Factors Associated with Attrition and Performance Throughout Surgical Training: A Systematic Review and Meta-Analysis

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Abstract

Background Attrition within surgical training is a challenge. In the USA, attrition rates are as high as 20–26%. The factors predicting attrition are not well known. The aim of this systematic review is to identify factors that influence attrition or performance during surgical training.

Method The review was performed in line with PRISMA guidelines and registered with the Open Science Framework (OSF). Medline, EMBASE, PubMed and the Cochrane Central Register of Controlled Trials were searched for articles. Risk of bias was assessed using the Newcastle–Ottawa scale. Pooled estimates were calculated using random effects meta-analyses in STATA version 15 (Stata Corp Ltd). A sensitivity analysis was performed including only multi-institutional studies.

Results The searches identified 3486 articles, of which 31 were included, comprising 17,407 residents. Fifteen studies were based on multi-institutional data and 16 on single-institutional data. Twenty-nine of the studies are based on US residents. The pooled estimate for overall attrition was 17% (95% CI 14–20%). Women had a significantly higher pooled attrition than men (24% vs 16%, \( p < 0.001 \)). Some studies reported Hispanic residents had a higher attrition rate than non-Hispanic residents. There was no increased risk of attrition with age, marital or parental status. Factors reported to affect performance were non-white ethnicity and faculty assessment of clinical performance. Childrearing was not associated with performance.

Conclusion Female gender is associated with higher attrition in general surgical residency. Longitudinal studies of contemporary surgical cohorts are needed to investigate the complex multi-factorial reasons for failing to complete surgical residency.

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Introduction

Attrition within surgical training is a challenge, in the USA, attrition rates are as high as 20–26% [1, 2]. It is a priority to retain surgical residents to meet the increasing healthcare demand and to reduce the significant costs associated with attrition.

Discrimination in the workplace is protected by US law [3]. Age, sex, disability, race, religion, gender reassignment, sexual orientation, pregnancy and maternity and marriage and civil partnerships are termed ‘protected characteristics’ and relate to personal characteristics or attributes. Differential attainment refers to the differences in performance between groups with and without protected characteristics [4]. The impact of protected characteristics on attrition and performance in general surgery residency is poorly understood.

The impact of gender on attrition from general surgery residency remains unclear. Two meta-analyses reported conflicting findings regarding differences in attrition between male and female general surgery residents [5, 6]. The focus of these meta-analyses was on attrition prevalence and timing as opposed to the impact of protected characteristics. The need for further studies to clarify the role these characteristics play in attrition and performance in general surgical training was highlighted in the 2019 American College of Surgeons (ACS) statement on Harassment, Bullying and Discrimination [7]. Similarly the UK regulatory body, the General Medical Council (GMC), is working to identify areas of inequality to ensure all doctors are treated fairly regardless of protected characteristics [8].

In recent years, there has been a push to increase the diversity of medical students [9]. Consequently, there is a change in the upcoming surgeons of the future, with women now representing over a third of US surgeons in training [10]. Most studies focus on dated cohorts and do not reflect the change in the demographics of present surgical residents.

In order to reduce attrition and ensure that all trainees are facilitated to meet their maximum potential and maintain a successful surgical career, factors affecting failure to complete training or those that adversely affect performance need to be identified.

Objectives

The aim is to identify factors that influence progression through or completion of surgical training and will address the following:

1. Are there any factors that predict attrition within postgraduate surgical training?
2. Are there any factors that predict performance during postgraduate surgical training?

Methods

Protocol registration

This systematic review was performed in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [11]. The protocol is available on the Open Science Framework (OFS) at https://osf.io/p5eby.

Eligibility criteria

The review sought to identify papers evaluating factors that affect attrition or progression through surgical training or identify factors affecting performance within surgical training. We included all types of study published as full papers with no restrictions on the language of or date of publication.

Exclusion criteria

1. Studies not investigating specialty surgical trainees, e.g. consultants/faculty, non-medical staff, undergraduate training.
2. Studies focused on selection into training.

Information sources, search and study selection

MEDLINE Ovid, Embase Ovid, PubMed and the Cochrane Central Register of Controlled Trials (CENTRAL) were searched electronically using a mixture of keywords and MeSH terms. The subject strategies for databases were modelled on the search strategy designed for MEDLINE Ovid (Supplemental Fig. 1). We searched the reference lists of included studies for further eligible studies.

Two review authors (CH and JJR) independently and in duplicate performed the title and abstract screening. The full text of all eligible and potentially eligible studies were further evaluated to identify studies meeting the inclusion criteria. Any disagreement was resolved by discussion or where necessary a third reviewer opinion.

Data collection process

Two review authors (CH and JJR) independently extracted the data. If clarification was needed for any aspect of the
included studies, the authors were contacted by email. The primary outcome measures were attrition and performance through training. Attrition was defined as voluntarily or involuntary discontinuation of surgical residency. Protected characteristics (age, sex, ethnicity, and marital and parental status), other factors (personal, workplace/programme, educational/academic) and factors related to performance (examination performance, personality/learning style, operative volume) were extracted from each study. Publication year, country of origin, study size and population, methodology and data source were recorded.

**Risk of bias in individual studies**

Methodology checklists for both cohort and case–control studies were reviewed and used to critically appraise and grade the evidence of included studies. Quality was assessed using the Newcastle–Ottawa scale [12].

**Synthesis of results**

The results were divided into studies that investigated factors affecting attrition and studies that focused on factors that affected performance. A random effects meta-analysis was performed to generate a pooled estimate of attrition prevalence. Two sensitivity analyses were performed including only multi-institutional studies and studies published after 2008. Between studies, heterogeneity was measured with the I² statistic. I² greater than 75% was taken as a high level of heterogeneity. Random effects meta-analyses was conducted for sex. In the event of more than one study including the same population of residents, the study with the largest sample was included in the meta-analysis. Subgroup differences were tested using the z test. It was not possible to perform a meta-analysis on any other factors due to variation in outcome measurement and study design. It was also not possible to look at attrition worldwide due to the lack of non-US studies. All analyses were performed in Stata version 15 (Stata Corp LP), with a p < 0.05 significance level.

**Results**

**Study selection**

The searches identified 3486 articles (Fig. 1). The main reason for exclusion on title and abstract screening was wrong outcome or wrong population. Thirty-one studies met the inclusion criteria (Table 1). Twenty-nine of the studies were from the USA, one from Pakistan and one from the UK. In regard to study quality, five studies were at high risk of bias, fifteen moderate risk and eleven low risk (Supplemental Table 1). Twenty-six studies reported attrition prevalence and were included in the meta-analysis, comprising 17,407 residents. The pooled estimate of overall attrition was 17% (95% CI 14–20%) with significant heterogeneity (I² = 96.84%, p < 0.001) (Fig. 2). The pooled estimate of attrition was 14% (95% CI 10–17%) on sensitivity analysis of only multi-institutional studies with greater heterogeneity (I² = 98.10%, p = 0.00), and therefore, initial analyses are presented (Supplemental Fig. 2).

After only including studies published after 2008, the overall attrition remained 17% (95% CI 13–20%, I² = 97.06%, p = 0.00) (Supplemental Fig. 3).

**Attrition**

**Age**

Two out of four studies found no association with age and attrition [1, 13] (Table 2). In the studies that found increasing age to be a risk factor for attrition, age was dichotomised to under and over 29 [14] and under and over 35 years [15] in the analysis. The positive finding in the study by Naylor [14] may be due to the outcome measure which combines attrition with failure to pass the board examination.

**Gender**

The pooled attrition prevalence for male residents on random effect meta-analysis was 16% (95% CI 12–20%), with significant between study heterogeneity (I² = 95.35%, p < 0.01) (Fig. 3). The pooled attrition prevalence for women was significantly higher at 24% (95% CI 18–30%, z = -4.6832 p < 0.001), again with significant heterogeneity (I² = 94.62%, p < 0.01). On sensitivity analysis, including only multi-intuition studies or those published after 2008 did not significantly affect the pooled attrition of male or female residents (Supplemental Fig. 4 and 5).

Four out of 16 studies found a significantly higher attrition amongst female residents [16–19] (Table 2). In the studies that found increasing age to be a risk factor for attrition, age was dichotomised to under and over 29 [14] and under and over 35 years [15] in the analysis. The positive finding in the study by Naylor [14] may be due to the outcome measure which combines attrition with failure to pass the board examination.
Ethnicity/race

Five studies investigated the association between race or ethnicity and attrition [1, 15, 17–19] (Table 2). Four studies reported that Hispanic residents were less likely to complete residency; however, 3 of these studies were based on the same population of residents [15, 17–19]. Therefore, it was not possible to perform a meta-analysis of the data. One study found that while white race was not associated with higher completion rates across both genders (69.7% completion vs 65.8% non-completion, \( p = 0.34 \)) [18], on subgroup analysis of women, white women had lower non-completion rates than non-white women (20% vs 30% \( p = 0.08 \)).

Marital and parental status

None of the studies found an association between parental status and attrition [1, 13, 15]; this included two large multi-institutional studies (Table 2). Only one study found those that were married were less likely to leave training, this was a small single-institutional study of 85 residents from 1999 to 2009 [13].

Personal factors

There was no association between attrition and ‘grit’ [20, 21] social belonging [22] or motivational personality
| Author     | Title                                                                 | Year | Country | Study size | Population                      | Methodology               | Source                   | Attrition rate reported |
|------------|------------------------------------------------------------------------|------|---------|------------|---------------------------------|---------------------------|--------------------------|-------------------------|
| Alterman   | The predictive value of general surgery application data for future resident performance | 2011 | USA     | 101        | General surgery residents 1990–2008 | Retrospective review      | Resident files ABSITE ACGME | Yes                     |
| Aufses     | The nature and fate of categorical surgical residents who 'drop out'    | 1998 | USA     | 88         | General surgery residents 1982–1995 | Retrospective review      | Resident files Medical school data | Yes                     |
| Bergen     | Gender-related attrition in a general surgery training program         | 1998 | USA     | 132        | General surgery residents 1984–1996 | Retrospective review      | National Residency Matching Program | Yes                     |
| Brown      | Pregnancy-related attrition in general surgery                         | 2014 | USA     | 85         | General surgery residents 1999–2009 | Retrospective review      | Resident files             | Yes                     |
| Burkhart   | Grit: A marker of residents at risk for attrition?                     | 2014 | USA     | 180        | General surgery residents 2012–2013 | Survey                    | Grit survey Resident files | Yes                     |
| Carter     | Women in surgery: A longer term follow-up                              | 2018 | USA     | 108        | General surgery residents 1996–2009 | Retrospective review      | Resident files             | Yes                     |
| Dodson     | Why do residents leave general surgery? The hidden problem in today’s programs | 2004 | USA     | 120        | General surgery residents 1990–2003 | Retrospective review      | Resident files             | Yes                     |
| Everett    | General surgery resident attrition and the 80 h workweek              | 2007 | USA     | 2555       | General surgery residents 2001–2004 | Survey to directors of general surgery residency programme | Survey | Yes                     |
| Falcone    | Home school dropout: a 20 year experience of the matriculation of categorical general surgery residents | 2014 | USA     | 104        | General surgery residents 1992–2011 | Retrospective review      | Resident files             | Yes                     |
| Farley     | Whatever happened to the General Surgery graduating class of 2001?     | 2001 | USA     | 53         | General surgery residents 1996–2001 | Cross-sectional           | Resident files             | Yes                     |
| Gifford    | Factors associated with general surgery residents’ desire to leave residency programs: A multi-institutional study | 2014 | USA     | 288        | General surgery residents Multi-institution 2004–2013 | Survey across residents Survey | Resident files             | Yes                     |
| Author    | Title                                                                 | Year | Country | Study size | Population                          | Methodology                          | Source                  | Attrition rate reported |
|-----------|-----------------------------------------------------------------------|------|---------|------------|-------------------------------------|--------------------------------------|-------------------------|-------------------------|
| Hayward   | Is there gender bias in the evaluation of surgical residents?        | 1987 | USA     | 144        | General surgery residents           | Retrospective review of faculty evaluations | Resident files   | N/A                     |
| Kelz      | Prevention of Surgical Resident Attrition by a Novel Selection Strategy | 2010 | USA     | 64         | General surgery residents           | Retrospective review                  | Electronic Resident Application System | Yes                     |
| Kim       | The effect of surgical resident learning style preferences on American board of surgery in-training examination scores | 2015 | USA     | 53         | General surgery residents           | Retrospective review                  | Fleming VARK learning styles inventory | N/A                     |
| Leibrant  | Has the 80 h work week had an impact on voluntary attrition in general surgery residency programs? | 2006 | USA     | 215 programmes | General surgery residents           | Questionnaire to programme directors  | Questionnaire | N/A                     |
| Longo     | Attrition of categoric general surgery residents: results of a 20 year audit | 2009 | USA     | 99         | General surgery residents           | Retrospective review                  | Resident files   | Yes                     |
| Nadeem    | Attrition in surgical residency programmes: Causes and effects        | 2014 | Pakistan | 106        | General surgery, orthopaedics, neurosurgery, ENT and urology residents | Questionnaire to residents and programme directors | Resident files | Yes                     |
| Naylor    | Factors Related to Attrition in Surgery Residency Based on Application Data | 2008 | USA     | 111        | Surgery doesn’t define              | Retrospective review                  | Residency application form             | Yes                     |
| Quillin   | How residents learn predicts success in surgical residency            | 2013 | USA     | 130        | General surgery residents           | Retrospective review                  | ACGME Operative log data                | Yes                     |
| Salles    | Grit as a predictor of risk of attrition in surgical residency        | 2017 | USA     | 73         | General surgery residents           | Survey to residents                   | Short grit scale | Yes                     |
| Author          | Title                                                                 | Year | Country | Study size | Population                                      | Methodology                  | Source                        | Attrition rate reported |
|-----------------|----------------------------------------------------------------------|------|---------|------------|------------------------------------------------|-----------------------------|-------------------------------|------------------------|
| Salles          | Social Belonging as a Predictor of Surgical Resident Well-being and Attrition | 2019 | USA     | 146        | General surgery, cardiothoracic, ENT, vascular, orthopaedics, plastic surgery, urology & neurosurgery residents 2010 2011, 2015 Multi-institutional Survey to residents | Survey Resident files | Yes                           |
| Schwed          | Association of general surgery resident remediation and program director attitudes with resident attrition | 2017 | USA     | 966        | General surgery residents 2010–2015 Multi-institutional Survey to programme directors | Survey General Surgery Qualifying Examination and General Surgery Qualifying Examination of the ABS | Yes                           |
| Scrimgeour      | Does the Intercollegiate Membership of the Royal College of Surgeons (MRCS) examination predict ‘on-the-job’ performance during UK higher specialty surgical training? | 2018 | UK      | 2750       | Higher surgical residents 2007–2016 Multi-institutional Longitudinal cohort study | Membership of Royal College of Surgeons examination ARCP outcomes | N/A                           |
| Sullivan        | Surgical residency and attrition: Defining the individual and programmatic factors predictive of trainee losses | 2013 | USA     | 2033       | General surgery 2008–2009 Multi-institutional Prospective study | National Study of expectations and Attitudes of Residents in Surgery Survey ABS resident roster | Yes                           |
| Symer           | The Surgical Personality: Does Surgery Resident Motivation Predict Attrition? | 2018 | USA     | 801        | General surgery 2007–2008 Multi-institutional Survey to residents, data review 2016 | Behavioural Inhibition/ Behaviour Approach scale | Yes                           |
| Symer, Wong     | Impact of medical school experience on attrition from general surgery residency | 2018 | USA     | 792        | General surgery 2007–2008 Multi-institutional Prospective cohort study | ABS resident roster | Yes                           |
| Wade            | Evaluations of surgery resident performance correlate with success in board examinations | 1993 | USA     | 48         | General surgery 1976–1988 Single institution Retrospective review | ABSITE Resident files | N/A                           |
traits [23] (Table 3). Grit was defined as perseverance and passion for long-term goals. The number of residents that did not complete training in these studies was small and therefore limits the power of statistical analysis. Quillin et al. reported that residents who learn by observation are more likely to leave the programme and opt for a non-surgical specialty [24].

Workplace and programme factors

Eight studies reported the impact of work place factors on failure to complete general surgery residency [1, 15, 17–19, 25–27] (Table 3). Early postgraduate year [1, 15], larger programme size [17, 18] and military programmes [18, 19] were found to be associated with higher attrition.

Educational and academic factors

Six studies investigated medical school factors affecting completion of residency [14, 17, 25, 28–30] (Table 3). Two studies reported an association between ABSITE score and attrition [25, 30]. Residents who felt medical school faculty were happy with their surgical careers were less likely to experience attrition [17], while those who got along well with attending surgeons during medical school had higher odds of attrition. Protective factors on the residency application were comments in the dean’s letter, participation in team sports [14] and residency interview score [30].

Performance

Six studies focused on factors that predicted performance throughout surgical residency [20, 24, 31–34] (Table 4). Performance included examination scores, operative case volume and in-training evaluations. Childrearing was not associated with operative case volume or examination performance [13]. Factors reported to affect US postgraduate surgical examination performance were learning preference [31] and faculty evaluation of clinical performance [34]. However, these studies are based on small sample sizes. The only UK-based study investigated whether postgraduate examination scores are a predictor of performance throughout UK surgical training [32].

Table 1 continued

| Author | Title | Year | Country | Study size | Population | Methodology | Source | Attrition rate reported |
|--------|-------|------|---------|------------|------------|-------------|--------|-------------------------|
| Yaghoubian | General surgery resident remediation and attrition: A multi-institutional study | 2012 | USA | 348 | General surgery residents 1999–2010 Multi-institutional | Retrospective analysis | USMLE ABSITE scores 3rd year medical school surgery performance scores | Yes |
| Yeo | A national study of attrition in general surgery training: Which residents leave and where do they go? | 2010 | USA | 3959 | General surgery residents 2007–2008 Multi-institutional | Retrospective analysis | National Study of Expectations and Attitudes of Residents in Surgery survey | Yes |
| Yeo | Who Makes It to the End?: A novel predictive model for identifying surgical residents at risk for attrition | 2017 | USA | 836 | General surgery residents 2007 Multi-institutional | Prospective cohort study with 8-year follow-up | ABS ABSITE | Yes |
| Yeo | Association of time to attrition in surgical residency with individual resident and programmatic factors | 2018 | USA | 836 | General surgery residents 2007–2008 Multi-institutional | Prospective cohort study With 9-year follow-up data linkage | National Expectations and Attitudes of Residents in Surgery Survey | Yes |

ABS American Board of Surgery, ABSITE American Board of Surgery In-Training examination, ACGME Accreditation Council for Graduate Medical Education, ARCP Annual Review of Competency Panel, USMLE United States Medical Licensing Exam
Discussion

This is the first study to report the association between protected characteristics and attrition and performance during surgical training. Overall, of the studies included in our systematic review 25 reported factors associated with progression or completion of surgical training and seven focused on factors affecting performance. The pooled attrition rate was high at 17% which causes a burden to residency programmes and existing residents. Efforts should be made to retain residents and to reduce the financial and training implications of attrition. Worryingly given the changing demographic of surgical trainees, rates of attrition were higher in women.

The limitations of this study are related to the included studies, the majority of which are conducted in a single institution which increases bias and reduces generalisability. A significant finding that limits generalisability to current surgical trainees is that fourteen of the studies include cohorts that started training over 20 years ago. During this time, training requirements and assessment processes have changed, as has the population of surgical trainees with an increase in female trainees. However, on sensitivity analysis including only studies published since 2008 did not affect the overall pooled attrition or that of attrition by gender. Nine of the included studies rely on
| Author | Year | Study size | Conclusions |
|--------|------|------------|-------------|
| Brown  | 2014 | 85         | Age not associated with attrition (OR 1.0 95% CI 0.8–1.4) |
| Yeo    | 2010 | 3959      | Age not associated with attrition (β 0.05 95% CI -0.03–0.13) |
| Naylor | 2008 | 111       | Age > 29 years associated with attrition (OR 0.11 95% CI 0.02–0.47) |
| Sullivan | 2013 | 2033    | Age ≥ 35 years associated with attrition (OR 0.28 95% CI 0.19–0.39) |
| Author | Year | Study size | Conclusions |
| Alterman | 2011 | 101     | No association with gender (not reported) |
| Aufses  | 1998 | 88      | No association with gender (32% vs 17%, p = 0.12) |
| Bergen  | 1998 | 132     | No association with gender (RR 2.26 95% CI 0.96–5.31) |
| Brown   | 2014 | 85      | No association with gender (OR 1.0 95% CI 0.2–3.6) |
| Carter  | 2018 | 108     | No association with gender (female 22% vs male 19%, p = 0.77) |
| Dodson  | 2004 | 120     | No association with gender (female 27% vs male 13%) |
| Falcone | 2014 | 103     | No association with gender (female 23.1% vs male 17.9%, p = 0.57) |
| Longo   | 2009 | 99      | No association with gender (female 39% vs 26% male) |
| Nadeem  | 2014 | 106     | No association with gender (female 54.5% vs male 34.5%, p = 0.07) |
| Sullivan | 2013 | 2033    | No association with gender (female 7% vs male 6.2%) |
| Yaghoubian | 2012 | 348    | No association with gender (female 47.3% vs male 52.7%, p = 0.08) |
| Yeo     | 2010 | 3959    | No association with gender (β -0.23 95% CI -0.72–0.30) |
| Gifford | 2014 | 371     | Significant difference between sexes (Female OR 1.9 CI 1.2–3.0) |
| Symer, Wong | 2018 | 792    | Significant difference between sexes (24% of women vs 16% of men left, p < 0.01) |
| Yeo     | 2017 | 836     | Significant difference between sexes (24% of women vs 17% of men left, p = 0.02) |
| Yeo     | 2018 | 836     | Significant difference between sexes (Female OR 1.40 95% CI 1.02–1.94) |
| Author  | Year | Study size | Conclusions |
| Yeo     | 2010 | 3959    | No association between race/ethnicity (β -0.09 95% CI -0.59–0.41) |
| Sullivan | 2013 | 2033    | Hispanic residents higher risk of attrition (OR 0.50 95% CI 0.38–0.65) |
| Black residents higher risk of attrition (OR 0.28 95% CI 0.20–0.40) |
| Symer, Wong | 2018 | 792    | Hispanic residents less likely to complete residency (13.1% non-Hispanic vs 7.8% Hispanic completed residency, p = 0.04) |
| Yeo     | 2017 | 836     | Hispanic residents less likely to complete residency (29% non-Hispanic vs 19% Hispanic completed residency, p = 0.03) |
| Yeo     | 2018 | 836     | Hispanic residents less likely to complete residency (OR 1.71 95% CI 1.06–2.76) |
| Author  | Year | Study size | Conclusions |
| Brown   | 2014 | 85      | No association with child rearing (OR 1.0 95% CI 0.1–9.6) |
| Association with marital status (Married OR 0.2 95% CI 0.01–0.9) |
| Sullivan | 2013 | 2033    | No association with child rearing (18% with children left vs 15% completed residency, p = 0.31) |
| No association with marital status (46% married left vs 42% completed residency, p = 0.34) |
| Yeo     | 2010 | 3959    | No association with child rearing (β 0.45 95% CI -0.32–0.98) |
| No association with marital status (OR 0.23 95% CI -0.32–0.78) |
survey data which are subject to response and recall bias. Also, as all but two of the included studies are from the USA, attrition rates and factors affecting this in other countries have not been investigated.

Attrition rates in general surgery residency remain higher than other surgical specialities [35–37]. In a study of Canadian surgical residents, 26.8% were considering leaving their training programme with poor work–life balance cited as the main reason [38]. This study provides clarity regarding the impact of resident gender on attrition after two previous meta-analyses reported differing findings [5, 6]. We found a significantly higher attrition rate for female residents on pooled meta-analysis. This is consistent with a meta-analysis that found female residents had a 25% pooled attrition rate compared to 15% of men [6]. This finding is not unique to general surgery; higher attrition rates for female residents have also been reported in neurosurgery [39, 40] and orthopaedics [36].
The findings regarding the impact of Hispanic ethnicity and attrition require further investigation. As three of the four studies reporting higher attrition amongst Hispanic residents are based on the same population, it is not possible to make firm conclusions. However, higher attrition for Hispanic residents has been reported across other specialties. A 2019 study of US emergency medicine residents found that a significantly greater proportion of Hispanic residents left the programme compared to white residents [41]. They also reported a higher rate of dismissal for Hispanic residents compared to Asian and white residents. The fact that Hispanic residents are an underrepresented group in postgraduate medicine may result in less access to role models they can identify with which may impede residency satisfaction [42].

Table 3 Studies investigating the effect of other factors on attrition (personal, workplace and programme and educational/academic factors)

| Author     | Year | Study size | Personal factors |
|------------|------|------------|------------------|
| Burkhart   | 2014 | 180        | No significant association with grit ($p = 0.246$) |
| Salles     | 2017 | 73         | No significant association with grit ($\beta = 85.83, p = 0.999$) |
| Salles     | 2015 | 146        | No significant association with lack of belonging ($r = 0.15, p = 0.1846$) |
| Symer      | 2018 | 801        | No significant association with motivational personality traits ($p = 0.51$) |
| Quillin    | 2013 | 130        | Association with learning style ($p = 0.0467$) |

| Author     | Year | Study size | Workplace and programme factors |
|------------|------|------------|---------------------------------|
| Everett    | 2007 | 2555       | Association with 80 h workweek (0.6 lost/programme/year pre vs 0.8 lost/programme/year post, $p = 0.0414$) |
| Leibrant   | 2006 | 215        | No association with 80 h work week (0.7 lost/programme/year pre vs 0.8 lost/programme/year post) |
| Sullivan   | 2013 | 2033       | Association with early postgraduate year (9.4% PGY-1 left vs 4.5% PGY-2, $p < 0.001$) |
| Yeo        | 2010 | 3959       | Association with regional location (Northeast HR 2.39 vs South, $p = 0.006$) |
| Yeo, Wong  | 2018 | 792        | Association with larger programme size (25.4% from large programme completed vs 34% small programme, $p = 0.03$) |
| Yeo        | 2017 | 836        | Association with larger programme size (24% from large programme left vs 18% small programmes, $p = 0.03$) |
| Yaghoubian | 2012 | 348        | Association with military programmes vs academic programmes vs community programmes (35% vs 20% vs 17%, $p = 0.03$) |
| Yaghoubian | 2012 | 348        | Association with military programmes vs academic programmes (OR 2.68 95% CI 1.36–5.29) |

| Author     | Year | Study size | Educational and academic factors |
|------------|------|------------|---------------------------------|
| Farley     | 2001 | 53         | No association with applicant ranking ($p = 0.18$) |
| Falcone    | 2014 | 103        | No association with place of medical degree ($p = 0.89$) |
| Yaghoubian | 2012 | 348        | No association with place of medical degree (0% vs 5.3% foreign medical graduate,$p = 0.09$) |
| Alterman   | 2011 | 101        | Association with special skill on medical school application (OR 3.59 95% CI 1.035–11.95) |
| Naylor     | 2008 | 111        | Association with residency interview score (OR 188.27 95% CI 3.757–9435.405), STEP1 score ($p = 0.001$) and ABSITE score ($p < 0.001$) |
| Symer, Wong| 2018 | 792        | Association with experience in surgical clerkship—perception that medical school faculty were happy with their careers (OR 0.57 95% CI 0.34–0.96), those that got along well with attending surgeons during medical school (OR 2.93 95% CI 1.34–6.39) |
programme which may partly explain the higher attrition [43].

Half of the studies found that age is associated with increased attrition; in both of these studies, age was dichotomised to an arbitrary number which may influence the findings [14, 15]. All three of the studies that analysed the effect of parental status find no increased rates [1, 13, 15]. These findings are reassuring given the increasing number of female surgical trainees and increasing acceptance of childrearing during residency. One study found that while the perception of negative attitudes towards pregnancy during training has decreased over time, some stigma persists [44]. It additionally reported that those who had graduated from medical school more recently were more likely to have a pregnancy during training than their older counterparts. The finding that childrearing does not affect attrition or performance should encourage residency programmes to develop clear guidance regarding parental leave, as in a recent study only 3.8% of residents were able to correctly identify the American Board of Surgery policy and felt unsupported [45].

The studies that focused on performance vary greatly in design and outcome measure. As with attrition, there was no association between childrearing or ‘grit’ and performance. The definition of performance is not uniform across studies and this limits interpretation. Four of these studies are based on populations commencing surgical residency more than 20 years ago, in one case from 1967. A 2017 study outlines the different assessment tools used during residency and highlights the lack of effective tools to measure competence [46]. Further studies investigating the relationship between attrition and performance using standardised measures of performance are warranted.

### Conclusion

Female residents have higher attrition than male residents in general surgery. Marital and parental status are not associated with increased risk of attrition in general surgery residency. Longitudinal studies of contemporary surgical cohorts are needed to investigate the complex and multifactorial reasons for failing to complete surgical residency internationally.

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### Compliance with ethical standards

#### Conflict of interest

The authors declare that they have no conflict of interest.

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