Supplementary materials

# Test sequence

One possible confounder for the friendship effect on pain tolerance is competition among peers. Since the adolescents are not all tested at the same time, it is possible for the participants of the cold-pressor test to tell the other study participants that they managed to endure the full time and were censored. This can induce peer pressure on the peers who are tested later. We therefore control for test sequence in the network autocorrelation model. The results are given in Table S1. We see that test sequence has a significant positive effect. When controlling for test sequence, the estimated correlation coefficient ρ decreases, but it is still significant.

Table S1: Fitted network autocorrelation model controlling for sex, age, school programme, smoking, physical activity and test sequence.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Sex | Age | School p. |
| Estimate | 0.19 | 16.30 | -1.82 | 16.8 |
| Std. dev | 0.074 | 2.56 | 1.58 | 3.63 |
| P-value | 0.012 | 2.14 | 0.25 | 3.60 |
|  | Smoke | Phys. act | Test seq. | Intercept |
| Estimate | -5.86 | 1.91 | 0.034 | 72.80 |
| Std. dev | 2.28 | 0.62 | 0.0055 | 28.10 |
| P-value | 0.010 | 0.0022 | 8.14 | 0.0096 |

Estimated coefficients in the network autocorrelation model using data from the Tromsø Study: Fit Futures I, standard deviation (std. dev) and p-values. School p. denotes school programme, phys. act denotes physical activity and test seq. denotes test sequence.

It is also possible that the effect of competition is a friendship effect, so that the test sequence among friends is important. We therefore also fit a network autocorrelation model, where we control for the test order among friends. The results are given in Table S2. We see that the test order among friends does not have a significant effect on the pain tolerance of the individual. In addition, including this covariate does not seem to affect the network autocorrelation coefficient.

Table S2: Fitted network autocorrelation model controlling for sex, age, school programme, smoking, physical activity and test order among friends.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Sex | Age | School p. |
| Estimate | 0.23 | 16.70 | -1.05 | 27.10 |
| Std. dev | 0.074 | 2.54 | 1.58 | 3.41 |
| P-value | 0.0021 | 5.15 | 0.43 | 2.00 |
|  | Smoke | Phys. act | Test ord. f. | Intercept |
| Estimate | -5.53 | 1.79 | 1.31 | 65.10 |
| Std. dev | 2.30 | 0.62 | 1.56 | 25.20 |
| P-value | 0.016 | 0.0042 | 0.40 | 0.0099 |

Estimated coefficients in the network autocorrelation model using data from the Tromsø Study: Fit Futures I, standard deviation (std. dev) and p-values. School p. denotes school programme, phys. act denotes physical activity and test ord. f. denotes test order among friends.

# Other pain modalities and pain threshold

## Other pain tolerance measures

### Heat pain tolerance

We plot the proportion of heat pain tolerant individuals versus their proportion of heat pain tolerant friends. The plot is given in Figure S1a. There seems to be a positive correlation between an individual's heat pain tolerance and the friends' heat pain tolerance, but the relationship is less clear than for cold-pressor pain tolerance (Figure 3 in the main article).

The estimated Kendall's τ for heat pain tolerance and friendship ties is 0.10, and the permutation test results in τ estimates in the range (-0.062, 0.068). The partial correlation coefficient controlled for sex is 0.037. The estimated 95% confidence interval from the permutation test is (-0.028, 0.028). The estimated p-value for the partial correlation is 0.010. The coefficients for the fitted network autocorrelation model for heat pain tolerance are given in Table S3. The effect of the average heat pain tolerance of friends on an individual's heat pain tolerance is not significant. As for cold-pressor pain tolerance, sex and school programme are significant. Hence, there is significant pairwise correlation in friends' heat pain tolerance, but the neighbourhood correlation is not significant.

When considering the effect of network centrality on the heat pain tolerance, we find that the in-degree is significant at the 0.05 significance level. The estimated effect of in-degree is 0.11 with a standard deviation of 0.032 and p-value of 0.00058. Thus, the heat pain tolerance increases with 0.11˚C on average, if the number of people who count you as (likely) one of their top five friends increases by one.

### Pressure pain tolerance – fingernail

We plotted the proportion of pressure pain tolerant individuals versus their proportion of friends who are pressure pain tolerant, for pressure pain tolerance at the fingernail. The plot is given in Figure S1b. Again, the relationship is positive.

The estimated Kendall's τ for pressure pain tolerance and friendship ties is 0.18, while the partial correlation coefficient controlled for sex is 0.14, indicating a positive correlation between pressure pain tolerance and friendship ties. The range of τ based on random permutations is (-0.072, 0.071). The range of partial correlations adjusting for sex based on random permutations is (-0.061, 0.066). Both Kendall's τ and the sex-adjusted τ fall outside the range of the permuted correlation coefficients and are thus significant. The coefficients for the fitted network autocorrelation model for pressure pain tolerance at the fingernail are given in Table S3. The effect of pressure pain tolerance of friends on an individual's pressure pain tolerance is significant. The estimated effect is that by increasing the average pressure pain tolerance of an individual's friends by one kPa, the individual's pain tolerance increases, on average, with 0.15 kPa. As before, sex and school programme are highly significant. There was no relationship between any of the centrality measures and pressure pain tolerance at the fingernail.

### Pressure pain tolerance – trapezius muscle

We plotted the proportion of individuals who are pain tolerant versus the proportion of their friends who are pain tolerant, for pressure pain tolerance at the trapezius muscle. The plot is given in Figure S1c. Again, there seems to be a positive correlation between an individual's pain tolerance and the proportion of friends who are pain tolerant.

The estimated Kendall's τ for pressure pain tolerance at the trapezius muscle is 0.093, with confidence interval from the permutation test (-0.064, 0.070). The partial correlation coefficient is 0.051, indicating a small positive correlation between pressure pain tolerance and friendship ties. The estimated 95% confidence interval for the permutation test for the partial correlation is (-0.031, 0.030), so the partial correlation is significant, with an estimated p-value of 0.0012. The estimated coefficients for the fitted network autocorrelation model are given in Table S3. The effect of friends' average pain tolerance is not significant at the 0.05 level, but it is borderline significant. Sex and school programme are significant, as for the other pain tolerance measures. When considering the network centrality measures, out-degree had a borderline significant effect, with an estimated effect of 12.97 (standard deviation 6.65, p-value 0.051). There was no relationship between any of the other centrality measures and pressure pain tolerance at the trapezius muscle.

## Pain threshold

### Heat pain threshold

The estimated correlation between friendship ties and heat pain threshold is 0.044 (95% confidence interval from permutation test (-0.028, 0.027), estimated p-value 0.0019). The partial correlation coefficient controlled for sex is 0.037, with 95% confidence interval from the permutation test (-0.028, 0.027). So when controlling for sex, the correlation is significant, with an estimated p-value of 0.0082.

We also fitted a network autocorrelation model with the autocorrelation term, sex, age and school programme as covariates. The estimated parameters are given in Table S4. There is no effect of friends' average pain threshold on the individual's heat pain threshold. Sex, age and school programme are all significant, but the direction of the effect of school programme is opposite from what we had for the pain tolerance measures. When considering the effect of centrality measures on heat pain threshold, we find that in-degree is significant, with an effect of 0.087, standard deviation 0.036 and an estimated p-value of 0.014.

### Pressure pain threshold – fingernail

The correlation between friendship ties and pressure pain threshold at the fingernail is 0.084, and the range from the permutation test is (-0.058, 0.066). The partial correlation coefficient controlled for sex is 0.051, with 95% confidence interval for the permutation test (-0.029, 0.029). So the partial correlation coefficient when controlling sex is significant, with an estimated p-value of 0.025.

Fitting a network autocorrelation model with the autocorrelation term, sex, age and school programme as covariates, we get the results shown in Table S4. There is a significant effect of friends' average pressure pain threshold on the individual's pressure pain threshold on the fingernail. We also note that sex and school programme are significant. None of the centrality measures had an effect on pressure pain threshold measured on the fingernail.

### Pressure pain threshold – trapezius muscle

The correlation between friendship ties and pressure pain threshold is 0.033, with a 95% confidence interval from the permutations of (-0.045, 0.046), so there is no significant correlation. The partial correlation coefficient controlling for sex is 0.0014, with 95% confidence interval from the permutation test (-0.030, 0.030). So the correlation between friendship ties and pressure pain threshold at the trapezius muscle is not significant.

Fitting a network autocorrelation model with the autocorrelation term, sex, age and school programme as covariates, gives the results shown in Table S4. There is no relationship between friends' average pressure pain threshold and the individual's pressure pain threshold on the trapezius muscle. Both sex, age and school programme are significant. None of the centrality measures had an effect on pressure pain threshold at the trapezius muscle.

a) b)



c)



Figure S1: Pain tolerance versus friends. Proportion of individuals who are pain tolerant as a function of the proportion of friends who are pain tolerant in the Tromsø Study: Fit Futures I. The best linear fits to the points are also plotted. a) Heat pain tolerance. b) Pressure pain tolerance at the fingernail. c) Pressure pain tolerance at the trapezius muscle.

Table S3: Fitted network autocorrelation model for different pain tolerance measures.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Heat pain tolerance** | | | | | |
|  | ρ | Sex | Age | School p. | Intercept |
| Estimate | 0.012 | 2.36 | 0.089 | 1.02 | 44.67 |
| Std. dev | 0.019 | 0.14 | 0.051 | 0.14 | 1.41 |
| P-value | 0.53 | <2.0 | 0.080 | 6.64 | <2.0 |
| **Pressure pain tolerance – fingernail** | | | | | |
|  | ρ | Sex | Age | School p. | Intercept |
| Estimate | 0.15 | 240.82 | 8.90 | 184.32 | 366.50 |
| Std. dev | 0.059 | 17.11 | 7.46 | 16.76 | 135.30 |
| P-value | 0.014 | <2.0 | 0.23 | <2.0 | 0.0068 |
| **Pressure pain tolerance – trapezius muscle** | | | | | |
|  | ρ | Sex | Age | School p. | Intercept |
| Estimate | 0.12 | 224.82 | 13.06 | 152.45 | 204.50 |
| Std. dev | 0.063 | 18.33 | 7.92 | 17.42 | 143.44 |
| P-value | 0.067 | <2.0 | 0.099 | <2.0 | 0.15 |

Estimated coefficients in the network autocorrelation model using data from the Tromsø Study: Fit Futures I, standard deviation (Std. dev) and p-values with pain tolerance as response. School p. denotes school programme.

Table S4: Fitted network autocorrelation model for different pain threshold measures.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Heat pain threshold** | | | | | |
|  | ρ | Sex | Age | School p. | Intercept |
| Estimate | 0.025 | 0.35 | 0.12 | -0.33 | 41.44 |
| Std. dev | 0.019 | 0.15 | 0.061 | 0.15 | 1.47 |
| P-value | 0.20 | 0.018 | 0.047 | 0.024 | <2.0 |
| **Pressure pain threshold – fingernail** | | | | | |
|  | ρ | Sex | Age | School p. | Intercept |
| Estimate | 0.18 | 106.15 | 6.96 | 32.37 | 179.91 |
| Std. dev | 0.060 | 9.09 | 3.85 | 7.94 | 70.86 |
| P-value | 0.0021 | <2.0 | 0.071 | 4.54 | 0.011 |
| **Pressure pain threshold – trapezius muscle** | | | | | |
|  | ρ | Sex | Age | School p. | Intercept |
| Estimate | 0.020 | 58.23 | 5.65 | 15.35 | 151.76 |
| Std. dev | 0.056 | 6.70 | 2.21 | 6.07 | 40.69 |
| P-value | 0.73 | <2.0 | 0.011 | 0.012 | 0.00019 |

Estimated coefficients in the network autocorrelation model using data from the Tromsø Study: Fit Futures I, standard deviation (Std. dev) and p-values with pain threshold as response. School p. denotes school programme.