disability. This may be because health insurance, as a basic living and medical insurance for older adults, meets their basic needs. Older people with health insurance tend to seek medical treatment or hospitalization on their initiative [51], which alleviates the reality of "difficult and expensive access to medical care" for older people and leads to the improvement of their health status and the problem of incapacitation.

## Conclusion

Our study unveils the complex dynamics of ADL impairment among Chinese older adults through an integrated life course and health ecology framework. A U-shaped age trajectory emerges, reflecting transient benefits of medical advancements against early functional decline, yet ultimately yielding to irreversible

age-related degeneration. Period effects capture the paradox of economic growth—transient reductions in ADL impairment overshadowed by rising "disease survival" burdens in hyper-aging populations. Birth cohort disparities reveal enduring impacts of early-life deprivation and later-life lifestyle shifts, with newer cohorts facing amplified chronic disease risks. Multilevel analyses identify female gender, chronic conditions, rural residency, and educational disadvantage as core risk clusters, while physical activity, healthcare access, and familial support demonstrate protective roles. Persistent urban–rural and regional health inequities underscore the urgency for context-specific interventions. It is suggested that our findings be linked with the background of China's healthy aging policy and that ADL screening be incorporated into chronic disease management plans to achieve early detection of functional decline. This approach would also provide feasible steps for health system reform.

This study has limitations. Firstly, the standardized understanding of "difficulty" in ADL measurement may vary among individual respondents. In addition, although our study focused on the trend of ADL impairment rate, ADL cannot use binary variables (damaged/undamaged) to capture the gradient of injury severity. Furthermore, although we used a health ecological model with a large number of independent variables and levels, the survey data lacked clinical biomarkers such as inflammatory markers and cardiopulmonary function. This limitation excludes the possibility of testing gene-environment interactions that may regulate specific vulnerabilities. In the future, we look forward to more comprehensive longitudinal data research to further investigate the severity and more complex mechanisms of ADL.

**Abbreviations**

| | |
|---|---|
| ADL | Activities of daily living |
| CFPS | The China Family Panel Studies |
| HAPC-CCREM | A hierarchical age-period cohort cross-classified random effects model |
| AIC | Akaike Information Criterion |
| BIC | Bayesian Information Criterion |
| CLHLS | The Chinese Longitudinal Healthy Longevity Survey |

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**Authors' contributions**
Xiaoju Li contributed to the development of the concept and design of the research; Xianqi Zhang conducted the data analysis and wrote the initial draft of the manuscript; Rong Fan, Jiaxin Dong and Xiaoying Shen assisted in the analysis; Li Zhao,Yiyao Li and other co-authors contributed to drafting the manuscript and revising themanuscript. All authors are in agreement with the manuscript and declare that thecontent has not been published elsewhere. All authors read and approved the final manuscript.

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**Data availability**
The datasets generated and/or analysed during the current study are available in the CFPS repository, https://www.isss.pku.edu.cn/cfps/download/login.

## Declarations

**Ethics approval and consent to participate**
The dataset that was used in this study, the China Family Panel Studies (CFPS), is publicly available (https://doi.org/https://doi.org/10.18170/DVN/45LCSO). The CFPS were approved by the Peking University Biomedical Ethics Review Committee (No. IRB00001052–14010), and all participants signed written informed consent forms upon study entry and follow-up. The authors assert that all methods and research processes for this study were performed in accordance with the Declaration of Helsinki guidelines and regulations.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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