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COHORT PROFILE

Cohort Profile: Wisconsin longitudinal study (WLS)

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The Wisconsin Longitudinal Study (WLS) is a longitudinal study of men and women who graduated from Wisconsin high schools in 1957 and one of their randomly selected siblings. Wisconsin is located in the upper midwest of the United States and had a population of approximately 14 000 000 in 1957, making it the 14th most populous state at that time. Data spanning almost 60 years allow researchers to link family background, adolescent characteristics, educational experiences, employment experiences, income, wealth, family formation and social and religious engagement to midlife and late-life physical health, mental health, psychological well-being, cognition, end of life planning and mortality. The WLS is one of the few longitudinal data sets that include an administrative measure of cognition from childhood. Further, recently collected saliva samples allow researchers to explore the inter-relationships among genes, behaviours and environment, including genetic determinants of behaviours (e.g. educational attainment); the interactions between genes and environment; and how these interactions predict behaviours. Most panel members were born in 1939, and the sample is broadly representative of White, non-Hispanic American men and women who have completed at least a high school education. Siblings cover several adjoining cohorts: they were born primarily between 1930 and 1948. At each interview, about two-thirds of the sample lived in Wisconsin, and about one-third lived elsewhere in the United States or abroad. The data, along with documentation, are publicly accessible and can be accessed at http://www.ssc.wisc.edu/wlsresearch/. Requests for protected data or assistance should be sent to wls@ssc.wisc.edu.

Why was the cohort set up?

The origins of the Wisconsin Longitudinal Study (WLS) can be traced back to a state-sponsored questionnaire administered during the spring of 1957 to all students in their final year of high school, in all Wisconsin high schools. In the United States, students enter high school around age 14 and typically graduate within 4 years, around age 18. Approximately 75% of students in Wisconsin graduated from high school in the late 1950s.[1] The survey was administered because the state officials wanted to know the demand for post-high school education, whether promising high school students were choosing to attend college or university and what circumstances contributed to their education plans.[2] In 1964, 7 years after the original questionnaire was administered, William H. Sewell, a researcher and Professor of Sociology at the University of Wisconsin-Madison, randomly selected one-third of

the members of the class of 1957 for further data collection. The original goal of the follow-up study was to examine how family background and childhood experiences and aspirations affected educational and occupational attainment. The survey has changed as the participants have aged to cover the relevant aspects of their life course, from family formation and occupational experiences to retirement and health and well-being at older ages.

Who is in the cohort?

WLS is based on a 1/3 random sample of all Wisconsin high school graduates in 1957 ($n = 10\,317$) born between 1938 and 1940. Nearly every student in their final year of high school completed the original survey, of whom a random 1/3 sample was drawn for the subsequent surveys. The original questionnaire covered topics such as the student's educational, occupational and marital aspirations, high school coursework and parental and teacher encouragement for post-high school schooling. The sample also includes a randomly selected sibling of these graduates, the majority of whom were born between 1930 and 1948 ($n = 7928$).[3,4] Spouses of the graduates and siblings were also interviewed in 2004. Sewell and Hauser[5] estimated that ~75% of Wisconsin youth graduated from high schools in the late 1950s. About 7% of siblings in the WLS did not complete high school, along with 9% of graduate spouses and 12% of siblings' spouses. Despite the educational selectivity of the graduate sample, there is substantial heterogeneity in social origins. For example, Hauser and Sweeney[6] estimated that >20% of the graduates lived in a household where the 4-year average of parents' income, 1957–1960, fell below the official poverty line. There is only a handful of African American, Hispanic or Asian persons in the WLS, which reflects the very small number of minorities among Wisconsin high school graduates when the WLS began.[6] Despite these limitations, the WLS provides valuable information about White non-Hispanic cohorts born in 1930s and 1940s. Among Americans aged 60–64 in 2000, 66.7% are non-Hispanic Whites who completed at least 12 years of schooling.[7]

How often have they been followed up?

The graduate respondents originally completed an in-person questionnaire in 1957, which was followed with data collection in 1964 (a mail survey of parents), 1975 (telephone survey), 1993 (telephone and mail surveys), 2004 (telephone and mail surveys) and 2011 (an in-person survey and mail survey—data collection under way). The paired sibling was randomly selected from a roster of all siblings except when the graduate was a twin, in which case the twin was selected. Roughly 2000 siblings were empanelled in 1977, and the full sibling sample was implemented in 1993. Once empanelled, siblings receive the same survey instrument as the graduate. In 2004, spouses of the siblings and graduates completed phone interviews: http://www.ssc.wisc.edu/wlsresearch/documentation/retention/cor1004_retention.pdf

As Table 1 demonstrates, response rates for the survey, especially for the graduates, have generally been high, especially considering the duration of the panel. Attrition has been due primarily to mortality, and response rates do exclude those who are deceased at each survey round. Generally, as Table 1 shows, response rates for siblings have been lower than response rates for the graduates. Further, response rates in 2004 interviews with spouses, especially for the spouses of the siblings, were low.

Table 2 shows predictors of attrition in WLS, which are similar to other studies, including being male, having lower levels of educational attainment and poorer health.[1] Although the distribution of the sample has changed across time on measures of sex, parental SES, education, IQ and health, Table 2 reveals that the magnitude of these differences is not large. Detailed analyses of non-response for the graduates and siblings show that higher response rates among women and those with higher educational attainment are explained by adolescent cognition, academic performance in high school and participation in civic organizations and volunteering.[8] Hauser (2005) provides a detailed analysis of non-response in the WLS over the history of the survey.[9]

What has been measured?

Table 3 describes the content of the surveys. The survey originally covered key aspects of early life course experiences including family, educational and occupational attainment. By the time the graduates had reached their early 50s, the study shifted towards topics most relevant for midlife and later life, especially health. Table 3 provides only a general overview of content. The 2004 and 2011 surveys, for example, each include around 20 000 variables. As with most other surveys, financial questions lead to the most item non-response. To address this non-response, WLS implemented a bracketing technique for questioning reluctant respondents and provides imputed data for earnings, incomes and assets since 1975 for graduates and since 1993 for siblings.

The WLS also now includes genetic data obtained from saliva samples collected from respondents in 2006–2007 using Oragene kits and a mailback protocol patterned closely on a previous Swedish study.[10] Oragene kits were selected because of their ability to be used in a mailback protocol (e.g. no need for immediate freezing) and their high average DNA yield relative to widely used alternatives for mailback

Table 1 Response rates in the WLS

	Graduate sample				Sibling sample			
	Sample frame	Deceased	Completed interviews	Response rate	Sample frame[a]	Deceased	Completed interviews	Response rate
1957	10 317		10 317	100%				
1964								
Mail	10 317	71	8922	90%				
1975								
Mail	10 317	175	9138	92%	2438	9	2133	87.81%
1993								
Phone	10 317	587	8493	86%	7812	462	4804	65.36%
Mail	10 317	587	6845	69%	7812	462	4065	55.31%
Either phone or mail	10 317	587	8493	86%	7812	462	5365	72.99%
2004								
Phone	10 317	1288	7265	73%	7928	1226	4298	64.13%
Mail	10 317	1288	6845	69%	7928	1226	4004	59.74%
Either phone or mail	10 317	1288	7732	78%	7928	1226	4703	70.17%
2004 spouse	7483	22	4076	58%	5750	22	2180	38.06%

[a]The sample frame for siblings for 1975 was a 1/3 random sample of one random living sibling for each graduate with a sibling. The 1993 eligible sibling sample excluded: siblings who were in the 1975 sample frame, but were not interviewed; siblings of graduates not interviewed in 1975; and interviews not completed owing to lacking funds. The 2004 eligible siblings sample excluded: siblings who were in the 1975 and/or 1993 sample frame, but were not interviewed; siblings of graduates not interviewed in 1975 or 1993.

protocols available at the time. Additional samples are currently being collected in-person from those who did not provide a sample in 2006–2007.

Finally, since its inception the WLS has collected a range of non–survey-derived measures, which are detailed in Table 4. As noted in Table 4, data users may access participants' Medicare claims records. Medicare is the universal federally funded health insurance program that covers nearly everyone in the United States age 65 and older. Data users will also have access to participants' Social Security lifetime earnings and benefits records. Social Security is the federal government's old-age public pension program that covers nearly all Americans. Access to Medicare and Social Security data, however, will require measures added to the downloadable public data given the sensitivity of these data. These data will be available in 2013. Information about access can be obtained via emails to wls@ssc.wisc.edu.

What are the main strengths and weaknesses?

Strengths

The WLS is one of the longest running studies of a single cohort of adults in the United States, spanning from participants' senior year in high school in 1957 to 2011 with our ongoing data collection. Sample members are tracked through to their deaths. Further, the graduate data are enhanced by parallel survey data on one randomly selected sibling per graduate, enabling researchers to explore sibling similarities in life course experiences. In 2004, spouses of the graduates and siblings also completed interviews, thus the WLS is well-suited for couple-level analyses. Retention is remarkably high given the length of the panel.

The WLS is a unique data resource, when compared with other large population-based longitudinal studies in the United States, owing to its duration, sibling data and extensive family histories and background. Survey content encompasses nearly every facet of the participants' lives. The WLS has been touted as the most comprehensive long-standing cohort study currently in existence.[11] Some elements of the survey that are particularly distinctive relative to other existing longitudinal cohort studies include administrative data on the participants' (including spouses) IQ scores when in high school, and full lifetime employment histories (including job characteristics). Most recently, WLS obtained high school yearbooks for the graduates. Researchers coded the yearbook data for a range of indicators including youthful facial attractiveness, body weight and school activity profiles, allowing one-of-a-kind analyses of the long-term influences of early life characteristics.

The WLS' distinctive attributes will be especially valuable when examined in tandem with the recently added genetic data. The length of the panel presents

Table 2 Major correlates of attrition in the WLS

	Graduate				Sibling			Spouse	
	1957	1975	1993	2004	1977	1993	2004	Grad report of spouse's education 2004	Interviewed spouses
Graduate's educational attainment in 1975								Grad report of spouse's education	
<High school					7.64	6.53	4.81	7.81	5.42
HS only		60.05	59.08	57.29	52.87	48.05	44.8	53.56	50.58
>High school		39.95	40.93	42.71	39.49	45.41	50.39	38.63	44
Self-rated health								Grad report of spouse's health	
Very poor			0.44	0.29		0.45	0.29	35.66	37.58
Poor			1.25	0.88		1.78	1.15	47.43	47.1
Fair			9.9	9.08		11.09	9.68	12.5	11.74
Good			59.59	59.93		59.92	60.18	3.56	2.9
Excellent			28.83	29.81		26.76	28.7	0.85	0.67
Sex									
Male	48.38	47.38	46.86	46.29	49.15	48.47	47.59		
Female	51.62	52.62	53.14	51.62	50.85	51.53	52.41		
Father's education									
<High school	61.36	61.72	61.55	60.66	61.84	60.49	59.25		
HS degree	23.81	24.18	24.2	24.38	24.5	24.52	24.69		
>High school	14.83	14.11	14.25	14.96	13.67	14.99	16.06		
Mother's education									
<High school	49.31	49.41	48.85	48.13	48.83	48.34	46.09		
HS degree	36.41	36.65	36.86	37.05	36.94	37.36	37.87		
>High school	14.28	13.94	14.29	14.81	14.23	14.31	16.04		
Mean Henmon–Nelson standardized IQ score	100.459	100.79	101.19	101.92	101.93	102.89	104.43		

Grad, graduate respondent.

researchers the opportunity to look at links between genes and phenotypic data for many participants from early adolescence into their early 70s. The WLS offers extensive measures of the environment in a 55-year longitudinal framework, allowing for attention to life course processes. This nearly full life course longitudinal panel, with extensive family, employment, educational, psychological, cognitive and health data, will provide a unique opportunity to evaluate interactions between gene variants and a series of carefully measured prospective variables. Further, WLS is unique as a population-based study of this size and breadth that includes genetic data on siblings.

Weaknesses

Despite these many strengths, the WLS has several weaknesses pertaining primarily to its limited generalizability. By design, all members of the graduate sample are high school graduates, and nearly all are White—reflecting the composition of Wisconsin high school graduates in the late 1950s. Thus, the findings necessarily apply to a single cohort of White adults with at least a high school diploma (although the sibling and spouse samples show greater educational and age heterogeneity). Despite these limitations, the sample is broadly representative of older White American men and women who have completed at least a high school education. Non-Hispanic Whites who have completed at least a high school education accounted for more than two-thirds all American women and men ages 70–74 in the 2010 US Census.

However, sample homogeneity provides certain advantages. First, sample homogeneity has strengthened many studies by helping to rule out unobserved variable bias as a source of causal relationships. Notable studies include Snowdon's sample of nuns and the Framingham Study.[12,13] Indeed, most multivariate statistical analyses are intended to reduce sample heterogeneity. Second, sample homogeneity is particularly useful for analyses using the genetic data. These features can strengthen the power of genetic studies using the WLS against population stratification and other factors.[14]

A further limitation is that detailed physical and mental health data were first obtained in the 1993

Table 3 Summary of WLS content

1957 (Self-administered questionnaire)
Marital aspirations and plans
Occupational aspirations and plans
High school coursework
Friends' occupational aspirations and plans
Parents' occupational and educational attainment
1964 (Parent reporting on the graduate)
Detailed current schooling and attainment since high school
Current and past job history
Marital status
Spouse's current schooling and occupation
1975 (Graduate and sibling respondents)
1964 Measures
Civic engagement (i.e. participation in fraternal organizations)
Time spent with family and friends
Religious orientation and participation
Marital history
Detailed military history
Detailed unemployment history
Current/last job characteristics and aspirations
Graduate and spouses' earnings
Fertility history (number, sex, birth year)
Educational, occupational and income aspirations and expectations for a selected child
1992 (Graduate and sibling respondents)
1975 Measures repeated
Detailed assets summary (including intertransfers)
Detailed income summary
Pension summary
Future plans and retirement
Health insurance information
Caregiving
Selected child (education, employment, marital status, relationship with parents)
Chronic conditions
Physical symptoms
Physical limitations/functional limitations
Menopause and hormone therapy
Smoking
2004 (Graduate and sibling respondents and their spouses)
1992 Measures repeated
Network data linking study participants
Volunteering
Internet use
End of life preparations
End of life experiences (death of spouse or parent)
Menstruation, menopause and hysterectomy
Hostility, anger, anxiety
Masculinity scale
Social support and relationships
Marital quality
Health Utility Index (functional measure)
More detailed measures of chronic illnesses than collected in 1992
Cognition-letter/category fluency
Cognition-similarities
Cogntion-word recall
Health care access and utilization
Retrospective childhood health[a]
Retrospective childhood abuse[a]
2011 (Graduate and sibling respondents)
2004 Measures repeated
Network data linking study participants
Financial literacy
Retirement attitudes
Risk preferences
Questions regarding the great recession
Special survey of parents of children with developmental disabilities or significant mental illness
Activities of daily living/instrumental activities of daily living
Cognition-delayed and immediate recall
Cogntion-cookie theft description
Extensive cognitive testing for 10% of the sample
Waist-hip ratio
Peak-flow capacity
Time gait test
Chair rise
Vision screener
Medication inventory
Detailed questions on diabetes knowledge
Anaesthesia experiences
Elder abuse

wave, when the respondents were ages 53–54, thus limiting researchers' ability to track health over the full life course. This limitation was partially corrected by asking participants in 2004 to retrospectively evaluate their physical and mental health at age 16. Further, the WLS collects complete employment histories, including spells of non-employment due to disability. Thus, researchers can construct broad proxies for poor health during young adulthood.

Table 4 WLS adminstrative data

Mortality data (updated quarterly)
Cause of death data (updated annually)
Wisconsin state tumour registry data
Medicare records
Social security lifetime earnings/benefits records
Geographical identifiers
Graduates' parents' earnings 1957–1960
Henmon–Nelson IQ scores 1954–1957
High school rank
School district data (teacher/student ratios, funding)
College/university characteristics
Data from high school yearbooks
Facial attractiveness
Facial mass index (obseity)
Participation in school activities (sports and interest clubs)
Respondent's voting data
Area Resource Files
6000 variables containing information on health care facilities, health professions, measures of resource scarcity, health status, economic activity, health training programs and socio-economic and environmental characteristics

What has it found? Key findings and publications

The WLS has been regarded historically as the premier data set for exploring status attainment processes over the life course. In recent decades, WLS data collection has focused on health and aging, thus generating important publications exploring three main areas: the long-term influences of early life factors on adult health; the use of sibling models to address the role of early life experiences; and the social stratification of healthy aging. Further, recent work incorporating genetic data points to the enormous potential of WLS to contribute to genetic research. A complete and searchable bibliography of publications is available at http://www.ssc.wisc.edu/wlsresearch/publications/.

First, the collection of data over a >50-year span has positioned the WLS as a premier data source for exploring the long-term physical and mental health consequences of a range of adolescent and young adulthood characteristics and experiences. The study has demonstrated how adversities in childhood and early life shape health well into late life. For example, negative childhood experiences, especially childhood physical abuse, exert strong and negative impacts on health in late life.[15,16] Being raised in a poor family, lower levels of educational and occupational attainment, in addition to working in jobs that lack autonomy and control, predict a range of poor health and mortality outcomes in mid to late life, including an increased risk of breast cancer mortality.[17–20] Extensive social measures in the study collected throughout the participants' entire lives have also been used to show that volunteering and positive relationships with parents, children and friends all exert strong and positive influences on health in late life.[21,22] Finally, the WLS data have more recently contributed to debates in cognitive epidemiology focused on how early life cognition influences late life health and mortality. In particular, these studies found that one's academic performance in high school was a much stronger predictor of late life health and mortality than was cognition.[23] Further, measures of cognition, from early to late life, and detailed life course measures of alcohol use, helped to identify the causal ordering of the association between cognition and drinking. Analysis shows that those with higher IQs in adolescence consume more alcohol than do those with lower IQs.[24]

Second, the sibling data have helped clarify the role that early life family context plays in a range of late life outcomes. Sibling models enable researchers to control for unobserved heterogeneity that results from shared early childhood experiences as well as focus on sibling resemblance. The WLS sibling data have been used to demonstrate that the effect of family background on occupational attainment is fully accounted for by its impact on cognition and educational attainment, as opposed to any kind of direct effect of family of origin.[25] More recent work focused on health outcomes demonstrated that although siblings exert important influences on each other's childhood development, they do not exert any influence on each other's health in later life.[26] Further, WLS sibling models revealed that childhood family context could not explain links between IQ and health in late life. Prior work in this area was limited by its inability to evaluate whether the link between IQ and health was a product of early life family experiences. The current collection of DNA data will allow investigators to further explore the social and genetic bases of sibling resemblance in future studies.

Third, the breadth and depth of measures obtained in the most recent waves of the WLS have generated a range of publications on social inequities in a range of later-life health experiences, health experiences not often measured in comparable cohort studies. For example, the WLS' extensive range of measures on women's reproductive health led researchers to discover that higher incomes and educational attainment reduce the risk of hysterectomy owing to health insurance advantages associated with better jobs.[27] Higher levels of educational attainment, occupational attainment and cognition were positively correlated with age of menstruation cessation.[28] Although higher socio-economic status is almost uniformly linked to positive health outcomes, analyses of WLS

data revealed that higher SES is associated with elevated risk of breast cancer, which may be due to women with higher SES tending to use hormone replacement therapy.[29] Further, the (on average) older age of women with higher SES at first birth also partly contributes to their elevated risk of breast cancer.[20]

The WLS has also shown how SES affects medical care. Those with higher levels of educational attainment have made more successful use of the internet to obtain health-related information,[30] and participate more extensively in health care decision making.[31] Higher educational attainment affects how people plan for the end of their lives. Those with higher educational attainment and richer economic assets are more likely to engage in advance care planning (i.e. living wills and informal discussion with family members).[32] Those with higher educational attainment were also more likely to want to continue medical treatments even if faced with the hypothetical scenario of terminal illness with physical pain.[33]

Finally, the recent inclusion of genetic data to the WLS has pointed to the role the study can play in the growing body of genetic research. In addition to its wealth of life course phenotypic data, the WLS' advantages include its relatively large sample size, which helps address the common problem of statistically underpowered analyses that have frequently led to false findings. One recent example of how a larger sample can address false findings is a study by Christopher Chabris *et al*.[34] who used administrative measures of intelligence from adolescence (the Henmon–Nelson intelligence test) and genotypes for 13 of the most common single nucleotide polymorphisms (the most frequent form of genetic variation found among people) reported to be associated with intelligence in existing published studies. They found that most of these associations were likely to be false positives and will not consistently replicate in other samples.[34]

In sum, the WLS data reveal the complex ways in which social statuses, roles and experiences over the life course affect midlife and late life health, with attention to the psychosocial, cognitive and biological pathways that contribute to health inequalities.

Can I get hold of the data? Where can I find out more?

WLS data collection has been funded by the United States' National Institute on Aging since 1991. Detailed documentation and data can be downloaded for free at http://www.ssc.wisc.edu/wlsresearch/. Protected measures, which are those measures that increase a subject's risk of identifiability, are available to qualified researchers by request. Researchers wanting to use the genetic data may submit a proposal that will be reviewed by an independent board. The board reviews the proposals only to ensure that the confidentiality of participants' information will be protected. To receive more information on how to access protected measures (including the genetic data) please email wls@ssc.wisc.edu.

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KEY MESSAGES

- A nearly 60-year longitudinal panel cohort design has demonstrated how adversities in childhood and early life, including childhood physical abuse and limited economic, cognitive and social resources, exert strong and negative impacts on health in late life.
- The sibling panel design has helped demonstrate the role that one's family plays in a range of late life outcomes, while simultaneously accounting for unobserved heterogeneity that results from shared early childhood experiences.
- The breadth and depth of measures obtained in the most recent waves of the WLS have demonstrated how low educational attainment, income and occupational attainment increase the risk for negative health outcomes and medical care experiences, such as general health and mortality, cardiovascular mortality, hysterectomy and the early cessation of menstruation. Studies have also demonstrated how individuals with more education and income engage more effectively in health care decision making and end of life care planning and decisions.
- The large sample size and rich array of life course phenotypic data, combined with the recent addition of genetic data, has begun to allow researchers to explore the interrelationships among genes, behaviours and environment.

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