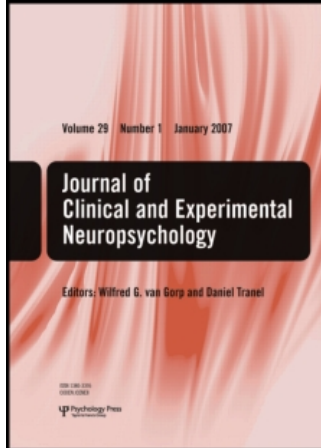


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# A proposed method to estimate premorbid full scale intelligence quotient (FSIQ) for the Canadian Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV) using demographic and combined estimation procedures

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Establishing a comparison standard in neuropsychological assessment is crucial to determining change in function. There is no available method to estimate premorbid intellectual functioning for the Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV). The WISC-IV provided normative data for both American and Canadian children aged 6 to 16 years old. This study developed regression algorithms as a proposed method to estimate full-scale intelligence quotient (FSIQ) for the Canadian WISC-IV. Participants were the Canadian WISC-IV standardization sample ( $n=1,100$ ). The sample was randomly divided into two groups (development and validation groups). The development group was used to generate regression algorithms; 1 algorithm only included demographics, and 11 combined demographic variables with WISC-IV subtest raw scores. The algorithms accounted for 18% to 70% of the variance in FSIQ (standard error of estimate, SEE=8.6 to 14.2). Estimated FSIQ significantly correlated with actual FSIQ ( $r=.30$  to  $.80$ ), and the majority of individual FSIQ estimates were within  $\pm 10$  points of actual FSIQ. The demographic-only algorithm was less accurate than algorithms combining demographic variables with subtest raw scores. The current algorithms yielded accurate estimates of current FSIQ for Canadian individuals aged 6–16 years old. The potential application of the algorithms to estimate premorbid FSIQ is reviewed. While promising, clinical validation of the algorithms in a sample of children and/or adolescents with known neurological dysfunction is needed to establish these algorithms as a premorbid estimation procedure.

Neuropsychological evaluation requires a comparison standard for determining change in neuropsychological functioning of an individual suspected of an acquired neurological insult. Group-administered standardized achievement testing—for example, American College Test (ACT; American College Testing Program, 1987) and Scholastic Achievement Test (SAT; College Board Tests, 1995)—can provide invaluable information regarding

an individual's cognitive functioning prior to the presumed neurological insult (see Baade & Schoenberg, 2004; Lezak, 1983, 1995; Putnam, Ricker, Ross, & Kurtz, 1999; Schinka & Vanderploeg, 2000). Unfortunately, standardized test results are rarely available within time frames necessary for most clinical settings. As a result, several methods to estimate premorbid intellectual functioning from demographic and/or current ability have become

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commonplace in establishing a comparison standard in neuropsychological evaluations for adults (e.g., Barona, Reynolds, & Chastain, 1984; Krull, Scott, & Sherer, 1995; Schoenberg, Duff, Scott, & Adams, 2003; Schoenberg et al., 2006; Schoenberg, Scott, Duff, & Adams, 2002; Vanderploeg & Schinka, 1995; Wilson et al., 1978) and, to a lesser extent, children (Reynolds & Gutkin, 1979; Schoenberg, Lange, Brickell, & Saklofske, in press; Vanderploeg, Schinka, Baum, Tremont, & Mittenberg, 1998).

Establishing a comparison standard for adults can often be considered less difficult than predicting premorbid cognitive functioning for children, since cognitive abilities in adults are generally fully developed, and intellectual functioning remains quite stable, at least until cerebral insult (e.g., Lezak, 1983; Wechsler, 1958). While some cognitive abilities change with age (e.g., Ivnik et al., 1992), some intellectual abilities (word reading, vocabulary) are resistant to cerebral insult and aging (e.g., Blair & Spreen, 1989; Donders, Tulsky, & Zhu, 2001; Fisher, Ledbetter, Cohen, Marmor, & Tulsky, 2000; McFie, 1975; Nelson & O'Connell, 1978; Psychological Corporation, 2001; Schwartz & Saffran, 1987; Wechsler, 1958; Yates, 1956; but see Larrabee, Lergen, & Levin, 1985). In contrast, children's intellectual and cognitive functioning is in a state of near constant change and development (e.g., Kaufman, 1990; Sattler, 1988, 2001). Thus, attempts to retrospectively establish a comparison standard for children and adolescents in neuropsychological assessment is complicated by ongoing neurodevelopment and the possible continued development of cognitive and behavioral skills with intra- or interhemisphere alterations in functional neuroanatomical organization (e.g., Chugani, Muller, & Chugani, 1996; Ewing-Cobbs, Barnes, & Fletcher, 2003; Hertz-Pannier et al., 2002; Kolb, Gibb, & Gorny, 2000; Liegeois et al., 2004; Papanicolaou et al., 2001; Yuan et al., 2006). Additionally, educational factors, rehabilitation programs, and other environmental variables (e.g., nutrition) may have profound effects on cognitive development preceding the neurological insult (Taylor & Alden, 1997; Taylor et al., 2002; Taylor et al., 2001; Yates et al., 1997).

Methods developed to estimate premorbid intellectual functioning have included: (a) demographic variables only (Barona et al., 1984; Reynolds & Gutkin, 1979; Wilson et al., 1978); (b) current ability (so called "hold") Wechsler Intelligence Scales subtests (e.g., McFie, 1975; Wechsler, 1958; Yates, 1956) and current reading ability (Blair & Spreen, 1989; Nelson, 1982; Nelson & O'Connell, 1978); and (c) approaches combining demographic variables with current ability (Crawford, Nelson, Blackmore,

Cochrane, & Allan, 1990; Krull et al., 1995; Schoenberg et al., 2003; Schoenberg et al., in press; Schoenberg et al., 2002, 2004a; Vanderploeg & Schinka, 1995; Vanderploeg et al., 1998). While methods to estimate premorbid intellectual functioning in adults has seen considerable development (e.g., Barona et al., 1984; Krull et al., 1995; Nelson & O'Connell, 1978; Schoenberg et al., 2003, 2004a; Vanderploeg et al., 1998), there has been comparatively little research devoted to predicting premorbid cognitive functioning in children and adolescents (except see, Klesges & Sanchez, 1981; Reynolds & Gutkin, 1979; Schoenberg et al., in press; Vanderploeg et al., 1998).

Clinically validated methods to estimate premorbid IQ for children using the Wechsler intelligence scales is limited to the Wechsler Intelligence Scale for Children-Revised (WISC-R, Wechsler, 1974) and Wechsler Intelligence Scale for Children-Third Edition (WISC-III, Wechsler, 1991). Reynolds and Gutkin (1979) developed algorithms from the WISC-R standardization sample combining the child's gender, ethnicity, residence (rural vs. urban), and geographic region (West, Midwest, South, East) with the father's occupational status to predict WISC-R, full scale intelligence quotient (FSIQ), verbal intelligence quotient (VIQ), and performance intelligence quotient (PIQ). The algorithms accounted for 44, 44, and 37% of variance, respectively. However, subsequent clinical validation studies by Klesges and Sanchez (1981) and Klesges (1982), suggested that the algorithms of Reynolds and Gutkin (1979) were of limited utility. Vanderploeg et al. (1998) developed algorithms to predict WISC-III FSIQ, VIQ, and PIQ scores using demographic variables. In addition, the authors also extended regression-based methods from adults to children to develop algorithms estimating WISC-III FSIQ, VIQ, and PIQ scores from current WISC-III subtest scores and demographic variables. The demographic-only algorithm combined the average of parents' education and child's ethnicity to account for 28, 27, and 20% of variance in FSIQ, VIQ, and PIQ scores, respectively. The algorithms combining current WISC-III subtest scaled scores with demographic variables accounted for 67, 66, and 50% of variance in WISC-III FSIQ, VIQ, and PIQ scores, respectively. Clinical application of the algorithms to 33 children who had suffered brain injuries and 66 matched healthy controls revealed that the estimated FSIQs derived from the algorithms combining (a) Vocabulary subtest scaled scores with demographic variables and (b) Picture Completion subtest scaled scores and demographic variables were superior to other combined current performance

and demographic variables algorithms, but did not provide better estimates of hypothesized premorbid FSIQs obtained from an algorithm using only demographic variables. Unfortunately, follow-up validity studies of these algorithms have been lacking. The void in premorbid prediction methods for children has been exacerbated by the recent release of the Wechsler Intelligence Scale for Children—Fourth Edition (WISC-IV; Wechsler, 2003a, 2003b).

The WISC-IV reflects a substantial revision of the WISC-III, in which several subtests have been added, and VIQ and PIQ scores are no longer provided. The difference between the WISC-III and WISC-IV is more pronounced with the differential release of the American WISC-IV (Wechsler, 2003a) and Canadian WISC-IV (Wechsler, 2003b). While Schoenberg et al. (in press) recently proposed algorithms designed to predict premorbid FSIQ for the American WISC-IV, there are no current or proposed methods to predict premorbid FSIQ for the Canadian WISC-IV.

The purpose of this study was to develop regression algorithms to predict WISC-IV FSIQ in Canadian children and adolescents. However, developing a method to predict premorbid intellectual functioning has been complicated by a fundamental deficiency in data—namely, premorbid FSIQ scores for patients with known or suspected dysfunction are often unavailable. A methodology to overcome this problem has been developed (see Powell, Brossart, & Reynolds, 2003; Reynolds, 1997; and Schoenberg, Scott, Ruwe, Patton, & Adams, 2004b, for recent reviews) and is based on several assumptions. First, estimates of premorbid FSIQ should be identical to current FSIQ in individuals with no known neurological dysfunction. Second, predicted premorbid FSIQ of individuals with known or suspected neurological dysfunction should (a) approximate a normal distribution of FSIQ scores for a healthy population (mean of 100 and standard deviation of 15) and (b) be significantly greater than the individual's current FSIQ. Framed within this methodology, the first step is to develop regression algorithms to estimate FSIQ in a sample of healthy participants. The estimates of FSIQ are then compared to participants' actual FSIQ. It is expected that the current algorithms will provide accurate estimates of current FSIQ. Clinical application is needed to validate these algorithms as a method to predict premorbid FSIQ. It is hoped that these algorithms will generate clinical research to validate these algorithms as a method to estimate premorbid WISC-IV FSIQ for Canadian adolescents and children.

## METHOD

### Participants

Participants were the Canadian WISC-IV standardization sample ( $N=1,100$ ; Wechsler, 2003b), obtained with permission from Harcourt Assessment, Inc. Demographic variables include age (in years), parent education (in years), gender (male, female), region of the country (i.e., central, east, west), and ethnicity (i.e., Caucasian, Asian, First Nations, Other). The Canadian WISC-IV standardization sample was selected to match the demographic characteristics of the 2001 Canadian Census (Statistics Canada, 2002) and is divided into 11 age groups ranging from age 6:0 to 16:11 years. Tables 1 and 2 present relevant demographic details. Information regarding the inclusion/exclusion criteria and further sample characteristics of this sample can be found in the WISC-IV Canadian Manual (Wechsler, 2003b).

### Measures and procedure

The Canadian WISC-IV standardization sample was randomly divided into two groups. The first group was used to generate algorithms to predict FSIQ (development group,  $n=553$ ), and the second group was used to validate these algorithms (validation group,  $n=547$ ). Group differences in age, parental education, FSIQ, and subtest raw scores were evaluated using one-way analyses of variance (ANOVAs). Differences between groups for ethnicity, region of the country, and gender were evaluated using chi-square analyses. Performance measures consisted of the subtest raw scores of the Vocabulary (VO), Information (IN), Picture Completion (PC), and Matrix Reasoning (MR) subtests. These subtests were included because of demonstrated reliability (Psychological Corporation, 1997) and resistance to neurological insult in adults (Donders, Tulsky, & Zhu, 2001; Fisher et al., 2000; Kaufman, 1990; Psychological Corporation, 1997; Schoenberg et al., 2003) and, to a lesser extent, children (e.g., Psychological Corporation, 2004; Tremont, Mittenberg, & Miller, 1999). Raw scores were used since age was a predictor variable.

Hierarchical regression was used to predict FSIQ. A total of 12 prediction algorithms were generated for FSIQ in all. Nonsignificant predictors ( $p > .05$ ) were removed from analyses, and the regression was recomputed such that all remaining demographic variables were significant predictors of FSIQ ( $p < .05$ ). When using subtest raw scores, one algorithm included all four subtests (i.e., IN/VO/MR/PC), another six algorithms included all

**TABLE 1**  
Descriptive statistics of demographic variables by group: Chi-square analysis

		<i>Development group</i>		<i>Validation group</i>		$\chi^2$	<i>p</i>
		<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>		
Gender	Male	270	48.8	280	51.2	0.615	.433
	Female	283	51.2	267	48.8		
Ethnicity	Caucasian	431	77.9	413	75.5	5.670	.129
	First Nations	30	5.4	30	5.5		
	Asian	50	9.0	72	13.2		
	Other	42	7.6	32	5.9		
Region	Central	248	44.8	278	50.8	3.939	.140
	East	64	11.6	56	10.2		
	West	241	43.6	213	38.9		
Parental education	Average	124	22.4	97	17.7	4.271	.118
	Father only	10	1.8	14	2.6		
	Mother only	419	75.8	436	79.7		

*Note.*  $N=1,100$ . Development group ( $n=553$ ), validation group ( $n=547$ ). All data are derived from the Canadian standardization sample of the *Wechsler Intelligence Scale for Children—Fourth Edition*, by D. Wechsler, 2003, San Antonio, TX: The Psychological Corporation. Copyright © 2003 by The Psychological Corporation, a Harcourt Assessment Company. Reprinted with permission. All rights reserved.

**TABLE 2**  
Means and standard deviations of WISC-IV scores by age group: Analysis of variance

	<i>Development group</i>		<i>Validation group</i>		<i>F</i>	<i>p</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Full-scale IQ	99.65	15.6	99.93	14.32	0.099	.754
Information (raw)	17.37	5.13	17.76	5.22	1.533	.216
Vocabulary (raw)	35.20	12.02	35.65	11.76	0.397	.529
Matrix Reasoning (raw)	20.39	6.30	20.58	5.94	0.282	.595
Picture Completion (raw)	25.33	6.70	25.42	6.65	0.056	.814
Age (in years)	11.42	3.24	11.55	3.11	0.430	.512
Parent education (in years)	16.01	4.40	15.72	4.75	1.149	.284

*Note.*  $N=1,100$ . Development group ( $n=553$ ), validation group ( $n=547$ ). All data are derived from the Canadian standardization sample of the *Wechsler Intelligence Scale for Children—Fourth Edition*, by D. Wechsler, 2003, San Antonio, TX: The Psychological Corporation. Copyright © 2003 by The Psychological Corporation, a Harcourt Assessment Company. Reprinted with permission. All rights reserved.

possible two-subtest combinations (i.e., IN/MR, VO/MR, IN/PC, VO/PC, VO/IN, PC/MR), and four algorithms were generated using each subtest alone (i.e., IN, MR, VO, PC). All demographic variables were dummy coded (e.g., Caucasian Yes/No, First Nations Yes/No, etc.) with the exception of age and parent education. Parental education was available in years for either one or both parents. Following Vanderploeg et al. (1998), when years of education for both parents were available, the average years of education was used. The coding schema for demographic variables used in previous research (e.g., Barona, Reynolds, & Chastain, 1984; Krull et al., 1995; Lange et al., 2005a; Schoenberg et al., 2002; Vanderploeg & Schinka, 1995) was not employed here because categorical variables (e.g., Ethnicity: 1=African-American;

2=Hispanic; 3=Other; 4=Caucasian) should not, from a statistical standpoint, be treated as continuous variables.

For each subtest model, five hierarchical regression analyses were completed using the FSIQ score as the dependent variable and demographic variables and subtest raw scores as the independent measures. For each of the five hierarchical regression analyses, the relevant subtest raw scores were forced into the regression analyses on the first step, followed by each of the five demographic variables (i.e., age, education, region of the country, gender, and ethnicity) in five subsequent steps. Age (in years) and parental education (in years) were continuous variables. Region of the country, gender, and ethnicity were each dummy coded variables. The significance of each demographic variable was

tested over and above all other variables on the final step of the hierarchy using  $R^2$  change statistics. Any demographic variable that did not add significantly ( $p < .05$ ) to the estimation of FSIQ in the final step was excluded from the equation. When one or more demographic variables were excluded during this first stage of equation building, the process was repeated using the remaining demographic variables until all remaining demographic variables contributed significantly to the regression equation.

## RESULTS

Descriptive statistics, chi-square analyses, and ANOVA results for the demographic variables and WISC-IV measures by group are presented in Tables 1 and 2. There were no significant differences between the development and validation groups in demographic variables (i.e., age, education, gender, ethnicity, region of the country), FSIQ, or subtest raw scores.

Summary results for the 12 regression equations generated from the development group ( $n=553$ ) are presented in Table 3, and the equations can be found in Appendix A. All algorithms were significant predictors of FSIQ, VIQ, and PIQ (all  $p < .001$ ). The demographic-only algorithm accounted for 18% of FSIQ variance. Algorithms that combined demographic variables with subtest performance accounted for 46% to 70% of the variance in FSIQ depending on the subtests employed.

Of the 12 algorithms evaluated, no algorithms retained all five demographic variables as significant

predictors of FSIQ. The demographic-only algorithm predicted FSIQ from parental education, ethnicity, and gender. Region of the country was never a significant predictor of FSIQ. Parent education was excluded from two algorithms (i.e., FSIQ-4ST and FSIQ-MR/VO), and gender was excluded from one algorithm (i.e., FSIQ-MR). Parental education level, Canadian ethnic group, and age were often retained as predictors of FSIQ.

The accuracy of the 12 algorithms was further evaluated with the validation group. Descriptive statistics, paired-samples  $t$  tests, and Pearson correlations between actual and estimated FSIQ are presented in Table 4. The average estimated FSIQ of the validation group did not differ significantly from the group's average actual FSIQ. The correlations between estimated and actual IQs were significant for all FSIQ algorithms ( $p < .001$ ) and ranged from  $r = .54$  to  $r = .80$ .

To examine the accuracy of the FSIQ algorithms at an individual level, each participant's estimated FSIQ was compared to their actual FSIQ to determine the base rate of estimation errors using six criteria. Table 5 presents estimation errors as a percentage of cases whose estimated FSIQ score fell within (a)  $\pm 5$  points of their actual FSIQ, (b)  $\pm 10$  points of their actual FSIQ, (c) the same ability classification level (ranging from *extremely low* to *very superior*), (d) one ability classification range, (e)  $\pm 1$  standard error of estimate, SEE, and (f) the 95% confidence interval. McNemar's test of paired proportions was used to compare the predictive accuracy of each algorithm. Using  $\pm 10$  points as the criterion, the predictive accuracy of estimated FSIQ

**TABLE 3**  
Regression results summary for estimating FSIQ scores from demographic variables and WISC-IV subtest raw scores:  
Development group

<i>Subtest model</i>	$R^2$	<i>SEE</i>	<i>F</i>	<i>p</i>	<i>Demographic variables</i>
FSIQ (4ST)	.70	8.57	142.27	<.001	Age, ethnicity, gender
FSIQ (VO/MR)	.67	8.98	159.32	<.001	Age, ethnicity, gender
FSIQ (IN/MR)	.63	9.52	116.74	<.001	Age, parental education, ethnicity, gender
FSIQ (IN/PC)	.60	9.96	100.88	<.001	Age, parental education, ethnicity, gender
FSIQ (VO/PC)	.63	9.55	115.46	<.001	Age, parental education, ethnicity, gender
FSIQ (VO/IN)	.62	9.73	108.92	<.001	Age, parental education, ethnicity, gender
FSIQ (MR/PC)	.57	10.34	88.57	<.001	Age, parental education, ethnicity, gender
FSIQ (VO)	.58	10.15	107.75	<.001	Age, parental education, ethnicity, gender
FSIQ (IN)	.52	10.90	82.99	<.001	Age, parental education, ethnicity, gender
FSIQ (MR)	.48	11.29	84.17	<.001	Age, parental education, ethnicity
FSIQ (PC)	.46	11.57	64.96	<.001	Age, parental education, ethnicity, gender
C-DEMO	.18	14.22	23.00	<.001	Parental education, ethnicity, gender

*Note.*  $N=553$ ; FSIQ=full-scale IQ; PC=Picture Completion; MR=Matrix Reasoning; VO=Vocabulary; IN=Information; 4ST=estimated FSIQ using all four subtests; C-DEMO=Canadian demographics only regression algorithm; SEE=Standard error of estimate. All data are derived from the Canadian standardization sample of the *Wechsler Intelligence Scale for Children-Fourth Edition*, by D. Wechsler, 2003, San Antonio, TX: The Psychological Corporation. Copyright © 2003 by The Psychological Corporation, a Harcourt Assessment Company. Reprinted with permission. All rights reserved.

TABLE 4

Descriptive statistics, mean comparisons, and correlation results between actual and estimated FSIQ scores: Validation group

	Obtained scores		Obtained vs. estimated IQ		Actual range	
	<i>M</i>	<i>SD</i>	<i>p</i>	<i>r</i>	<i>Min</i>	<i>Max</i>
Obtained FSIQ						
FSIQ	99.93	14.31	—	—	44	150
Predicted FSIQ						
FSIQ (4ST)	100.04	11.68	.771	.80	60	132
FSIQ (VO/MR)	99.92	11.69	.970	.78	60	130
FSIQ (IN/MR)	100.08	11.01	.714	.75	59	135
FSIQ (IN/PC)	99.97	10.88	.933	.70	49	128
FSIQ (VO/PC)	99.78	11.25	.708	.74	60	130
FSIQ (VO/IN)	100.14	11.57	.606	.75	56	134
FSIQ (MR/PC)	99.44	10.06	.284	.66	66	124
FSIQ (VO)	99.89	11.30	.911	.73	59	132
FSIQ (IN)	100.19	10.57	.577	.67	51	131
FSIQ (MR)	99.56	9.77	.441	.61	59	123
FSIQ (PC)	99.35	9.47	.267	.54	64	121
C-DEMO	99.43	6.91	.396	.30	68	113

Note.  $N=547$ ; FSIQ=full-scale IQ; PC=Picture Completion subtest raw score; MR=Matrix Reasoning subtest raw score; VO=Vocabulary subtest raw score; IN=Information subtest raw score; 4ST=estimated FSIQ using 4 subtests (i.e., IN, VO, MR, PC); C-DEMO=Canadian demographics only algorithm estimating FSIQ. All data are derived from the Canadian standardization sample of the *Wechsler Intelligence Scale for Children—Fourth Edition*, by D. Wechsler, 2003, San Antonio, TX: The Psychological Corporation. Copyright © 2003 by The Psychological Corporation, a Harcourt Assessment Company. Reprinted with permission. All rights reserved.

TABLE 5

Predictive accuracy of estimated IQ scores: Validation group

Prediction algorithm	Percentage within					
	$\pm 5$ points	$\pm 10$ points	Same category <sup>1</sup>	One category	One SEE	95% CI band
FSIQ (4ST)	44.8	74.2	55.6	95.2	64.7	95.4
FSIQ (VO/MR)	44.8	74.2	55.4	94.3	69.3	95.6
FSIQ (IN/MR)	45.0	73.9	54.5	94.5	69.8	96.7
FSIQ (IN/PC)	45.3	69.7	54.3	91.2	69.7	95.8
FSIQ (VO/PC)	43.0	74.0	54.1	94.0	68.2	95.4
FSIQ (VO/IN)	41.0	75.0	52.7	94.5	75.0	97.4
FSIQ (MR/PC)	42.2	69.8	52.7	89.6	69.8	93.1
FSIQ (VO)	38.6	70.7	52.5	93.6	70.7	96.9
FSIQ (IN)	40.8	68.2	51.6	92.3	72.4	97.1
FSIQ (MR)	37.3	67.3	52.7	89.8	69.7	94.9
FSIQ (PC)	37.5	65.4	51.2	87.9	68.7	93.6
C-DEMO	31.4	57.4	49.7	85.7	72.0	95.6

Note.  $N=547$ ; SEE=Standard error of estimate; CI=confidence interval; FSIQ=full-scale IQ; PC=Picture Completion; MR=Matrix Reasoning; VO=Vocabulary; IN=Information; 4ST=all four subtests; C-DEMO=Canadian demographics only algorithm estimating FSIQ; <sup>1</sup>Category = ability classification (e.g., borderline, low average, superior, etc). All data are derived from the Canadian standardization sample of the *Wechsler Intelligence Scale for Children—Fourth Edition*, by D. Wechsler, 2003, San Antonio, TX: The Psychological Corporation. Copyright © 2003 by The Psychological Corporation, a Harcourt Assessment Company. Reprinted with permission. All rights reserved.

using the FSIQ-4ST, FSIQ-VO/MR, FSIQ-IN/MR, FSIQ-VO/PC and FSIQ-VO/IN algorithms were significantly higher than all other FSIQ algorithms (range:  $p < .001$  to  $p = .04$ ), with the exception of the FSIQ-VO algorithm compared to the FSIQ-4ST

( $p = .06$ ), FSIQ-VO/MR ( $p = .06$ ), and FSIQ-IN/MR ( $p = .19$ ) algorithms. The lowest predictive accuracy rate was yielded by the demographic-only algorithm (C-DEMO), which was significantly lower than all other FSIQ algorithms ( $p < .01$ ).

Prediction errors as a function of FSIQ ability level (e.g., extremely low to very superior ranges) are presented in Table 6. The percentage of estimation errors are presented for FSIQ-4ST, FSIQ-VO/IN, and FSIQ-VO/MR algorithms only. These three algorithms were selected based on the highest percentage of estimated scores that fell within  $\pm 10$  points of actual FSIQ and are presented for illustrative purposes only. Using  $\pm 10$  points as the criterion, chi-square analyses revealed that the predictive accuracy of these algorithms was consistently and significantly lower for individuals with actual FSIQ falling in the superior and very superior range ( $p < .001$  to  $p = .012$ ) as well as when actual FSIQ fell below the low average range ( $p < .001$  to  $p = .010$ ).

## DISCUSSION

These algorithms provided accurate estimates of current FSIQ in a healthy sample that met the first assumption for developing a premorbid estimate procedure when an a priori index of premorbid functioning (e.g., standardized achievement test score) is not available. The standard error of estim-

ate (SEE) varied from 8.57 to 14.22 points. When applied to the cross-validation group, the mean estimated FSIQ scores did not differ significantly from actual FSIQs, approaching a mean of 100 and a standard deviation of 15. However, the proposed algorithms may or may not provide estimates of premorbid WISC-IV FSIQ for Canadian children and adolescents with known or suspected neurological dysfunction, as clinical validation has not been completed. Clinical data of a sample of Canadian children and/or adolescents were not available, and it is hoped that these proposed algorithms will lead to future clinical validation studies. Clinical validation must involve estimating WISC-IV FSIQ for Canadian individuals with known neurological dysfunction. Ideal samples would include patients aged 6 to 16 years old with a clinical presentation of mild to moderate closed head injury, status-post temporal lobectomy (6–12 months post), or stroke. When predicting premorbid FSIQ of individuals with known neurological injury, estimates of FSIQ should be significantly greater than the individual's current actual FSIQ, and the average estimated premorbid FSIQ for the neurologically impaired sample should approximate that of the WISC-IV Canadian normative sample (i.e.,

**TABLE 6**  
Predictive accuracy of estimated FSIQ scores by FSIQ ability level: Validation group

Prediction algorithm	Percentage within					95% CI band
	$\pm 5$ points	$\pm 10$ points	Same category <sup>1</sup>	One category	One SEE	
<b>FSIQ (4ST)</b>						
Borderline and lower	22.0	46.3	24.4	75.6	31.7	87.8
Low average	52.4	77.4	40.5	100	71.4	97.6
Average	50.0	83.6	76.6	99.3	73.1	98.6
High average	44.6	70.7	38.0	100	67.4	94.6
Superior and higher	18.2	40.9	13.6	68.2	34.1	79.5
<b>FSIQ (VO/MR)</b>						
Borderline and lower	22.0	46.3	31.7	73.2	36.6	87.8
Low average	52.4	77.4	39.3	98.8	72.6	97.6
Average	50.0	83.6	75.9	99.0	79.0	98.6
High average	44.6	70.7	35.9	100	67.4	95.7
Superior and higher	18.2	40.9	15.9	63.6	34.1	79.5
<b>FSIQ (VO/IN)</b>						
Borderline and lower	17.1	51.2	22.0	73.2	51.2	92.7
Low average	35.7	72.6	27.4	97.6	67.9	96.4
Average	50.7	82.9	75.5	98.6	77.3	99.3
High average	37.0	73.9	34.8	100	67.4	98.9
Superior and higher	18.2	52.3	18.2	70.5	45.5	79.5

Note.  $N=542$  (Borderline or lower,  $n=41$ ; low average,  $n=84$ ; average,  $n=286$ ; high average,  $n=92$ ; superior and higher,  $n=44$ ). SEE=Standard error of estimate; CI=confidence interval for actual FSIQ; FSIQ=full-scale IQ; PC=Picture Completion; MR=Matrix Reasoning; VO=Vocabulary; IN=Information; 4ST=all four subtests. <sup>1</sup>Category=ability classification (e.g., borderline, low average, superior, etc). Borderline/extremely low and superior/very superior categories were combined due to small sample sizes. All data are derived from the Canadian standardization sample of the *Wechsler Intelligence Scale for Children—Fourth Edition*, by D. Wechsler, 2003, San Antonio, TX: The Psychological Corporation. Copyright © 2003 by The Psychological Corporation, a Harcourt Assessment Company. Reprinted with permission. All rights reserved.

normal distribution with a mean of 100 and a *SD* of 15). This study confirmed the first portion of the method to evaluate procedures to predict premorbid intellectual function—namely, FSIQ estimates did not significantly differ from actual FSIQ in a healthy sample. Thus, these algorithms should be considered to provide a good estimate of current Canadian WISC-IV FSIQ scores until research has clinically validated the proposed algorithms.

The predictors of Canadian WISC-IV FSIQ was similar to that found by Vanderploeg et al. (1998) and American WISC-IV (Schoenberg et al., in press), although the current demographic-only algorithm did not account for as much variance in FSIQ as the WISC-III algorithm. The WISC-IV Vocabulary, Information, Picture Completion, and Matrix Reasoning subtests were employed in the current study based on the subtests' previous use as predictors of premorbid intellectual functioning in adults (Krull et al., 1995; Lange et al., 2005b; Schoenberg et al., 2003; Schoenberg et al., 2002; Vanderploeg & Schinka, 1995) and children (Scott, Krull, Williamson, Adams, & Iverson, 1997; Vanderploeg et al., 1998). The demographic predictors included parental education, ethnicity, age, and, to a lesser extent, gender. Similar to predicting premorbid FSIQ for the American WISC-IV (Schoenberg et al., in press), region of country (central, east, west) was not a significant predictor of FSIQ. This finding mirrors Vanderploeg et al. (1998) that parental education and ethnicity were the only demographic predictors of WISC-III IQ (parental occupation was a trend predictor). The beta weight of age was always negative, such that older age lowered estimated FSIQ. Ethnicity was often a significant predictor of WISC-IV FSIQ, but accounted for little variance in FSIQ. The small but significant association of each demographic variable to FSIQ was also found for the American WISC-IV (Schoenberg et al., in press).

Evaluation of the 12 algorithms developed for the Canadian standardization sample found that the algorithms combining one subtest with demographics tended to account for less variance in actual FSIQ scores than did algorithms combining two or four subtests. The demographic-only algorithm (C-DEMO) was least predictive of FSIQ. The algorithm combining four subtests with demographic variables (4ST) accounted for the most variance in FSIQ. However, based on our previous work predicting premorbid FSIQ scores (Schoenberg et al., 2003; Schoenberg et al., 2006, in press) we caution against assuming that the algorithm using four subtests (4ST) will perform well as an estimate of *premorbid* intellectual functioning because this algorithm has proved to provide poor

estimates of premorbid FSIQ in adult clinical studies (Schoenberg et al., 2003). Algorithms combining one (or two) subtests with demographic variables may perform better as estimates of premorbid intellectual functioning (e.g., Schoenberg et al., 2003). The algorithm combining Vocabulary and Matrix Reasoning raw scores with demographics performed comparably to the 4ST algorithm. Among single-subtest algorithms, the algorithm using Picture Completion yielded the least accurate estimates of FSIQ.

Clinical application is critical to establish these algorithms as a method to predict premorbid WISC-IV FSIQ for Canadian children and adolescents. Previous research utilizing similar methodology with the WISC-III (Vanderploeg et al., 1998) argues that the current algorithms may have clinical utility as a method to predict premorbid WISC-IV FSIQ in Canadian children suspected of sustaining an acquired neurological insult. It is anticipated that the demographic-only algorithm and those algorithms combining single WISC-IV subtests with demographic variables will offer better estimates of premorbid FSIQ than those combining two or more subtests (see Schoenberg et al., 2003; Vanderploeg et al., 1998). While the demographic-only based algorithm did not perform particularly well in the current study, it may prove to be a better estimator of premorbid FSIQ than the other proposed algorithms, as Vanderploeg et al. (1998) found that the algorithm using only demographic variables predicted premorbid WISC-III FSIQs as well as, and sometimes better than, algorithms combining WISC-III subtest scores with demographic variables. We hypothesize that the algorithms using the Vocabulary or Matrix Reasoning subtests may prove useful to predict premorbid FSIQ. Clearly, these algorithms require clinical validation in sample(s) of participants with known acquired neurological dysfunction.

Limitations of the current prediction method are broader than those commonly noted for similar methodology used in adults (Krull et al., 1995; Schoenberg et al., 2003; Schoenberg et al., 2002; Vanderploeg & Schinka, 1995). The issue of using current test scores as a predictor of premorbid ability is a particularly difficult issue in children and adolescents. Among the WISC-IV subtests, those associated with more crystallized abilities may be inferred to be less sensitive to neurological insult (e.g., Kaufman, 1990); however, because children's cognitive skills continue to develop, current functioning and acquisition of vocabulary or visuospatial reasoning may be expected to continue to lag behind what the individual's ability would have been if the child had not sustained an injury. Thus,

one might expect that a child's/adolescent's premorbid level of intellectual functioning would be increasingly underestimated as the duration of time between suspected onset of neurological injury and the administration of the Canadian WISC-IV increases. If the WISC-IV is administered more than 8–12 months following the presumed neurological insult, one might expect systematic underestimation of premorbid abilities. When available, clinicians are encouraged to predict premorbid cognitive functioning from available premorbid indices such as standardized achievement test scores and school grades, although Reynolds (1997) reminds us that grades are less useful as an index of premorbid ability since grades are subjective and less reliable due to variability in schools, teachers, and class content.

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## REFERENCES

- American College Testing Program. (1987). *ACT Assessment Program technical manual*. Iowa City, IA: Author.
- Baade, L. E., & Schoenberg, M. R. (2004). A proposed method to estimate premorbid intelligence utilizing group achievement measures from school records. *Archives of Clinical Neuropsychology, 19*, 227–244.
- Barona, A., Reynolds, C., & Chastain, R. (1984). A demographically based index of premorbid intelligence for the WAIS-R. *Journal of Consulting and Clinical Psychology, 52*, 885–887.
- Blair, J., & Spreen, O. (1989). Predicting premorbid IQ: A revision of the National Adult Reading Test. *The Clinical Neuropsychologist, 3*, 129–136.
- Chugani, H. T., Muller, R. A., & Chugani, D. C. (1996). Functional brain reorganization in children. *Brain & Development, 18*, 347–356.
- College Board Tests. (1995). *SAT: Technical manual*. New York: Author.
- Crawford, J. R., Nelson, H. E., Blackmore, L., Cochrane, R. H. B., & Allan, K. M. (1990). Estimating premorbid intelligence by combining the NART and demographic variables: An examination of the NART standardisation sample and supplementary equations. *Personality and Individual Differences, 11*, 1153–1157.
- Donders, J., Tulskey, D. S., & Zhu, J. (2001). Criterion validity of new WAIS-III subtest scores after traumatic brain injury. *Journal of the International Neuropsychological Society, 7*, 892–898.
- Ewing-Cobbs, L., Barnes, M. A., & Fletcher, J. M. (2003). Early brain injury in children: Development and reorganization of cognitive function. *Developmental Neuropsychology, 24*, 669–704.
- Fisher, D. C., Ledbetter, M. F., Cohen, N. J., Marmor, D., & Tulskey, D. S. (2000). WAIS-III and WMS-III profiles of mildly to severely brain-injured patients. *Applied Neuropsychology, 7*, 126–132.
- Hertz-Pannier, L., Chiron, C., Jambaque, I., Renaux-Kieffer, V., Van de Moortele, P. F., Delalande, O. et al. (2002). Late plasticity for language in a child's non-dominant hemisphere: A pre- and post-surgery fMRI study. *Brain, 125*, 361–372.
- Ivnik, R. J., Malec, J. F., Smith, G. E., Tangalos, E. G., Petersen, R. C., Kokmen, E., et al. (1992). Mayo's older Americans normative studies: WAIS-R norms for ages 56–97. *The Clinical Neuropsychologist, 6*(suppl.), 1–30.
- Kaufman, A. S. (1990). *Assessing adolescent and adult intelligence*. Boston: Allyn and Bacon.
- Klesges, R. C. (1982). Establishing premorbid levels of intellectual functioning in children: An empirical investigation. *Clinical Neuropsychology, 4*, 15–17.
- Klesges, R. C., & Sanchez, V. C. (1981). Cross-validation of an index of premorbid intellectual functioning in children. *Journal of Consulting and Clinical Psychology, 49*, 141.
- Kolb, B., Gibb, R., & Gorny, G. (2000). Cortical plasticity and the development of behavior after early frontal cortical injury. *Developmental Neuropsychology, 18*, 423–444.
- Krull, K. R., Scott, J. G., & Sherer, M. (1995). Estimation of premorbid intelligence from combined performance and demographic variables. *The Clinical Neuropsychologist, 9*, 83–88.
- Lange, R. T., Schoenberg, M. R., Chelune, G., Scott, J., & Adams, R. A. (2005a). Development of the WAIS-III General Ability Index-Estimate (GAI-E). *The Clinical Neuropsychologist, 19*, 73–86.
- Lange, R. T., Schoenberg, M. R., Woodward, T. S., & Brickell, T. A. (2005b). Development of the WAIS-III Estimate of Premorbid Ability for Canada (EPAC). *Archives of Clinical Neuropsychology, 20*, 1009–1024.
- Larrabee, G. J., Largen, J. W., & Levin, H. S. (1985). Sensitivity of age-decline resistant (“hold”) WAIS subtests to Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology, 7*, 497–504.
- Lezak, M. (1983). *Neuropsychological assessment* (2nd ed.). New York: Oxford.
- Lezak, M. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford.
- Liegeois, F., Connelly, A., Cross, J. H., Boyd, S. G., Gadian, D. G., Vargha-Khadem, F., et al. (2004). Language reorganization in children with early-onset lesions of the left hemisphere: An fMRI study. *Brain, 127*, 1229–1236.
- McFie, J. (1975). *Assessment of organic intellectual impairment*. New York: Academic Press.
- Nelson, H. E. (1982). *National adult reading test (NART): Test manual*. Windsor, UK: NFER-Nelson.
- Nelson, H. E., & O'Connell, A. (1978). Dementia: The estimation of premorbid intelligence levels using the new adult reading test. *Cortex, 14*, 234–244.
- Papanicolaou, A. C., Simos, P. G., Breier, J. I., Wheless, J. W., Mancias, P., Baumgartner, J. E., et al. (2001). Brain plasticity for sensory and linguistic functions: A functional imaging study using magnetoencephalography with children and young adults. *Journal of Child Neurology, 16*, 241–252.
- Powell, B. D., Brossart, D. F., & Reynolds, C. R. (2003). Evaluation of the accuracy of two regression-based methods for estimating premorbid IQ. *Archives of Clinical Neuropsychology, 18*, 277–292.

- Psychological Corporation, The. (1997). *Wechsler Adult Intelligence Scale-3rd Edition/Wechsler Memory Scale-3rd Edition (WAIS-III/WMS-III) technical manual*. San Antonio, TX: Author.
- Psychological Corporation, The. (2001). *Manual for the Wechsler Test of Adult Reading*. San Antonio, TX: Author.
- Psychological Corporation, The. (2004). *WISC-IV technical and interpretive manual*. San Antonio, TX: Author.
- Putnam, S. H., Ricker, J. H., Ross, S. R., & Kurtz, J. E. (1999). Considering premorbid functioning: Beyond cognition to a conceptualization of personality in postinjury functioning. In J. J. Sweet (Ed.), *Forensic neuropsychology: Fundamentals and practice. Studies on neuropsychology, development, and cognition* (pp. 29–81). Lisse, The Netherlands: Swets & Zeitlinger.
- Reynolds, C. R. (1997). Postscripts on premorbid ability estimation: Conceptual addenda and a few words on alternative and conditional approaches. *Archives of Clinical Neuropsychology, 12*, 769–778.
- Reynolds, C. R., & Gutkin, T. B. (1979). Predicting the premorbid intellectual status of children using demographic data. *Clinical Neuropsychology, 1*, 36–38.
- Sattler, J. M. (1988). *Assessment of children* (3rd ed.). San Diego, CA: Author.
- Sattler, J. M. (2001). *Assessment of children* (4th ed.). San Diego, CA: Author.
- Schinka, J. A., & Vanderploeg, R. D. (2000). Estimating premorbid level of functioning. In R. D. Vanderploeg (Ed.), *Clinicians guide to neuropsychological assessment* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Schoenberg, M. R., Duff, K., Dorfman, K. D., & Adams, R. L. (2004a). Differential estimation of verbal intelligence and performance intelligence scores from combined performance and demographic variables: The OPIE-3 verbal and performance algorithms. *The Clinical Neuropsychologist, 18*, 266–276.
- Schoenberg, M. R., Duff, K., Scott, J. G., & Adams, R. L. (2003). An evaluation of the clinical utility of the OPIE-3 as an estimate of premorbid WAIS-III FSIQ. *The Clinical Neuropsychologist, 17*, 308–321.
- Schoenberg, M. R., Lange, R. T., Brickell, T. A., & Saklofske, D. H. (in press). A proposed method to estimate premorbid general cognitive functioning for the American WISC-IV: Demographic and a combined demographic and current performance approach. *Journal of Child Neurology*.
- Schoenberg, M. R., Lange, R. T., Chelune, G. J., Iverson, G. I., Scott, J. G., & Adams, R. L. (2006). Clinical validation of the General Ability Index-Estimate (GAI-E) for evaluating premorbid intellectual functioning. *The Clinical Neuropsychologist, 20*, 365–381.
- Schoenberg, M. R., Scott, J. G., Duff, K., & Adams, R. L. (2002). Estimation of WAIS-III intelligence from combined performance and demographic variables: Development of the OPIE-3. *The Clinical Neuropsychologist, 16*, 426–438.
- Schoenberg, M. R., Scott, J. G., Ruwe, W., Patton, D., & Adams, R. L. (2004b). Assumptions that underlie predicting premorbid IQ: A comment on the "Evaluation of the accuracy of two regression-based methods for estimating premorbid IQ." *Archives of Clinical Neuropsychology, 19*, 1103–1106.
- Schwartz, M., & Saffran, E. (1987). *The American-NART: Replication and extension of the British finding on the persistence of word pronunciation skills in patients with dementia*. Unpublished manuscript.
- Scott, J. G., Krull, K. R., Williamson, D. J. G., Adams, R. L., & Iverson, G. L. (1997). Oklahoma Premorbid Intelligence Estimation (OPIE): Utilization in clinical samples. *The Clinical Neuropsychologist, 11*, 146–154.
- Statistics Canada. (2002). *2001 census of population (20% sample database)* [CD ROM]. Ottawa, Ontario, Canada: Statistics Canada.
- Taylor, H. G., & Alden, J. (1997). Age-related differences in outcomes following childhood brain insults: An introduction and overview. *Journal of the International Neuropsychological Society, 3*, 555–567.
- Taylor, H. G., Wade, S. L., Stancin, T., Yates, K. O., Drotar, D., & Minich, N. (2002). A prospective study of short- and long-term outcomes after traumatic brain injury in children: Behavior and achievement. *Neuropsychology, 16*, 15–27.
- Taylor, H. G., Yeates, K. O., Wade, S. L., Drotar, D., Stancin, T., & Burant, C. (2001). Bidirectional child-family influences on outcomes of traumatic brain injury in children. *Journal of the International Neuropsychological Society, 7*, 755–767.
- Tremont, G., Mittenberg, W., & Miller, L. J. (1999). Acute intellectual effects of pediatric head trauma. *Child Neuropsychology, 5*, 104–114.
- Vanderploeg, R. D., & Schinka, J. A. (1995). Predicting WAIS-R IQ premorbid ability: Combining subtest performance and demographic variable predictors. *Archives of Clinical Neuropsychology, 10*, 225–239.
- Vanderploeg, R. D., Schinka, J. A., Baum, K. M., Tremont, G., & Mittenberg, W. (1998). WISC-III premorbid prediction strategies: Demographic and best performance approaches. *Psychological Assessment, 10*, 277–284.
- Wechsler, D. (1958). *The measurement and appraisal of adult intelligence* (4th ed.). Baltimore, MD: Williams & Wilkins.
- Wechsler, D. (1974). *Manual for the Wechsler Intelligence Scale for Children-Revised (WISC-R)*. New York: The Psychological Corporation.
- Wechsler, D. (1991). *Wechsler Intelligence Scale for Children-Third Edition (WISC-III) manual*. San Antonio, TX: Psychological Corporation.
- Wechsler, D. (2003a). *Wechsler Intelligence Scale for Children-Fourth Edition: American manual*. San Antonio, TX: The Psychological Corporation.
- Wechsler, D. (2003b). *Wechsler Intelligence Scale for Children-Fourth Edition: Canadian manual*. San Antonio, TX: The Psychological Corporation.
- Wilson, R. S., Rosenbaum, G., Brown, G., Rourke, D., Whitman, D., & Grisell, J. (1978). An index of premorbid intelligence. *Journal of Consulting and Clinical Psychology, 46*, 1554–1555.
- Yates, A. (1956). The use of vocabulary in the measurement of intelligence deterioration: A review. *Journal of Mental Science, 102*, 409–440.
- Yates, K. O., Taylor, H. G., Drotar, D., Wade, S., Stancin, T., & Klein, W. (1997). Preinjury family

environment as a determinant of recovery from traumatic brain injury in school-age children. *Journal of the International Neuropsychological Society*, 3, 617–630.

Yuan, W., Szaflarski, J. P., Schmithorst, V. J., Schapiro, M., Byars, A. W., Strawsburg, R. H., et al. (2006). fMRI shows atypical language lateralization in pediatric epilepsy patients. *Epilepsia*, 47, 593–600.

## APPENDIX

Algorithms for estimating FSIQ for the Canadian WISC-IV

**C-DEMO** = (79.578 + P-ED\*1.171) + Ethnicity + Gender.

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–12.376)	Asian (2.987)	Other (–2.413)
<i>Gender</i>	Male (nil)	Female (3.715)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (4ST)** = 84.185 + (VO\*0.727) + (MR\*0.940) + (IN\*0.904) + (PC\*0.417) + (AGE\*–4.985) + Ethnicity + Gender.

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–3.273)	Asian (3.369)	Other (–0.308)
<i>Gender</i>	Male (nil)	Female (2.562)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (VO/MR)** = 89.701 + (VO\*1.113) + (MR\*1.181) + (AGE\*–4.761) + Ethnicity + Gender

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–3.124)	Asian (4.046)	Other (0.113)
<i>Gender</i>	Male (nil)	Female (1.721)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (IN/MR)** = 79.392 + (IN\*2.078) + (MR\*1.289) + (AGE\*–4.203) + (P-ED\*0.299) + Ethnicity + Gender

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–4.541)	Asian (0.859)	Other (2.309)
<i>Gender</i>	Male (nil)	Female (2.810)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (IN/PC)** = 74.027 + (IN\*2.100) + (PC\*1.009) + (AGE\*–3.936) + (P-ED\*0.404) + Ethnicity + Gender

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–5.886)	Asian (–1.886)	Other (–1.525)
<i>Gender</i>	Male (nil)	Female (4.410)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (VO/PC)** = 83.274 + (VO\*1.106) + (PC\*0.815) + (AGE\*–4.322) + (P-ED\*0.266) + Ethnicity + Gender

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–4.327)	Asian (6.044)	Other (0.542)
<i>Gender</i>	Male (nil)	Female (3.059)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (IN/VO)** = 87.659 + (VO\*1.000) + (IN\*1.301) + (AGE\*–4.473) + (P-ED\*0.215) + Ethnicity + Gender

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–2.766)	Asian (5.147)	Other (–0.789)
<i>Gender</i>	Male (nil)	Female (3.119)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (MR/PC)** = 72.940 + (PC\*1.032) + (MR\*1.326) + (AGE\*–3.171) + (P-ED\*0.544) + Ethnicity + Gender

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–8.393)	Asian (1.711)	Other (–0.801)
<i>Gender</i>	Male (nil)	Female (2.732)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (VO)** = 90.773 + (VO\*1.420) + (AGE\*–4.125) + (P-ED\*0.268) + Ethnicity + Gender

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–3.347)	Asian (6.492)	Other (0.149)
<i>Gender</i>	Male (nil)	Female (2.540)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (IN)** = 80.503 + (IN\*2.853) + (AGE\*–3.483) + (P-ED\*0.467) + Ethnicity + Gender

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–5.269)	Asian (2.300)	Other (–2.819)
<i>Gender</i>	Male (nil)	Female (4.229)		

Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

**FSIQ (MR)** = 79.660 + (MR\*1.925) + (AGE\*–2.550) + (P-ED\*0.650) + Ethnicity

<i>Ethnicity</i>	Caucasian (nil)	First Nat (–8.482)	Asian (0.740)	Other (–1.769)
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Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ – \_\_\_\_\_

Continued

## Appendix Continued

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$$\text{FSIQ (PC)} = 70.226 + (\text{PC} * 1.642) + (\text{AGE} * -2.300) + (\text{P-ED} * 0.764) + \text{Ethnicity} + \text{Gender}$$

<i>Ethnicity</i>	Caucasian (nil)	First Nat (-10.379)	Asian (3.625)	Other (-0.499)
<i>Gender</i>	Male (nil)	Female (4.241)		

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Estimated FSIQ = \_\_\_\_\_ (95% C. I. = ±1.96 SEE) \_\_\_\_\_ - \_\_\_\_\_

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*Note.* These algorithms should not be used clinically to estimate premorbid intellectual ability in patients with neurological dysfunction until clinical validation studies have been completed. *Directions for research application:* Insert values for the relevant demographic variables into the equation. PC=Picture Completion raw score; MR=Matrix Reasoning raw score; VO=Vocabulary raw score; IN=Information raw score; AGE=age in years; P-ED=parents' education in years. If two parents, use the average of both parents; Ethnicity/Gender=select relevant value under each equation; nil=beta weight was zero or nearly zero and contributed less than 0.5 points to estimated FSIQ; FSIQ=full-scale IQ. Ethnicity: Identified by the child's parents or guardians as belonging to one of four categories: Caucasian, Asian (e.g., Chinese, Japanese, Korean, Filipino, or Southeast Asian (e.g., Cambodian, Indonesian, Laotian, Vietnamese, East Indian, Pakistani, Punjabi, Sri Lankan), First Nat (First Nations; e.g., Inuit, Metis, North American Indian), or Other. SEE=Standard error of estimate; CI=confidence interval. *Data:* All data are derived from the Canadian standardization sample of the *Wechsler Intelligence Scale for Children-Fourth Edition*, by D. Wechsler, 2003, San Antonio, TX: The Psychological Corporation. Copyright © 2003 by The Psychological Corporation, a Harcourt Assessment Company. Reprinted with permission. All rights reserved.