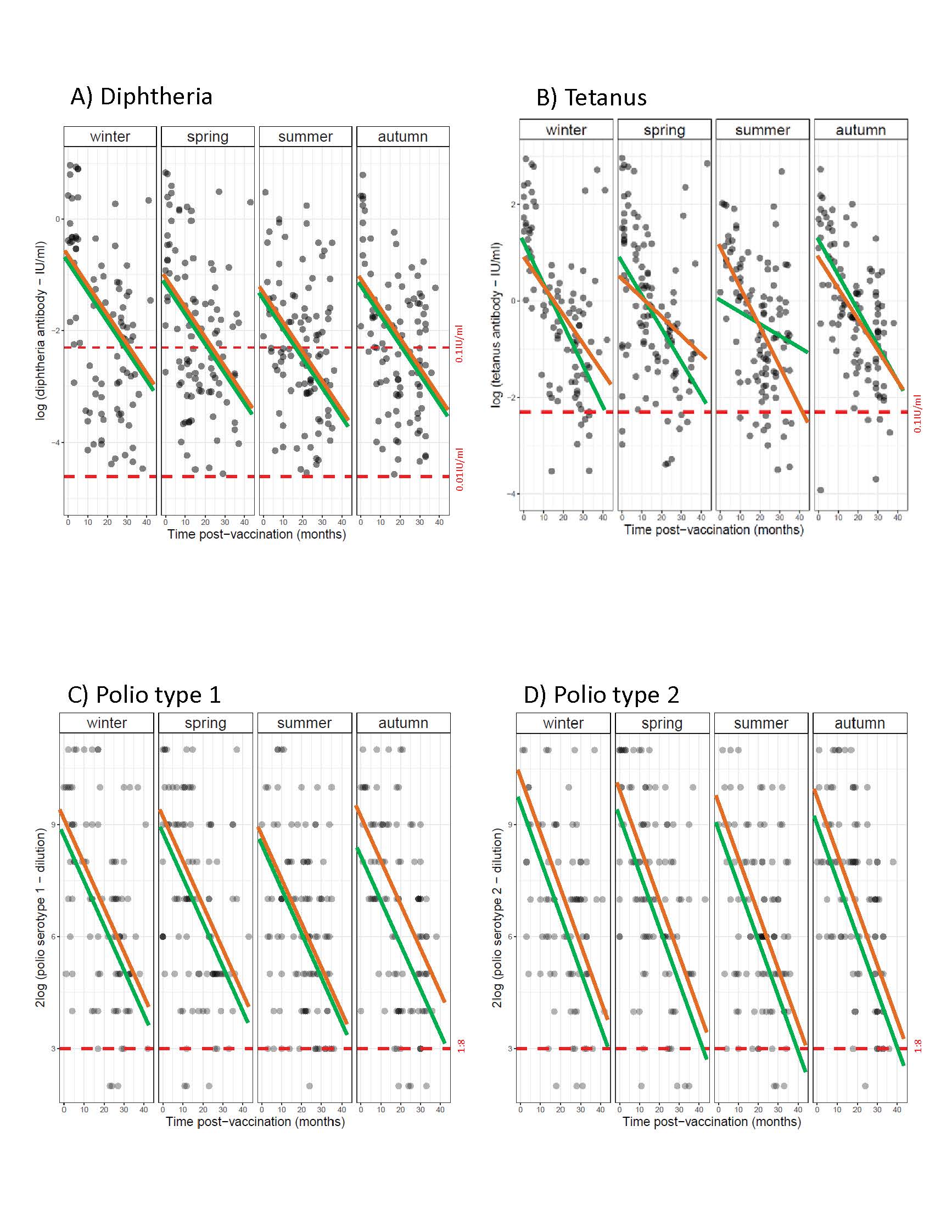
**SUPPLEMENTARY MATERIAL**

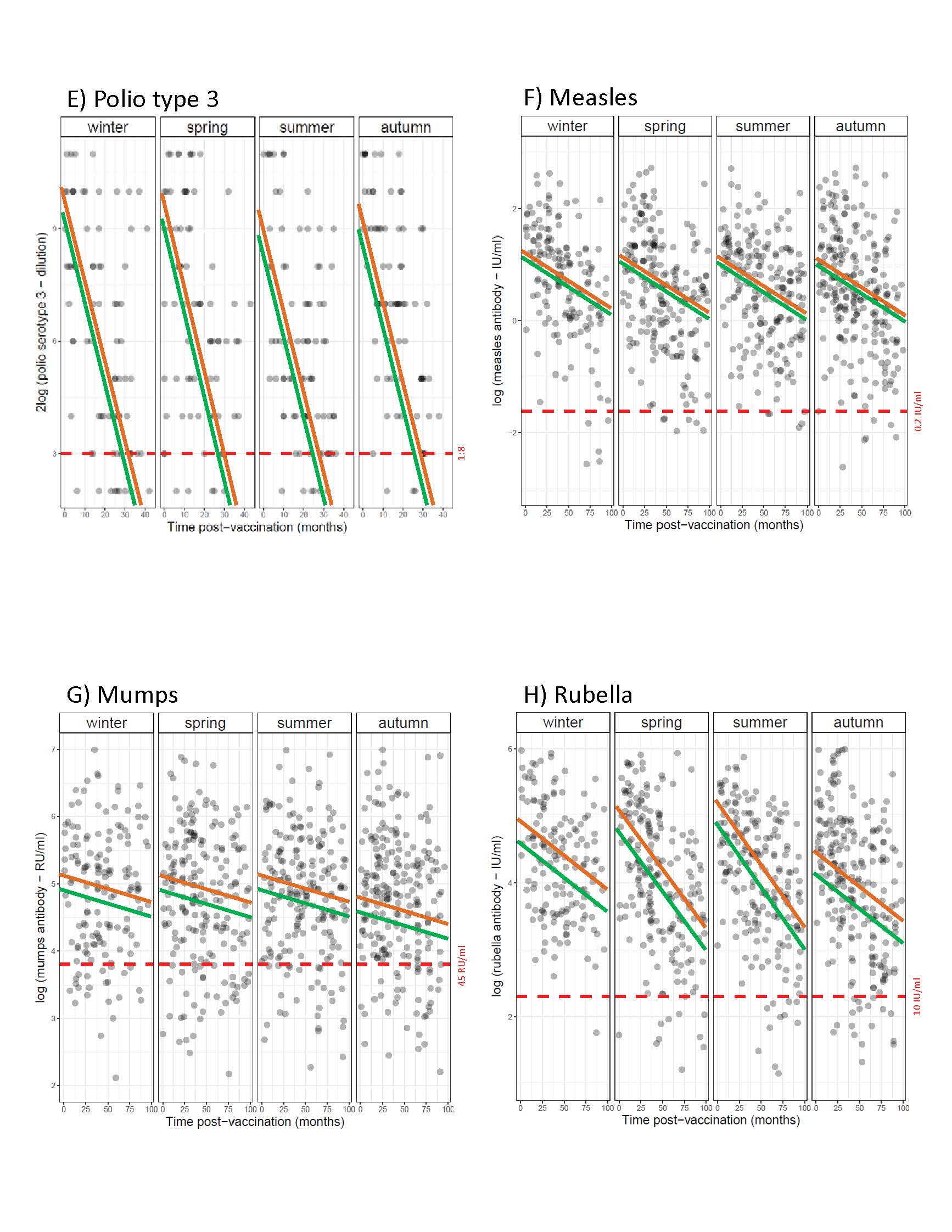
**Supplementary Figure 1. Observed antibody levels against time post-vaccination, by season of vaccination per pathogen. Regression lines predicted by the final models per sex per pathogen, Pienter-2 Study.**

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Sex : girl boy

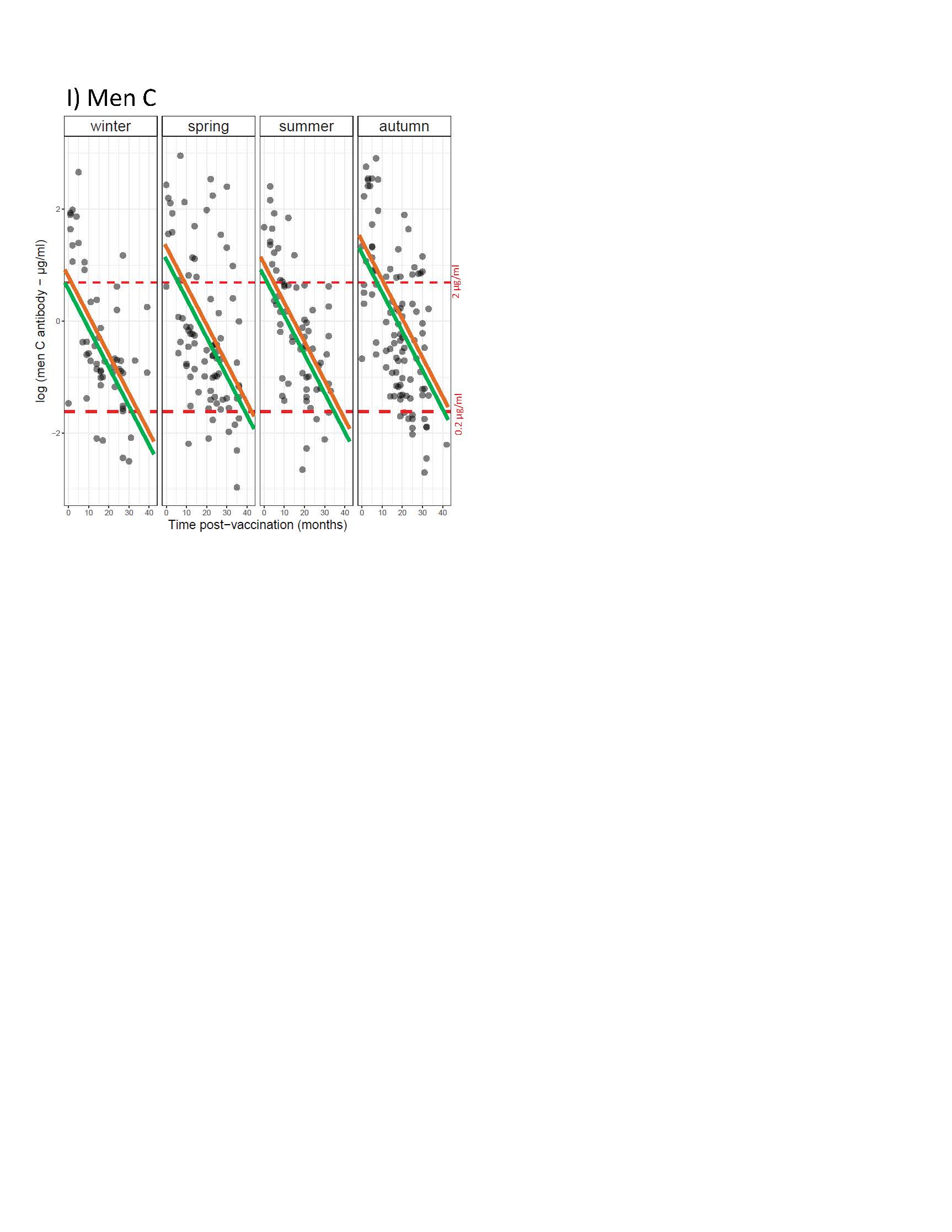
Note: Darker points correspond to overlap of observations; Dashed horizontal red lines are thresholds of protection.

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Sex: girl boy

Note: Darker points correspond to overlap of observations; Dashed horizontal red lines are thresholds of protection.

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Sex: girl boy

Note: Darker points correspond to overlap of observations; Dashed horizontal red lines are thresholds of protection.

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| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Supplementary Table 1. Seroconversion rate per season of vaccination, Pienter-2 Study.** | | | | | | | | | | | | | | | | |  | | ***Seroconversion threshold*** | | ***Winter*** | | ***Spring*** | | ***Summer*** | | ***Autumn*** | | ***Overall*** | | ***p-valuea*** | | Diphtheria | 0.01 IU/ml | | 93% | | 91% | | 92% | | 97% | | 93% | | 0.249 | | | | | Tetanus | 0.1 IU/ml | | 93% | | 91% | | 92% | | 97% | | 93% | | 0.424 | | | | | Polio type 1 | 1:8 | | 92% | | 93% | | 97% | | 91% | | 93% | | 0.291 | | | | | Polio type 2 | 1:8 | | 93% | | 91% | | 92% | | 91% | | 92% | | 0.936 | | | | | Polio type 3 | 1:8 | | 77% | | 75% | | 71% | | 71% | | 73% | | 0.677 | | | | | Measles | 0.2 IU/ml | | 95% | | 97% | | 97% | | 96% | | 96% | | 0.932 | | | | | Mumps | 45 RU/ml | | 85% | | 81% | | 85% | | 80% | | 82% | | 0.372 | | | | | Rubella | 10 IU/ml | | 99% | | 94% | | 94% | | 90% | | 93% | | 0.010 | | | | | MenC | 0.2 µg/ml | | 88% | | 88% | | 90% | | 87% | | 88% | | 0.594 | | | |   ***a****Chi-square test* |  |  |  |

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| **Supplementary Table 2. Pairwise Pearson correlation between individuals’ antibody levels, Pienter-2 Study.** | | | | | | | | | | | | | | |
| ***Antibody*** | *1* | *2* | *3* | *4* | | *5* | | *6* | | *7* | | *8* | | *9* |
| *1 Diphtheria* | 1.00\*\*\* |  |  |  | |  | |  | |  | |  | |  |
| *2 Tetanus* | 0.69\*\*\* | 1.00\*\*\* |  |  | |  | |  | |  | |  | |  |
| *3 Polio type 1* | 0.46\*\*\* | 0.50\*\*\* | 1.00\*\*\* |  | |  | |  | |  | |  | |  |
| *4 Polio type 2* | 0.51\*\*\* | 0.57\*\*\* | 0.63\*\*\* | 1.00\*\*\* | |  | |  | |  | |  | |  |
| *5 Polio type 3* | 0.41\*\*\* | 0.53\*\*\* | 0.62\*\*\* | 0.66\*\*\* | | 1.00\*\*\* | |  | |  | |  | |  |
| *6 Measles* | 0.06 | 0.01 | 0.03 | -0.01 | | -0.08 | | 1.00\*\*\* | |  | |  | |  |
| *7 Mumps* | 0.05 | -0.06 | -0.05 | -0.03 | | -0.04 | | 0.39\*\*\* | | 1.00\*\*\* | |  | |  |
| *8 Rubella* | 0.07 | -0.03 | -0.06 | 0.001 | | -0.01 | | 0.50\*\*\* | | 0.52\*\*\* | | 1.00\*\*\* | |  |
| *9 MenC* | 0.21\*\*\* | 0.28\*\*\* | 0.15\*\* | 0.21\*\*\* | | 0.25\*\*\* | | 0.12\* | | 0.08 | | 0.14\* | | 1.00\*\*\* |
|  | | | | |  | |  | |  | |  | |  | |
| Levels of significance: \*\*\*p< 0.001; \*\*p< 0.01; \*p< 0.05  Level of significance adjusted for multiple testing (Bonferroni correction): \*\*\*p< 0.001 (0.05/45 tests) | | | | | | | | | | | | | | |

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| **Supplementary Table 3. Sensitivity analysis excluding oversampled migrants: Linear Multivariate Regression Model estimates for antibody levels as a function of season of vaccination, time post-vaccination and sex for DT-IPV sub-sample, Pienter-2 Study.** | | | | | | | | | | | | | | | | | | |
|  | ***Diphtheriaa*** | | | ***Tetanusa*** | | | | | ***Polio type 1b*** | | | | | | ***Polio type 2b*** | | | ***Polio type 3b*** |
|  | *girls* | | | *boys* | | | *girls* | | *boys* | | |
| *Intercept* | -1.02\*\* (-1.47, -0.58) | | 0.90\*\* (0.33, 1.47) | | | 1.49\*\* (0.91, 2.07) | | 8.63\*\* (7.37, 9.90) | | | 8.92\*\* (7.94, 9.89) | | | 9.69\*\* (8.90, 10.47) | | | 9.38\*\* (8.49, 10.27) | |
| *Winter vaccination* | *ref.* | | *ref.* | | | *ref.* | | *ref.* | | | *ref.* | | | *ref.* | | | *ref.* | |
| *Spring vaccination* | -0.44 (-0.91, 0.02) | | -0.22 (-0.81, 0.37) | | | -0.01 (-0.85, 0.84) | | 0.40 (-0.89, 1.69) | | | -0.20 (-1.31, 0.92) | | | -0.44 (-1.27, 0.39) | | | -0.53 (-1.47, 0.41) | |
| *Summer vaccination* | -0.52\* (-0.99, -0.06) | | 0.10 (-0.48, 0.68) | | | -1.29\* (-2.40, -0.18) | | -0.05 (-1.32, 1.23) | | | -0.71 (-1.84, 0.42) | | | -0.72\* (-1.55, 0.11) | | | -0.98\* (-1.92, -0.05) | |
| *Autumn vaccination* | -0.25 (-0.73, 0.22) | | 0.28 (-0.34, 0.90) | | | -0.17 (-1.20, 0.85) | | 0.23 (-1.15, 1.60) | | | -0.60 (-1.70, 0.49) | | | -0.13 (-0.97, 0.71) | | | -0.45 (-1.40, 0.51) | |
| *[1] Time post-vaccination****c*** | -0.06\*\* (-0.08, -0.04) | -0.08\*\* (-0.09, -0.06) | | | -0.09\*\* (-0.12, -0.06) | | | -0.11\*\* (-0.15, -0.07) | | | -0.12\*\* (-0.16, -0.08) | | | -0.16\*\* (-0.19, -0.14) | | | -0.21\*\* (-0.24, -0.18) | |
| *Girl* | 0.01 (-0.33, 0.35) | | - | | | - | | - | | | - | | | 0.70\* (0.11, 1.30) | | | 0.46 (-0.21, 1.14) | |
| *Winter vaccination x [1]* | *-* | | *-* | | | *ref.* | | *-* | | | *-* | | | *-* | | | *-* | |
| *Spring vaccination x [1]* | - | | - | | | -0.02 (-0.06, 0.03) | | - | | | - | | | - | | | - | |
| *Summer vaccination x [1]* | - | | - | | | 0.05 (-0.01, 0.10) | | - | | | - | | | - | | | - | |
| *Autumn vaccination x [1]* | - | | - | | | 0.01 (-0.03, 0.06) | | - | | | - | | | - | | | - | |
| Observations | 294 | | 134 | | | 160 | | 134 | | | 160 | | | 294 | | | 294 | |
| Adjusted R square | 0.17 | | 0.33 | | | 0.36 | | 0.17 | | | 0.2 | | | 0.33 | | | 0.38 | |
| Residual Standard Error | 1.45 (df = 288) | | 1.18 (df = 129) | | | 1.18 (df = 152) | | 2.61 (df = 129) | | | 2.59 (df = 155) | | | 2.57 (df = 288) | | | 2.91 (df = 288) | |
| F Statistic | 12.80\*\* (df = 5; 288) | 17.34\*\* (df = 4; 129) | | | 13.76\*\* (df = 7; 152) | | | 7.58\*\* (df = 4; 129) | | | 11.08\*\* (df = 4; 155) | | | 29.27\*\* (df = 5; 288) | | | 37.41\*\* (df = 5; 288) | |
| alog-transformed; blog2-transformed; cin months. Notes: Confidence Intervals (95% CI) in parentheses; Reference levels are winter (season of vaccination) and boy (sex); Levels of significance: \*\*p< 0.01; \*p< 0.05. | | | | | | | | | | | | | | | | | | |
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| **Supplementary Table 4. Sensitivity analysis excluding oversampled migrants: Linear Multivariate Regression Model estimates for antibody levels as a function of season of vaccination, time post-vaccination and sex for MMR sub-sample, Pienter-2 Study.** | | | | | | |
|
|  | | ***Measlesa*** | | ***Mumpsa*** | ***Rubellaa*** | |
| *Intercept* | | 1.17\*\* (0.93, 1.42) | | 4.82\*\* (4.55, 5.08) | 4.48\*\* (4.09, 4.87) | |
| *Winter vaccination* | | *ref.* | | *ref.* | *ref.* | |
| *Spring vaccination* | | -0.16 (-0.41, 0.09) | | -0.05 (-0.32, 0.23) | 0.22 (-0.28, 0.72) | |
| *Summer vaccination* | | -0.17 (-0.43, 0.09) | | 0.01 (-0.27, 0.29) | 0.21 (-0.30, 0.72) | |
| *Autumn vaccination* | | -0.24\* (-0.48, 0.01) | | -0.22 (-0.48, 0.05) | -0.40 (-0.88, 0.08) | |
| *[1] Time post-vaccination****b*** | | -0.01\*\* (-0.01, -0.01) | | -0.003 (-0.01, 0.0003) | -0.01\* (-0.02, -0.001) | |
| *Girl* | | 0.13 (-0.03, 0.30) | | 0.23\* (0.05, 0.42) | 0.27\*\* (0.09, 0.44) | |
| *Winter vaccination x [1]* | | *-* | | *-* | *ref.* | |
| *Spring vaccination x [1]* | | - | | - | -0.01 (-0.02, 0.0002) | |
| *Summer vaccination x [1]* | | - | | - | -0.01 (-0.02, 0.001) | |
| *Autumn vaccination x [1]* | | - | | - | -0.0002 (-0.01, 0.01) | |
| Observations | | 617 | | 617 | 617 | |
| Adjusted R square | | 0.07 | | 0.01 | 0.13 | |
| Residual Standard Error | | 1.06 (df = 611) | | 1.15 (df = 611) | 1.10 (df = 608) | |
| F Statistic | | 9.81\*\* (df = 5; 611) | | 2.69\* (df = 5; 611) | 12.33\*\* (df = 8; 608) | |
| alog-transformed; bin months. Notes: Confidence Intervals (95% CI) in parentheses; Reference levels are winter (season of vaccination) and boy (sex); Levels of significance: \*\*p< 0.01; \*p< 0.05 | | | | | | |
| **Supplementary Table 5. Sensitivity analysis excluding oversampled migrants: Linear Multivariate Regression Model estimates for antibody levels as a function of season of vaccination, time post-vaccination and sex for MenC sub-sample, Pienter-2 Study.** | | | | |
|  | | ***MenCa*** | | |
| *Intercept* | | 0.57\* (0.13, 1.02) | | |
| *Winter vaccination* | | *ref.* | | |
| *Spring vaccination* | | 0.42 (-0.03, 0.88) | | |
| *Summer vaccination* | | 0.15 (-0.32, 0.63) | | |
| *Autumn vaccination* | | 0.47\* (0.03, 0.92) | | |
| *Time post-vaccination****b*** | | -0.07\*\* (-0.09, -0.06) | | |
| *Girl* | | 0.19 (-0.12, 0.49) | | |
| Observations | | 266 | | |
| Adjusted R square | | 0.24 | | |
| Residual Standard Error | | 1.25 (df = 260) | | |
| F Statistic | | 17.86\*\* (df = 5; 260) | | |
| alog-transformed; bin months. Notes: Confidence Intervals (95% CI) in parentheses; Reference levels are winter (season of vaccination) and boy (sex); Levels of significance: \*\*p< 0.01; \*p< 0.05 | | | | |
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| **Supplementary Table 6. Comparative results of model fit (adjusted R square): Time post-vaccination (original scale) *versus* Time post-vaccination (log-transformed), Pienter-2 Study.** | | | |
|  |  | *Final model adjusted R square* | |
|  |  | **Time post-vaccination (original scale)** | **Time post-vaccination (log-transformed)** |
| Diphtheriaa |  | 0.14 | 0.21 |
| Tetanusa | *girls* | 0.21 | 0.21 |
|  | *boys* | 0.28 | 0.31 |
| Polio type 1b | *girls* | 0.20 | 0.20 |
|  | *boys* | 0.22 | 0.19 |
| Polio type 2b |  | 0.29 | 0.27 |
| Polio type 3b |  | 0.35 | 0.33 |
| Measlesa |  | 0.07 | 0.03 |
| Mumpsa |  | 0.02 | 0.01 |
| Rubellaa |  | 0.14 | 0.10 |
| MenCa |  | 0.26 | 0.25 |
| alog-transformed; blog2-transformed | | | |

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| **Supplementary Table 7. Comparative results of estimates of waning MMR antibodies: Linear Mixed Model (longitudinal cohort) *versus* Linear Multivariate Regression Model, Pienter-2 Study** | | | | | | | | | |
|  |  | ***Measlesa,d*** | |  | ***Mumpsa,d*** | |  | ***Rubellaa,d*** | |
|  |  | *Longitudinal cohort* | *Pienter-2 Study* |  | *Longitudinal cohort* | *Pienter-2 Study* |  | *Longitudinal cohort* | *Pienter-2 Study* |
| *Intercept* |  | 0.85\*\* (0.34, 1.35) | 1.12\* (0.91, 1.32) |  | 4.08\*\* (3.69, 4.47) | 4.82\* (4.59, 5.05) |  | 5.24\* (4.91, 5.57) | 4.48\* (4.27, 4.70) |
| *Time post-vaccinationb* |  | 0.0001 (-0.009, 0.009) | -0.01\* (-0.02, -0.01) |  | 0.02\*\* (0.01, 0.03) | -0.003 (-0.01, 0.001) |  | -0.01\*\* (-0.02, -0.01) | -0.01\* (-0.02, -0.01) |
| *Girl* |  | 0.16 (-0.52, 0.84) | 0.11 (-0.07, 0.29) |  | 0.86\*\* (0.35, 1.38) | 0.19 (-0.01, 0.39) |  | 0.18 (-0.34, 0.55) | 0.24\* (0.05, 0.43) |
| Observations |  | 106 | 483c |  | 103 | 483c |  | 106 | 483c |
| alog-transformed; bin months; cChildren aged between 15 to 50 months were included in the analysis for comparability purposes; dModels adjusted for sex only. | | | | | | | | | |
| Notes: Confidence Intervals (95% CI) in parentheses; Reference levels are winter (season of vaccination) and boy (sex); Levels of significance: \*\*p< 0.01; \*p< 0.05 | | | | | | | | |  |