**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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| **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\*\*\* |
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| 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.** |
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|  | ***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 |  |