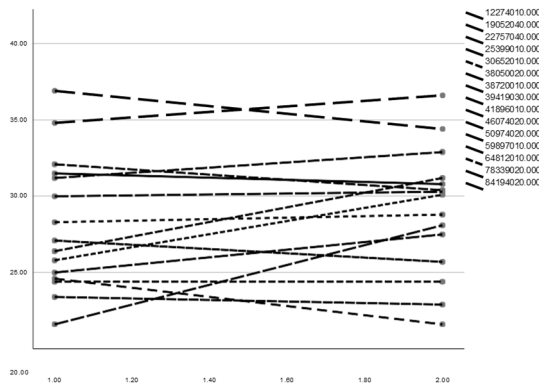
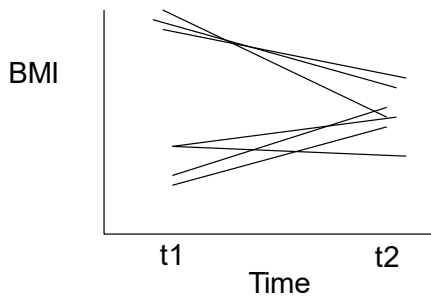


### Longitudinal Examples

Below is a graph of the BMI (body mass index) values from the first time point to the second time point for a few individuals (from the Health and Retirement Study of middle-aged and older adults). Notice that those who start out with a higher BMI tend to decline, and those who start out with a lower BMI tend to increase over the two-year period. This is typical of regression to the mean, which occurs whenever there is a less than perfect correlation between measures at two time points. (It is also the case that the middle values of BMI at the beginning tend to move out to either higher or lower BMI scores).



Had we selected the individuals with the highest and lowest weight at the beginning, we would likely see a pattern like this (probably a bit exaggerated in comparison with the above graph for illustration purposes).



If we had designed a study with an intervention in between t1 and t2, we would have assumed that the changes were due to the intervention. This also illustrates that we should expect a variable positively correlated with BMI to be negatively correlated with BMI difference scores—those high on BMI, and hence the correlated variable, tend to decrease in BMI over time; and those low on BMI (or the correlated variable), would tend to increase in BMI over time.<sup>1</sup>

The correlation table below examines the relationship between vigorous activity measured at the first time point and BMI difference scores ( $bmidiff = s8bmi - s7bmi$ ). First, notice that there is a negative correlation between BMI at the first time point ( $s7bmi$ ) and the difference scores ( $bmidiff$ ). This is typical because of the regression to the mean pattern we saw above. If we imagine for a moment that we had measured sedentariness (the opposite of vigorous activity), then the correlation between sedentariness and BMI at the first time point would be positive, .144. The correlation between sedentariness and BMI difference scores

<sup>1</sup> The negative correlation between initial scores and difference scores is typical, although not inevitable. The negative correlation can be viewed as an indication of the regression toward the mean phenomenon (Campbell & Kenny, 1999).

would be  $-.024$ , mirroring the relationship between BMI at the first time point and BMI difference scores. The result below is not significant, but you can imagine more extreme cases in which there is a higher correlation between the two variables at baseline and, thus, a significant relationship between the predictor variable and the difference scores that occurs simply because of the regression toward the mean phenomenon.

**Correlations**

		S7BMI S7BMI: W7 Body Mass Index=kg/m2	S8BMI S8BMI: W8 Body Mass Index=kg/m2	bmidiff	vigact7
S7BMI S7BMI:W7 Body Mass Index=kg/m2	Pearson Correlation	1	.888	-.153	-.144
	Sig. (2-tailed)		<.001	<.001	<.001
	N	5182	4489	4489	5180
S8BMI S8BMI:W8 Body Mass Index=kg/m2	Pearson Correlation	.888	1	.318	-.145
	Sig. (2-tailed)	<.001	<.001	<.001	<.001
	N	4489	4693	4489	4534
bmidiff	Pearson Correlation	-.153	.318	1	.024
	Sig. (2-tailed)	<.001	<.001		.108
	N	4489	4489	4489	4488
vigact7	Pearson Correlation	-.144	-.145	.024	1
	Sig. (2-tailed)	<.001	<.001	.108	
	N	5180	4534	4488	5277

**Difference Score Regression**

The simple regression with vigorous activity predicting BMI difference scores shows the same pattern as observed in the correlation matrix above, with the standardized coefficient equal to the correlation coefficient.

**Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics			
						F Change	df1	df2	Sig. F Change
1	.024 <sup>a</sup>	.001	.000	2.54719	.001	2.578	1	4486	.108

a. Predictors: (Constant), vigact7

**Coefficients<sup>a</sup>**

Model		Unstandardized Coefficients		Standardized Coefficients		t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta	Std. Error			Tolerance	VIF
1	(Constant)	.181	.070			2.603	.009		
	vigact7	.046	.028	.024	.015	1.606	.108	1.000	1.000

a. Dependent Variable: bmidiff

**Lagged regression**

The lagged regression (or ANCOVA) approach examines the relationship between vigorous activity and BMI but taking into account (partialling out) the initial relationship between vigorous activity and BMI.

**Descriptive Statistics**

	Mean	Std. Deviation	N
S8BMI S8BMI:W8 Body Mass Index=kg/m2	28.0880	5.48532	4488
vigact7	2.06194	1.341656	4488
S7BMI S7BMI:W7 Body Mass Index=kg/m2	27.8127	5.26103	4488

**Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics			Sig. F Change
						F Change	df1	df2	
1	.888 <sup>a</sup>	.789	.789	2.51852	.789	8399.900	2	4485	<.001

a. Predictors: (Constant), S7BMI S7BMI:W7 Body Mass Index=kg/m2, vigact7

**Coefficients<sup>a</sup>**

Model		Unstandardized Coefficients		Standardized Coefficients		t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta	Std. Error			Tolerance	VIF
1	(Constant)	2.329	.222			10.499	<.001		
	vigact7	-.001	.028	.000	.007	-.045	.964	.974	1.027
	S7BMI S7BMI:W7 Body Mass Index=kg/m2	.926	.007	.888	.007	127.901	<.001	.974	1.027

a. Dependent Variable: S8BMI S8BMI:W8 Body Mass Index=kg/m2

Though neither of the two regression approaches are significant, the difference score model has a larger effect and is much closer to the .05 level than the lagged regression model below. The discrepancy is a (modest) illustration of Lord's paradox (Lord, 1967). We might conclude different things from the two analyses in many instances. Because the difference score regression does not take into account the association between the predictor and outcome at baseline, we cannot know whether the association between the predictor and the difference scores might stem from regression toward the mean. The difference score regression helps identify who increases or decreases in absolute value over time, whereas the lagged regression attempts to examine temporal precedence and whether *X* precedes *Y* causally.

**References**

Campbell, D. T., & Kenny, D. A. (1999). *A primer on regression artifacts*. New York: Guilford.  
 Lord, E. M. (1967). A paradox in the interpretation of group comparisons. *Psychological Bulletin*, 68, 304–305.