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Trends in diagnostic tests ordered for children: a retrospective analysis of 1.7 million laboratory test requests in Oxfordshire, UK from 2005 to 2019

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ABSTRACT

Objective To better understand testing patterns in children, we measured temporal trends in paediatric testing from 2005 to 2019 in Oxfordshire, UK.

Design Descriptive study of population-based secondary data.

Setting Oxfordshire University Hospitals National Health Service Trust laboratories.

Participants Children aged 0–15 years in Oxfordshire who received at least one blood test.

Main outcome measures We estimated average annual percentage changes (AAPCs) in test use using joinpoint regression models. Temporal changes in age-adjusted rates in test use were calculated overall and stratified by healthcare setting, sex, and age.

Results Between 2005 and 2019, 1 749 425 tests were performed among 113 607 children. Overall test use declined until 2012, when test rates appeared to increase (AAPC 1.5%, 95% CI –0.8% to 3.9%). Most tests were performed in inpatient settings, where testing rates stayed steady (AAPC –0.6%, 95% CI –2.1% to 0.9%). Increases were highest in females, those aged 6–15 years and in the outpatient setting. The greatest increase in testing was for vitamin D (AAPC 26.5%), followed by parathyroid hormone (9.8%), iron studies (9.3%), folate (8.4%), vitamin B₁₂ (8.4%), HbA1c (8.0%), IgA (7.9%) and coeliac (7.7%).

Conclusions After an initial decline, laboratory test use by children in Oxfordshire demonstrated an apparent increase since 2012. Test use increased in outpatient and general practice settings, however remained steady in inpatient settings. Further research should examine the root causes and implications for test increases, and whether these increases are warranted. We encourage clinicians to consider the individual and systemic implications of performing blood tests in children.

BACKGROUND

Diagnostic testing plays an important role in the provision of healthcare. In England, laboratory and pathology services (including biochemistry, haematology, microbiology, histopathology and cytology tests) are estimated to cost £2.5 billion annually, comprising 3–4% of the National Health Service (NHS) budget.¹ It is estimated that 70–80% of all healthcare decisions affecting diagnosis or treatment involve a pathology test.^{1–4}

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Diagnostic test practices influence diagnostic rates. Too much testing can lead to overdiagnosis whereas too little can lead to underdiagnosis.
- ⇒ There is substantial variation in diagnostic test use among adults, but test use in children is poorly understood.

WHAT THIS STUDY ADDS

- ⇒ Test use is increasing in children. The magnitude of change differs by test, age and healthcare setting.
- ⇒ The different patterns of variation for each test, age group and setting highlight tests that are potentially overused such as vitamin D.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Temporal variation in test use highlights potential areas of inappropriate testing, prompting the need for improved clinical guidance in these areas.
- ⇒ Our findings highlight the specific settings where efforts should be targeted to mitigate unnecessary testing.
- ⇒ Further research should measure geographical variation in test use, examine the appropriateness of testing practices, and explore drivers of variation using clinical records and individual patient-level data.

Substantial variation has been demonstrated in diagnostic test use across primary and secondary care in the UK.^{5–7} The 2017 Atlas of Variation in NHS Diagnostics explored unwarranted variation in a range of imaging, endoscopy, physiological, and screening services. However, most of the reported diagnostic measures focused on adults, as does much of the existing literature on diagnostic testing.^{7, 8} Children constitute 19% of the UK's population⁹ and over 85% of children are registered with an NHS general practitioner (GP).^{10, 11} Clinicians often face uncertainty around diagnostic investigations for children as failure to perform necessary diagnostic tests can lead to missed diagnoses, but unnecessary diagnostic laboratory tests (overtesting) may lead to physical and psychological harms to children as well as straining already limited healthcare resources.¹²



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Table 1 Characteristics of included patients and tests

	Number of children	%
Females	52 207	46.0
Males	61 400	54.0
Total	113 607	100.0
Age group	Number of tests	%
Total tests	1 749 425	100.0
<1 year	580 636	33.2
1–5 years	439 770	25.1
6–10 years	319 387	18.3
11–15 years	409 632	23.4
Setting		
General practice	293 506	16.8
Inpatient	1 232 556	70.5
Outpatient	223 363	12.8
	Median no of tests per child*	IQR
Total	5	3–8
General practice	5	3–8
Inpatient	5	3–7
Outpatient	4	2–8

*In children who had at least one test.

There is a paucity of comprehensive data exploring laboratory testing in children. This study aims to determine the most frequently performed diagnostic laboratory tests for children in the Oxfordshire region from 2005 to 2019 and explore temporal changes in test use by sex, age, and healthcare setting.

METHODS

Study design and data sources

This was a retrospective observational study of diagnostic laboratory test data.

Setting

We obtained laboratory testing data from Oxford University Hospitals (OUH) and Oxfordshire general practices from 1 January 2005 to 31 December 2019. The laboratory is the sole referral centre for 67 general practices and 4 hospitals, making up over 95% of the tests carried out in Oxfordshire. For further details, refer to the extended methods (online supplemental file 1).

Data from all laboratory tests conducted among children aged 0–15 years were included in this analysis. We excluded point-of-care tests (e.g., blood gas, glucose) as these tests are not consistently sent to the laboratory for analysis.

Variables and data sources

We extracted non-identifiable data from the OUH Trust database, including the name of the test, indication for the test, patient sex and age, and setting of the test request. Test type was indicated by standard codes and grouped according to panels provided in the online supplemental file 2.

Statistical analysis

We estimated the proportion of tests requested in general practice, inpatient and outpatient (hospital paediatric clinic) settings each year. We estimated crude and age-standardised test rates per 1000 child-years. Testing rates were stratified by gender and age group.

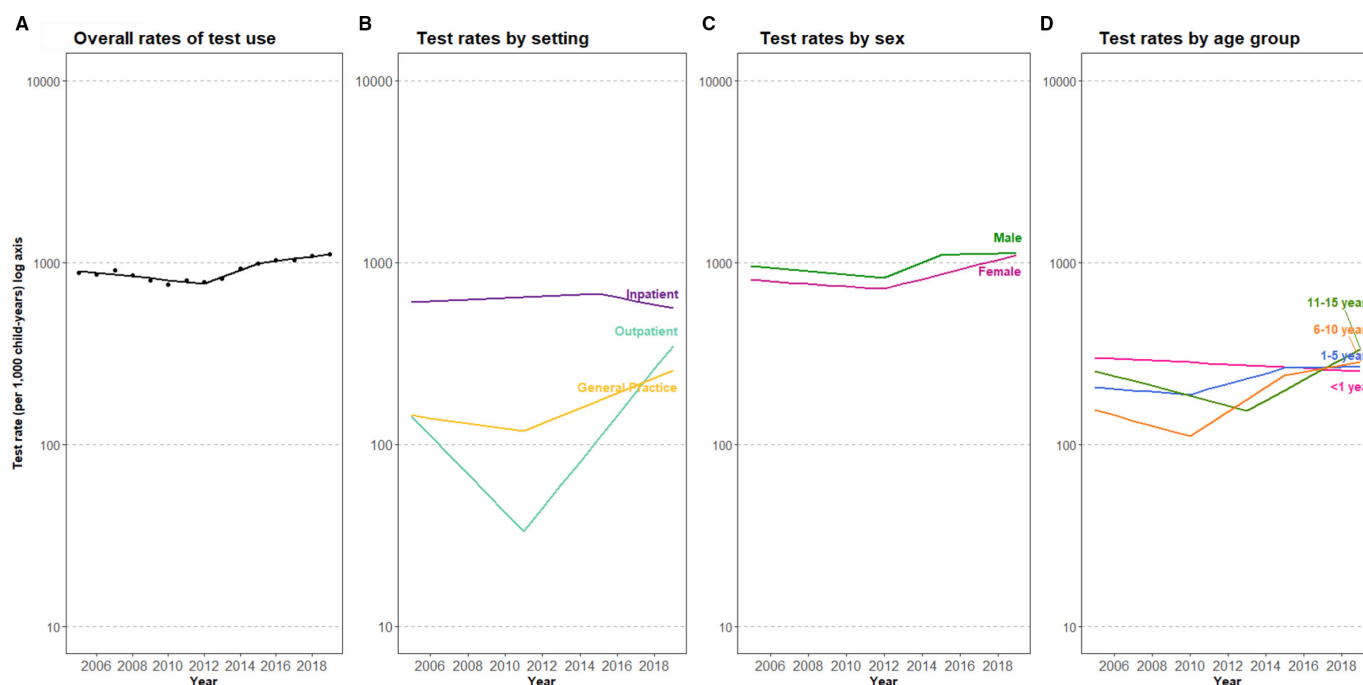


Figure 1 Test use among children in Oxfordshire from 2005 to 2019. (A) Overall test use, (B) by healthcare setting, (C) by sex and (D) by age group. (A) AAPC=1.5% (95% CI –0.8% to 3.9%, p=0.2); APC 2005–2012=–2.2% (95% CI –3.8% to –0.6%, p=0.01); APC 2012–2015=9.0% (95% CI –3.0% to 22.5%, p=0.1); APC 2015–2019=2.8% (95% CI –0.5% to 6.3%, p=0.09). (B) AAPC by setting: general practice=4.2% (95% CI 1.5% to 6.9%, p=0.002); inpatient=–0.6% (95% CI –2.1% to 0.9%, p=0.4); outpatient=6.6% (95% CI 1.9% to 11.5%, p=0.005). (C) AAPC by sex: female=2.3% (95% CI 1.3% to 3.3%, p<0.001); male=1.2% (95% CI –1.3% to 3.8%, p=0.3). (D) AAPC by age group: <1 year=–1.2% (95% CI –2.2% to –0.2%, p=0.02); 1–5 years=1.9% (95% CI –0.8% to 4.6%, p=0.2); 6–10 years=4.4% (95% CI 2.6% to 6.3%, p<0.001); 11–15 years=2.0% (95% CI –1.1% to 5.2%, p=0.2). AAPC, average annual percentage change; APC, annual percentage change.

We used joinpoint regression to model temporal changes in age-adjusted rates from 2005 to 2019, similar to prior studies.^{8 13} Joinpoint regression assumes that calendar time can be subdivided into subsets with distinct linear trends. Points where significant changes in rates occurred (joinpoints) were identified and annual percentage changes (APCs) between joinpoints were estimated. We also estimated the average APC (AAPC), a summary measure of the trend from 2005 to 2019, stratified by setting, sex, and age. APCs and AAPCs were estimated for the 25 most frequently requested tests. APCs and AAPCs were modelled in Joinpoint software, and all other statistical analyses were performed using R. There were no missing data in the variables of interest.

RESULTS

Characteristics of included participants

There were 1 749 425 tests performed on 113 607 children from 1 January 2005 to 31 December 2019, of which 46% (52 207 of 113 607) were female (table 1 and online supplemental table 1). Seventy-one per cent of tests (1 232 556 of 1 749 425) occurred in the inpatient setting, 17% in general practice and 13% in the outpatient setting. Of the children who had at least one test, each child had a median of five blood tests (IQR 3–8).

Temporal change in test use

The age-adjusted rate of total test use increased from 878 tests per 1000 child-years in 2005 to 1107 tests per 1000 child-years in 2019, though this change was not statistically significant (AAPC 1.5% (95% CI –0.8% to 3.9%, $p=0.2$), (figure 1A and online supplemental table 2). Test rates initially decreased by 2.2% per year between 2005 and 2012 (95% CI –3.8% to –0.6%, $p=0.01$, figure 1). From 2012 to 2015, the APC was 9% per year (95% CI –3.0% to 22.5%) and then between 2015 and 2019 was 2.8% per year (95% CI –0.5% to 6.3%).

Figure 1B shows a temporal change in test use by setting. Testing rates remained steady in the inpatient setting (AAPC –0.6%, 95% CI –2.1% to 0.9%, $p=0.4$). In general practice, test use was stable until 2011 (AAPC –3.3%, 95% CI –8.3% to 1.9%, $p=0.2$), and then increased by 10.1% per year (95% CI 6.5% to 14.0%, $p<0.001$). Testing in outpatients decreased by 21.6% per year until 2011 (95% CI –28.3% to –14.2%, $p<0.001$) and then sharply increased by 34.1% per year (95% CI 26.6% to 42.2%, $p<0.001$).

Figure 1C illustrates test use by sex. Testing rates for males and females followed similar trends until 2015 when test use in males stabilised (AAPC 1.0%, 95% CI –2.6% to 4.7%, $p=0.5$), whereas testing in females continued to rise by 6.4% per year from 2012 (95% CI 4.7% to 8.0%, $p<0.001$).

The rates of test use by age group are presented in figure 1D. Test use declined overall in children under 1 year (AAPC –1.2%, 95% CI –2.2% to –0.2%, $p=0.02$). Testing in all other age groups increased after 2010; this was particularly striking for children aged 6–10 years (AAPC 4.4%, 95% CI 2.6% to 6.3%, $p<0.001$) and children aged 11–15 years from 2013 (APC 13.8%, 95% CI 6.9% to 21.1%, $p<0.001$).

The proportion of children in Oxfordshire receiving at least one test in any setting increased by 39% (from 8.8% to 12.3%, figure 2 and online supplemental table 3). Increases were highest in the outpatient setting, where the proportion of children receiving at least one test increased by 84% (from 2.2% to 4.0%).

Test ranking

The most frequently ordered tests are shown by setting and age group in figure 3. The top five tests were: full blood count; urea and electrolytes; liver function tests; C reactive protein (CRP); and calcium, magnesium and phosphate levels. The top five tests were reasonably consistent for all age groups and settings (online supplemental table 4).

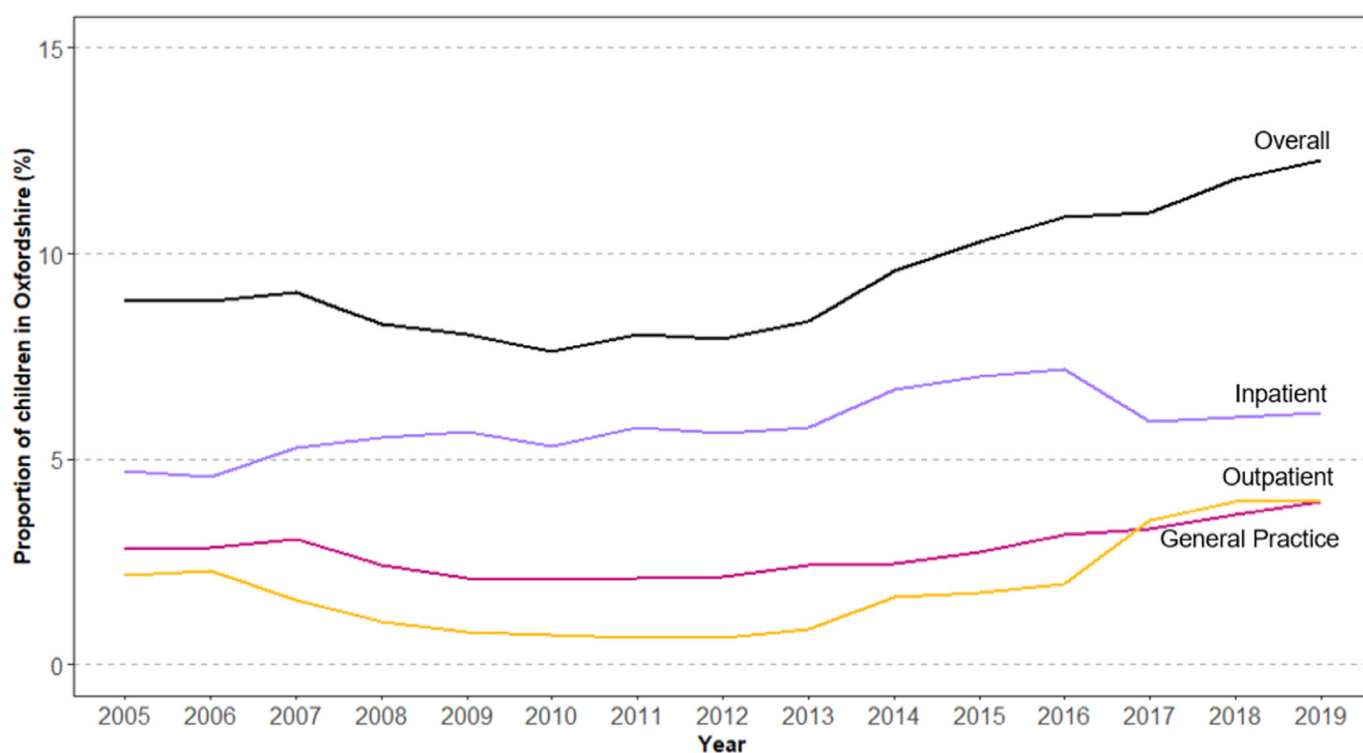


Figure 2 Proportion of children in Oxfordshire who had at least one test from 2005 to 2019 overall, and in each healthcare setting.

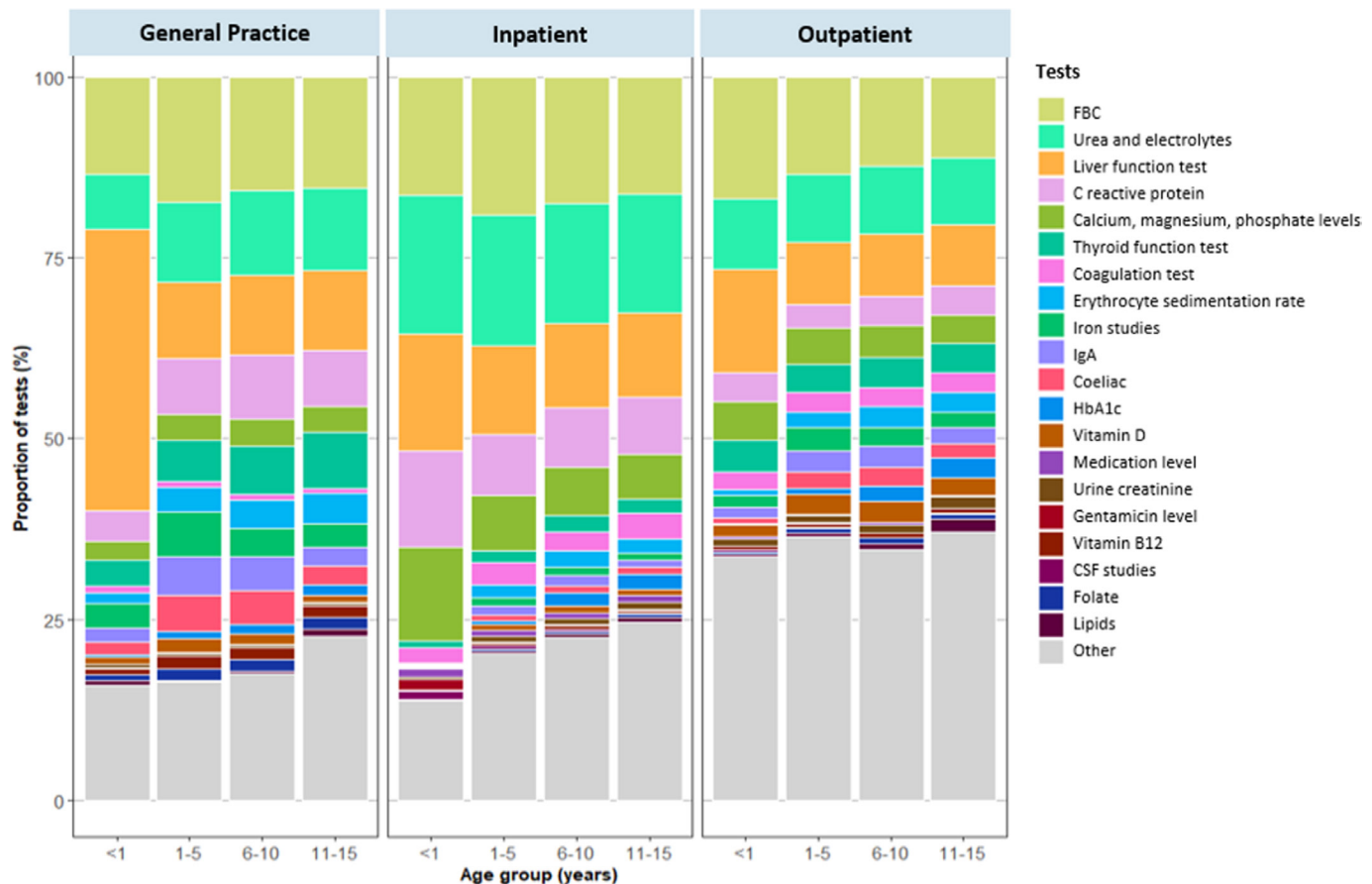


Figure 3 The most frequently requested tests for children in Oxfordshire from 2005 to 2019, by setting and age. CSF, cerebrospinal fluid; FBC, full blood count.

Trends in specific test use

The temporal changes in the top 25 most frequently requested tests are shown in online supplemental figure 1. Tests that demonstrated a continuous increase included coeliac testing, creatine kinase, cerebrospinal fluid studies, folate, HbA1c, IgA, iron studies, medication level, parathyroid hormone, thyroid function test, vitamin B₁₂ and vitamin D. A continuous decrease in test use was observed for coagulation tests, gentamicin levels and monospot tests for glandular fever.

The AAPC for each test is presented in figure 4. Vitamin D testing had the highest AAPC, increasing by 26.5% per year (95% CI 23.7% to 29.3%, $p < 0.001$). Testing for glandular fever decreased by the largest margin of 8.8% per year (95% CI –11.4% to –6.1%, $p < 0.001$).

Changes in test use by age and setting

When stratified by age group (online supplemental figure 2) and setting (online supplemental figure 3), testing increased consistently for vitamin D. For other tests, trends were not uniformly distributed across ages and settings. For example, parathyroid hormone levels, iron studies, folate and vitamin B₁₂ testing increased in the children 1–15 years old, more so in general practice compared with other settings. CRP testing significantly increased in general practice, with an annual percentage increase of 9% per year after 2011 (95% CI 5.1% to 13.0%, $p < 0.001$).

DISCUSSION

In this descriptive study, we identified trends in test use for children from 2005 to 2019 in Oxfordshire by sex, age, and setting.

Our results demonstrated that after an initial decline, testing rates for children appeared to increase from 2012 to 2019. Testing increases were more pronounced in females than males, and in children aged between 6 and 15 years compared with the other age groups. The largest relative increases occurred in the outpatient setting followed by general practice. The changes observed in overall testing rates can likely be attributed to testing increases in these settings and subgroups.

Of the most common tests, testing for vitamin D, parathyroid hormone, iron studies, folate and vitamin B₁₂ increased by the greatest proportion annually. Relative increases in these tests were most pronounced in general practice. These are consistent with temporal changes in test use by adults in UK primary care from 2000 to 2015,⁸ where O'Sullivan and colleagues reported increases in testing for vitamin D (which increased by 54% per year). Iron, ferritin, vitamin B₁₂ and folate testing in adults increased by 16–19% per year. In recent years, there has been greater awareness of vitamin D deficiency and iron deficiency, making it more likely that doctors will test for these conditions. Increased disease prevalence may also explain the rise in testing.¹⁴ Iron studies, folate, B₁₂, thyroid function tests, and creatine kinase form part of the workup for fatigue. A 2007 prospective study of British adolescents reported the point prevalence of fatigue was 38%, but more recent estimates are lacking.¹⁵ Most of these tests (vitamin D, iron studies, folate, vitamin B₁₂, coeliac test, serum IgA) are also included in investigations for malnutrition and faltering growth, suggesting increasing clinician concern and/or incidence of these conditions.

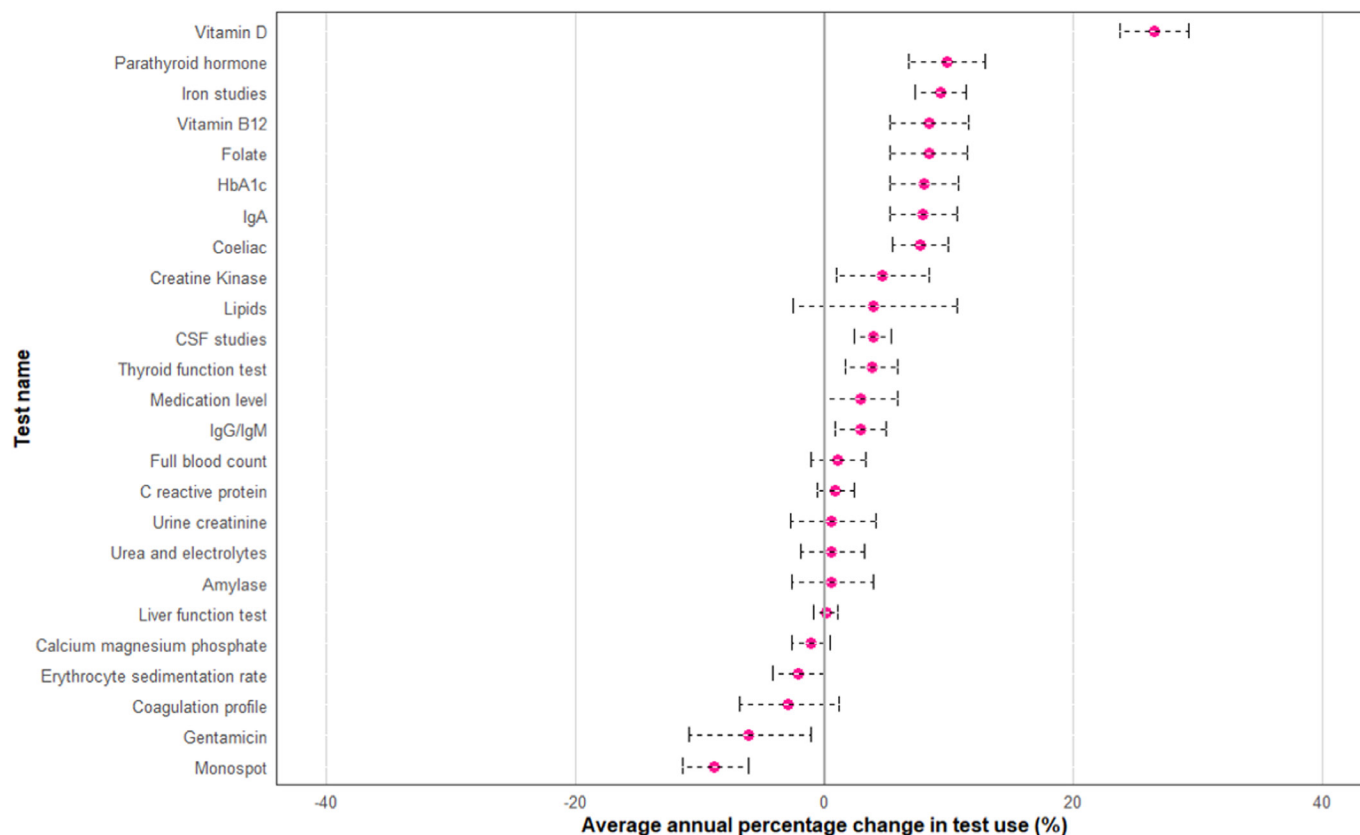


Figure 4 Average annual percentage change in test use for 25 specific tests from 2005 to 2019. CSF, cerebrospinal fluid.

Testing rates in Oxfordshire decreased between 2005 and 2012 and then appeared to increase. Decreases in the early period mirrored decreasing inpatient and outpatient attendances at OUH.^{16 17} The inflection point in testing rates aligned with a major service change in 2011, when 11 new general paediatric consultants were appointed in Oxfordshire. While all staff were appropriately qualified, newer members of staff may have been inclined to test more,^{18 19} which may be one explanation for change in trends in testing rates. In addition, parental expectations and anxiety levels have increased. In primary care, there has been a decline in experienced family doctors who are more likely to reassure parents without testing and referring children, and a concurrent rise in less experienced GPs who may test and refer more.²⁰ Parents of children referred by these GPs may present to outpatient appointments expecting a diagnostic workup.

The most pronounced increases in testing occurred in the outpatient setting, which expanded during the study period. According to NHS digital data, from 2009 to 2020, the number of children seen in OUH outpatient clinics increased by 63% (with a sharp increase in 2013).¹⁶ Since the Oxford Children's Hospital opened in 2007, the tertiary specialty workload has grown, with an increased number of referrals from all around the region outside of Oxfordshire (including Berkshire, Buckinghamshire, Wiltshire, Milton Keynes). We could not distinguish between tests that were conducted among Oxfordshire residents and referrals for tests from other areas, or which tests were for specialty or general paediatric patients. As a result, the appropriateness of the denominator may have changed over time, influencing the observed trends.

Some of the observed increases in testing rates warrant further investigation as to their appropriateness. The National Institute for Health and Care Excellence guidance only recommends

vitamin D testing in children if they have musculoskeletal symptoms, abnormal serum bone profile or X-ray findings, suspected bone disease such as osteomalacia, or known bone disease such as osteoporosis.²¹ A retrospective analysis of vitamin D testing in the Northumbria Healthcare NHS Trust from 2002 to 2017 found that over 75% of the tests performed on those aged below 30 had an inappropriate clinical indication.²²

The clinical implications of these reported trends should be considered on a test-by-test basis. Our findings of vitamin D testing trends mirror those of a recently published study from Australia, which reported that vitamin D test requests for children increased 30-fold in general practice from 2003 to 2018 with the odds of detecting low levels remaining stable.²³ The incidence of nutritional rickets in children (the sequelae of vitamin D deficiency) was also reported to be low, with an annual incidence of 0.48 per 100,00 children under 16 in a UK-based surveillance study from 2015 to 2017,²⁴ reinforcing the need to mitigate this low-value practice. Instead, for asymptomatic children, routine supplementation could be considered rather than testing. Comparing testing rates with rates of abnormal tests for ferritin, B₁₂ and folate would help to assess whether this represents low-value testing. We did not conduct such analyses because information on past laboratory analytical methods and reference ranges was unavailable. Efforts to reduce unnecessary tests should also target specific settings based on the observed trends, for instance, haematinics in general practice.

Unnecessary testing in children has important cost implications. Assuming the cost of a vitamin D test was £10 (OUH NHS Trust laboratory price), expenditure on vitamin D tests for children in Oxfordshire in 2019 was £37900. In UK primary care alone, an estimated £1.7 million was spent on vitamin D tests on children aged 0–17 years in 2014.²⁵ Given the subsequent

increases in vitamin D testing, it is likely that current national expenditure on vitamin D tests in children is far higher than this figure across primary and secondary care. The financial consequences of unnecessary tests also extend beyond the cost of tests alone; tests generate increased workload for laboratory staff as well as the clinicians who must review and action the result. An abnormal result often leads to further investigation and monitoring, treatment and/or referrals, which also costs the health system.

Our study is the first to describe long-term trends in test use in a population-based study of children. One limitation is that we did not have individual patient-level data containing clinical indications for each test, preventing further analysis exploring the appropriateness of tests against existing clinical guidelines. If patient-level data were available, sensitivity analyses excluding children with high testing rates (ie, those who have complex conditions or frequently visit hospital) would provide a more accurate view of trends in testing for the general population.

The generalisability of our findings beyond Oxfordshire is unclear. Oxfordshire, on average, is a less socially deprived region with high educational attainment, and our results of increased test use over time may reflect greater access to laboratory tests in this area. These findings should be compared with other settings to examine if the changes in test use are consistent across England and in other places with similar paediatric healthcare systems. Individual patient-level data including demographics could be used to determine if testing rates are linked to deprivation levels and ethnicity.

We limited testing data until the end of 2019 to eliminate the impacts of the COVID-19 pandemic, during which diagnostic testing decreased substantially.²⁶ The pandemic could serve as a natural experiment, allowing us to examine the impacts of decreased healthcare utilisation. More recent data would also allow us to examine how testing rates recovered following the pandemic, in response to the subsequent increase in healthcare presentations.

Further analyses of testing variation could also include other tests, including urine testing, microbiology and infection, imaging, and spirometry.

CONCLUSIONS

Laboratory test use by children in Oxfordshire demonstrated an apparent increase since 2012 after an initial decline. Test rates for children who present to their GP or outpatient clinics in Oxfordshire increased, though remained stable in the inpatient setting. While testing is crucial in certain situations, every clinician should consider if a test is likely to yield more benefit than harm to the child, their family, and the overall health system.

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Contributors ETT contributed to study conceptualisation and methodology, completed the data cleaning, management and analyses, wrote the original draft and is the guarantor. DRW reviewed the statistical aspects of the study and provided critical input on the original manuscript. BS extracted, cleaned and verified the data, contributed to data interpretation and reviewed the draft manuscript. PG provided supervisory input and comments and feedback on the manuscript. RP provided supervisory input, contributed to conceptualisation and methodology, and reviewed the statistical aspects of the study and revision of the manuscript. CH also provided supervisory input, and contributed to conceptualisation, methodology, data interpretation and revision of the manuscript. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. The deidentified laboratory test data for this study are available upon reasonable request to Dr Brian Shine (email: brian.shine@ouh.nhs.uk). The study protocol, statistical analysis plan and analytical code are openly available. The study protocol was preregistered on the Open Science Framework (OSF: <https://doi.org/10.17605/OSF.IO/KE6DM>). All R code used for data management, analysis and creating the figures is archived online at <https://github.com/elizabeththomas/paediatric-testing-oxfordshire>.

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