Biological and hormonal markers of chlamydia, human papillomavirus, and bacterial vaginosis among adolescents attending genitourinary medicine clinics

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Objective: To assess maturity indices, menstrual patterns, hormonal factors, and risk of adolescent genital tract infections.

Methods: Cross sectional study in three genitourinary medicine clinics. Females 17 years or less, within 5 years of menarche, or reporting oligo-amenorrhea were screened for genital tract infections and menstrual cycle characteristics determined. The outcome measures were risk factors associated with chlamydia, human papillomavirus (HPV DNA) and bacterial vaginosis (BV), separately and pooled. Correlations between estrone-3-glucuronide (E3G) and pregnanediol-3α-glucuronide (P3G) hormone concentrations and chlamydia, HPV, and BV.

Results: Among 127 adolescents, HPV was present in 64.4% (95% CI: 54.5 to 74.3), BV in 33.9% (19.1 to 34.5), and chlamydia in 26.8% (19.1 to 34.5). Breast maturity, oligoamenorrhea, and older gynaecological age were associated with lower risk of all infections. After adjustment for calendar age, race, and behavioural factors, gynaecological age remained significant (OR = 0.7, 0.6–0.9; p = 0.008). Behavioural risk factors differed by infection. Smoking was protective for HPV (OR = 0.1, 0.0 to 0.9; p = 0.007), and a new recent partner for chlamydia (OR = 0.3, 0.1 to 0.9; p = 0.024). Sex during menses was associated with increased BV risk (OR = 3.3, 1.5 to 7.2; p = 0.003). Chlamydia was higher among adolescents who used emergency contraception (2.5; 1.1 to 5.9; p = 0.029) and lower among those using condoms at last sex (OR = 0.3, 0.1 to 0.9; p = 0.015). Among 25 adolescents not using hormonal contraceptives, 15 had disturbed or anovulatory cycles. Chlamydia risk was inversely associated with P3G concentrations (Mann-Whitney; p = 0.05).

Conclusions: Adolescents engaging in high risk behaviour at a young gynaecological age are susceptible to multiple infections. Adolescent clinical assessment should include gynaecological age.
**Trophomonas vaginalis** and **Candida albicans**. Vaginal pH was measured and a Gram stain for bacterial vaginosis (BV) was prepared. A blood sample was collected for detection of antibodies to **T. pallidum** and anonymous HSV-1/HSV-2 screening. Adolescents not using hormonal contraception were offered, and shown how to use, a fertility monitor (ClearPlan Easy, Unipath) over one menstrual cycle, in order to characterise their cycles and the predicted peri-ovulatory luteinising hormone surge. Self collected urine samples were obtained on alternate days between days 12 and 26 of the menstrual cycle. These samples were stored frozen (−80°C) at the University of Southampton Endocrine Unit for determination of estrone-3-glucuronide (E3G) and pregnanediol-3α-glucuronide (P3G).

**Analysis of specimens**

**Microbiological tests**

Chlamydia samples were tested using a standardised commercial polymerase chain reaction (PCR) test (Cobas AmpliCor, Roche Diagnostics), and HPV DNA samples using a generic GAP+ primer mediated PCR system at the virology laboratory, Manchester Royal Infirmary. A Gap-DH PCR was performed to check the integrity of the DNA and for presence of PCR inhibitors. Type specific PCR detected HPV 6/11, 16, 18, 31, 33, 52, and 58. HSV-1 and HSV-2 antibodies were detected using an IgG ELISA (Gull Laboratories, Inc, USA). Cell cultures were used to detect HSV and if positive, typed by fluorescent staining using commercial monoclonal reagents. Gram stains for BV were read by one laboratory technician, following Nugent's criteria. A score of >6 defined presence of BV. Amsel criteria were used to classify seven slides that could not be graded. Other tests were completed at on-site laboratories. **N. gonorrhoea** was cultured on lysed blood Columbia agar. Treponemal antibodies were measured (IgG/IgM Murex ICE syphilis assay). Microscopy for **T. vaginalis** and **C. albicans** was undertaken and yeasts were cultured on Sabouraud or blood agar plates.

**Hormonal tests**

A time resolved fluorescence immunoassay for the measurement of E3G and P3G in urine was used which had low interassay and intra-assay variation (≪6%). All urinary hormone measurements were creatinine standardised.

**Data analysis**

**Menstrual patterns**

Definitions of the menstrual cycle were: (i) “normal ovulatory,” if between 21 and 41 days in length, the monitor registered an ovulatory event, the mid-luteal phase mean 3PG concentrations were above 2 μg/ml over three measurements, the follicular phase was less than 21 days and luteal phase at least 10 days in length; (ii) “disturbed ovulatory,” if the follicular phase was 21 days or more and the luteal phase less than 10 days; (iii) “anovulatory,” if the monitor registered no ovulatory event; and (iv) 3PG concentrations remained below 2 μg/ml following a luteinising hormone peak, (v) oligomenorrhoea, if occurring at intervals of 42–180 days. To calculate gynaecological age adolescents were asked their year of menarche and if it was within the past year, between 1 and 2 years ago, 2 and 3 years ago, etc. The mid-point of the onset year of menarche was subtracted from the recruitment calendar age.

**Risk analysis and end points**

Frequencies of sexual behaviour and sociodemographic risk factors and biological markers were generated. Condom use at last sex was selected as a surrogate marker for general use. Univariate logistic regressions were performed for three infection end points: chlamydia, HPV DNA, BV. Odds ratios (OR), 95% confidence intervals (CI), and p values were calculated for each risk factor and each infection end point. In tables, reference categories for categorical variables are indicated; for dichotomous variables the OR is for the presence of the factor, and for continuous variables, it is for a unit increase in the observed value.

Chlamydia, HPV, and BV were analysed together in a multivariate analysis to test for differences in the risks for each infection, and to compute a pooled risk estimate. A binomial mixed effect model was used with subject fitted as a random effect. The 95% CIs were calculated for a single pooled OR for each factor. To test for heterogeneity in the response between the three infections, the infection by factor interaction was tested using a likelihood ratio test. These analyses used the xlogit procedures in Stata (StataCorp, TX, USA).

Hormonal concentrations were transformed to a log scale. Median concentrations were determined before and after ovulation, and over the entire measured portion of the cycle. Correlations between biological risk factors, BV, HPV DNA and chlamydia, and median E3G and P3G concentrations were investigated, using Spearman's test for continuous variables and Mann-Whitney U tests for dichotomous variables.

**RESULTS**

**Description of the population**

Between September 2000 and December 2001, 310 adolescents were approached to join the study; 124 were ineligible and 59 refused, providing a sample of 127. Mean age was 17.8 years (SD 1.1); 73% (92) were white, 24.6% (31) were black, or mixed race, and 2.4% (3) were Asian. Most were students (51.5%, n = 65) and, of the remainder, 24.6% (31) are.
were working and 23.8% (30) were unemployed. Parental occupations were unskilled/unemployed (40%, n = 48), professional (38.3%, n = 46), or skilled (21.7%, n = 26). Many adolescents smoked (58.3%, n = 74) or used to smoke (25.2%, n = 32). Other characteristics are summarised in table 1. All were sexually active; 18.1% were of young gynaecological age (<3.5 years), and almost half described themselves as not fully developed (less than Tanner stage 5 for breast and pubic hair).

Prevalence of genital tract infections
The three most common adolescent infections were HPV DNA (64.4%), BV (33.9%), and chlamydia (26.8%) (table 2). Of the 58 HPV DNA positive samples, 55.2% (32) could be typed, showing 28 high risk types (16, 18, 31, 33), five low risk types (6/11), and one dual high and low risk type. Multiple genital infections were common; 56.9% (33) of adolescents with HPV DNA had at least one co-infection.

### Table 2
Prevalence of genital tract infections among adolescents attending genitourinary medicine clinics

<table>
<thead>
<tr>
<th>Infection</th>
<th>% (No)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSV-2 (antibodies)</td>
<td>4.3 (116)</td>
<td>1.4 to 9.8</td>
</tr>
<tr>
<td>HSV-1HSV-2 (viral shedding)</td>
<td>3.9 (127)*</td>
<td>1.3 to 8.9</td>
</tr>
<tr>
<td>HPV DNA</td>
<td>64.4 (90)†</td>
<td>53.7 to 74.3</td>
</tr>
<tr>
<td>Ano-genital warts</td>
<td>16.9 (89)</td>
<td>9.8 to 26.3</td>
</tr>
<tr>
<td>Chtyida</td>
<td>26.8 (127)</td>
<td>19.3 to 35.4</td>
</tr>
<tr>
<td>Gonorrhoea</td>
<td>1.6 (127)</td>
<td>0.2 to 5.6</td>
</tr>
<tr>
<td>Candidiasis</td>
<td>6.3 (127)</td>
<td>0.3 to 12.0</td>
</tr>
<tr>
<td>Bacterial vaginosis</td>
<td>33.9 (127)</td>
<td>25.7 to 42.8</td>
</tr>
<tr>
<td>Trichomoniasis</td>
<td>31 (127)</td>
<td>0.9 to 7.9</td>
</tr>
<tr>
<td>Syphilis</td>
<td>0.0 (127)</td>
<td>0.0 to 2.9</td>
</tr>
<tr>
<td>No infection</td>
<td>15.6 (90)</td>
<td>8.8 to 24.7</td>
</tr>
<tr>
<td>Single infection</td>
<td>43.3 (90)</td>
<td>32.9 to 54.2</td>
</tr>
<tr>
<td>Two or more infections</td>
<td>44.1 (90)</td>
<td>34.0 to 55.3</td>
</tr>
</tbody>
</table>

*includes two girls who did not give swabs because of painful herpes lesions.
†HPV screening started after 3 months.

Risk factors associated with chlamydia, HPV, and BV
Risk factors significantly associated with lower risk of all three infections were breast maturity, gynaecological age, long menstrual cycles (oligomenorrhoea), and professional parental occupation (table 3). A new partner after drinking or drug use significantly increased the risk of all infections, as did vaginal cleansing. Gynaecological age (but not breast stage, ectopy, or long cycles) remained a significant predictor of the three infections (OR = 0.7, 0.6 to 0.9; p = 0.008) after controlling for age, number of sex partners and eight other behavioural risk factors (cf table 3).

Several behavioural factors showed significant differences between infections. Smoking was a positive risk factor for chlamydia and BV, but a negative risk factor for HPV (p = 0.007). A recent new partner was associated with a higher risk of HPV and BV, but a lower risk of chlamydia (p = 0.024). Sex during a menstrual period was associated with a higher risk of BV (p = 0.003), but not chlamydia or

### Table 3
Individual and pooled risk factors for chlamydia, HPV and bacterial vaginosis

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Chlamydia</th>
<th>HPV</th>
<th>BV</th>
<th>Pooled estimate (three infections)</th>
<th>Heterogeneity*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)†</td>
<td>OR (95% CI)†</td>
<td>OR (95% CI)†</td>
<td>OR (95% CI)†</td>
<td>p Value</td>
</tr>
<tr>
<td>Parental occupation‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional</td>
<td>3.6 (1.0 to 12.8)</td>
<td>0.8 (0.2 to 2.5)</td>
<td>1.9 (0.7 to 5.2)</td>
<td>1.7 (0.8 to 3.5)</td>
<td>0.043</td>
</tr>
<tr>
<td>Semiskilled</td>
<td>4.9 (1.6 to 14.8)</td>
<td>1.4 (0.5 to 3.7)</td>
<td>1.5 (0.6 to 3.7)</td>
<td>2.1 (1.2 to 4.0)</td>
<td>0.97</td>
</tr>
<tr>
<td>Unskilled/unemployed</td>
<td>1.2 (0.4 to 3.6)</td>
<td>0.1 (0.0 to 0.9)</td>
<td>2.5 (0.8 to 8.0)</td>
<td>1.0 (0.5 to 2.0)</td>
<td>0.65</td>
</tr>
<tr>
<td>Frequency of sex**</td>
<td>2.2 (0.9 to 5.3)</td>
<td>2.2 (0.7 to 6.4)</td>
<td>2.5 (1.1 to 5.9)</td>
<td>1.3 (0.8 to 2.3)</td>
<td>0.74</td>
</tr>
<tr>
<td>New partner after drugs/alcohol*</td>
<td>0.3 (0.1 to 0.9)</td>
<td>2.2 (0.8 to 6.4)</td>
<td>1.3 (0.6 to 2.9)</td>
<td>1.0 (0.6 to 1.8)</td>
<td>0.98</td>
</tr>
<tr>
<td>Practised sex during period**</td>
<td>0.1 (0.4 to 2.1)</td>
<td>0.6 (0.2 to 1.5)</td>
<td>3.3 (1.5 to 7.2)</td>
<td>1.3 (0.8 to 2.3)</td>
<td>0.30</td>
</tr>
<tr>
<td>Cleansed vagina after sex*</td>
<td>0.3 (0.1 to 0.9)</td>
<td>1.0 (0.4 to 2.3)</td>
<td>0.8 (0.4 to 1.7)</td>
<td>0.6 (0.4 to 1.1)</td>
<td>0.89</td>
</tr>
<tr>
<td>Gynaecological age**</td>
<td>0.7 (0.5 to 0.9)</td>
<td>0.8 (0.6 to 1.0)</td>
<td>0.8 (0.6 to 1.0)</td>
<td>0.7 (0.6 to 0.9)</td>
<td>0.001</td>
</tr>
<tr>
<td>Emergency contraception (last 12 months)</td>
<td>2.5 (1.1 to 5.9)</td>
<td>0.7 (0.3 to 1.7)</td>
<td>0.9 (0.4 to 1.8)</td>
<td>1.2 (0.7 to 2.0)</td>
<td>0.54</td>
</tr>
<tr>
<td>Breast stage (Tanner)**</td>
<td>0.6 (0.3 to 1.1)</td>
<td>0.6 (0.3 to 1.2)</td>
<td>0.6 (0.4 to 1.1)</td>
<td>0.6 (0.4 to 0.9)</td>
<td>0.082</td>
</tr>
<tr>
<td>Cycle regularity (days)</td>
<td>1.7 (0.7 to 3.7)</td>
<td>0.8 (0.3 to 2.0)</td>
<td>2.2 (1.0 to 4.7)</td>
<td>1.6 (0.9 to 2.7)</td>
<td>0.086</td>
</tr>
<tr>
<td>Cycle regularity (&lt;20)</td>
<td>2.2 (0.7 to 7.0)</td>
<td>0.9 (0.2 to 3.6)</td>
<td>2.0 (0.6 to 6.2)</td>
<td>2.0 (0.6 to 6.2)</td>
<td>0.027</td>
</tr>
<tr>
<td>Cycle regularity (≥42) (oligomenorrhoea)</td>
<td>NA</td>
<td>0.3 (0.1 to 1.8)</td>
<td>0.3 (0.0 to 2.6)</td>
<td>0.3 (0.0 to 2.6)</td>
<td>0.027</td>
</tr>
</tbody>
</table>

*Univariate logistic regression.
††Pooled estimate of the risk of infection assuming the risks of the three infections do not differ (multivariate logistic regression).
*Significance level of a test that the risks are not homogeneous across the three infections. Significance suggests that the three infections may have different responses to the risk factor.
**Entered as continuous variables. Gynaecological age is expressed as risk per year, frequency of sex is grouped into three categories: <1, 1–4, and ≥4 times per week.
*Variables entered into the adjusted analysis, together with calendar age and lifetime number of partners.
NA, not computable because of zero events.
HPV. In univariate analyses, use of emergency contraception was associated with increased chlamydia risk ($p = 0.024$) and using condoms at last sex with lower risk ($p = 0.015$).

**Correlations with E3G and P3G hormonal concentrations**

Altogether, 49 adolescents not using hormonal contraceptives collected a home fertility monitor. Of these 19 failed to collect any data, two became pregnant, and three developed oligo-amenorrhoea. Of 25 adolescents completing the study, cycles of 10 (40%) were normal, eight (32%) disturbed ovulatory, and seven (28%) anovulatory.

Correlations between median sex steroid hormone concentrations, and presence or absence of biological characteristics and genital tract infections were assessed. Adolescents who were chlamydia positive were more likely to have elevated P3G concentrations (Mann-Whitney U test: $p = 0.05$). BMI was inversely correlated with P3G concentrations (Spearman: $r = -0.40$, $p = 0.05$). There were no significant correlations of the biological factors listed in table 3, or genital infections (chlamydia, HPV DNA, BV) with median E3G concentrations.

**DISCUSSION**

In this study of adolescents attending genitourinary medicine clinics, younger gynaecological age was associated with a high risk of genital infections. Adolescents with oligomenorrhoea, a menstrual disorder associated with ovulatory dysfunction, had a lower overall risk.

This study was unique because it investigated biological risk markers, whereas most research has focused on sexual risk behaviour and young age. One exception was a study in racially diverse adolescents, which reported a significant fall in vaginal pH as gynaecological age increased. Vaginal pH could account for increased risk of BV in less mature adolescents. Biological susceptibility was inferred by previous studies that could not account for a disproportionate risk of sexually transmitted infections among female adolescents, and in studies finding high infection rates among adolescents with a history of few sexual partners. In our study, the high infection rate was not explained by recent onset of sexual activity, although the timing of onset is critical. We suggest that a sexually active 18 year old with late menarche may be more susceptible to multiple infections than a sexually active 15 year old with early menarche.

We also assessed menstrual cycle patterns and hormonal concentrations in a subgroup of 25 adolescents not using contraception. Among these, 60% had disturbed menstrual cycles. The sample size was insufficient for subgroup analysis of menstrual patterns and infection rates, reflecting the difficulties of following up a high risk population who frequently used contraceptives. Contraceptives help to normalise menstrual cycle patterns, and in the total sample, contraceptive use (except emergency contraception) did not significantly increase the risk for any infection end point. Analysis of hormone concentrations identified an association between higher P3G and chlamydia. This was of interest because in the total sample, adolescents who had used emergency contraception, containing levonorgestrel, in the past 12 months, had a 2.5 times increased risk of chlamydia. This could be the result of unprotected sex as condom use was protective (table 3). However, none of seven adolescents with oligomenorrhoea, a menstrual disorder associated with lower progesterone levels, was chlamydia positive (table 3). _C. trachomatis_ preferentially infects endocervical columnar cells present on the ectocervix, and these cells bind progesterone at high levels. These results suggest that higher progesterone levels increase chlamydia risk.

Self assessment of maturity stages may have been less accurate than clinical assessment and the selection criteria excluded older adolescents with early menarche. Early matures (<12 years) have elevated oestrogen levels, a faster rate of pubertal progression than late matures, achieve regular menstrual patterns sooner, tend to be heavier, and have lower pregnanediol levels. This profile could contribute to reduced biological susceptibility to genital infections for a given exposure rate. Black girls experience menarche earlier than white girls and future studies should be large enough to stratify by gynaecological age and ethnicity.

Whereas young gynaecological age increased susceptibility to all three infections, behavioural risk factors were often infection specific. Other associations may have been detected had we elicited histories of different types of sexual practice (for example, anal sex) or verified sexual histories. The lower risk of chlamydia in adolescents with a new recent partner might be explained by a lower prevalence of chlamydia in adolescent male partners or by higher condom use with new partners. Condoms may be more protective against chlamydia than HPV, which can appear at sites not covered by the condom. Smoking, a marker for high risk behaviour, is also anti-oestrogenic. Smoking protected against HPV infection in this and a previous US cohort study. Future studies might explore whether perceptions of size (for example, breast development and weight) influence partner selection, sexual behaviour, and infection risk.

**Implications**

Adolescents exposed to genital infections at younger gynaecological ages are highly susceptible. Exposure to multiple infections is a consequence of risky sexual behaviour and was characteristic of these adolescents. Co-infections with HPV were frequent. Elevated levels of the cytokine IL-12 have been detected in adolescents concomitantly infected with both HPV and one or more STIs. Presence of HPV may influence the magnitude of immune protection in the genital tract. Associations between multiple infections, gynaecological age, and long term sequelae need to be investigated in longitudinal studies. Age at first sexual intercourse has declined, which potentially increases the proportion of adolescents exposed before maturity. Gynaecological age is a useful marker of adolescent risk and we recommend its inclusion in clinical assessment.

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CONTRIBUTORS
LB conceived the study and wrote the paper; EB contributed to study design, recruited participants, and helped draft the paper; DM, SPH and SC advised on clinical issues, collected the data, and reviewed the paper; SR undertook the statistical analyses and contributed to writing the paper; PW and GB completed the hormone assays, advised on hormonal analyses, and reviewed the paper; HCK reviewed the study design and analysis.

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