

## **S1 File. The model diagnostic results**

The model diagnostics are methods for determining whether a fitted model adequately represents the data. To evaluate the ordinal regression models in this study, we need to determine whether the model improves our ability to explain the outcome. We do this by comparing the ordinal regression model without any explanatory variables (the “Intercept Only” model) against the model with all the explanatory variables (the “Final” model). We compare the Final model against the Intercept Only model to see whether it significantly improves the fit to the data. S1 File Tables 1 and 2 show the model fitting information. The statistically significant chi-square statistics indicate that the Final models are a significant improvement over the Intercept Only models.

A standard statistical maneuver for testing whether a model fits is to compare the observed data with the fitted model for consistency. From the observed and expected frequencies, the usual Pearson and Deviance goodness-of-fit measures are computed in S1 File Tables 3 and 4. We start from the null hypothesis that the fit is good. If we do not reject this hypothesis (i.e., if the p value is large), then we conclude that the observed data and the model predictions are similar and that we have a good model. The results for our analysis suggest all models in this study fitted well ( $p > 0.01$ ).

To assess the strength of association, there are several  $R^2$ -like statistics that can be used to measure the strength of the association between the response variable and the explanatory variables. In this study, three commonly used pseudo  $R^2$  statistics are employed to measure the strength of association. The results are shown in S1 File Tables 5 and 6.

Here, the Nagelkerke’s pseudo  $R^2$  values (16.80% for the 28 countries’ data and 8.80% for the China data) indicate that the model explains a relatively small proportion of the variation between people in their happiness levels. This is just as we would expect, because there are numerous factors that affect personal happiness.

Multicollinearity occurs when statistical models have two or more explanatory variables that are highly correlated with each other. This leads to problems with understanding which variable contributes to the explanation of the response variable and technical issues in calculating an ordinal regression. Determining whether there is multicollinearity is an important step in ordinal regression. To test for this assumption, we require creating dummy variables for each level of the categorical explanatory variables in this study. We use the Variance Inflation Factor (VIF) value for each

variable as a check for multicollinearity, and as a rule of thumb, we use the VIF of an explanatory variable greater than 10 as a cutoff for variables that may merit further investigation. The results in S1 File Tables 7 and 8 indicate that the VIF values are all quite acceptable for the significant variables in this study. Two variables, “smoking cigarettes” and “past 12 months: have visited a doctor,” have large VIF values. Both of them, however, are non-significant in our models.

The key assumption for fitting an ordinal regression is that the effects of any explanatory variables are consistent or proportional across different thresholds; hence this is usually termed the assumption of proportional odds (SPSS calls this the assumption of parallel lines). We evaluate the appropriateness of this assumption through “the test of parallel lines” in SPSS. This test compares the ordinal model, which has one set of coefficients for all thresholds (labelled Null Hypothesis), to a model with a separate set of coefficients for each threshold (labelled General). The test results in S1 File Tables 9 and 10 give a significantly better fit to the two datasets than the ordinal model, and thus we were led to reject the proportional odds assumption. The test of the proportional odds assumption has been described as anti-conservative, however, in that it nearly always results in rejection of the proportional odds assumption [1], particularly when the number of explanatory variables is large [2], the sample size is large [3, 4], or there is a continuous explanatory variable in the model [3]. It is important to examine the data using multinomial logistic regression to explicitly see how the odds ratios (ORs) for our explanatory variables vary at the different thresholds. We use the 2-day period ordinal regression for 28 countries as an illustration. Looking at the separate ORs of continuous explanatory variables across the six splits in S1 File Table 11, the difference in ORs appears negligible (0.963 to 1.005 for *Age*), so a common OR for each of these continuous explanatory variables is a very plausible assumption. The proportional odds assumption is also upheld for most of the categorical variables.

The categorical variable most out of line with the proportional odds assumption is smoking cigarettes. Of 25,096 respondents to this question, 12,432 (49.50%) replied, “Do not smoke and never did”; 6,567 (26.25%) replied, “Do not smoke now but smoked in the past”; 1,544 (6.20%) replied, “Smoke 1-5 cigarettes per day”; 1,683 (6.70%) replied, “Smoke 6-10 cigarettes per day”; 2,296 (9.10%) replied, “Smoke 11-20 cigarettes per day”; 518 (2.10%) replied, “Smoke 21-40 cigarettes per day”; and 56 (0.20%) replied, “Smoke more than 40 cigarettes per day.” The ORs for smoking cigarettes from the separate logistic regressions differ hugely. In this particular case, it might be reasonable to conclude that the ORs from the ordinal

regression model do underestimate the extent of the over-representation at the “Do not smoke and never did” level, the “Do not smoke now but smoked in the past” level, the “Smoke 6-10 cigarettes per day” level, and the “Smoke 11-20 cigarettes per day” level, and do overestimate the extent of the under-representation at the “Smoke 1-5 cigarettes per day” level and the “Smoke 21-40 cigarettes per day” level. This finding was obscured in the single cumulative OR for each level of smoking cigarettes, and summarizing this relationship in a single OR misses this observation. Thus, smoking cigarettes may well be the major factor underlying the overall rejection of parallel lines. The Chi-square test that led to the rejection of the proportional odds assumption probably reflects the large sample size in our datasets. We think the violation of the proportional odds assumption is quite minor.

#### References:

- [1] O'Connell, A. (2006). Logistic regression models for ordinal response variables. Thousand Oaks: Sage Publications.
- [2] Brant, R. (1990). Assessing proportionality in the proportional odds model for ordinal logistic regression. *Biometrics*, 46, 1171-1178.
- [3] Allison, P. D. (1999). Logistic regression using the SAS system: Theory and application. Cary, NC.: SAS Institute.
- [4] Clogg, C., & Shihadeh, E. S. (1994). Statistical models for ordinal variables. Thousand Oaks, California: Sage Publications.

S1 File Table 1. Model fitting information for ordinal regressions of 28 countries' data

Model Fitting Information			
Model		Intercept Only	Final
-2 Log Likelihood	2 Days	61923.621	58188.923
	4 Days	62036.285	58279.698
	8 Days	62146.090	58373.945
Chi-Square	2 Days		3734.699
	4 Days		3756.587
	8 Days		3772.145
df	2 Days		34
	4 Days		34
	8 Days		34
Sig.	2 Days		0.000
	4 Days		0.000
	8 Days		0.000

S1 File Table 2. Model fitting information for ordinal regressions of China data

Model Fitting Information			
Model		Intercept Only	Final
-2 Log Likelihood	2 Days	11737.973	11308.496
	4 Days	11737.973	11309.800
	8 Days	11737.973	11306.994
Chi-Square	2 Days		429.476
	4 Days		428.173
	8 Days		430.979
df	2 Days		33
	4 Days		33
	8 Days		33
Sig.	2 Days		0.000
	4 Days		0.000
	8 Days		0.000

S1 File Table 3. Goodness of fit for ordinal regressions of 28 countries' data

Goodness-of-Fit			
Model		Pearson	Deviance
Chi-Square	2 Days	131907.774	58170.901
	4 Days	132316.281	58261.677
	8 Days	132543.978	58355.923
df	2 Days	130964	130964
	4 Days	131228	131228
	8 Days	131438	131438
Sig.	2 Days	0.033	1.000
	4 Days	0.017	1.000
	8 Days	0.016	1.000

S1 File Table 4. Goodness of fit for ordinal regressions of China data

Goodness-of-Fit			
Model		Pearson	Deviance
Chi-Square	2 Days	21090.711	11301.565
	4 Days	21127.919	11302.868
	8 Days	21075.581	11300.063
df	2 Days	20731	20731
	4 Days	20731	20731
	8 Days	20731	20731
Sig.	2 Days	0.039	1.000
	4 Days	0.026	1.000
	8 Days	0.046	1.000

S1 File Table 5. The Pseudo R-Square of 28 countries' data

Pseudo R-Square			
	2 Days	4 Days	8 Days
Cox and Snell	0.157	0.158	0.158
Nagelkerke	0.167	0.168	0.168
McFadden	0.060	0.061	0.061

S1 File Table 6. The Pseudo R-Square of China data

Pseudo R-Square			
	2 Days	4 Days	8 Days
Cox and Snell	0.079	0.079	0.080
Nagelkerke	0.088	0.088	0.089
McFadden	0.037	0.036	0.037

S1 File Table 7. VIF values of variables for diagnosing multicollinearity of 28 countries' data

Model	Coefficients <sup>a</sup>		
	Collinearity Statistics		
	VIF		
	2 Days	4 Days	8 Days
(Constant)			
Q26 Health status (Poor)	1.646	1.647	1.648
Q26 Health status (Fair)	2.785	2.788	2.791
Q26 Health status (Good)	3.127	3.136	3.143
Q26 Health status (Very good)	2.494	2.499	2.505
Q18a Past 12 months: visit a doctor (Never)	3.066	3.064	3.065
Q18a Past 12 months: visit a doctor (Seldom)	4.174	4.172	4.173
Q18a Past 12 months: visit a doctor (Sometimes)	3.965	3.965	3.967
Q18a Past 12 months: visit a doctor (Often)	2.604	2.602	2.601
Q24 Smoking cigarettes (Do not smoke and never did)	20.257	20.293	20.327
Q24 Smoking cigarettes (Do not smoke now but smoked in the past)	15.692	15.712	15.745
Q24 Smoking cigarettes (Smoke 1-5 cigarettes per day)	5.534	5.540	5.545
Q24 Smoking cigarettes (Smoke 6-10 cigarettes per day)	5.895	5.898	5.899
Q24 Smoking cigarettes (Smoke 11-20 cigarettes per day)	7.439	7.450	7.465
Q24 Smoking cigarettes (Smoke 21-40 cigarettes per day)	2.547	2.547	2.550
Q25a How often: drink alcohol (Never)	9.690	9.692	9.696
Q25a How often: drink alcohol (Once a month or less often)	7.589	7.586	7.586
Q25a How often: drink alcohol (Several times a month)	4.908	4.912	4.915
Q25a How often: drink alcohol (Several times a week)	2.397	2.402	2.402
Q25b How often: physical activity (Never)	1.890	1.891	1.892
Q25b How often: physical activity (Once a month or less often)	1.632	1.632	1.632
Q25b How often: physical activity (Several times a month)	1.827	1.826	1.826
Q25b How often: physical activity (Several times a week)	1.920	1.920	1.920
Q25c How often: eat fresh fruits or vegetables (Never)	1.029	1.029	1.029
Q25c How often: eat fresh fruits or vegetables (Once a month or less)	1.059	1.059	1.058
Q25c How often: eat fresh fruits or vegetables (Several times a month)	1.146	1.145	1.146
Q25c How often: eat fresh fruits or vegetables (Several times a week)	1.150	1.150	1.151
Sex of Respondent (Male)	1.166	1.166	1.167
GDP (Decrease)	1.097	1.102	1.109
TEMP	3.897	4.045	4.292
DEWP	3.791	3.924	4.181
VISIB	1.099	1.110	1.113
WDSP	1.079	1.094	1.103
city_z_new	1.214	1.231	1.255
Age of respondent	1.255	1.256	1.256

a. Dependent Variable: Q1 How happy or unhappy

S1 File Table 8. VIF values of variables for diagnosing multicollinearity of China data

Coefficients <sup>a</sup>				
Model	Collinearity Statistics			
	VIF			
	2 Days	4 Days	8 Days	
(Constant)				
Q26 Health status (Poor)	2.442	2.446	2.446	
Q26 Health status (Fair)	3.538	3.541	3.544	
Q26 Health status (Good)	2.791	2.792	2.791	
Q26 Health status (Very good)	2.889	2.889	2.889	
Q18a Past 12 months: visit a doctor (Never)	8.812	8.817	8.818	
Q18a Past 12 months: visit a doctor (Seldom)	10.640	10.641	10.641	
Q18a Past 12 months: visit a doctor (Sometimes)	8.848	8.849	8.850	
Q18a Past 12 months: visit a doctor (Often)	5.554	5.554	5.554	
Q24 Smoking cigarettes (Do not smoke and never did)	22.460	22.455	22.444	
Q24 Smoking cigarettes (Do not smoke now but smoked in the	6.730	6.729	6.729	
Q24 Smoking cigarettes (Smoke 1-5 cigarettes per day)	6.978	6.977	6.976	
Q24 Smoking cigarettes (Smoke 6-10 cigarettes per day)	6.441	6.439	6.438	
Q24 Smoking cigarettes (Smoke 11-20 cigarettes per day)	9.953	9.952	9.950	
Q24 Smoking cigarettes (Smoke 21-40 cigarettes per day)	3.462	3.461	3.461	
Q25a How often: drink alcohol (Never)	4.732	4.732	4.733	
Q25a How often: drink alcohol (Once a month or less often)	3.173	3.172	3.173	
Q25a How often: drink alcohol (Several times a month)	2.041	2.041	2.042	
Q25a How often: drink alcohol (Several times a week)	1.809	1.810	1.810	
Q25b How often: physical activity (Never)	1.801	1.801	1.801	
Q25b How often: physical activity (Once a month or less often)	1.528	1.528	1.529	
Q25b How often: physical activity (Several times a month)	1.360	1.360	1.361	
Q25b How often: physical activity (Several times a week)	1.313	1.313	1.313	
Q25c How often: eat fresh fruits or vegetables (Never)	1.017	1.017	1.017	
Q25c How often: eat fresh fruits or vegetables (Once a month or	1.036	1.036	1.036	
Q25c How often: eat fresh fruits or vegetables (Several times a	1.044	1.046	1.048	
Q25c How often: eat fresh fruits or vegetables (Several times a	1.063	1.065	1.066	
Sex of Respondent (Male)	1.871	1.872	1.871	
TEMP	3.808	4.378	5.510	
DEWP	4.168	4.712	5.730	
VISIB	1.471	1.442	1.327	
WDSP	1.073	1.071	1.096	
city_z_new	1.376	1.409	1.393	
Age of respondent	1.213	1.214	1.214	

a. Dependent Variable: Q1 How happy or unhappy

S1 File Table 9. Tests of parallel lines for ordinal regressions of 28 countries' data

Test of Parallel Lines <sup>a</sup>			
		Null Hypothesis	General
-2 Log Likelihood	2 Days	58188.923	57369.177 <sup>b</sup>
	4 Days	58279.698	57447.346 <sup>b</sup>
	8 Days	58373.945	57530.960 <sup>b</sup>
Chi-Square	2 Days		819.746 <sup>c</sup>
	4 Days		832.352 <sup>c</sup>
	8 Days		842.985 <sup>c</sup>
df	2 Days		170
	4 Days		170
	8 Days		170
Sig.	2 Days		0.000
	4 Days		0.000
	8 Days		0.000

S1 File Table 10. Tests of parallel lines for ordinal regressions of China data

Test of Parallel Lines <sup>a</sup>			
		Null Hypothesis	General
-2 Log Likelihood	2 Days	11308.496	11089.825 <sup>b</sup>
	4 Days	11309.800	11094.175 <sup>b</sup>
	8 Days	11306.994	11078.619 <sup>b</sup>
Chi-Square	2 Days		218.672 <sup>c</sup>
	4 Days		215.625 <sup>c</sup>
	8 Days		228.375 <sup>c</sup>
df	2 Days		99
	4 Days		99
	8 Days		99
Sig.	2 Days		0.000
	4 Days		0.000
	8 Days		0.000

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.<sup>a</sup>

a. Link function: Logit.

b. The log-likelihood value cannot be further increased after maximum number of step-halving

c. The Chi-Square statistic is computed based on the log-likelihood value of the last iteration of the general model.

Validity of the test is uncertain.



S1 File Table 11. Results of multinomial logit regression for personal happiness

Q1 How happy or unhappy	Coefficients						Odds Ratios					
	Completely unhappy	Very unhappy	Fairly unhappy	Neither happy nor unhappy	Fairly happy	Very happy	Completely unhappy	Very unhappy	Fairly unhappy	Neither happy nor unhappy	Fairly happy	Very happy
Intercept	-287.101	-302.764	266.606	-14.704	-104.700	80.871	-	-	-	-	-	-
WDSP	-.038	.003	-.028	-.005	-.016	.005	.963	1.003	.972	.995	.984	1.005
VISIB	-.048	-.001	.004	-.006	.010	.008	.953	.999	1.004	.994	1.010	1.008
TEMP	.013	-.011	.001	.001	.010	.013	1.013	.989	1.001	1.001	1.010	1.013
DEWP	-.021	.011	-.004	-.006	-.012	-.015	.979	1.011	.996	.994	.988	.985
AGE	-.002	-.003	.004	.006	.007	-.001	.998	.997	1.004	1.006	1.007	.999
city_z_new	-.040	-.006	-.025	-.037	-.031	-.024	.961	.994	.975	.963	.970	.976
Past 12 months: visit a doctor (Never)	-1.134	-.213	.054	.386	.377	.164	.322	.808	1.056	1.471	1.458	1.178
Past 12 months: visit a doctor (Seldom)	-.944	-.351	.260	.492	.546	.447	.389	.704	1.297	1.636	1.726	1.563
Past 12 months: visit a doctor (Sometimes)	-.640	-.334	.221	.508	.478	.361	.527	.716	1.247	1.662	1.612	1.435
Past 12 months: visit a doctor (Often)	-1.287	-.687	-.024	.271	.109	.046	.276	.503	.976	1.311	1.116	1.048
[V42=5]												
Smoking cigarettes (Do not smoke and never did)	282.679	299.390	-270.313	12.362	103.300	-81.587	5.8348E+122	1.055E+130	4.025E-118	233830.388	7.2916E+44	3.691E-36
Smoking cigarettes (Do not smoke now but smoked in the past)	282.234	299.209	-270.462	12.347	103.316	-81.546	3.7397E+122	8.809E+129	3.464E-118	230257.621	7.4043E+44	3.845E-36
Smoking cigarettes (Smoke 1-5 cigarettes per day)	282.895	299.161	-270.359	12.381	103.174	-81.641	7.238E+122	8.395E+129	3.840E-118	238280.289	6.4224E+44	3.499E-36
Smoking cigarettes (Smoke 6-10 cigarettes per day)	283.129	299.372	-269.972	12.448	103.198	-81.815	9.1479E+122	1.037E+130	5.656E-118	254632.337	6.5816E+44	2.938E-36
Smoking cigarettes (Smoke 11-20 cigarettes per day)	282.853	299.356	-269.917	12.756	103.549	-81.567	6.9414E+122	1.02E+130	5.977E-118	346569.468	9.3471E+44	3.768E-36
Smoking cigarettes (Smoke 21-40 cigarettes per day)	283.992	300.464	-269.443	12.620	103.013	-81.870	2.1682E+123	3.09E+130	9.605E-118	302399.364	5.4695E+44	2.783E-36
[V55=7]												
How often: drink alcohol (Never)	1.174	-.480	-.062	.054	-.145	.018	3.236	.619	.940	1.055	.865	1.018
How often: drink alcohol (Once a month or less often)	.720	-.223	.182	.104	.097	.154	2.055	.800	1.200	1.110	1.102	1.166
How often: drink alcohol (Several times a month)	.942	-.107	.235	.239	.231	.215	2.564	.898	1.265	1.270	1.260	1.240
How often: drink alcohol (Several times a week)	.730	.343	.646	.325	.202	.143	2.076	1.409	1.907	1.384	1.224	1.154
[V56=5]												
How often: physical activity (Never)	.257	-.074	.127	.145	-.045	-.057	1.292	.929	1.135	1.156	.956	.944
How often: physical activity (Once a month or less often)	-.330	-.302	.101	.224	.324	.194	.719	.740	1.106	1.251	1.383	1.214
How often: physical activity (Several times a month)	-.473	-.094	.138	.153	.255	.186	.623	.911	1.149	1.166	1.290	1.205
How often: physical activity (Several times a week)	-.238	-.105	.287	.068	.239	.176	.788	.901	1.333	1.071	1.269	1.192
[V57=5]												
How often: eat fresh fruits or vegetables (Never)	4.944	1.001	.445	.458	.238	.040	140.375	2.720	1.560	1.582	1.269	1.040
How often: eat fresh fruits or vegetables (Once a month or less often)	1.908	1.661	1.629	.331	-.047	-.081	6.741	5.264	5.097	1.393	.954	.923
How often: eat fresh fruits or vegetables (Several times a month)	.118	.824	1.042	.408	.100	.033	1.125	2.279	2.835	1.503	1.105	1.034
How often: eat fresh fruits or vegetables (Several times a week)	.098	.283	.415	.261	.120	.069	1.103	1.327	1.514	1.299	1.127	1.071
[V58=5]												
Health status (Poor)	9.178	8.217	6.541	3.871	2.851	1.504	9679.177	3702.193	693.154	48.012	17.298	4.499
Health status (Fair)	3.239	3.791	3.813	3.586	2.803	1.450	25.512	44.305	45.305	36.073	16.495	4.264
Health status (good)	2.311	2.322	2.510	2.549	2.645	1.470	10.086	10.198	12.302	12.798	14.079	4.347
Health status (Very good)	1.818	1.552	1.715	1.680	1.983	1.567	6.161	4.723	5.558	5.365	7.267	4.790
[V59=5]												
Sex of Respondent (Male)	-.185	-.194	-.218	-.119	-.088	-.073	.832	.824	.804	.888	.916	.929
[SEX=2]												
GDP (Decrease)	-.135	-.020	.047	.227	.126	-.011	.874	.981	1.048	1.255	1.134	.989
[GDP=1.0]												